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THE POWER TO CREATE WEALTH:

A Systems-based Theory of the Rise and Decline of Great Powers in the 20th Century

by

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Abstract

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By

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Great Powers are central to the processes of the international system. When Great Powers rise and decline relative to other Great Powers, the consequences for all nations is profound. This dissertation proposes a theoretical framework for understanding the causes of the relative rise and decline of Great Powers by focusing on their machinery production capacities.

Because this topic is complex, I have developed a theory of systems in order to organize the theoretical elements that describe production processes within polities. Systems are composed of elements, which constitute systems in turn. Two facets of systems are central to this study: first, many systems contain a generative subsystem, which produces output, and an allocative system, which distributes the output among the elements of the system; and second, systems contain negative feedback processes which serve to stabilize and balance a system, and positive feedback processes which are the basis for change, growth, and decay.

My general theory of systems is used to construct theories of economic, political, and political economic systems, as well as hypotheses. I focus on the generative subsystem of the economy, the system of production. Relative performance in production is the driving force in the processes of relative rise and decline of nations and Great Powers. The source of productive power is the capability to generate goods and services, which is based on the capability to produce the production machinery which generates output. Production machinery, in turn, is created by classes of machinery which collectively reproduce themselves, such as machine tools, which I call reproduction machinery. This reproductive potential gives industrial societies the ability to sustain exponential growth. Human capital, in the form of scientific researchers, engineers, and skilled production workers, are the source of technological innovations and machinery production.

The Great Powers constitute a global oligopoly of the machinery industries, including military equipment. This capacity enables them to control the reallocation of territory in the international system. The management and development of the production system by the state and financial sectors of a Great Power will have a powerful effect on its rise or decline relative to other nations.

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CHAPTER 1

WHAT IS A GREAT POWER?

Most international relations scholars assume that there is a set of countries, called Great Powers, that have a greater effect on world politics than all of the other countries combined. Political scientists focus a great deal of attention on the consequences of the rise and decline of such countries. This dissertation proposes a theoretical framework for understanding the causes of the relative rise and decline of Great Powers. Before proposing such a framework, I will survey the literature concerning, first, the definition of the term "Great Power", and second, previous theories of the rise and decline of Great Powers.

Because of the importance of the Great Powers in the international political system, political scientists emphasize the importance of Great Powers. For example, Waltz states that "the number of consequential states is small. From the Treaty of Westphalia to the present, eight major states at most have sought to coexist peacefully or have contended for mastery. Viewed as the politics of the powerful, international politics can be studied in terms of the logic of small-number systems" (Waltz 1979, 131). For Gilpin, "Both individually and in interaction with one another, those states that historically have been called the great powers and are known today as the superpowers establish and enforce the basic rules and rights that influence their own behavior and that of the lesser states in the system" (Gilpin 1981, 30). Gilpin also quotes Raymond Aron to the effect that "the structure of international systems is always oligopolistic. In each period the principal actors have determined the system more than they have been determined by it" (Gilpin 1981, 29). Morgenthau's concern with the balance of power is always focused, in his historical examples, on "first-rate" powers (Morgenthau 1973). Martin Wight states that "the most conspicuous theme in international history is not the growth of internationalism. It is the series of efforts, by one power after another to gain mastery of the states-system – efforts that have been defeated only by a coalition of the majority of other powers at the cost of an exhausting general war" (Wight 1978, 30). While not all of international affairs can be explained in terms of the Great Powers, it is impossible to understand most of history or current global processes without considering the Great Powers.

Since the set of countries that are known as the Great Powers have a preponderant influence on the processes of international relations, it would seem reasonable to know how a Great Power is defined. While "the state" has normally been introduced as the main unit of analysis in international political scholarship, the focus on Great Powers has in fact superseded the attention given to "the state", conceived of as an abstract entity. However, the definition of a Great Power has been problematic. In almost all cases, the final list which is chosen for various historical epochs seems to be intuitive, and thus not open to a scientific discussion of merits. In any scientific endeavor, the unit of analysis should be carefully specified, or else there is no basis on which a discussion among researchers can take place. Ideally, the definition of the most important unit of analysis within an area of study should be consistent with, if not integral to, the theory of which it is a part.

There are two major criteria in the international relations literature that is used to specify when a particular country was a Great Power. First, there is the alleged "consensus" choice; everybody agrees that a particular state was a Great Power during a specific period of time. Second, a list of the capabilities that characterize national power is presented, and a threshold level is discerned which differentiates a Great Power from a non-Great Power. This dividing line is almost never specified.

Criterion 1: Consensus

Figure 1 shows the list of Great Powers, for the period 1870 to approximately the 1980s (depending on the author). Each author has his own term for Great Power, but many also have terms for several different kinds of Great Power. Figure 1 shows that among these six authors, there is certainly no consensus, except for short time periods. What are the bases for their choices?

Singer and Small claim that "we do achieve a fair degree of reliability on the basis of 'intercoder agreement'. That is for the period up to World War II, there is high scholarly consensus on the composition of this oligarchy" (Singer and Small 1972). In a later statement, Singer and his co-authors state that "we emphasize that our criteria – quite intentionally – are less than operational. That is, rather than define the major power sub-system over time in terms of certain objective power and/or prestige indicators, we adhere to the rather intuitive criteria of diplomatic historians" (Singer, Bremer, Stuckey 1972). It is never demonstrated that diplomatic historians have either a consensus or "intuitive" criteria. If anything, historians such as Paul Kennedy look to political scientists for theory. Historians in general tend to concentrate on the time period before World War I, and almost never venture in their studies beyond 1945; on the other hand,

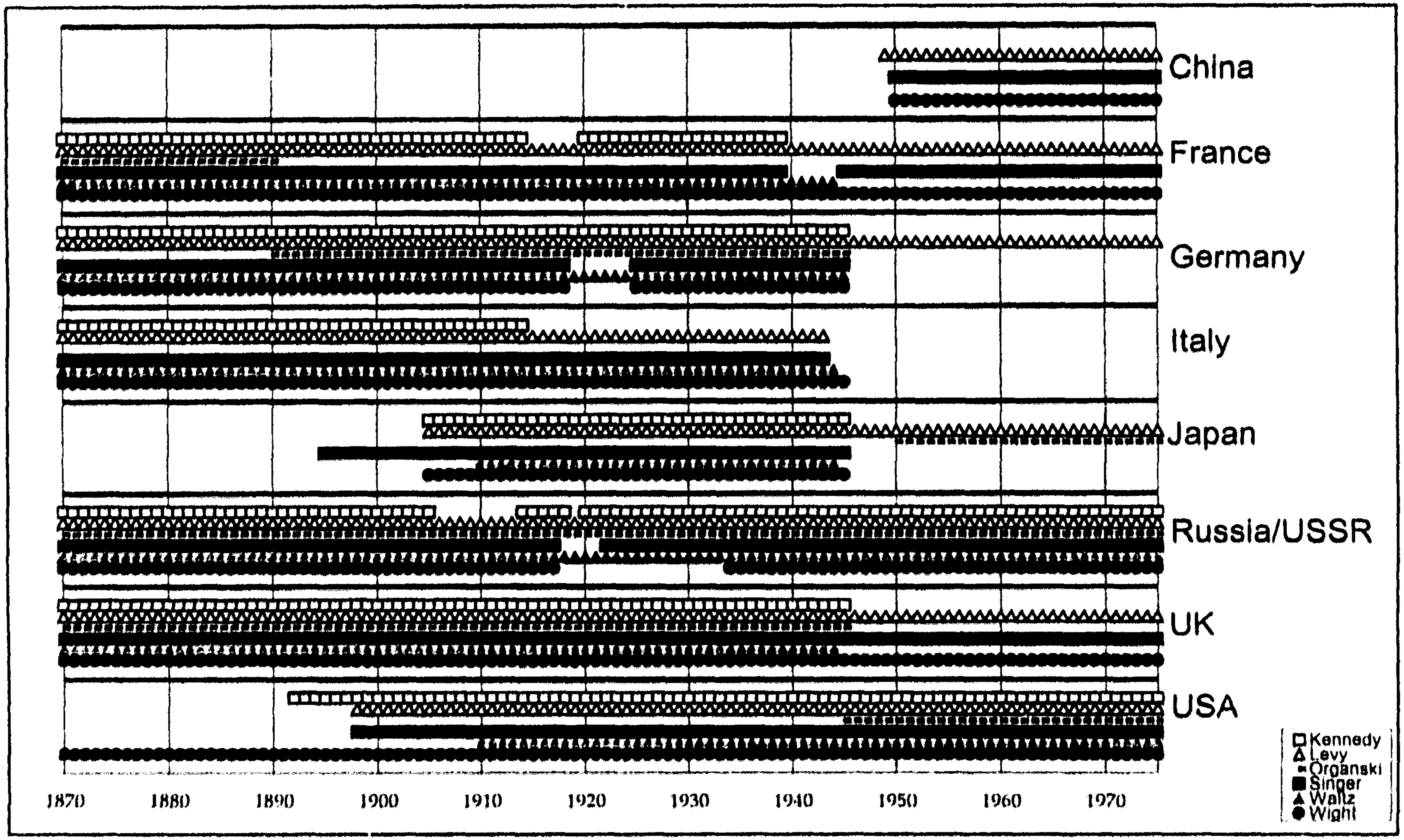


Fig. 1. Great Power time periods according to various scholars

political scientists do most of their scholarly work for the period after 1945, leaving the interwar period as a kind of scholarly orphan.

Waltz also states that there is a consensus of historians. For Waltz, "Historically, despite the difficulties, one finds general agreement about who the great powers of a period are, with occasional doubt about the marginal cases...Counting the great powers of an era is about as difficult, or as easy, as saying how many major firms populate an oligopolistic sector of an economy. The question is an empirical one, and common sense can answer it" (Waltz 1979, 131). The reader is not informed of the reasons behind the construction of his list, because it is "adapted from Wright, 1965, Appendix 20, Table 43" (Waltz 1979, 162). Table 43 of Appendix 20 of Quincy Wright's "A Study of War" is a list of wars entitled "Participation of Powers in General Wars, 1600 - 1941". Wright gives no criteria for defining a war as general, and at the end of the list he states that "This summary indicates that, with very few exceptions, all the great powers of the time participated in each of these general wars" (Wright 1965, 649); thus, who was a Great Power seems to be assumed. The status of various states is then treated in clauses: "Austria, which ceased to be a great power in the twentieth century...Prussia, which became a great power in the eighteenth century...Russia which became a great power in the eighteenth century, and Italy...which did not become a great power until the nineteenth century...Japan and the United States did not become great powers until the twentieth century" (Wright 1965, 649). Apparently France and England were Great Powers throughout history.

This grouping of Great Powers was also followed by Spiegel, who on page 118 alludes to a footnote 20 in chapter three of his book, which reads: "These calculations of great powers are based on W.T.R. Fox's interpretation" of Appendix 20, table 43 "as used in Government G6801X 'Systemic World Politics,' Fall 1969, Columbia University" (Spiegel 1972). Unfortunately, the rest of the scholarly community did not attend G6801X, and consequently we do not know why these countries were chosen. Thus it would appear that there are certain groups of scholars, each with his own "intuitive" list; one is derived from Singer, the other is centered on Quincy Wright.

Martin Wight is both forthright about his ignorance and mistaken about the scholarly consensus. "What is a Great Power?" he asks, then answers: "This is one of the central questions of international politics. It is easier to answer it historically, by enumerating the great powers at any date, than by giving a definition, for there is always broad agreement about the existing great powers." (Wight 1978, 41). He then presents his list. He defines two sorts of "powers": "As a dominant power is a power that can confidently contemplate war against any likely combination of other powers, so a great power is a power that can confidently contemplate war against any other existing single power" (Wight 1978, 52-53). Von Ranke (1833) called a "Great Power" that which Wright labeled a "dominant power". We are never given an argument as to what criteria would allow one to "confidently" predict the performance of one power against another.

Organski and Kugler also use several definitions. Since they are trying to explain why major wars occur, they need to know which states are major powers: "The elite nations are few enough to stand out clearly from the rest of the members of the international system on such critical dimensions as population, economic productivity, and military might; international relations specialists have long agreed on their identity" (Organski and Kugler 1980, 42). They then give a general list based on Singer.

However, they enumerate three kinds of major power. I have graphed only one kind: contending powers.[1] Their recipe for constructing a list is that "the most powerful nation in the world at any given time is always a member of the contending class. Any other nation whose score is at least as high as 80 percent of the capabilities of the strongest nation would also be considered a contender. When no other nation in a given period met this criterion, we considered as contenders the three strongest nations in the system" (Organski and Kugler 1980, 44).

Sophisticated statistical processes were carried out in an effort to substantiate international relations theory based on arbitrary numbers like 80% and the number 3. But apparently there are more "intuitive" criteria; Organski and Kugler maintain that the U.S. was not a contender until 1945, despite the fact that this contradicts their previous criteria: "She appears on this list only with World War II because it was not until then that she had come to view herself as part of the central system." (Organski and Kugler 1980, 45).

The most exhaustive analysis of previous definitions of the term "Great Power" was undertaken by Levy, who sets out a series of criteria, and then makes an effort to apply these criteria to the various Great Powers. Most of the criteria are rather vague, such as differentiating Great Powers based on their "behavior" (Levy 1983, 17) or their "interests" (Levy 1983, 16), or else consisting in part of other states' perceptions of the Great Powers. Perception is important in explaining foreign policy, but should not be part of a definition of Great Power because such a definition should be based on objective factors. This does not mean that the objective criteria will lead to an infallible ability to predict outcomes, but simply that by distinguishing between subjective and objective factors, scholars may be in a position to separate the resources that states have available to them from the ways in which states use those resources in foreign policy.

A parable might be useful in showing the need to focus on objective criteria for determining Great Power status. Suppose that, on an island that is close to most countries, some people have constructed a mound of mud which they have convinced all the other countries is very powerful; all countries' leaders believe that this mound can wreak great destruction. Perhaps all of the Great Powers take the power of the mound of mud very seriously in their foreign policy deliberations, and any explanation of such policy would have to consider the position of the mound of mud in the decision-makers' minds. However, this would not be an objective consideration; in the event of a war, or the rise of a state that eliminated the mound of mud by simply blowing it up, the mud would eventually be shown to have been powerless. This is because, as Waltz has pointed out, in an anarchic system such as the international political system, eventually the forces of competition (and socialization) will force out those kinds of states which fall far behind in their possession of the resources of power.

Perception is a problem of foreign policy, but does not enter into calculations of national power. In an attempt to show that perception is an important indicator of power, Singer and Small (1966) tried to use the number of ambassadors that a country received as an indication of power, but found that Spain was therefore the most important country before World War I!

Instead, Levy claims that "most important, a Great Power possesses a high level of military capabilities relative to other states" (Levy 1983, 16). This is an objective criterion. When Levy explains his choices of Great Powers, however, the descriptions are rather short, since he is covering the 480 years from 1495 to 1975, and he often seems to rely on "intercoder agreement".[2]

Paul Kennedy never gives an explicit list of Great Powers. His definition of a Great Power is of "a state capable of holding its own against any other nation" (Kennedy 1987, 539). This definition is claimed to be based on Martin Wight's definition quoted above, but Kennedy's is actually based on a defensive criteria, whereas Wight's was more general (The list in figure 1 is based on various of Kennedy's comments that he spread throughout his book, and that I compiled). Kennedy is exhaustive when it comes to strengths and weaknesses[3] (which generally are based on both Organski and Morgenthau, who will be examined below), and shy about giving us a list. His most common indicator of national power, at least in the 20th century, is clearly the industrial base[4].

Kennedy uses a series of tables – which are composed of Singer's industrial data, among others – which are very inclusive. The "Powers", as he refers to them in these tables, are Austria-Hungary, France, Germany, Great Britain, Italy, Japan, Russia, and the United States between 1890 and 1938. On the other hand, he makes various statements about various powers that are not consistent with this list, for the US[5], Italy[6], Russia[7], and Austria-Hungary and France[8].

Thus, although he treats Austria-Hungary, Italy, and France at length, Kennedy is not clear as to whether or not they are Great Powers in the first half of the twentieth century. There is less confusion in the second half, but all is not clear. He refers to Germany, France, Japan, Italy, and Britain as "those former Great Powers" (Kennedy 1987, 365), although he then mentions that Great Britain was "one of the Great Powers of the world" (Kennedy 1987, 367). He refers again to the list of "former Great Powers" at the same time that he presents a table of "Powers" which includes the US, USSR, Britain, France and China (Kennedy 1987, 395). Since the latter table deals with nuclear weapons, perhaps he has shifted his definition of Great Power to encompass nuclear capability. By the 1970s, we are again told of the "former Great Powers" (Kennedy 1987, 422). By the early 1980s, the UK "was now just an ordinary, moderately large power, not a Great Power" (Kennedy 1987, 425).

Counter to Singer's thoughts of scholarly consensus, Kennedy quotes other diplomatic historians, but each historian has compiled a different list. Whereas the weaker Great Powers present a definitional problem before World War II, and for some the United States also presents problems, Europe as a whole seems exasperating after World War II. Kennan's "very plausible geopolitical argument" (Kennedy 1987, 376) was that there were only "five centers of industrial and military power in the world which are important to us from the standpoint of national security" (Kennedy 1987, 376), "the United States itself, its rival the USSR, Great Britain, Germany and central Europe, and Japan". On the other hand, by 1973 Kissinger "identified five important regions, the United States, the USSR, China, Japan, and western Europe" (Kennedy 1987, 408), eliminating Great Britain as a separate power and adding China. Nixon used the same list in 1971 (Kennedy 1987, 413). Kennedy talks of a "multipolar distribution of global economic balances" by the 1980's, and shows indicators for the US, USSR, Japan, the EEC, and China. But we are never informed as to what kind of unit western Europe represents.

China is also something of a mystery. Clearly, the US and USSR are superpowers, yet Kennedy refers to China as "the poorest of the major Powers" (Kennedy 1987, 447), and talks of "China's emergence as a Great Power militarily" (Kennedy 1987, 449), although he refers to a set of "existing Great Powers" (Kennedy 1987, 450) that doesn't include China. On the other hand, China relates to "the other Powers" (Kennedy 1987, 457). Japan too is one of the "major Powers" (Kennedy 1987, 461). "It is only in the EEC that an organization and structure exists, at least *potentially*, for a fifth world power." (Kennedy 1987, 471) "In its *potential*, the EEC clearly has the size, the wealth, and the productive capacity of a Great Power" (Kennedy 1987, 472). Thus, instead of consensus holding for the twentieth century, there are some difficult problems of definition which many theorists have avoided by assuming some kind of scholarly agreement.

We have seen that there is no clear consensus on who is a Great Power and when, and that there are rather paltry efforts to link a set of criteria with the construction of the list of Great Powers. Some scholars attempt to enumerate the list of capabilities which are indicators of international political power; presumably, the Great Powers would have more power than other countries. Perhaps, armed with a solid list of capabilities, it would be possible to construct a list of Great Powers.

Criterion 2: Capabilities

A Great Power is presumed to enjoy certain advantages that most other states are denied. According to Waltz, for instance, "States are placed in the top rank because they excel in one way or another. Their rank depends on how they score on *all* of the following items: size of population and territory, resource endowment, economic capability, military strength, political stability and competence" (Waltz 1979, 131). For Martin Wight, "The power that makes a 'power' is composed of many elements. Its basic components are size of population, strategic position and geographical extent, and economic resources and industrial production. To these must be added less tangible elements like administrative and financial efficiency, education and technological skill, and above all moral cohesion" (Wight 1978, 26). These scholars simply list capabilities, much as they and others list Great Powers, without specifying theoretical reasons for doing so. In chapters 5 and 10, I will attempt to construct a theoretically-based definition of a Great Power.

The main problem that all of these theorists are trying to overcome is the problem of aggregation. Can we find one measure that combines all of the different capabilities of a state, and therefore reliably measure the relative position of each state in the international system? In a very similar way, economists have always tried to construct aggregate measures of capital and labor when discussing growth, but have been unsuccessful, as shall be shown later. Can capabilities be aggregated?

Singer's Capabilities

J. David Singer and his associates have attempted just such an indicator (Singer 1993). They have researched the total population, urban population, military expenditures, military personnel, energy consumption, and iron/steel production figures for all the countries of the world as far back as possible (see Figure 2). These six indicators are meant to represent demographic, military, and economic capabilities, which are assumed to be the three important categories for assessing national power. Each country's indicator as a percentage of the world total is then calculated; and the six indicators are then aggregated to give a single number.

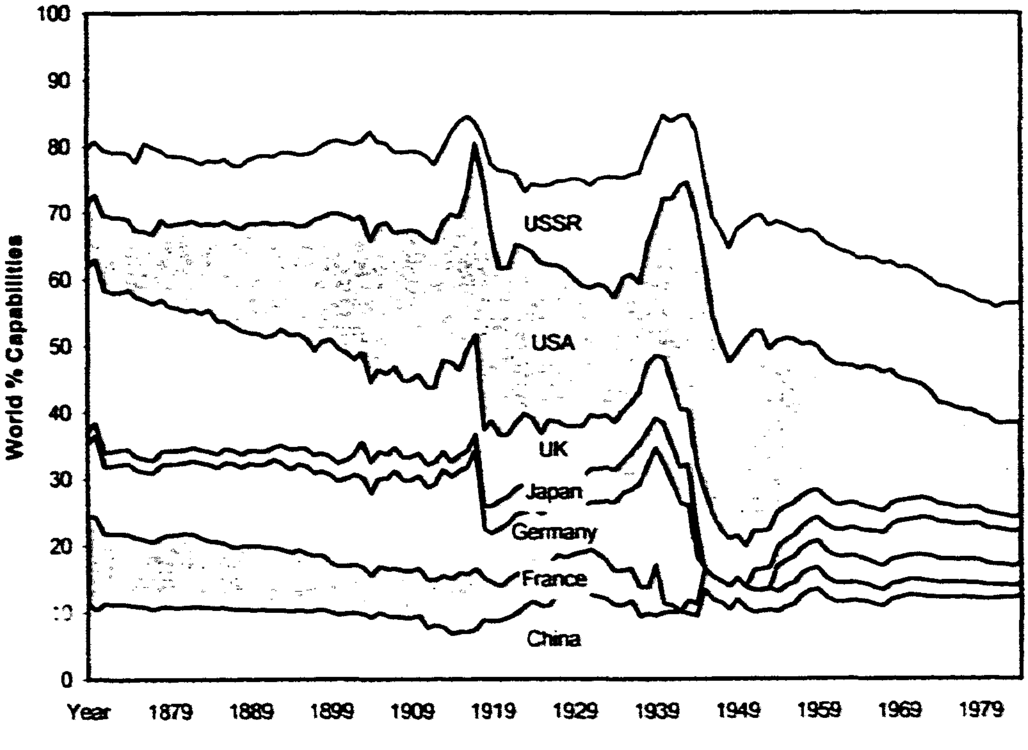


Fig. 2. Singer's national capabilities.

By comparing the great power chart and the national power chart, we can see that there are a great many inconsistencies. The US becomes a Great Power, according to Singer, in 1898: yet it has the 2nd highest aggregate capability in the world by 1880 (and in the 1860s). Japan becomes a Great Power (3 years before the US!) and continues to be one while it is the 6th most powerful nation; yet in the post-war period it becomes the 4th most powerful, and yet it is not a Great Power. One the other hand, France and Britain are Great Powers in the post-WWII era, even though Japan and Germany, which have more national aggregate power, are not! The predictive power of this model is suspect - the USSR has become more "powerful" than the US by about 1974, even though every post-mortem on its collapse paints a picture of a country that had been declining since the 1950s. It also seems doubtful that warlord-torn China is "twice" as powerful as Japan during the period when, in the 1930s, Japan was conquering China. By the 1980s, China is allegedly nearly as powerful as the US.

Part of the problem may be that population is overweighted; if a country has a large population, it may also have a large amount of military personnel, total population, urban population, and energy consumption. Another problem stems from aggregating different kinds of capabilities; military capabilities are notoriously dynamic (witness World War II), while economic capabilities are more important in long-term calculations. Energy consumption may indicate great waste, not efficient use. However, the Singer indicators have the great virtue, which Singer stresses, that relatively reliable figures do exist for them.

Organski's power capabilities

Organski attempts to bring the list of capabilities down to two, an economic and a political capability. In his book *World Politics*, he first examines six determinants of national power. He points out that geographical size does not correlate with power[9]. As for resources, as Organski points out, "The nation that can turn its raw materials into manufactured goods possesses even greater powers of reward. The great manufacturing nations have always been great powers" (Organski 1968, 139). This relationship is confirmed in the statistical appendix of this dissertation.

As in the case of geographic size and natural resources, the ranking of population does not correlate strongly with national power. The ten countries in the following table, from 2000, constitute 58% of world population:

Table 1. Population of Ten Largest Countries in 2000

Country	Population (000)	World %
China	1,277,558	21.1%
India	1,013,661	16.7%
United States	278,357	4.6%
Indonesia	212,108	3.5%
Brazil	170,116	2.8%
Pakistan	156,484	2.6%
Russian Federation	146,934	2.4%
Bangladesh	129,155	2.1%
Japan	126,714	2.1%
Nigeria	111,506	1.8%

Source: http://www.un.org/Depts/unsd/social/population.htm

Organski reserves his greatest enthusiasm for the economic and political determinants of power. Economic power, as he so eloquently explains, ultimately can be reduced to technological power, which is based on machinery:

> In a modern, industrial economy, each worker produces far more [than in a backward one], for he is part of an elaborate and efficient economic organization were tools, techniques, motivation and opportunity combine to make him productive. He finds placed at his disposal a vastly superior technology. Most important, he has the use of the machine. Compare the peasant with his horse-drawn plow, his scythe and flail with the modern farmer with his tractor and his combine. Compare the man who transported goods by team and wagon with the modern trucker. Or a scribe and a typist, a seamstress with a needle and one with a sewing machine, a mathematician with an abacus and one with an electronic brain. Unquestionably, the greatest boost to productivity has come with the machine. Aided by what is in fact an extension of himself, the modern worker in an industrial economy produces infinitely more than the worker of a nonindustrial economy could possibly produce, no matter how diligently he applied himself to his work. The modern worker produces far more than he requires for his own subsistence. He produces a surplus, and it is this surplus which contributes to a nation's power.(Organski 1968, 156)

This machinery-based power is set into motion by a self-reinforcing process:

> The greatest resource of the industrial nations and the greatest need of underdeveloped lands is capital, the wealth that is not used by consumers and can therefore be used to produce still further wealth. Without extensive capital, modern industry could not exist, for it is only by plowing large amounts of production back into the building of still further production facilities that great industries can be created. In the long run, it is as important to build steel plants as it is to produce the steel itself, and if a nation wishes to produce airplanes or bridges or electric lights, it must first produce the tools to make the tools to make the goods desired. What the economy of a nation will produce tomorrow depends in large part upon the capital investments made today. (Organski 1968, 163)

Thus, Organski highlights two critical ideas which will be greatly elaborated in Chapters 6 through 8 of this study: that technological progress in machinery leads to changes in national power, and that there is a positive feedback process at work in the economy, in which investment in capital yields more capital, that is at the heart of modern industrial economies.

Organski does not pursue these technological themes, however. Instead, he attempts to construct an index that will reflect technological prowess: "High per capita product accompanies high productivity per worker and can be used to give a rough idea of it. Per capita product, therefore, is the index we shall use for productivity" (Organski 196", 157). This is how productivity is usually defined in economic and development literature. However, as he points out, a list of the highest per capita countries includes several, such as Austria and the Scandinavian countries, which are not the most powerful. On the other hand, "population size is the most important determinant of national power. With it, a lack of other determinants can be overcome. Without it, great power status is impossible" (Organski 1968, 203-4). Therefore, one can multiply product per capita times population, which equals Gross National Product, or GNP (Organski 1968, 208-9), and arrive at a combined measure of economic power.

While economic resources are crucial to power, so is "the capability and more particularly the efficiency of the national government in utilizing these resources in pursuit of national goals...The single most important tool available to any national government for mobilizing its human and natural resources is the governmental bureaucracy" (Organski 1968, 170-2). In addition, "Control of the military bureaucracy is particularly important. A monopoly of the use of force must rest in the hands of any effective government" (Organski 1968, 172). Thus, bureaucracy, the machinery of government, and the monopoly of force in a territory, are identified as the two most critical aspects of the state. These ideas will be pursued further in chapter 6 of this study.

Without quite saying so, Organski uses the reintegration of China by the Communist Party in 1949 as his most important case study of political power:

> This case amounts almost to a natural experiment. Geography, resources, population size, and economic development remained constant or nearly so. Only one major determinant of power had changed: there had been a massive modernization of the political system, and for the first time in centuries the central government of China had the capacity to reach and to mobilize the Chinese masses. (Organski 1968, 175)

In Organski and Kugler, an attempt is made to construct a quantitative index of political development, using the ability to extract resources as the main indicator[10]. One indicator would then be tax revenue, or a measure of tax revenue with certain qualifiers which they call "tax effort" (Organski and Kugler 1980, 77). This measure does not apply to developed countries because the US does not extract the most resources.[11]

Organski and Kugler have proposed one variable to use as an index, tax effort, but then when it does not conform to their predictions, they eliminate the variable. Instead, they imply the usefulness of another variable, which by itself is very significant: the level of democracy. The tax effort is eliminated as an important variable because peoples in developed countries have the right to decide, and since they might not decide to incur a large tax burden, the rate of taxation cannot be used as an indicator of political development. Therefore, it would seem that "the right to decide" is more important than the tax effort itself.

Organski and Kugler argue that using GNP as an indicator yields a similar ranking of relative position as the Singer national capability index. However, there is one large question to be answered: Whose estimate of GNP should be used?

One might think that, as Organski and Kugler state, "the data available [for GNP] are probably more reliable for that measure than the several series gathered to construct the Singer index" (Organski and Kugler 1980, 38). The problem is that there are several indices of GNP. Many economists have decided that it is now possible to change the official GNP numbers to better reflect the "reality" of how the various nations actually perform economically; they wish to compare "purchasing power parity" (PPP), not GNP at official exchange rates. Figure 3 shows GNP as calculated for PPP by Angus Maddison (1995), starting from 1870, and figure 5 shows Maddison's calculations from 1960 to 1989. A previous study by Angus Maddison was used as the base for the Organski and Kugler calculations. Figure 4 shows the Penn World Tables, revision 5.6, (Penn World Tables 1991), which are PPP data developed by economists based at the University of Pennsylvania and used for statistical explorations by many economists, also from 1960 to 1989. There are many differences between the Maddison and Penn World Tables, and between Maddison and the Singer aggregate data.

Let us compare the Penn World Tables, Maddison, and UN data at official exchange rates (from the 1989 Statistical Yearbook), for percentage of world GNP, and ranking, from 1960 to 1989, for seven countries:

Table 2: Comparison of Rankings of Selected Countries

	Maddison		Penn		UN 1989	
	%	Ranking	%	Ranking	%	Ranking
China	7.4 to 11.8	3 to 2	5.9 to 7.1	3 to 4	2.1	7
France	6 to 3.9	5 to 6	4.1 to 3.6	7 to 6	4.7	5
Germany	5.9 to 4.5	4 to 5	5.7 to 4	4 to 5	5.8	4
Japan	4.6 to 8.7	7 to 3	4.3 to 7.9	6 to 3	14.1	2
USSR	10.7 to 8.1	2 to 4	8 to 10.4	2 to 2	7.4	3
UK	5.7 to 3.7	6 to 7	5.6 to 3.6	6 to 7	4.1	6
USA	25.6 to 21.6	1 to 1	27.8 to 21	1 to 1	25.5	1

We see that for the USA and UK, the change in rankings (rise or decline) and percentages are fairly similar. The biggest discrepancies are for China and the USSR; for Maddison, China is rising relatively in this period and the USSR declining, while the reverse is evident for the Penn calculations. This should not be too surprising, as these countries are notoriously difficult to estimate. Germany, Japan, and France are fairly similar.

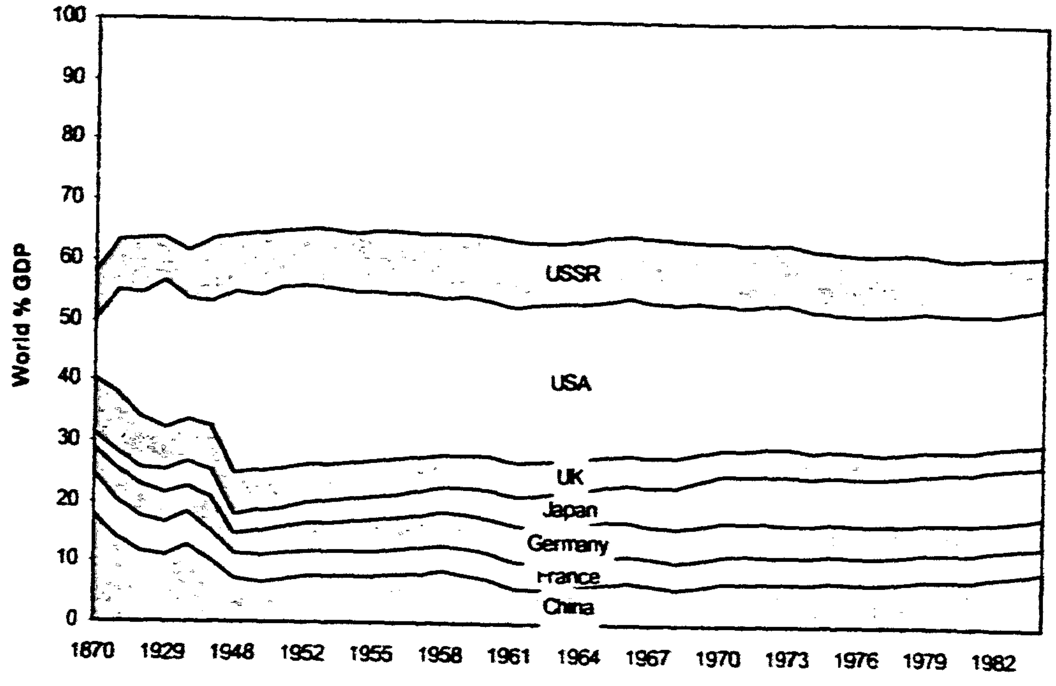
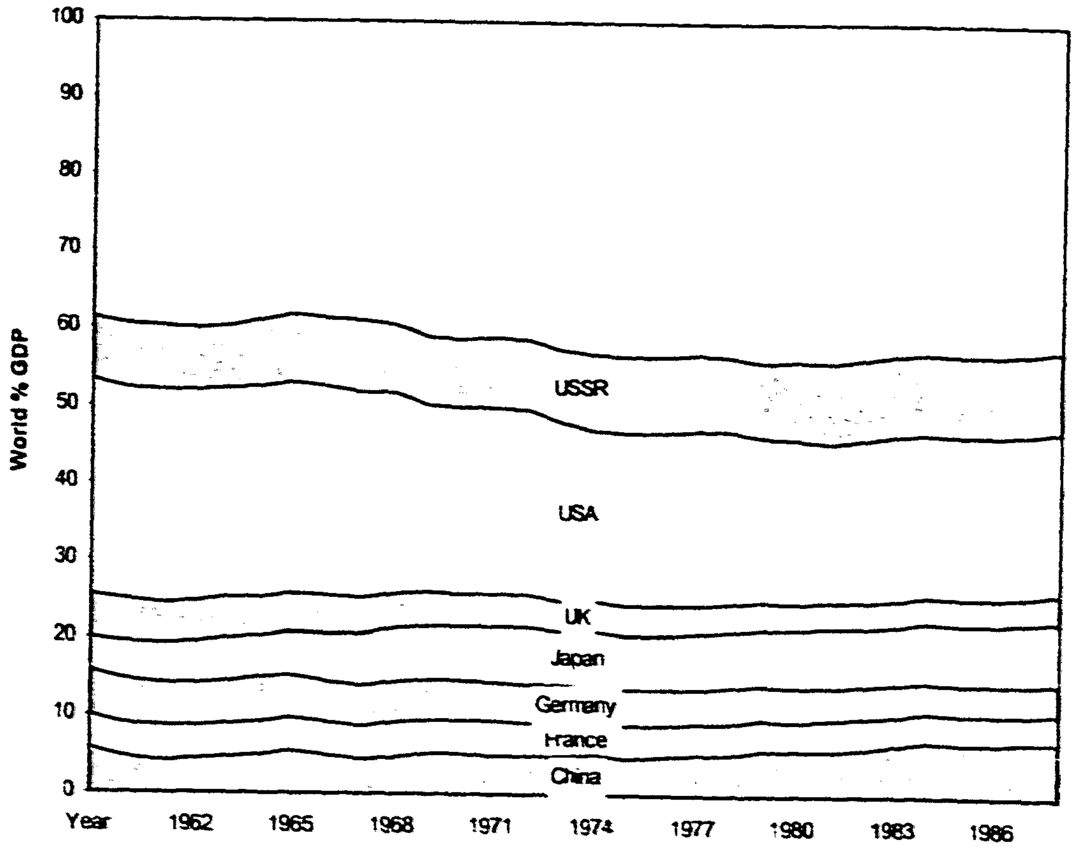


Figure 3. Madison's PPP for 1870 to 1984.



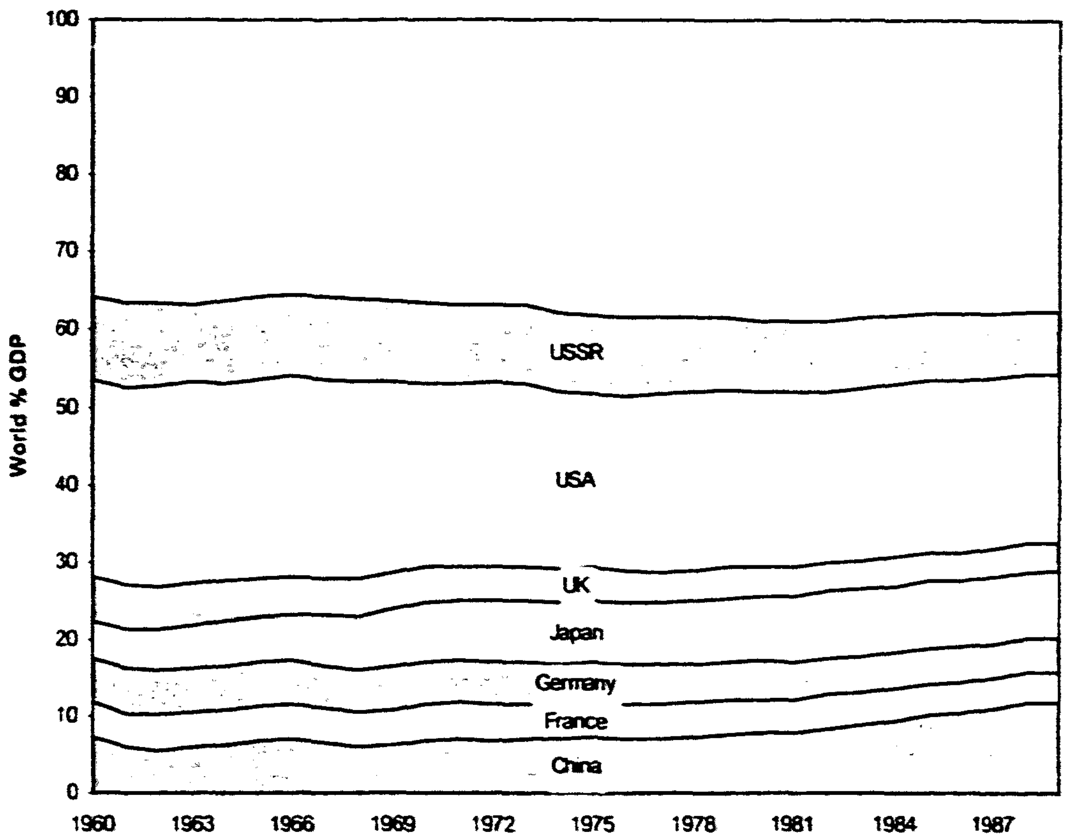


Figure 5. Maddison estimates of PPP from 1960 to 1989.

Coming to an agreement on GNP can be difficult. The problem with the UN data is that the Chinese and Soviet regimes reported not GNP, but Net Material Product (NMP), which mainly includes what we would call the industrial sector. The governmental and service sectors are left out of NMP, requiring Western scholars to make adjustments. But the Purchasing Power Parity (PPP) numbers, which Maddison and the Penn World Tables teams used, also have grave comparative problems.

The major justification for using PPP is that comparing national economies by using their exchange rates is misleading (Kravis, Heston and Summers, 1978). When a country devalues its currency by 25%, its GNP does not instantaneously decrease by 25%. When an apple costs $1 in Japan, it means that the consumer in Japan is poorer than indicated by his or her paycheck, since more of the paycheck must be spent buying an apple in Japan than in the U.S. In particular, problems of comparing national economies, so it is claimed, loom very large when goods and services are not traded regularly. How does one compare the cost of a haircut in Turkey vs. a haircut in the U.S.? Haircuts, and many other services, including most conspicuously governmental services, are not traded. It is claimed that, particularly in less developed countries, their GNP is underestimated because of the low cost of their services.

As Organski, Kennedy, and many other scholars have argued, however, the industrial sector is the most important part of the economy when measuring national power. Therefore, this study will concentrate on manufactured goods, which are, for the most part, tradable. While exchange rates do bias some comparisons, it has been shown that exchange rates generally tend to converge toward the PPP values, in the long-run (Rogoff 1996); this studied is concerned with the long-run.

Perhaps an even more troubling aspect to the process of calculating PPP numbers is the opaqueness of the data. It is very hard to find out exactly how these "objective" values were arrived at. One suspects that there are many conceptual mistakes made. For instance, Maddison points out that in the case of a different team of PPP researchers who were calculating educational costs, "for several poor countries they assume higher productivity than in developed countries because the classes are bigger" (Maddison 1983, 34). How many more miscalculations such as this enter into these data?

It can be very difficult to equate different products of different countries. When simple commodities are compared – apples or cheese, for instance – one can assume a certain consistency of product. But it is particularly difficult to assume the equality of different pieces of machinery. As an OECD report on their PPP study points out, "It is extremely important that the values identified and the prices selected should relate to exactly the same items if both the resulting parities at the basic heading level and the overall index are to be accurate and meaningful" (OECD 1985, 39).

The report goes on to discuss the great difficulties of calculating machinery comparisons; in some cases, they needed to match by using physical characteristics OECD 1985, 57). In Japan, because of various problems, "certain product comparisons therefore had to be rejected" (OECD 1985, 58). Should a group of economists employed by the OECD be trusted to pass judgment on the relative merits of various pieces of complicated machinery?

Data on production machinery are hard enough to obtain without complicating the issue by waiting for an international agency to provide statistics which can not be independently verified and are problematic in any case. I have therefore chosen to concentrate my comparison figures on official, exchange-rate values. Considering the faith put in the price-setting capabilities of the marketplace, it is somewhat surprising that economists spend so much energy trying to second-guess its conclusions, especially when it comes to heavily traded goods.

Since the communist countries only reported industrial totals, and the manufacturing sector is generally more comparable across countries than governmental and other services, this study will use, not GNP, but the manufacturing sectors of various countries for broad measures of comparison. The statistical appendix for this dissertation uses various categories of machinery production, using official exchange rates, for comparison.

Organski has raised several very important points. The capability to produce machinery and accumulate capital, and the importance of the bureaucracy and monopoly of violence over a territory, will be used later in this study as part of an attempt to define economic and political power. However, the actual measures that Organski and Kugler arrive at to build their indexes need refinement.

Morgenthau's capabilities

Hans Morgenthau (1973) used a list of capabilities that are similar to Organski's, although he is not as explicit about his ordering, and not as quantitative. On the one hand, the quality of government is deemed to be important[12]; by "quality of government", Morgenthau seems to have in mind the distribution of domestic political power, because democracies receive greater support from the population than dictatorships[13]. He is also very concerned about the quality of national diplomacy[14].

On the other hand, Morgenthau is very aware of the material aspects of power:

> Since victory in modern war depends upon the number and quality of highways, railroads, trucks, ships, airplanes, tanks and equipment and weapons of all kinds, from mosquito nets and automatic rifles to oxygen masks and guided missiles, the competition among nations for power transforms itself

> largely into competition for the production of bigger, better, and more implements of war. The quality and productive capacity of the industrial plant, the know-how of the working man, the skill of the engineer, the inventive genius of the scientist, the managerial organization – all these are factors upon which the industrial capacity of a nation and, hence, its power depend.
>
> Thus it is inevitable that the leading industrial nations should be identified with the great powers, and a change in industrial rank, for better or for worse, should be accompanied or followed by a corresponding change in the hierarchy of power. (124-5)
>
> What distinguishes the superpowers from all other nations, aside from their ability to wage all-out nuclear war and absorb a less than all-out nuclear attack, is their virtual industrial self-sufficiency and their technological capacity to stay abreast of the other nations... the fate of nations and of civilizations has often been determined by a differential in the technology of warfare for which the inferior side was unable to compensate in other ways. (126)

Thus, Morgenthau forcefully argues for the proposition that industrial power leads to military power, and that military power is the basis of national power. Chapters 5 through 10 will construct hypotheses along similar lines of argument.

Morgenthau also considers the importance of geography, military leadership[15] and population[16]. But like Organski, he seems to have two main themes: a technological, or economic, capability, and a social, or political, capability, are the most important bases of national power. Morgenthau concept of "national morale" is similar to Organski's "political development", although Morgenthau lays greater stress on diplomacy.

Conclusion

In conclusion, it seems that scholars are not in agreement concerning either the specifics of which country was a Great Power when, or the more general criteria for the capabilities that characterize national power. Many important insights have been explored by these writers, and in particular it seems that two broad types of capabilities are identified. On the one hand, technological or economic aspects of national power have great explanatory potential. These are relatively easy to measure, at least in terms of money value. On the other hand, there are a set of political factors, such as the bureaucracy, democracy or lack of it, and military control of a territory, which are critical but less amenable to quantitative measurement. Chapter five of this study will elaborate on these two central aspects of national power, and will combine them with a discussion of international systems theory in an attempt to construct a theoretically consistent and empirically meaningful definition of Great Power.

NOTES

[1] "The distinction between center and periphery is indicated by alliances among the relevant actors ...[since]...the behavior of uninvolved nations cannot be expected to follow the rules of the power-distribution models and, so, is not predictable...". The list of nations which have been both central and peripheral basically encompasses all of the countries and time periods all authors have posited. However, "contenders alone are strong enough to determine the direction the politics of the world order are to take" (Organski and Kugler 1980, 43). This definition is closer to my definition than their others; but more importantly, their statistical tests are significant only for contenders, not for all major powers (Organski and Kugler 1980, 51). Thus, the contender class seems the most significant.

[2] "The status of France as a member of the Great Power system from its inception in 1495 until the German occupation in 1940 is unquestioned","There is no doubt that England's Great Power status continued until the mid-twentieth century","There is no question regarding the continuation of [Russia's] Great Power status until the present day", "The continuation of Great Power status for Prussia and then Germany is not in doubt until Hitler's defeat in 1945", and "there is no doubt regarding [the United States'] Great Power rank throughout the twentieth century"(Levy 1983, 29, 30, 40, 40).

[3] "Countries with virtually identical industrial output might nonetheless merit substantially different ratings in terms of Great Power effectiveness, because of such factors as the internal cohesion of the society in question, its ability to mobilize resources

for state action, its geopolitical position, and its diplomatic capacities" (Kennedy 1987, 202).

[4] For instance, "Industrial productivity, with science and technology, became an ever more vital component of national strength. Alterations in the international shares of manufacturing production were reflected in the changing international shares of military power and diplomatic influence"(Kennedy 1987, 197).

[5] "It was not until 1892 that the European Great Powers upgraded the rank of their diplomatic representatives to Washington from minister to ambassador – the mark of a first-division nation"... By 1914, "the United States had definitely become a Great Power. But it was not part of the Great Power system" (Kennedy 1987, 194, 248).

[6] He clearly has consistent misgivings about considering Italy a Great Power, whether in 1913 when it "marginally entered the listings of Great Powers", or before World War II when "given the almost irredeemable weaknesses which afflicted the Italian economy under fascism, it would be rash to suggest that it could ever have won a war against another proper Great Power" (Kennedy 1987, 205, 295). According to his definition then, Italy was not a Great Power.

[7] Referring to 1905, Kennedy describes Russia as "unexpectedly reduced to a second-class power for some years to come", and considering that it was eventually defeated by Germany, one wonders whether it was really a Great Power in World War I at all, at least according to Kennedy's definition. However, he says that WWI weakened Russia "more than any of the other Great Powers" (Kennedy 1987, 252, 321).

[8] . He quotes the opinion that "the heart of the mater...was simply that Austria-Hungary was trying to act the part of a great power with the resources of a second-rank one". Even more damning, according to his criterion, is that "if the mark of a Great Power is a country which is willing and able to take on any other, then France (like Austria-Hungary) had slipped to a lower position" by 1914. In discussing the alliance system of World War I, he comes to the conclusion that neither Italy, Austria-Hungary, nor France could have kept going at a certain point without the help of their allies. France seems problematic even before World War II. "Japan had not only become much stronger economically than Italy, but had also overtaken France in all of the indices of manufacturing and industrial production". Yet he refers to France as a Great Power in the 1930's, although clearly France was not "a state capable of holding its own against any other nation", since it was quickly overcome by Germany (Kennedy 1987, 218, 224, 299, 310).

[9] Organski provides a list of the largest nations, circa 1966, in this order: USSR, Canada, China, US, Brazil, Australia, India, Argentina, Sudan and Algeria (Organski 1968, 128). As he points out, this list does not correlate well with a ranking of national power. Natural barriers and size may help in national defense (Organski 1968, 134); one thinks of Hitler and Napoleon exhausting their resources on the expanses of Russia, or the

advantages for defense accruing to the US, Japan, and UK as a result of their "island" status.

[10] "Political development means capacity, and capacity is dependent on political performance in two areas: penetration of the national society by central governmental elites to control as many subjects/citizens as possible within the political jurisdiction of the state; and the capability of the government to extract resources from its society" (Organski and Kugler 1980, 72).

[11] "One example will clarify the point. Sweden taxes far more than the United States. But one cannot infer from this that the Swedish political system is more effective than that of the United States" (Organski and Kugler 1980, 81), because Americans might want fewer services than Swedes.

[12] "National character and , above all, national morale and the quality of government, especially in the conduct of foreign affairs, are the most important, but also the most elusive, components of national power" (Morgenthau 1973, 224).

[13] "National morale is the degree of determination with which a nation supports the foreign policies of its government in peace or war"(Morgenthau 1973, 140), and "the adage that free men fight better than slaves can be amplified into the proposition that nations well governed are likely to have a higher national morale than nations poorly governed"(Morgenthau 1973, 146).

[14] "Of all the factors that make for the power of a nation, the most important, however unstable, is the quality of diplomacy", which seems to be the active element of a nation's power: "All the other factors that determine national power are, as it were, the raw material out of which the power of a nation is fashioned. The quality of a nation's diplomacy combines those different factors into an integrated whole" (Morgenthau 1973, 146).

[15] "Aside from the timely use of technological innovations, the quality of military leadership has always exerted a decisive influence upon national power" (Morgenthau 1973, 128).

[16] "No country can remain or become a first-rate power which does not belong to the more populous nations of the earth" (Morgenthau 1973, 130).

CHAPTER 2

THEORIES OF RISE AND FALL, PART 1:

ROBERT GILPIN AND DOUGLASS NORTH

Great Powers are the most important states. Any understanding of change in the international political system must be based on an understanding of the change in relative position among the Great Powers. If Great Powers to a considerable extent determine the functioning of the international system, then any change in the make-up of those Great Powers may lead to long-term and far-reaching change in the workings of the international system. Therefore it is important to understand how and why Great Powers rise and decline.

However, most theories of international relations are silent about the causes of rise and decline. This lacuna can create difficulties when the rankings of Great Powers change. For instance, when the Cold War ended, neorealist theory itself was questioned. Because neorealists had not expounded a theory of change, and had instead concentrated on stability and equilibrium as dominant tendencies, international relations scholars became skeptical when change occurred, as it always does.

As Morgenthau shows, however, realists have generally been very aware of the traumatic consequences that have followed from rise and decline. What theories are available to explain rise and decline of Great Powers, and can those theories be used to more adequately understand the long-term processes of international political change?

Many theories have been put forward to explain rise and decline. The most important post-war theories have centered around neo-classical economic theory, partly because any explanation of change in power must come to terms with change in economic performance, and partly because many scholars have considered the academic discipline of economics to be "scientific". This seems to be the attitude of Robert Gilpin, who prefers to quote neoclassical economists, even on political subjects. Douglass North has had a great influence on political scientists, even though he is an economist. Finally, neoclassical growth theorists, and most importantly Robert Solow, are considered to be our greatest experts on the causes of economic growth. These three theorists will therefore be the focus of this review of theories of rise and decline.

Just as international relations theorists generally identify two sources of national power, one technological and the other political, so the neoclassical theorists rely on a combination of social and technological causes to explain rise and decline.

All historians, economists, and political scientists with an interest in these issues agree that technological change is an important part of the explanation of rise and decline. Most authors either have great difficulty explaining progress in technology, or simply assume that technological change is exogenous to their model (that is, that it is a force operating from outside that is not explainable from within the model, i.e., endogenously). Neoclassical growth theory, for instance, treats technology as exogenous.

In the neoclassical approaches, the concept of diminishing returns takes the place of technological change as an explanatory variable for rise and decline. Diminishing returns in production means that, given more than one input to production, if only one input is increasing and the others are staying the same, the total output will increase at a decreasing rate. David Ricardo originally developed the idea; he claimed that if one input of production, land, was fixed, then if one kept adding a variable factor of production, labor, eventually each additional unit of labor added would yield less and less increase in output. According to John Stuart Mill, in agriculture "every increase of produce is obtained by a more than proportional increase in the application of labour to the land. This general law of agricultural industry is the most important proposition in political economy" (Mill 1948, 177).

However, if one continues to add both more labor *and* more land, diminishing returns will not necessarily result. Sometimes authors misunderstand this point, and refer to diminishing returns of one factor of production in isolation. The economic meaning of diminishing returns applies to more than one factor, with all but one held constant.

One might be able to explain decline with this approach, since output per unit of input is decreasing. But it still leaves the problem of rise without an answer, since one can't explain an increase by reference to a process in which decrease is dominant. Gilpin and neoclassical growth theory both use the concept of diminishing returns, and both have difficulties explaining rise, or growth.

The social variable in neoclassical theories is generally discussed under the general category of "property rights" [1]. Property rights indicate who has the legal right to certain actions with certain kinds of property. An individual (or set of individuals) has the right to undertake a certain set of actions vis-à-vis a set of objects, which may be physical or intellectual. Neoclassical authors generally feel that the ideal society is one in which every individual (or possibly corporation) has total control over a set of objects; in other words, property is completely privatized.

When all objects are under some person's or corporation's absolute control, then a second social variable can be used to explain rise and decline: exchange and trade. If everyone has control over their own objects, then those objects can be traded. As Gilpin puts it when explaining the neoclassical world view, "it is more blessed to consume than to produce" (Gilpin 1981,129). Exchange and property rights, which lead to consumption, are more important variables in the neoclassical explanations than is technological change, which has greater effects on production.

Robert Gilpin

The most comprehensive modern treatment of the question of rise and decline has been articulated by Robert Gilpin in *War and Change in the Global System*. Although almost every possible cause of change is dealt with in the book, his argument is based most fundamentally on the ideas of property rights and diminishing returns.

Basing his argument on the work of Douglass C. North, Gilpin argues that some countries rise because their property rights are more efficient than others . For Gilpin, "Property rights and the rules embodying them are the basic means for ordering domestic social, economic, and political affairs. The definition and distribution of such property rights reflect the powers and interests of the dominant members of society." (Gilpin 1981, 37). We might therefore diagram his chain of causation thus: dominant members' power → property rights → social order. The power of the dominant members is a given. Gilpin never explains why different societies are characterized by different internal distributions of power, or why certain kinds of dominant members might behave differently.

The last step in the chain, social order, is important because "the most critical factor in the growth of power of a society is the effect of the political and economic order on the behavior of individuals and groups" (Gilpin 1981,103); it is group and individual behavior which is the ultimate cause of rise and decline (Gilpin 1981, 103). Property rights lead to this social organization (Gilpin 1981, 104), which leads to behavior. So the full expression of Gilpin's domestic causal sequence now becomes: dominant members' power → property rights → social order → behavior → national power. This sequence will be referred to as Gilpin's causal sequence of power.

The state is also defined in terms of property rights (Gilpin 1981, 17). Each state, as a result of its own causal sequence of power, is characterized by a certain level of power relative to other states in the international system. The Great Powers "establish and enforce the basic rules and rights that influence their own behavior and that of the lesser states in the system" (Gilpin 1981, 30), because they are at the peak of this international hierarchy of power. According to Gilpin's causal sequence of power, then, Great Powers are those dominant members that set the property rights and social order of the system; they are therefore at the base of the entire sequence[2]. Gilpin's international causal sequence may be diagrammed as the following: Great Powers → property rights → social order → behavior → degree of stability (Gilpin 1981, 42–43).

How does a state rise? Gilpin's main answer seems to be that it is the constitution which is constructed at the establishment of a state that leads to a trajectory of rise and, eventually, decline. His most important example, as expounded by Polybius, focuses on the rise of Rome. Rome was a republic and had a citizen (nonmercenary) army, which gave it a great advantage against its neighbors; Gilpin notes that Machiavelli, as well as Montesqieu, also praised this arrangement. But the constitution of a state is not the same thing as its property rights. The constitution determines political structure, which then has important consequences for property rights.

Gilpin is therefore advancing two lines of argument on the causes of the rise of a state(in his section on "Domestic Sources of Change" [Gilpin 1981,96-105]). We might diagram his "constitution"-based argument as follows: constitution → social ordering → behavior → social power. Thus, the constitution has supplanted the previous position of property rights in his causal sequence of rise. Since "dominant members' power" is also at the base of his "property rights" version of the causal sequence, and the constitution specifies control of the state, both sequences give central importance to the distribution of power within the state.

Gilpin fully acknowledges the importance of the distribution of power in the international sphere: "The distribution of capabilities and the ways in which this distribution of capabilities changes over time are perhaps the most significant factors underlying the process of international political change" (Gilpin 1981,86). In addition, while his definition of governance in the international system seems to center around rules and rights, "The distribution of power...determines who governs the international system and whose interests are principally promoted by the functioning of the system" (Gilpin 1981,29). In the international system, at least according to Gilpin's logic, distribution of power is a more important cause of change than property rights.

For Gilpin, the only point at which change takes place in the domestic sphere is at the beginning of the causal sequences, that is, either in the constitution or the composition of the dominant members. Thus, there is no theory of domestic change *after* the establishment of the state. He quotes Montesqieu: "At the birth of societies, the leaders of republics create the institutions; thereafter, it is the institutions that form the leaders of the republics" (Gilpin 1981,101). In other words, once a society has been institutionally set in place, it will move in a certain trajectory until a cataclysm leads to a rebirth.

This analysis is actually quite similar to that of Arnold Toynbee, as elaborated in his "Study of History" (Toynbee 1947, particularly 230-43). For Toynbee, the great works of advancement and progress are undertaken by the "creative minorities" of a civilization, who inspire the "proletariat" (that is, the nondominant majority) to take the society in a different direction. The "creative minority", ensconced in a society which is becoming more powerful and wealthier through time, eventually becomes a "dominant minority", that is, basically parasitic. The civilization then declines, because the proletariat is no longer willing to follow the leaders, but only obeys them out of fear. Eventually, a piece of the proletariat may break away, forming a new society and a new creative minority. Thus in Toynbee's conception, as for Karl Marx, a struggle for power among classes may lead to a rebirth of a civilization.

For Gilpin, "tradition and vested interests inhibit further reordering and reform of the society"(Gilpin 1981, 103). Gilpin doesn't even acknowledge the possibility that there may be revolutionary forces which break away from the old society, as does Toynbee. Gilpin enumerates various reasons that the progressive leadership becomes regressive. The republican virtues may turn into tyrannical vices, the militaristic élan might transform into pleasure-seeking sloth, or the hardy entrepreneur might become the frivolous rentier (Gilpin 1981, 153-154). This cycle might be termed as a "rise-leads-to-fall" process.

Many scholars have postulated a "rise-leads-to-fall" sequence. There are two groups of theories. The first may be called the "commercial-zenith" theory. Historians such as Charles Kindleberger (1996), Janet Abu-Lughod (1989), and Carroll Quigley (1961) have written richly descriptive historical essays on the rise and decline of various civilizations and states. While no theoretical framework is proposed in these works, the general theme is that competence in production leads the society to become rich, at which point, when the civilization is at its zenith, the resources of the society move into commercial, financial, and luxury ventures. Quigley explicitly notes that the surplus of the society moves into less productive outlets (Quigley 1961, 139), while Kindleberger and Abu-Lugod tend simply to describe the decline from commercial zenith to weaker power.

The second group of scholars can be described as "long-cycle" theorists. These writers believe that history, at least since 1500, can be characterized as being dominated by a "hegemon" during its cycle of rise and decline, which lasts for approximately 100 years. This literature is filled with statistical analyses, even though economic data before the Industrial Revolution, or even the 20th century, is notoriously unreliable. The works of these scholars are also usually focused on the problem of describing the alleged long cycles, instead of analyzing why the hegemon rose or fell. Joshua Goldstein (1988) makes probably the best attempt to construct a theory of rise and decline: "The heart of the theory…is the two-way causality between war and production – a dialectical movement in which economic growth generates war and is disrupted by it" (Goldstein 1988, 260). Gilpin's analysis is much more sophisticated, and takes Goldstein's argument into account. Goldstein does not explain how growth takes place.

Modelski and Thompson (1996) also propose a major theory of long cycles, but they rely on W.W. Rostow's theory that a leading sector somehow pulls the rest of the economy into a "takeoff" into growth. While this theory was widely discussed in the 1960s, it is no longer taken seriously by economic historians, because of the difficulty of empirically identifying the takeoff and the leading sector.

The biggest problem with the long cycle theories, however, is that there is no long cycle. When Kondratieff originally coined the term "long wave" to characterize economic history, he was referring to price levels. Rise and decline is a process of variation in output, not prices. Perhaps the fallacy of the argument can be best summed up in a graph presented by Fernand Braudel (1992 [1979], 81). Braudel shows the Kondratieff price cycles from 1710 to 1950, superimposed on a production curve in the same time period. The production curve, with minor variations, is rising the entire period. Braudel simply writes, "note its discordance with the price curve".

Gilpin's version of "rise-leads-to-fall" cycle is to argue that, as the society grows wealthier, consumption and military needs take larger and larger pieces of the economic pie of the state. "As a consequence, the efficiency and productivity of the productive sector of the economy on which all else rests will decline"(Gilpin 1981,158). In terms of Organski's discussion of economic power, one might say that the capital which leads to more capital is allowed to deteriorate, or the society is "eating its own seed corn", as the common expression puts it.

According to Gilpin's (and Toynbee's) scenario, then, the rise of a Great Power would consist of the following sequence: at the beginning, a society is organized or reorganized, at which point a leader or group of leaders "orders" the society in accordance with a certain set of property rights and a different political structure, as embodied in a constitution; after the beginning, this social "trajectory" has been set, and the trajectory will not change because of a certain calcification process (Mancur Olson, in *The Rise and Decline of Nations* (1982), calls this a "sclerotic" situation). Finally, the fortunes of the society will depend on how well it is ordered vis-à-vis the trajectories of all of the other societies within the international system[3].

This "trajectory" is not a straight, upward-sloping line, leading to greater power. Instead, according to Gilpin, diminishing returns eventually set in, resulting in a falling trajectory:

> Every society in every age is governed by the law of diminishing returns. The society can grow and evolve in wealth and power within the existing social and political framework only to the point at which it begins to encounter diminishing returns…these fetters must be removed through political-institutional change and especially, although not necessarily, through territorial or economic expansion. (Gilpin 1981, 80)

Since the most important part of the "social and political framework" for Gilpin is the set of property rights that the state has established, then according to his logic, the fetters to be removed are those of inadequate property rights. Altering property rights becomes difficult, because the power of the dominant groups enables them to specify property rights, and such power does not change easily. In fact, there is no mechanism in his theory for an internal reordering of power to occur.

At the heart of Gilpin's explanation of rise and decline, then, is a combination of a change in property rights and the process of diminishing returns. A particular set of property rights starts a society along a particular trajectory; the society eventually experiences diminishing returns because one set of "inputs" to the production of power, property rights, remains fixed, while the other main "inputs", the labor, land, and capital of the society, increases.

For descriptive purposes, we could use the following diagram:

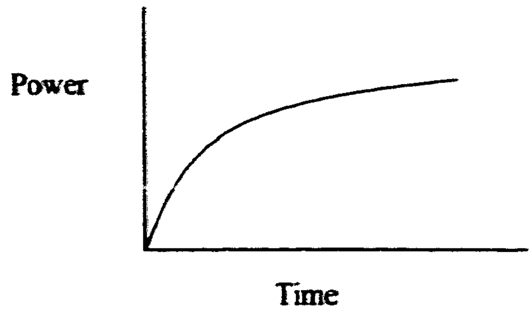


Figure 6. Diminishing returns to investment in power.

Here we see a case of diminishing returns. While at first power is increasing at an increasing rate, at a certain point in time the increase becomes smaller the longer we look at the "curve of power"; the returns to investment are decreasing (see Gilpin 1981, 78-80).

For Gilpin, rise occurs as a result of the establishment of a set of property rights, and decline takes place because of the phenomenon of diminishing returns. The three main problems with this approach are contained within his own work: the distribution of power, the phenomenon of increasing returns, and the role of technological change.

First, the distribution of power within a state is treated as a given, as a phenomenon which does not need to be explained. Yet the groups that hold power, and the ways in which that power is distributed among all members of society, has a controlling effect on the specification of the property rights which Gilpin holds to be of central importance.

The second factor that Gilpin treats as secondary is the phenomenon of the increasing returns, or positive feedback, of power. Power often leads to more power: "The growth of power of a state and its expansion tend to reinforce one another, as expansion increases the economic surplus and resources available to the expanding state"(Gilpin 1981, 146). This is a process of positive feedback, or increasing returns; the greater presence of an element that occurs in a system, the greater will be the possibility that even more of such an element will become present. Any positive feedback situation may run out of control, as, for example, during an explosion. Indeed, if one surveys the historical record, there have been many "explosions" of one state, or set of states, that have swept away all opponents. One can think of Napoleon, the Mongols, or the European conquest of much of the world as examples of positive feedback. Of course, all explosions die out because of limiting factors; if political explosions didn't stop, "the logic of this situation would culminate in a universal political empire" (Gilpin 1981, 146).

However, Gilpin does not put the phenomenon of positive feedback at the center of his analysis. If he did, the "trajectory" that is established at the beginning of a state might have a nonlinear, upward slope. Instead, when *diminishing* returns are the central theoretical feature, the state can only go *downhill* from its beginning position.

Because of this lack of interest in the forces of positive feedback, when Gilpin seeks to explain the limits to expansion, he gives short shrift to the concept of the balance of power and instead accentuates the internal problems of expansion. Balance of power is a concept which involves the coaction of several actors. As a state becomes more and more threatening, more and more states cooperate to block the increase of power of the aggressive state. Power is balanced in the international system in order to stop the process of positive feedback which results from continual, successful conquest.

Instead, Gilpin concentrates on factors which are similar to diminishing returns. First, he discusses the case of "loss-of-gradient", that is, the diminishing returns of trying to control a greater and greater space (Gilpin 1981, 146, but mainly 56-59). Second, he is concerned with what might be called diminishing returns to control (Gilpin 1981, 147-152). At some point, "increasing scale tends to stimulate centrifugal forces and fragmentation on the part of groups that believe they can maximize their own gains by breaking off" (Gilpin 1981, 152). The onset of diminishing returns tends to be an internal process; by ignoring positive feedback, he ignores the constraining effect of other states.

The third factor that is underemphasized by Gilpin is the role of technology. It has always seemed to economists that technological change is inherently outside of their field. Technology is therefore treated as a given, as is the distribution of power. But the argument of the primacy of diminishing returns in production is actually a technical argument that the single most important characteristic of production is the characteristic that output will decrease if one factor of production is fixed while another is increasing. Most of Gilpin's historical examples took place before the Industrial Revolution, but diminishing returns is not a fruitful starting point from which to understand the technological change of the last two centuries.

There has been an exponential increase in production in the last two centuries, which has totally outpaced population growth, at least in the industrialized countries. If diminishing returns are primary, why has growth of output been spectacular? If anything, we should be looking for a basic aspect of production which leads to a positive feedback, an increasing returns process, not a diminishing returns process.

Gilpin acknowledges some of these points. He states, "In the modern era…the law of diminishing returns has lost much of its power…It was, of course, this revolutionary development of technological advances that gave us the phenomenon of sustained economic growth and in turn created the modern era of affluent industrial societies" (Gilpin 1981, 71). But neither will he let go of the centrality of diminishing returns: "In the absence of new spurts of innovation or a borrowing of technology from abroad, the growth of the wealth and power of a society begins to slow…thus the modern industrial economy ultimately may not be any better at escaping the law of diminishing returns than its preindustrial predecessors" (Gilpin 1981, 159-160). The infatuation with the idea of diminishing returns leads neoclassical authors to assume that diminishing returns are more basic than increasing returns in the economy (see also statements in Gilpin 1981, 54, 79-82, 123, 159).

In fact, Gilpin offers another theory concerning rise and fall, which contradicts the precedence he gives to diminishing returns and property rights: "The diffusion of military and economic technology from more advanced societies to less advanced societies is a key element in the international redistribution of power" (Gilpin 1981, 177). However, "whether diffusion takes place depends on the recipient society's capacity and willingness to learn", but "for reasons beyond our present understanding, societies differ greatly in terms of capacity to learn from others" (Gilpin 1981, 178)[4]. Does technological learning have anything to do with property rights? What is the relative causal importance of the two processes?

The diffusion argument is actually a combination of the two causal processes of changing distribution of power and technological change: diffusion of technology among nations implies the redistribution of *technological* power.

Gilpin thus rests the core of his explanation of rise and decline on two rather thin reeds, property rights and diminishing returns, while relegating technological change and distribution of power to secondary status. Like many other neoclassical authors, including Douglass North and Robert Solow, the Nobel-laureate theorist of economic growth, Gilpin argues that property rights in the form of patent rights can explain technological change. He argues that because of diminishing returns, a demand for technological innovations arises; "The most important mechanism for stimulating this incentive is the creation and enforcement of new types of property rights…thus the innovation of the patent system extended the notion of property rights to intellectual creations in order to encourage industrial invention" (Gilpin 1981, 81). But creating a structure of incentives, no matter how optimal, will not bring forth the technology if the skills and resources are not available to create the technology. A patent system in ancient Rome would not have brought forth the computer, no matter how well property rights were protected.

No scholar has attempted to explain the difference among industrialized countries in terms of differences in patent laws, or even in property rights in general. The collapse of the Soviet Union is not a good case for property rights causation because the *rise* of the Soviet Union was characterized by even *worse* property rights, under Stalin, than were in existence at the fall, under Gorbachev.

The consensus among historians of technology is that there is no consensus about the usefulness of patents in encouraging innovation (Mokyr 1990, 247-252). Patents hold an ambiguous position in economic theory because they confer monopoly rights on the owner. Monopoly is usually supposed to lead to decreased welfare because monopoly prevents competition.

Gilpin, unlike most neoclassical economists, acknowledges the importance of the *relative* position of states. Ironically, he does not extend this awareness of the interplay of states to the core of his theory of rise and decline. In his sequence of rise and decline, he begins with a dominant power, enforcing rules and rights. Then, its power starts to erode because of the effect of diminishing returns and the processes of rise-leading-to-fall. As its power declines, the opportunities for other societies to step into the vacuum left by the hegemon expands. But haven't there also been positive steps that the challengers have been taking? The only hint we get of this is either 1) that the challengers are rearranging their property rights, for whatever reason, to be more efficient, or 2) that they have become more technologically adept, again for reasons that are not clearly spelled out.

In Gilpin's system, the explanation of decline is dominant. Indeed, in much of the literature on rise and decline, there is more decline than rise. For example, a major collaboration of historians was entitled "The Decline of Great Powers" (Lundestad 1994).

Gilpin addresses internal causes of decline, such as rise-leads-to-fall and diminishing returns, but does not focus on external causes, such as balance of power and the rise of other societies. He notes the reasons for the establishment of internal property rights and constitutions that lead to rise, but he does not have an explanation for variations in growth thereafter. Change is still outside of his model; technology and redistribution of power within a state seem to be the ultimate forces of change, but the behavior of these processes remains unexplained.

Douglass North

Gilpin leans heavily on property rights as the key to rise and decline. In doing so, he is following the lead of Douglass North, who has written several well-known works on property rights and their relation to economic performance. North (1990) attempts to explain "divergence" of economic performance among the nations of the world (see also North 1990, 6-7). This is not exactly the same as explaining relative rise and fall. Like Gilpin and Toynbee, there is a tendency to inquire as to the "trajectory" that a society takes once it has been ordered in a particular way. For North, there is a "lock-in" (North 1990, 7) that societies suffer or prosper by, which can last for decades, or even hundreds of years.

There are two parts to the problem of relative rise and decline. On the one hand, one can inquire as to the reasons for the relative difference in power among a set of countries during one time period. In other words, the ranking among countries is static; there is no need to explain a change in the rankings. This is the question that North mainly addresses.

On the other hand, one can inquire as to the reasons for an absolute rise and decline of a country. Toynbee was particularly focused on such an inquiry, as is Gilpin.

Combining the two together, however, does not answer the question of the causes of the relative rise and decline of Great Powers. That is, we can understand why Britain is currently less powerful than the U.S.; or we can understand why Britain declined over the last two centuries. But these explanations do not tell us why Britain, which was far ahead of the U.S. two centuries ago, is now far behind, although we would have some important insights into the process. One should be able to explain, not just why there is a static ranking among Powers, but why there is a change of rank.

In neoclassical economics, there are two separate and contradictory conclusions concerning relative ranking, which may be grouped under the headings of convergence and comparative advantage. On the one hand, in the process of "convergence", there should be a period during which the various countries converge to the same level of economic performance[5]. In a perfect market, information and knowledge should diffuse effortlessly among all regions of the world. In addition, according to North, "over time inefficient institutions are weeded out, efficient ones survive, and thus there is a gradual evolution of more efficient forms of economic, political, and social organization" (North 1990, 92), which should spread all across the world.

For North, the differences in property rights among nations explain the differences in economic performance. The diffusion of knowledge is not costless, but is characterized by what North calls transaction costs. Property rights decrease or increase transaction costs, and thus make it easier to learn the latest techniques and to capture gains from trade.

For North, then, there may be a "lock-in" of a society, so that it cannot move up or down. In neoclassical thinking, all economies should automatically move toward the best techniques. Once they are at this optimum point, however, there should be no movement in relative rankings, since all Powers would be at the same ranking. This state of affairs, in which all economies are at the same level, is contradicted by another theory of economics, comparative advantage.

David Ricardo (1970, chapter 7) first put forward the theory of comparative advantage in order to show that free trade would maximize welfare among countries. The crucial assumption in his argument, which makes the theory unusable for a theory of relative rise and fall, is that the relative productivities among nations stay the same. If they do, then wealth is maximized when each country concentrates exclusively on what it does best – even if another country is more productive at what the first country does best. Ricardo concluded, in the early nineteenth century, that "it is this principle which determines that wine shall be made in France and Portugal, that corn shall grown in America and Poland, and that hardware and other goods shall be manufactured in England" (Ricardo 1970, 134).

Unfortunately for Ricardo's theory, Americans since the early 1800s have been much better known for manufactured goods. Even in Ricardo's time, his primary example should have led to skepticism. England was advanced in textile manufacture, and Portugal had sunk to concentrating on Port wine, because the competencies of the two countries had reversed in the three centuries before Ricardo, whose family was originally from Portugal, had written. By the late 1400s, Portuguese ships were traversing the globe, while the English were specializing in the sale of raw wool. If the two countries had precociously taken Ricardo's advice , Portugal would have been richer than England in the early nineteenth century, and Ricardo would probably have been justifying the situation with reference to comparative advantage – in Portuguese.

Gilpin and North never use the idea of comparative advantage. Gilpin is concentrating on change, while comparative advantage is a theory about stasis. North is concerned about the static ranking of nations, but he has put forward a theory which has more explanatory power than the theory of comparative advantage.

Over his career, North has stressed different variables to account for divergence. In his book *Structure and Change in Economic History*, North (1981) focused on property rights, as does Gilpin. In his book *Institutions, Institutional Change, and Economic Performance*, however, he shifts his focus to what he calls "institutions", which are "the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction" (North 1990, 1), because the "institutional framework is the critical key to the relative success of economies, both cross-sectionally as well as through time" (North 1990, 69).

Therefore, if the rules change, the economic performance of a country should change; different rules in different countries should explain different economic performance, at least over the short-term. There are several problems with this approach.

First, constraints can never provide the entire explanation for performance; there must be a set of agents acting to generate a particular level of performance. Constraints can only *guide* behavior; they never *produce* behavior. Only agents, or actors, can produce something. North sometimes writes as though constraints produce effects (for example, North 1990, 92, 95); but in fact actors produce, constraints guide.

Second, rules do not, by themselves, lead to change. That is why they are rules – they stay constant. North (1990, 84) therefore introduces different variables to account for change. The sequence of causation is the following: Changes in technology, factor price ratios, or information costs → changes in relative prices → change in bargaining power of entrepreneurs → change in institutions (in other words, rules) → change in behavior of entrepreneurs → change in economic performance (note that this sequence is similar to Gilpin's, although North tries to explain bargaining power). Changes in relative prices lead to greater bargaining power for some and less bargaining power for others, and eventually "changes in bargaining power lead to efforts to restructure contracts, political as well as economic" (North 1990, 69).

Neoclassical economists such as North have great difficulty in integrating the idea of power into their theories because they have based their academic discipline on the idea of exchange. Exchange is normally defined in terms of a set of voluntary actions, in which at best both parties to the exchange profit from the action, and at worse neither profits. Another word for exchange, usually associated with exchange among nations, is the term *trade*; so as North puts it, "For 200 years the gains from trade made possible by increasing specialization and division of labor have been the cornerstone of economic theory" (North 1990, 27). North 1990, These he often refers to, respectively, as "information costs" or "measurement costs", and "enforcement costs". These costs "are the sources of social, political, and economic institutions" (North 1990, 27). Thus, theoretically, exchange, and the costs associated with exchange, logically lead to the construction and importance of institutions.

However, exchange is supposed to be beneficial for both parties. But when power is exercised, often (although not always) one party gains and the other party loses. In fact, in North's causal chain, a change in bargaining power leads to changes in institutions ("it is the bargaining strength of the individuals and organizations that counts" [North 1990, 68]); somebody lost and somebody gained. He seems to be using the term "bargaining power" as a way to square the circle, to have power involved with exchange, but neoclassical economists in general assume the problem away by simply assuming a "given" distribution of bargaining power (as does Gilpin in the domain of domestic power). For instance, North claims that "given the initial bargaining strength of the decision-making parties, the function of rules is to facilitate exchange, political or economic" (North 1990, 47).

There is always the possibility that power won't be used to "bargain"; it will be used to simply force behavior. Much of North's work has shown the critical role played by the state in enforcing contracts and rules, without which modern economies are not possible (North 1990, 58-59). States can use their power to make institutions as they wish, whether or not such institutions make economic sense, and the distribution of power over the state organizations will therefore have a critical effect on institutions. Like Gilpin, North confuses rules and property rights with distribution of power. Power cannot be reduced to exchange; any theory of institutional change must include distribution of power as one of the variables.

If the distribution of bargaining power determines, to a large extent, the form of institutions, then it follows that the causes of the distribution of bargaining power are at least as important as the rules. North emphasizes that changes in relative prices lead to a change in bargaining power; however, those relative prices are determined by other forces.

In North's sequence of causation, probably the most important source of change of relative prices is technological change. North divides economic activity into transaction (or exchange) and transformation (or production) (North 1990, 118; Wallis and North 1986). North implies that as institutions are to exchange, technology is to production – that is, institutions and technology explain change in exchange and production, respectively.

Furthermore, according to North, technology determines institutions and institutions determine technology (North 1990, 61). The use of technology in institutions is clear. As Gilpin and others have commented, for instance, advances in communication and transportation technology obviously decrease transaction costs, and computers make information costs lower. The reverse is not so easily demonstrated. The examples North uses, such as the fact that "the firm's entrepreneur must be able to ascertain the quantity and quality of a firm's inputs and outputs", fall short because the control of quality of output is a part of production, not exchange; transaction costs, as a category, cover exchange. Insuring quality of inputs, insofar as it refers to ensuring that the supplier lived up to its contract, is certainly a part of transaction cost. But the effect of technology on transaction costs is certainly more important than the effect of transaction costs on technology.

North, like Gilpin, attempts to show the importance of property rights to technology by invoking the power of patent law (North 1990, 75, 78), even though "the long-run growth of skills and knowledge... are the underlying determinants of economic growth"(North 1990, 79). If skills are so important, one would think that the role of skills should be on the same level of explanatory power as institutions.

Perhaps in anticipation of arguments in favor of the primacy of technology, North argues that "the traditional historian's focus on the Industrial Revolution and technological change as the key to utopia is likewise deficient because much of the world has failed to realize the potential benefits of technology"(North 1990, 132-3).

Historians are generally careful not to give technology a monocausal role in world history, and it is actually economists who expect "convergence", not the historians. In order for technical knowledge to flow across or even within borders, the requisite skills must exist within the population, and the resources must be available, to be able to transfer technology from one place to another.

Like Gilpin, North attempts to use a social variable, rules and institutions, as the major variable explaining differences in economic performance. Even the logic of his argument, however, leads back to the importance of technological change and distribution of power. The empirical data that he supplies in another book, *Structure and Change in History* (1981), also points to the greater explanatory power of power and technology, as opposed to his chosen variable in the book, property rights (North 1981, 59).

Using only the material presented in his book, it can be shown that property rights are not the most important social variable. Instead, following the logic of his examples, it would seem that the distribution and existence of political power in a society is more important than property rights. Distribution of political power refers to the nature of the control of the apparatus of the state by segments of the population, including those that make up the state. The existence of the state refers to whether or not a particular piece of territory has the majority of its violence controlled by the state, as opposed to a state of anarchy.

North places the state in a central position in various societies in the ancient world (North 1981, 91, 94, 96). In the case of the Athenians he states that "the state specifies the property rights according to the interest of the dominant group in power" (North

1981, 106), which would indicate that the distribution of political power causally antedates the property rights; "As in the case of the Greek polis, the [Roman] military necessity of having a self-equipped hoplite army wrung concessions from the aristocracy" (North 1981, 107), so that in the Greco-Roman world, the distribution of political power was powerfully influenced by military considerations. Thus, we see a pattern that seems to occur often in North's narrative, as well as in history in general; political power is dispersed among a large, or larger, section of the population than previously because the state needs the resources, either economic or political, of a larger portion of the population. This is not a problem of property rights or rules; it is a process of the controllers of the state exchanging some of that control for the resources of the population.

North seems to concede this point when he writes that "the struggle over [distribution of wealth and income], both within and between states, is the most fundamental source of [economic] change and decline" (North 1981, 113). Again, the political organization produces, or causes, the property rights.

Often in North's writings, he stresses the importance of the security, or lack of security, of property rights. If an economic actor is afraid that his or her resources will be arbitrarily expropriated, then the actor will be much less willing to engage in economic activity in the first place, and the society will become poorer. But the security of property rights is not caused by property rights; it is the consequence of the existence of the state, as he shows in the case of Rome (North 1981, 110).

Another theme of North's is that overtaxation leads to decline. He seems to want to categorize taxation as an exercise in changing property rights, although he is never explicit; one could say that a tax is the state's claim on the property of its population. However, this would be stretching the meaning of the concept of property rights, which should be referring to the possessor's use and exchange of the property. According to Tilly and Ardant, taxes are, along with monopolization of violence, the most important element of the state (Tilly 1975). Taxes are the way the state mobilizes resources from within the society. As an explanation of Rome's fall, North says that "taxes and confiscations alter the structure of property rights so that there is a reduced incentive to undertake productive activity" (North 1981, 115), and "the end result...was increasingly unequal land distribution...perhaps decisive was the alteration from the polis to a bureaucratic empire" (North 1981, 108). Confiscation, taxation, land distribution and bureaucracy are all aspects of the existence of the state and the way its power is distributed (North 1981, 119-123).

In explaining the rise and fall of feudalism, North tries to use neoclassical reasoning but instead relies on political factors. The original feudalization was not the result of any "contractual" agreement between lords and serfs: "The warrior class was analogous to the Mafia in extracting income from the peasantry" (North 1981, 130), and "no voluntary agreement was involved" (North 1981, 131) between the peasants and lords. The ultimate decline of feudalism was ensured by the needs for larger and larger political units and the rise of technology (North 1981, 138).

A scarcity of labor during feudal times led to an increase in political power for the population, and technology led to "arms races" that doomed the manorial system. Since "the critical factor was the ability to increase tax revenues" (North 1981, 138-139), and "[the ruler] could grant privileges – property rights and the protection of property rights –

in return for revenue"(North 1981, 140), the economic wealth mobilized by the state was critical. But it was not simply privileges that were being granted, but actual control over the state. North claims that the persistence of early Parliaments "is the key to future differential patterns of development" (North 1981, 141) among the powerful states in early modern Europe.

Parliaments are organizations whose explicit reason for existence is to decentralize the distribution of power over the state. They may change property rights, as a result of the decentralization; in particular, and of great concern to North, Parliaments will not be ruinous in their taxation, and will tend to prevent confiscatory practices of the state. But distribution of power causes changes in property rights and security of property, not vice versa.

North engages in what Alexander George calls a "focused, comparative" case study approach (George 1979) to explain why England and the Dutch rose in early modern Europe, and Spain and France declined. Those countries which lost their parliaments – Spain and France – developed overly centralized governments which overtaxed the population. This, in turn, led to a slowdown or reversal in economic output. The Dutch, and particularly England, developed Parliamentary institutions that blocked the development of a "predatory state". Again, even using North's evidence, distribution of power affected taxation and property rights.

The explanation for the variation in strength of Parliaments is significant. In the case of Spain and France, the countries had been torn apart by constant battles, either between lords inside the country or in wars against neighbors (England and Burgundy in the case of France, the Moors in the case of Spain). The parliaments were willing to concede power to the central government as a way of ending the discord, and to ensure powerful military leadership. The English, on the other hand, although also undergoing internal strife, were protected by the English channel. The Dutch, too, were somewhat isolated by the nature of the geography of the Low Countries. Because of this, the level of taxation did not need to be so high, and the military apparatus of the country did not need to permeate the entire population. Therefore, military considerations were important for the political structure of the state, which in turn led to various levels of taxation. Property rights would seem to be a minor cause of variation in existence of parliaments and therefore for economic performance (North 1981, 156).

North seems on strongest ground when arguing the case for property rights in the case of the Dutch. Since Holland was mainly a commercial society, property rights – which should be most directly involved when dealing with exchange – would have greater importance.

In the Spanish case, the Mesta (North 1981, 150-151), which was an organization that controlled much of the countryside because of their monopolization of sheep, is called a "guild" by North, but was really more like a commercial monopoly. North notes that monopolies encouraged stagnation in France and Spain, and that England and the Dutch had less of them. To call a monopoly a "property right", however, is to again stretch the term too far. The central fact of a monopoly is that control is centralized in one unit within a particular domain, as opposed to an oligopoly, in which many participate, or a competitive system, in which no one unit has any control over price. The distribution of power within the market is a better explanatory variable than the nature of the property right.

Thus, in North's most impressive display of historical comparison, the forces of technology, military considerations, and political structure seem to operate at a higher causal level than property rights or rules.

North feels that the effect of organization and property rights on the size of the market can explain different rates of technological change during the Industrial Revolution (North 1981, 165-6). However, the size of the market is itself generally the consequence of transportation and communication technologies, and the ability of the state to spread its monopoly of violence over a territory.

During the Industrial Revolution, North claims, "the costs to the merchant of ensuring quality control were less by the [factory] form of organization than by [a series of market transactions]" (North 1981, 168). Thus, "the Industrial Revolution came about as a result of organizational changes to improve the monitoring of workers". The chain of causation ran "from central workplace, to supervision, to greater specialization, to better measurement of input contributions, to technical change" (North 1981, 169), because the entrepreneur could see, in the factory, how to replace hands with machines.

However, he presents several ideas which show that the acceleration of technological change was more important than centralizing work in the factory. To explain the start of the Industrial Revolution, he includes factors that require skill ("The development of the scientific disciplines", and "the intellectual interchange between scientists and inventors during the Industrial Revolution") and a factor that requires skill and government intervention ("a good part of the basic research has been financed by government and takes place in universities" [North 1981, 172-173]). He also mentions "patent laws [and] the growth of complementary law", although by the middle of the nineteenth century most advanced nations had fairly similar patent laws.

In order to understand the social and technological causes of the industrial revolution, North quotes Alfred Chandler, who states that "the rise of modern mass production required fundamental changes in the technology and organization of the processes of production". But Chandler's concept of organization is much different than North: he stresses coordination, and never mentions property rights. According to Chandler, "Such economies [of scale] came more from the ability to integrate and coordinate the flow of materials through the plant than from greater specialization and subdivision of the work within the plant" (North 1981, 175).

When the focus is on production and distribution, as it is with Chandler, workers are seen as part of a system of production and distribution, and the biggest problem is how to coordinate this system in order to produce something. North criticizes Chandler for "missing" the problems of exchange (North 1981, 176), but actually it is North that misses the problems of coordinating systems.

For North, the biggest problem in a factory is not coordination, but the need to prevent "free riding". One must prevent workers from shirking their responsibilities. Thus for North, the problem of cooperation is a problem of eliminating a negative tendency. In the modern era, however, the problem of cooperation is the problem of how to make many machines and people work together in an efficient way. It is the positive problem of designing systems. This is the view of Chandler, who is trying to explain the rise of American and German corporations to world dominance in the early twentieth century.

A possible reason for North's preoccupation on free riding is that neoclassical economists focus on exchange. In an exchange, the difficulty is to make sure that everyone who is party to the exchange lives up to their word: this is why there are transaction costs, according to North, which arise from the enforcement of contracts and the measurement of transactions. The actual technical needs of production, which always involve coordination, are ignored. In the neoclassical world, the economy is conceived to be composed of atomized, undifferentiated units. Like a gas in a container, no coordination is necessary.

In reality, however, there is a strongly defined differentiation of function within a production unit and among production units. Adam Smith originally referred to this differentiation as a "division of labor". He claimed that this division of labor was effectively organized as if by an "invisible hand". But within the modern corporation, as Chandler has shown, coordination is essential; this is why he entitled his book, from which North quotes, "The Visible Hand" (Chandler 1977).

Thus, for every period of history that North analyzes, we see that technological change and distribution of power are more important variables than North's choice, rules and property rights. In addition, the importance of production and coordination has been highlighted by North, even though he has focused on the problems of exchange. As I will show in the next chapter, neoclassical growth theory also focuses on exchange even while acknowledging the centrality of technological change in the processes of economic growth.

NOTES

[1] Gilpin's main definition of property rights comes from the work of Harold Demsetz, an economist from the University of Chicago: "An owner of property rights possesses the consent of fellowmen to allow him to act in particularly ways. An owner expects the community to prevent others from interfering with his actions, provided that these actions are not prohibited in the specifications of his rights" (Demsetz 1967, 17). Demsetz also says that "property rights specify how persons may be benefited and harmed, and, therefore, who must pay whom to modify the actions taken by persons" (Demsetz 1967, 347). Alchian, another important economic theoretician, says more simply that "a property right is a socially enforced right to select uses of an economic good" (Alchian 1989, 232). Thus, a patent is the right to restrict use of a certain piece of knowledge to the creator of that knowledge. For John Stuart Mill, "The institution of property...consists in the recognition, in each person, of a right to the exclusive disposal of what he or she have produced by their own exertions, or received either by gift or by fair agreement, without force or fraud, from those who produced it"(Mill 1965, 218), although Mill was speaking specifically about private property. For North, "property rights are the rights individuals appropriate over their own labor and the goods and services they possess" (North 1990, 33).

[2] Unlike Kenneth Waltz, who uses the concept of anarchy to characterize the international system, Gilpin is closer to Hedley Bull and others in conceiving of the international system as a society (Gilpin 1981, 28); for Gilpin, "governance" is a very important aspect of the international system. Gilpin is never very explicit about his definition of control and governance. The index of the book lists page 29 as containing the definition of governance, but that page only discusses how power is distributed, not what it is. The best guess is that "rules and rights" are what are to be controlled by a governing body.

[3] Both Gilpin and Toynbee have an evolutionary perspective. For Toynbee, his focus of interest was why some civilizations were able to respond to the challenge of a changing environment in such a way that the civilization became "stronger". For Gilpin, too, the question is whether a society, once ordered, can adapt to a changing environment: "the nature of domestic arrangements confers on a society a relative advantage or disadvantage with respect to its capacity to adapt itself to specific environmental changes and opportunities" (Gilpin 1981, 102). But do "domestic arrangements" equal property rights, constitutions, or both?

[4] W. W. Rostow (1990), in the conclusion to his long book on the history of the thought of economic growth, comes to a similarly vague conclusion.

[5] See the book, *Convergence of Productivity* (Baumol et. al. 1994), for a well-respected discussion.

CHAPTER 3

THEORIES OF RISE AND FALL, PART 2:

NEOCLASSICAL ECONOMIC GROWTH THEORY

In neoclassical economics, the entire edifice of the theory of growth is built on a concept of decline – the concept of diminishing returns. Because of this reliance on the concept of diminishing returns, growth theory in neoclassical economics has left most practitioners very unsatisfied with the theory as it now stands.

The crux of the problem is that it is difficult, if not impossible, to describe how something increases if the main process used to describe the increase is a process of decreasing values. Because of this paradox, neoclassical economic theorists, like Gilpin, North, and Solow, tend to accentuate a particular set of social concepts, such as diminishing returns, and then to use technology as an explanatory variable when the other concepts are seen to not have sufficient explanatory power.

Samuelson presents "*the law of diminishing returns*: An increase in some inputs relative to other fixed inputs will, in a given state of technology, cause total output to increase; *but after a point the extra output resulting from the same additions of extra inputs is likely to become less and less*. This falling off of extra returns is a consequence of the fact that the new 'doses' of the varying resources have less and less of the fixed resources to work with" (Samuelson 1975, 27, italics in original).

Note that diminishing returns hold when one input is *fixed*, and the other input is *increasing*. As explained in the discussion of Gilpin's work, Ricardo first claimed that if one has a particular fixed area of land, the addition of more and more labor will result in diminishing returns to each additional unit of labor. If both land and labor are increased at the same rate, however, there may be no diminishing returns; there may be "constant returns to scale", which is "a state where there is no reason for diminishing returns to operate, since *all* factors grow in balance, and where all economies of large-scale production have already been realized" (Samuelson 1975, 453ff). When economies of scale are being realized, then an across-the-board increase in the factors of production will actually result in *increasing* returns to investment, not decreasing returns.

In the case of the modern economy, the two factors of production most often discussed are those of capital and labor. The problems of characterizing capital will be examined later, but for now capital will be defined as the machinery and buildings of a factory which produces goods. With capital and labor as the inputs to production, we have two possibilities for diminishing returns: 1) Capital is held constant (assume that no new factories are built or expanded) and labor is increased, in which case there are diminishing returns to each additional unit of labor; and 2) labor is held constant (which might happen, for instance, in a condition of full employment), and capital is increased, leading to diminishing returns to each additional unit of capital. The first case is referred to as decreasing marginal productivity of labor, the second as the decreasing marginal productivity of capital.

At some point, in these two situations, the moment arrives when either an additional unit of capital yields only enough returns to barely cover its costs, or in the other case, an additional unit of labor yields only enough returns to barely cover the additional costs. This moment equals the price of capital and labor, respectively. In

1899, John Bates Clark therefore claimed that capital and labor receive as income that which they contribute to production (Clark 1927). Therefore, he reasoned, we can know how much labor and capital, in the national aggregate, contributed to the economy simply by finding out how much each factor of production received, in the aggregate. Neoclassical growth theory is based on this theoretical construction.

This model, as Clark realized, does not apply if diminishing returns do not apply. If there are returns do not diminish, then there is no point at which returns to capital or labor just equal the cost of capital or labor. If there are increasing returns, then no matter how much of labor or capital is added (in either case), the next additional unit of labor or capital will earn more and more money, without limit.

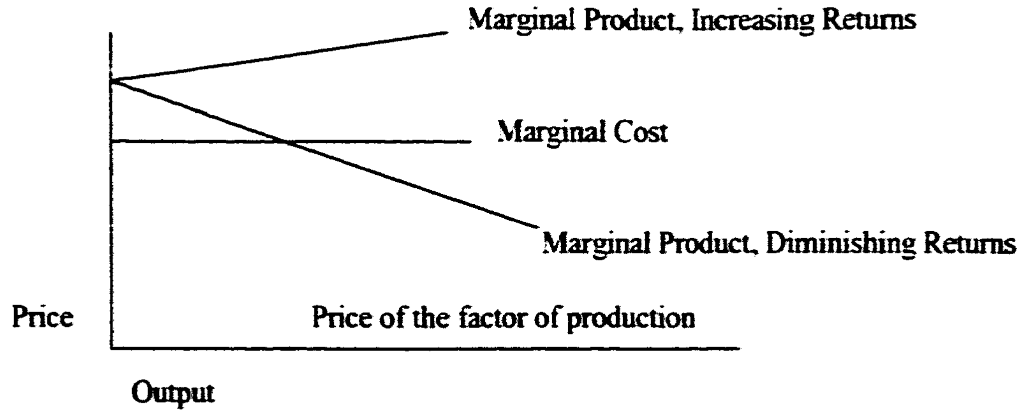


Fig. 7. Increasing and diminishing returns.

As we can see from the figure 7, if the marginal product from one additional unit of the varying factor of production is experiencing diminishing returns, we can find one level of output which matches the cost of the factor of production. This point is the unique solution to the problem of the determination of price. But if there are only increasing (or constant) returns, no single price/output decision can be made.

Neoclassical economists tend to concentrate on short-run economic processes. The short-run is defined as the time period before capital can be increased; that is, capital is fixed. So in the short-run, by definition, we have a process of diminishing returns where capital is fixed and labor is increasing. We should therefore have a decreasing marginal productivity of labor. However, factories are generally designed for a specific number of a certain kind of machine, to be tended by a specific number of a certain kind of worker. There is generally no room for either decreasing or increasing the number of workers. If it takes 20 men to operate a certain section of the assembly line, then the 21st man will yield *no* return; he or she will be standing around. If a worker is taken away, the assembly line will either completely break down, or the other workers will have to scramble to make up the work, most probably leading to a more than proportional loss in output for the loss of one worker. Thus, the case of diminishing returns to labor (vis-à-vis capital) is not a very important explanation of how the economy operates. [1]

In the long-run, when capital can be increased, then both factors of production (labor and capital) can be increased proportionally, and therefore constant returns may prevail. However, "in many industrial processes, when you double *all* inputs, you may find that your output is more than doubled; this phenomenon is called "*increasing* returns to *scale*" (Samuelson 1975, 28). This fact, according to Samuelson, is "not a direct refutation of the law of diminishing returns" (Samuelson 1975, 28), because of his belief that eventually diminishing returns set in, as one factor of production becomes fixed. However, if capital and labor are increasing proportionately, there may not be decreasing returns; and if in fact increasing returns occur for any level of output, monopoly could be the result, because "under decreasing Marginal Cost, the first firm to get a head start will find its *advantage increasing the greater it grows*!" (Samuelson 1975, 473)[2].

Since much of the economy is characterized by either monopoly or oligopoly, one would assume that increasing returns are more important than decreasing returns, at least for the structure of the market. This snowball effect, in which the unit which has an initial advantage is able to turn that advantage into a larger and larger one, has been previously analyzed in this study under the concept of positive feedback. If increasing returns to scale dominate in the economy, as opposed to diminishing returns when there is a fixed factor of production, then economists should be concentrating on positive feedback processes.

In the international political arena, an aggressor state can take advantage of the positive feedback of its conquests (as I will claim in my Chapter on Theory of Political

Systems). Waltz, Morgenthau and other realists therefore stress the operation of the balance of power, which is designed to constrain this process of positive feedback. Positive feedback is important in both international relations and in economics.

Since oligopoly and monopoly have characterized much of the twentieth century, and since technological change has been so extensive, one would think that increased returns would be the focus of much economic theory (W. Brian Arthur [1997] is one noted economist who has written extensively on positive feedback and increasing returns). Instead, growth theorists have made the concept of diminishing returns central to their efforts.

In 1956, Moses Abramovitz analyzed the aggregate economic data for the United States for the period from the 1870s to the early 1950s (Abramovitz 1989). The net national product per capita grew by approximately four times in this period. This is obviously a huge increase. According to neoclassical theory, as we have seen, each factor of production receives income according to the output it has contributed to the economy. The income of capital, defined mainly as profits and interest, has constituted only about between one-third and one-fourth of national income. Labor, in the form of wages and salaries, has received the rest, through most of American history. But capital has increased much more than labor.

In fact, according to Abramovitz's figures, capital per person had gone up three times (measured in constant dollars) during this time period. The number of man-hours per capita had actually gone down by 6 percent. Since labor's contribution to output is allegedly about three times the contribution of capital (because of their respective share of the national income), Abramovitz calculated that the weighted increase of the factors of production, capital and labor, was equal to 1.14. In other words, output per capita should have increased only slightly in this period, not by a factor of four. Input had hardly increased, according to the neoclassical assumptions, and output had quadrupled, so "this seems to imply that almost the entire increase in net product per capita is associated with the rise in productivity" (Abramowitz 1989, 132); that is, more output was produced with the same amount of inputs. Abramovitz famously concluded:

> This result is surprising in the lopsided importance which it appears to give to productivity increase, and it should be, in a sense, sobering, if not discouraging, to students of economic growth. Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth in the United States and some sort of indication of where we need to concentrate our attention (Abramowitz 1989, 133).

This "measure of our ignorance", as some still refer to it, has gone through several name changes, recalculations, and premature announcements of its demise. At first, it was called simply the "residual". It later came to be called "technological progress", but currently enjoys the more scientific sounding title, "total factor productivity". There are three main points to be made concerning neoclassical growth theory: 1) the "residual" has never been explained; 2) the core of the theory claims that "technology" is responsible for sustained growth, and this technology cannot be explained; and 3) the assumption of diminishing returns puts into question the validity of the entire theory in any case.

For 40 years, many economists have attempted to explain the "residual". In 1957, surveying the *previous* 40 years of growth, Robert Solow estimated that "it is possible to argue that about one-eighth of the total increase is traceable to increased capital per man hour, and the remaining seven-eighths to technical change" (Solow 1957, 316). Denison, in particular, is well-known for trying to estimate factors that could account for the remaining seven-eighths (Denison 1967). But as Solow noted in his lecture accepting the Nobel prize in economics, "the main refinement has been to unpack 'technical progress in the broadest sense' into a number of constituents" (Solow 1988,313); Solow argues that, according to Denison's calculations, "the growth of 'capital' accounts for 12 percent of the growth of output; this is coincidentally almost exactly what I found [in 1957]" (Solow 1988, 313-314). Further, according to Solow, "this detailed accounting is an improvement on my first attempt, but it leads to roughly the same conclusion" (Solow 1988, 314).

Denison is known for making the most Herculean labors in an attempt to explain the "residual". He tries to explain productivity increase by renaming certain parts of it. In a review of Denison's efforts, Abramovitz noted that "Advance of knowledge", which is really the old "technical progress", is made to account for 20% of growth from 1929-1957 (Abramovitz 1989, 162), while "economies of scale" are said to account for 37% in that period, which, "as Denison makes amply clear, constitutes no more than his own sober judgment", and "the fact remains that the theory on which Denison relies is no more than speculation and his special formula no more than a guess" (Abramovitz 1989, 154-5). Abramovitz concludes about this kind of effort to decompose the "residual":

> We can draw up a catalogue of the kinds of elements of which such an explanation must be composed: unconventional inputs, like labor intensity and education; economies of scale; and advances in knowledge of techniques and organization. Denison's attempts to attach numbers to these elements, however, still falls short of success. And this unfortunate fact is just the inevitable consequence of the present state of the art. (Abramovitz 1989,164)

The second point about neoclassical growth theory is that any sustained level of growth is shown by Solow to be due *solely* to technology: "The permanent rate of growth of output per unit of labor input is independent of the saving (investment) rate and depends entirely on the rate of technological progress in the broadest sense" (Solow 1988, 309). This conclusion flows from a particular kind of equation, called an aggregate production function, and follows from the way Solow combined this function with the fact of depreciation and population growth.

The aggregate production function is the staple of neoclassical discussions of growth[3]. It has the general form $Y = F(K,L) = K^{\alpha}L^{1-\alpha}$, where α is the contribution of capital to output for the entire economy, that is, between 25% and 33%, and therefore $1 - \alpha$ is the contribution of labor, between 75% and 67%. K is the amount of capital, usually measured as the dollar value of the plant and equipment of an economy, and L is the amount of labor, usually counted as total man-hours used in an economy over the course of one year. Y is the national output, usually defined as the gross domestic product (GDP).

Recall that the national income of a factor of production is supposed to match the marginal productivity, in the aggregate, of the particular factor of production. In other words, each factor of production receives as income that which it contributes to production. The particular form of the aggregate production function, $Y = K^{\alpha}L^{1-\alpha}$, is popular among economists because of two properties it possesses. First, when both K and L (capital and labor) are multiplied by the same amount (say, doubled), then Y will be doubled; that is, there are *constant returns to scale*. For example, if the plant and machinery of a country doubled and, at the same time, the number of man-hours doubled, the GDP would exactly double, according to the aggregate production function. The second aspect of the equation is that the two exponents, α and $1-\alpha$, add up to one. Since the factors of production are supposed to reap exactly that which they sow, the equation encompasses all of national income[4].

According to neoclassical economics, when one factor of production is held constant, and another is increased, the latter factor will yield diminishing returns. The aggregate production function can be transformed into the equation $Y/L = (K/L)^{\alpha}$, which means that output per worker man-hour increases in proportion to the increase of capital per worker, but at a diminishing rate (Y/L = output per worker man/hour, and K/L = amount of plant and machinery per worker man-hour, and α = percentage of national income received by capital, i.e., interest and profits) . There are two main aspects to this form of the equation.

First, more capital per worker leads to more output per worker. If one worker has a more expensive piece of equipment to work with, the worker will be producing more output. The worker that tends a modern textile machine, with, say, 100 spindles, produces much more output than a preindustrial worker with a spinning wheel.

Second, the exponent, α, is less than one, because it represents the percentage that capital receives of the national income, and this exponent describes a process of diminishing returns. For example, an aggregate production function might be of the form $Y/L = (K/L)^{1/3}$, which is the cube root of (K/L). Let's say capital per worker (K/L) is 8; the cube root of 8 is 2. So output per worker in such a situation will be 2. Now, assume that capital per worker increases to 64; the cube root of 64 is 4; therefore, output per worker has only doubled, while capital per worker has increased by 8 times. *There are diminishing returns to capital*, and therefore this equation is accepted by the mainstream of economics because it is consistent with the idea of marginal productivity and diminishing returns. Because each new addition of capital per worker yields less and less addition to output, the capital-output ratio (K/Y) is supposed to go up. In other words, a large increase in capital will yield a smaller proportional increase in output, because of diminishing returns to capital; if K increases more rapidly than Y, the ratio K/Y increases.

The problem is that this process of diminishing returns is contradicted by the data; *the ratio of capital to output has remained constant.* As more and more capital has been added, even with about the same amount of labor, the output keeps going up at the same rate as capital. The data show no diminishing returns:

Table 3: Capital and Output, 1930 to 1995

Year	1930	1940	1950	1960	1970	1980	1985	1990	1995
Capital (billions)	316	361	974	1,676	3,239	10,323	13,737	18,283	22,608
Output (billions)	90	100	287	527	1,036	2,784	4,181	5,744	7,254
Ratio	3.48	3.61	3.39	3.18	3.22	3.71	3.29	3.18	3.17

The capital figures, in billions of current dollars (that is, not adjusted for inflation), are taken from the article "Improved Estimates of Fixed Reproducible Tangible Wealth, 1929-95", in *Survey of Current Business*, May 1997, Table 1, "Current-Cost Net Stock of Fixed Reproducible Wealth, 1929-95", p. 77, as private and public equipment and structures. The output figures, in billions of current dollars, are taken from GDP figures of the United States Statistical Abstract of 1997, p.447. The ratio is the fixed wealth divided by the GDP.

Economists refer to an increase in capital per worker (K/L) as "capital deepening"; as Samuelson puts it:

> Instead of observing a steady rise in the capital-output ratio as the deepening of capital invokes the law of diminishing returns, we find that the capital-output ratio has been approximately constant in this century...A steady profit rate [that is, share of capital in national income] and a steady capital-output ratio are incompatible with the more basic law of diminishing returns under deepening of capital. We are forced, therefore, to introduce *technical innovations* into our statical neoclassical analysis to explain these dynamic facts. (Samuelson 1975, 747, emphasis in original).

A consistent and obvious contradiction of an integral part of economic theory has been brushed aside by Samuelson by invoking a *deus ex machina*, technology. We are not "forced" to question the underlying theory, according to Samuelson; we are "forced" to introduce an exogenous variable, technology, in order to save the underlying theory.

When data contradict a theory, there are two possible responses: one can question the underlying theory, or one can try to augment the theory by adding another variable. The neoclassical economists have chosen the second alternative. However, the new variable, technology, is not independently measured. It continues to be, in Abramovitz's phrase, simply a "measure of our ignorance", or a "residual". It is the number which is necessary in order to save the theory, not a number whose existence is independently confirmed. Sometimes scientists temporarily postulate a missing factor which will make up the difference between the theory and the observed data. However, the theory is considered unproven until the existence of the missing factor is confirmed.

If the physical sciences were to operate by consistently integrating forces which had not been confirmed, they would be much less successful. For instance, the response of the Ptolemaic astronomers to the development of sun-centered astronomy by Copernicus, Kepler, Galileo and Newton could have been the following: "Well, we can make all of our calculations match the observed data by adding an X variable that is equal to the difference between the Ptolemaic system and the data". Scientific progress is not possible if all theories can be "fixed" in this way.

One reason that this contradiction has not made more of an impression on the economic community is that growth theory is not central to the profession. Jonathan Temple has gone so far as to call growth theory a "backwater"(Temple 1998, 39); for Nicholas Stern, growth theory "has, however, been a popular topic for those involved in formal economic theory only for short periods, notably from the mid 1950s to the late 1960s" (Stern 1991, 122), which is basically the era of the elaboration of the Solow model and discussion of the "residual". The economics profession has concentrated on equilibrium, stability, the allocation of a given set of resources, and the determination of price. None of these concepts is helpful in understanding the very dynamic process of the long-term growth experience of an industrial economy. For growth theory to instigate a fundamental discussion of core neoclassical theories would be like the tail wagging the dog for economists. Indeed, the accomplishment of Solow and others is to create a model of growth which is consistent with the assumptions of neoclassical economics – *not to explain growth itself*. A fuller explanation of Solow's model will show that it is actually a model explaining why, without technology, there is no sustained growth.

Recall that we have a function of the form $Y/L = (K/L)^{\alpha}$. As Solow points out, capital per worker will decrease, in this model, if we add more workers without adding more capital. Alternatively, capital per worker will decrease if there is less capital, which is what happens when plant and machinery depreciate; capital does not exist forever, but eventually breaks down and disappears. In either case, there is a decrease in the capital-to-labor ratio, which is bad for the economy, because a smaller capital-to-labor ratio translates to less output per worker.

Solow uses the term $(n + d)k$ to model this decrease of capital per person, where n is the rate of labor expansion, d is the depreciation rate, and k is capital per worker. As long as the increase in capital just offsets this $(n + d)k$ value, there will be no deterioration in the income per person in the society. The amount of new capital will just offset the amount of depreciation, on the one hand, or will just accommodate the new additions to labor, on the other hand. The economy will be at equilibrium; it will not become richer, and it will not become poorer.

The following diagram will be used to show how Solow's model works.

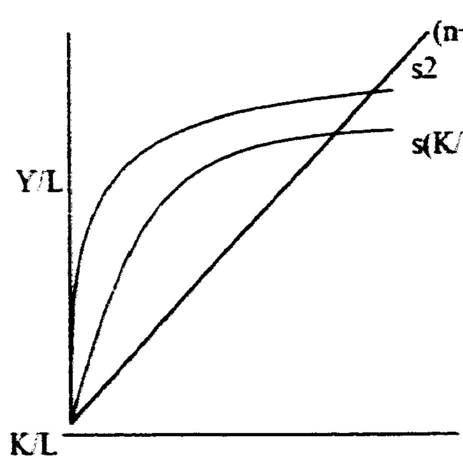


Figure 8. Solow's growth model.

The curve s(K/L) represents the amount of investment in new capital per man-hour; s is the savings rate. s is usually around 10% to 20% of the economy. More capital translates into more output, but since there are diminishing returns, the curve flattens out after a while. The point at which the s(K/L) curve crosses the line (n+d)k is the equilibrium point; the amount of added capital (in the form of investment per worker) just cancels out the amount taken away by the addition of new workers and/or depreciation. There is no growth per person, but neither is there any decrease.

The important part of the model is the process that takes place if the economy, for whatever reason, is not investing just enough to offset either depreciation or added workers. Like any accepted economic model, Solow had to show that the economy would move *automatically* back to the equilibrium point, and would stay there, unless something pushed the model off of equilibrium.

In the case of this model, there are two possible nonequilibrium situations. If the economy is investing too little, then the economy is at a point on the s(K/L) curve to the left of the (n+d)k line. In this case, because the returns to investment are *greater* than the depreciation or population growth rate, more capital per man-hour will be furnished to the economy by entrepreneurs; s(K/L) will go up, and the economy will automatically move along the s(K/L) curve, eventually reaching its equilibrium point where it crosses the (n+d)/k line. The economy will have been in disequilibrium, but will have moved back to equilibrium.

On the other hand, if the economy is investing too much, then the economy will be on a point to the right of the (n+d)k line. In this case the economy will be adding much more capital then it is getting back in the form of greater output. It will be running faster and faster just to advance a little bit. But in this situation, there will be huge amounts of capital piling up; and because the depreciation rate is still the same, large quantities of machinery will be retired. Entrepreneurs will not want to invest in capital, capital will decrease because of depreciation, and so the economy will automatically slide back to the equilibrium point.

Thus, the model has a stable equilibrium. It is the kind of model in which, even if the economy is out of equilibrium, the economy moves back to equilibrium automatically. It is the same situation as a marble at the bottom of a cup; move the ball up the wall of the cup, and as soon as you release the ball, it will be pulled back down by the force of gravity to a resting point. In Solow's model, rational decision making is analogous to the force of gravity.

According to this model an economy can grow in one spurt, and then stop growing, if the investment level is increased. The curve marked s2 on the graph above is the same curve as s(K/L), except that the s factor is increased. So if a society *permanently* increases its savings rate from, say, 10% to 14%, according to this model, its output will grow, but then the economy will reach equilibrium and stop growing. This is why Solow says that the growth rate is *independent* of the investment rate (the savings rate is assumed to be the same as the investment rate). Countries can achieve a one-time increase of their GDP by increasing their savings rate, but the economy can not enjoy continuous, or *sustained*, growth.

There is only one way of sustaining growth in this model: technological progress. In order to have continuous growth, at every point on the s(K/L) curve, the Y/L, or output per worker-hour, would have to be greater. The same amount of machinery per worker would have to yield more output per worker than before, and therefore labor productivity would increase, if technology improved. This will come about because better machinery has been developed, or the means of production have been organized more efficiently, both of which are considered to be technological progress, and more properly within the realm of the engineer than the economist. If the investment rate stays the same, and the engineers maintain the rate of technological progress (that is, increasing the amount of output per worker), the economy will grow continuously.

Solow has therefore succeeded in completely removing all possible sources of sustained growth from his model, other than technological progress. Put another way, there is no sustained growth without technological progress, according to Solow's model. Obviously, there has been tremendous, sustained growth in the last two centuries. Solow concludes that "increasing the rate of per capita growth is not only not easy in this model, it is impossible unless the rate of technological progress can be altered deliberately. This reversal of conclusions has led to a criticism of the neoclassical model: it is a theory of growth that leaves the main factor in economic growth unexplained" (Solow 1994, 48). He continues that "there is some truth in that observation, but also some residual misconception", which seems to consist of pointing to the work of the Endogenous Growth theorists, which will be discussed below.

Neoclassical growth theory has explained growth by showing how growth cannot be explained by neoclassical growth theory. The unknown, "residual" element has never been satisfactorily specified, and the main conclusion of the theory itself is that technology creates growth. This, in itself, would indicate that an understanding of technological change would be the appropriate focus of research into the rise and decline of Great Powers.

But there is a second reason to doubt the usefulness of neoclassical theory. Since the theory cannot explain why the prediction of diminishing returns has not taken place, except to postulate an invisible variable, the entire theory is on shaky ground. Thus whether diminishing returns are plausible, or whether they are not significant, the theory fails to provide a convincing base from which to analyze rise and decline. Recently, however, there has been an attempt to deal with the problem of diminishing returns, and this theory has been named "endogenous growth theory", to underline the idea that technology can be explained from within the model.

Romer (1986 and 1990) attempts to work around the problem of diminishing returns by invoking a new factor of production, knowledge. In addition to the factors of production of capital and labor, as in the Solow model, Romer postulates that the knowledge of how to design and organize production is itself a factor of production. Unlike capital and labor, however, we can never have "too much" knowledge. There are no diminishing returns to knowledge, in other words.

This knowledge is itself the product of a sector of the economy which Romer calls the "research" sector. However, as Stern puts it, "it is extremely difficult to identify anything approximating to a knowledge-producing sector in real economies" (Stern 1991, 127). According to Howard Pack, "the long-term imprint of any growth theory must ultimately depend on the extent to which it generates a productive empirical literature. In this task, endogenous growth theory has led to little tested empirical knowledge" (Pack 1994, 69).

Solow's model, the Endogenous Growth theory, and the concept of an aggregate production function suffer from a similar problem: they are attempting to aggregate a factor of production, capital, that is more profitably used in a disaggregated state. Worse, economics – classical and neoclassical – do not have models of how the economy works which include representations of the plant and machinery that make modern industrial economies possible. As Kurz asserts, "capital theory is notorious for being perhaps the most controversial area in economics. This has been so ever since the very inception of systematic economic analysis" (Kurz 1990, 79)[5]. How can one construct a theory of rise and fall in the twentieth century without including plant and machinery?

Adam Smith (1994 [1776]) first pointed out the importance of capital. In his schema, there are two types of capital: circulating capital are those goods which move from producer to producer, that is, they are ordinarily intermediate goods which are in the process of being turned into final products; and fixed capital, which is comprised of "all useful machines and instruments of trade which facilitate and abridge labour" (Smith 1776, 305), commercial buildings, improvements of land, and the "acquired and useful abilities" (Smith 1776, 306) of labor. For Smith,

> To maintain and augment the stock which may be reserved for immediate consumption, is the sole end and purpose both of the fixed and circulating capitals. It is this stock which feeds, clothes, and lodges the people. Their riches or poverty depends upon the abundant or sparing supplies which those two capitals can afford to the stock for immediate consumption. (Smith 1776, 307)

In other words, capital generates the goods that comprise the substance of the economy.

Later theorists, however, took a step backward in their treatment of capital. The problem started with Ricardo. Ricardo was not trying to understand "The Wealth of

Nations", which is the focus not only of Adam Smith but of the present study, but the distribution of income of the nation. Ricardo wanted to know how profit could be understood in terms of wages, rent, and output. In order to keep his models simple, he resorted to the extreme position of considering seed corn as both the wage of labor and the capital to be used to create output. While this made the model easier to construct, fixed capital, that is, plant and machinery, disappeared from his model of the economy.

Later in the nineteenth century, the neoclassical economists developed what came to be known as the "Austrian theory of capital and interest". The two main neo-classical expositors were Bohm-Bawerk and Wicksell. For Bohm-Bawerk, "the role of capital in production is to permit adoption of more productive but also more time-consuming 'roundabout' methods of production" (Blaug 1996, 480). The more 'roundabout' a production process was, the more 'capital' was involved, because "all of Bohm-Bawerk's work and most of Wicksell's was concerned with ...continuously applied circulating capital" (Blaug 1996, 489), but not with fixed capital. Capital turns into a fund from which to support the workers while they produce; capital is no longer something which is directly involved in production. The longer a production process took, the more capital was needed to support the employees who were working on production (Blaug 1996, 482).

But taking more time to produce something is an indicator that the process is a *less* efficient process, not more efficient, as Bohm-Bawerk wanted to show. As Blaug asks, "Is it never possible at a given state of technical knowledge to increase the total product by investing in less time-consuming methods of production?" (Blaug 1996, 481).

Indeed, most of the technological progress that is supposed to explain growth in the Solow model is of the form of *decreasing* the period of production.

For example, while the tools that Adam Smith describes for the production of the pin factory were relatively crude, the machines available to make pins today have enormously speeded up production. According to Pratten (1980), "Adam Smith estimated that each person 'might be considered as making 4800 pins in a day'", while in 1980 "approximate output per employee for one of the U.K. companies is 800,000 pins per day. An increase of 167 times in 200 years" (Pratten 1980, 94) occurred, caused by improvements in production machinery. According to the "roundabout" theory of capital, these machines are worth less than the crude 18-century tools, because they decrease the time involved in production!

Thus ended the attempt to rigorously define capital in the aggregate. Yet, as we have seen in the case of the aggregate production function, economists continue to aggregate. There were tremendous debates over this problem in the 1960s, retold, for example, by Harcourt (1969). Samuelson admitted that there was a problem, but economists have tended to proceed as if there were no difficulties.

Blaug comes to the conclusion, as do many others, that "in the real world in which we live, capital like labor is as heterogeneous as output and there is no such thing as *the* marginal product of the total stock of capital in the economy, just as there is no such thing as *the* marginal product of the labour force" (Blaug 1996, 450). Part of the reason is that "A whole class of well-behaved microeconomic production functions, having all the properties economists favor…simply will not aggregate into a well-behaved macroeconomic production function" (Blaug 1996, 452).

Capital is problematic in the theories of neoclassical economists, particularly as capital applies to problems of growth theory. Both neoclassical and endogenous growth theory are based on the aggregation of capital and labor, in an unrealistic way, and both assume diminishing returns which may not in fact exist. In addition, both theories rely on an exogenous force, technology, which they can not explain.

As two prominent scholars of innovation have put it:

> For most economists, assessing technological change appears something of a puzzle, far removed from economic reality. The main reason for this goes back to the traditional economic framework, within which technology is reduced to an 'exogenous' external factor whose impact on, for example, economic growth can be best described…in terms of a particular parametric value: a 'black box' variable, not to opened except by scientists and engineers (Freeman and Soete 1997, 426).

It would seem natural, then, to focus on the exploration of this crucial force, technological change in the service of production.

Conclusion

Three mainstream theories have been reviewed, and all three have major weaknesses when used for fulfilling the task of explaining rise and decline of Great Powers. Gilpin and North try to use property rights to explain the position of societies in the international system, but their expositions show that technological change and the distribution of power within the state might have greater theoretical power. For North, technological change seems to be the main cause of the change in property rights, but the change in the distribution of power seems to be more important than property rights as a cause of change of behavior. For Gilpin, the internal ordering of the state is a mix of property rights and distribution of power, without clearly indicating the role of either variable. Technological change for Gilpin has an ambiguous role as well.

Neoclassical theory gives the central role in growth to technology. But theorists such as Solow rely on the process of diminishing returns to construct their theory, even though diminishing returns on an aggregate level does not seem to have an empirical basis. The various theories of the functioning of the economic system either do not acknowledge the existence of machinery, or try to use an aggregated measure of machinery, even though such a measure has not been shown to make theoretical sense. There is no clear sense of what technological progress is, other than as an increase in labor productivity.

North's theory concentrates on the reasons for the relative ranking of various countries, but does not investigate the reasons for *changes* in these rankings. Gilpin concentrates mainly on internal causes of decline (and to some extent rise), but he does not focus on the reasons for the relative ranking of countries. Neoclassical theory cannot explain why technological levels are different among countries, or why the technological prowess of countries changes through time. Thus, there is currently no consistent and empirically-based theory of relative rise and decline.

There are grounds, therefore, to try to construct a theory of relative rise and fall which is not based on any of the existing, mainstream theories. The theories reviewed here have tried to use various combinations of the ideas of property rights and diminishing returns. They have all implied, in various ways, that technological change and the distribution of power are more powerful ideas with which to approach the inquiry into the causes of relative rise and decline. In order to investigate these two concepts, in the next chapter I will construct a systems-based framework for understanding the complexity of the processes of the rise and decline of Great Powers.

NOTES

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[1] There is another current of neoclassical economics which ignores the idea of diminishing returns and marginal productivity, called general equilibrium theory, but this theory has its own problems General equilibrium theory has never been used to even attempt a theory of growth. Mark Blaug, the respected historian of economic thought, gave this assessment:

> After a century or more of endless refinements of the central core of general equilibrium theory, an exercise which has absorbed some of the best brains in twentieth-century economics, the theory is unable to shed any light on how market equilibrium is actually attained...We must perforce conclude that general equilibrium theory as such is a *cul-de-sac*: it has no empirical content and never will have empirical content...[general equilibrium theory] has proved in the fullness of time to be an utterly sterile innovation (Blaug 1996, 570)

[2] The graph shows increasing marginal productivity, but we can also have constant marginal productivity with decreasing marginal costs, particularly when both factors increase, which leads to the same process of increasing returns.

[3] The following discussion is based on the textbook by Charles Jones (1998, Chapter 2).

[4] This form was developed in an article by Cobb and Douglas (1928).

[5] Freeman and Soete (1997, 328) comment that "capital too in the usual sense is absent in most of the 'new' growth theories. It is either assumed that physical capital is absent, and only investment in knowledge matters (Romer 1986) or, in more sophisticated models, that there is only an intermediate good which, contrary to physical capital in the usual sense, does not accumulate".

CHAPTER 4

A THEORY OF SYSTEMS

The first three chapters of this study examined the work of many scholars as applied to the problem of the rise and decline of Great Powers. I found that students of international relations have not directly addressed the crucial question of what constitutes a Great Power, and the writings concerning rise and decline have not seriously investigated the nature of technological change as applied to production. In both cases, then, critical questions have gone unanswered.

When these issues are raised, the answers given are, to a certain extent, ad hoc. According to Webster's dictionary, "ad hoc" means "for this (special purpose)". The definition of a Great Power, and the causes of productive technological change, are ad hoc because they are not linked to a wider, general purpose set of theories which are constructed in order to address these issues. By constructing a set of theories in the next several chapters, I will attempt to anchor the answers to these important questions onto a firm theoretical foundation.

In order to address these questions, therefore, it is necessary to start by investigating how to explain complex systems in general. Once a wider view of a complex system has been constructed, then it will be possible to become more concrete. It will become possible to explore systems that are pertinent to the questions of rise and fall of Great Powers, in particular, political, economic, and production systems. These theories, in turn, can then be used to suggest hypotheses, which are amenable to empirical validation or refutation. By the end of this process, the definition of Great Powers and the causes for their rise and decline should be understood as part of a theoretical framework, not as a set of ad hoc answers.

Reduction and Emergence

What is the proper way to model a phenomenon as complex as the rise and decline of Great Powers? There are two basic techniques for understanding complex phenomena, analysis and systemic explanation (Laszlo 1996).

Analysis has been the mainstay of scientific and social scientific scholarship (Waltz 1979, 39). Researchers investigate a subject of study, and break down the large unit, such as an economy, into smaller units, such as industries. Once the smaller unit is understood, the scholar can then *aggregate* the results obtained for the smaller units in order to understand the larger one. The most common example of such a methodology takes place in the realm of physics, in which a mechanical system can be understood by being divided into its parts, and by summing the results of the analysis of those parts in order to understand the whole.

The assumption in using analytical methodology is that a unit of analysis is decomposable. Once the unit has been separated into components, those components may likewise be disaggregated into yet smaller units, and so on. Any phenomenon can be disaggregated into its smaller parts, and those parts can likewise be decomposed. This process of decomposition can be carried on until the realm of subatomic physics is reached, in which decomposition is no longer possible (although physicists are constantly trying to explore smaller levels).

This movement from one subject matter to another can be characterized as movement from one *domain of inquiry* to another. A domain of inquiry can be defined as a general class of phenomena that are usually studied together, and are often categorized in terms of academic disciplines, such as biology, chemistry, and physics.

Since the analytical process can proceed across several levels of inquiry, any domain of inquiry can be conceived to be located at a certain level in a *hierarchy* of domains (O'Neill et al. 1986). For example, biologists commonly describe their field in terms of multiple levels of inquiry. Starting with the study of large organic chemicals, a biology textbook might move to the study of cells and their components (microbiology), then to the study of organs and the organism (physiology), and finally to a discussion of ecology. Ecology can also be studied at various levels: from the study of populations of the same species (population ecology) to the study of communities of plants and animals (community ecology) to the ecosystem as a whole, which includes inanimate forces (see for example, [Campbell et al. 1999, Chapter 1] as well as [Mayr 1997, 18]).

All of these biological levels occur within the same academic discipline, although usually practicing biologists specialize in one level. Once we descend downward below biology, however, the domain of inquiry moves to the entirely different discipline of chemistry. Below this level, the discipline may change again, to the physics of atoms and finally to the quantum mechanics within the atom.

The following diagram is an example of a complete hierarchy:

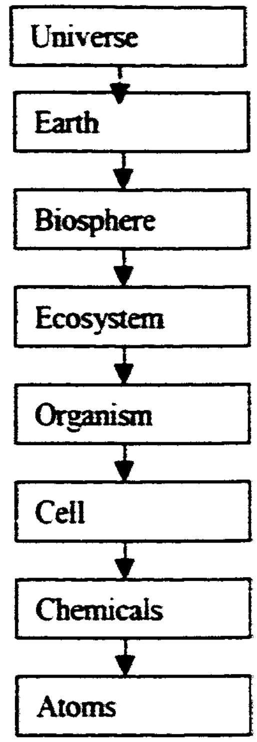


Fig. 9. Example of complete hierarchy.

Each level can be decomposed into components at the level below, and each level generally contains several levels. We can imagine many different manifestations of this hierarchy.

For instance, we might consider humans as a kind of organism, and we might further disaggregate human society thus:

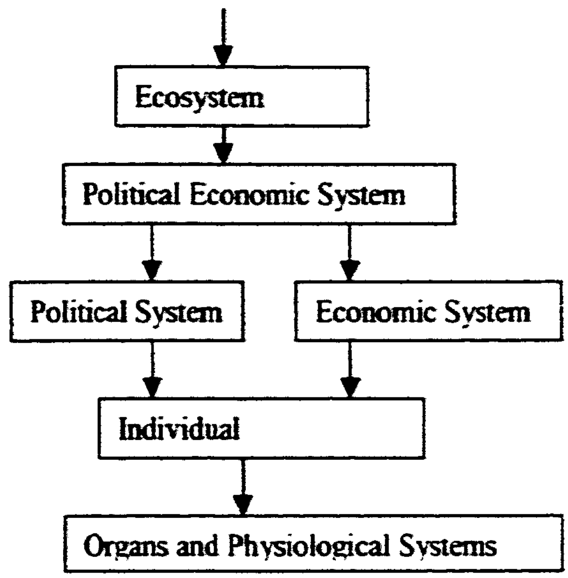


Fig. 10. Example of human society as hierarchy.

The arrows pointing into and out of this diagram indicate that there are other levels in the hierarchy, but they are not all being shown here.

There may be different hierarchies of domains of inquiry depending on the phenomena that are of interest. Figure 10 will serve as a guide to the next chapters, which will expand on the simple model of conceiving of human society as a system of political economy composed of political and economic subsystems.

The act of describing one domain of inquiry in terms of the domain below it is called *reduction*. The field of the philosophy of science is filled with debates on the appropriateness and applicability of this process (see for example, [Mayr 1997], [Nagel 1961], or [Phillips 1976]). At one extreme in the debate is the famous claim made by the mathematician LaPlace, that if he knew the position of every piece of matter in the universe at a particular point in time, he could predict all following events (Nagel 1961, 281). Chaos theory, or more formally nonlinear dynamic theory, has had the result of throwing this claim into serious doubt, even for mechanical processes (see, for example, Holte 1993).

At the other end of the debate, some have argued that the unit of analysis, far from being understood as an aggregation of parts, must be understood as containing properties which are only apparent at the level of the unit or whole, not at the level of the components. Instead of using the methodology of analysis, these authors are concerned with *systemic explanation*, or holistic thinking. One famous example is water; one could not predict the properties of water just by knowing the properties of its constituent parts, oxygen and hydrogen. New properties are said to *emerge* (Phillips 1976, 14 and Mayr 1997, 19) from the interaction of oxygen and hydrogen. Thus, instead of going *down* the hierarchy of domains, one can go *up* the hierarchy in order to understand more completely the phenomena in question. In figures 9 and 10, the arrows would flow up, instead of down.

The extreme position, sometimes ascribed to Hegel or Hegelians, is that one cannot understand an object unless one understands the whole of which it is a part, and to understand the whole one must understand the whole of which *it* is a part, until one arrives at the position that one must understand the entire universe in order to understand anything. Bertrand Russell was thus afforded the opportunity to quip, "If all knowledge were knowledge of the universe as a whole, there would be no knowledge" (Phillips 1976, 11).

Both "extreme" positions would seem to be impractical. The extreme reductionist approach would always fail, because even with the fastest, largest computers imaginable, it would still be impossible even to fully predict the action of one ocean wave, much less the entire universe. The extreme holistic approach would paralyze research, because even if it were true that one must understand everything in order to understand anything absolutely, no person could achieve such wisdom in one lifetime. The practical solution is to assume that, at each level in a hierarchy of inquiry, new properties do emerge, and further that much of the functioning of a whole can be explained by analyzing the components. In short, both reduction and emergence are useful, whether or not they have some ultimate, untestable validity.

The eminent biologist Mayr calls this synthesis in biology "organicism", which "is best characterized by the dual belief in the importance of considering the organism as a whole, and at the same time the firm conviction that this wholeness is not to be considered something mysteriously closed to analysis..." (Mayr 1997, 20).

Systems

This thing which is the object of inquiry, whether it is an economy, atom, organism, or universe, shall be called a *system* in this study, and the component parts shall be called units, elements, or components, interchangeably. It shall be assumed that all phenomena, with the possible exception of subatomic particles, are systems composed of units, and that all systems, with the possible exception of the universe, are themselves components of other systems.

There have been many proposals for a theory of systems (see, for example, [Buckley 1968], and [Jervis 1997, 6]). The concept of cybernetics (Wiener 1954) in particular has been used by scholars in many disciplines as a theory of systems. The development of cybernetics was motivated by the functioning of machinery. The focus was on machinery which processes information, such as computers, or production machinery and weapons which use sophisticated control systems. The classic example of a cybernetic system, however, is a heating system with a thermostat. The basic idea in a cybernetic system is that there is a target value at which the system should stabilize. If the system is not at this target value, it should move toward it. Any deviations from this target are automatically removed or minimized by the actions of the system. A thermostat, for example, turns on the heating system when the ambient temperature is less than the target temperature, and turns off the heating system when the ambient temperature is greater than the target temperature. A cybernetic system is therefore often called a negative feedback process, because it tends to be stable, it tries to minimize change, and it is capable of monitoring its variables.

This approach caught the imagination of many thinkers and scientists in the 1960's. For instance, Ludwig van Bertalanffy developed a "General Systems Theory" which was closely patterned on the cybernetic model (Bertalanffy 1968). He used his theory to describe many processes, mainly in the cell and in the organism. General Systems Theory could claim to model such domains, since there is a control element, or aspect, of a cell and an organism that allows for cybernetic-like negative feedback processes to occur.

However, the vast majority of systems do not have a control element which senses the environment and adjusts the other elements accordingly. In particular, economic and ecological systems do not generally have any centralized control, and even political systems do not have the fine-tuned control elements that are useful in machinery. A theory of systems does not require the inclusion of a master controller which keeps the system from flying apart; ecosystems and economies are a testament to this fact.

In addition, systems theory based on cybernetics cannot explain change which is not consciously designed; unplanned change is considered to be a breakdown of a cybernetic system. Most systems, such as economies and ecosystems, are not only capable of unplanned change, but actually thrive on it. Most innovation is unplanned. Thus, cybernetic theories have many of the problems of neoclassical economic theories, which concentrate on stability and equilibrium.

The international relations theorist Kenneth Waltz has drawn on cybernetic and other systems theorists (Waltz 1979, 40) to construct a theory of systems which will be used as a basis for the theory of systems proposed in this study. Although Waltz also stresses the stability of systems, by extending his framework and further incorporating many of the scholarly sources of Waltz's work, it will be possible to construct a theory of systems which is useful for explaining change and stability.

The first task in constructing a theory of systems is to distinguish between, first, the elements and their interactions, and second, the emergent properties of the system (Waltz 1979, 78-80). The *unit level* of a system can be described as the collection of elements and their interactions. The *system level* of a system can refer to two sets of properties that emerge from the interaction of those components: 1) the domain of the system; and 2) the structure of the system.

The *domain* of a system serves to describe the object as a whole, and helps to place the system within a hierarchy of domains; thus we can refer to an ecosystem, an economy, or a polity, as the domain of a system. This is an abstract definition; when we discuss an actual occurrence of, say, an economy or nation, we are referring to an *instantiation* of a domain; thus we refer to the "French economy" or "the United States", which are instantiations of economies and polities. Part of the definition of the domain includes the boundary between an instantiation of a system and its environment, as between one polity and the rest of the international political system.

Sometimes it is desirable to divide a domain. For instance, the social sciences contain disciplines such as economics and political science, which study different phenomena within society. We can call these *subdomains*. Such a classification was shown in figure 10; in later chapters the definitions of the subdomains of politics and economics will be explored.

Finally, each abstract definition may be further subdivided into various *types* or kinds of the particular system; for instance, there are democratic political systems and dictatorial political systems. These types are differentiated according to the second aspect of a system, the structure; a different structure yields a different type of a particular class of systems.

Structure

The structure is the way in which the elements are arranged within a system; a structure is the way in which a system is organized. There have been myriad attempts to define the term 'structure' (see Phillips 1976, chapter 6). Perhaps Plato had the most extreme view of the importance of structure, or form. He postulated that reality was a reflection of various forms, which were thought to be prior to material reality. Plato's concept of forms was asserted to be more important than the concept of substance, which interested the Greek philosophers of the time (thus, the substances of fire, water, air and earth were said to be basic). Aristotle, Plato's student, then took the logical high road and claimed that form and substance were both important (see introductions of Aristotle's *Physics* [Aristotle 1996] and *Metaphysics* [Aristotle 1998]). This study will take a similar position; the elements or units of a system may be seen to be its substance, or material, and the structure may be said to be its form.

For Waltz, both the elements and structure are important, but he wishes to concentrate his attention on the structure, which will be the focus of this study as well. By focusing on the structure of production in chapters 6 through 8, it will be possible to fruitfully explore the question of productive technological change.

In Waltz's view, the organization of the elements in a system can be further divided into two general aspects: first, an ordering principle; and second, the way the parts are arranged in accordance with the ordering principle. For instance, to take one of Aristotle's favorite examples, a statue is ordered in space; the various parts of the bronze statue are placed in various positions relative to other pieces of bronze, and the relative positions of the various pieces are responsible for replicating the desired image. If the positions of the pieces are changed, the new statue is said to be different than the old, even if the pieces are the same. One could take the same quantity of bronze and produce a statue of a person or a fish; the difference in structure would yield the difference between the two.

The anthropologist Claude Levi used the example of a symphony to explicate two other orderings. Each instrument in a symphony plays notes at specific points in time, while at each moment in time within a symphony certain instruments are playing and certain instruments are not playing. The symphony is ordered both in time and as a set of specific interacting units (Phillips 1976, 88). Thus, there may be more than one ordering principle at work within a structure.

Waltz's concepts of ordering principle and organization seem to have been influenced by a paper he references, by Angyal. For Angyal, "the members of a system...do not become constituents of the system by means of their immanent qualities, but by means of their distribution or arrangement within the system. The object does not participate in the system by an inherent quality but by its *position in the system*" (Angyal 1939, 28, emphasis in original). This position of the members may be spatial or temporal. Further, since objects must be separable in order to study them, Angyal argues that "multiplicity of objects is only possible in some kind of dimensional medium. The clearest examples of dimensional media are space and time...*Systems are the kinds of distributions of the members in a dimensional medium*" (Angyal 1939, 29, emphasis in original). Waltz and this study use the term "ordering principle" instead of the term dimensional medium. Angyal also emphasizes that a system is not the same as the interactions of the elements: "In a system the members do not hang together among themselves but they hang together as a whole" (Angyal 1939, 30).

While Waltz bases his ideas on the writings of scholars who use orderings of time and space as illustrative examples, Waltz himself is concerned with political systems. He therefore uses the social ordering principle of hierarchy as his sole "dimension medium". In an organization or polity, there exists a fairly strict line of authority, emanating from a top officer, such as a CEO or President, flowing downward through various middle levels of the bureaucracy, and finally enforcement imposed on the citizens or employees who are required to follow the laws that are enacted further up the hierarchy. In the international political system, on the other hand, there exits no sequence of command. Truly independent states are said to be in an anarchic relation with each other; that is, there is no relation of authority and command. Waltz's ordering principle yields two possible values for a political system: hierarchic or anarchic.

Realist scholars such as Waltz have always been concerned with the lack of moral restraint on the part of states which an anarchic condition seems to encourage. Modern realists have not been particularly interested in the position of states in space or time, however. The idealist scholar in international relations has also treated states as a set of entities which did not exist in space or time, but which exist in a "society" that orders the states and therefore constrains their behavior. Hedley Bull combined the two concepts in his important work, *The Anarchic Society* (Bull 1977).

An earlier group of international relations scholars, interested in the geographical or "geopolitical" aspects of international power, were concerned with the structure of the international system in terms of an ordering in space. Mackinder conceived of the globe as being affected by the existence of a "Heartland", a "Rimland", and lands in between, all having a particular spatial relation. Mahan emphasized the importance of the seas, since these provided a way to encircle enemies and connect imperial possessions and trade routes (Luard 1992, 231-6). Thus various ordering principles have been used by international relations scholars.

This study will be concerned with ordering in time within a system, as well as hierarchic ordering. Rise and decline occurs through time, and it will be shown that economies and systems of political economy are ordered, in part, through time.

The Arrangement of Parts

Waltz divides his second aspect of structure, the arrangement of parts, into two other concepts, functional differentiation and the distribution of capabilities.

The understanding of function has been very important in anthropology, from which much of the discussion of structure arose (see Phillips 1976, chapter 6). Domestic political systems are also characterized by functional differentiation, as in the American division among the legislative, executive, and judicial branches, as well as the Federal distribution between the national and the state governments.

One branch of social science that has been virtually impervious to any discussion of functional differentiation is economics. Whether the goal is to explain the setting of prices or the existence of competition, oligopoly, or monopoly, all firms are conceived of as being essentially the same except in terms of size. In other words, in neoclassical economic analysis, the units are identical except for size. Instead, my conceptions of economic and production systems will emphasize the functional differentiation among elements, as I will explain in chapters 6 through 8.

Waltz uses the basic idea of the similarity of elements except for size in order to characterize the international political system. Like an industrial sector, all states are essentially similar; instead of differing in size, according to Waltz, states differ in terms of relative capabilities. Therefore, one of the aspects of the arrangement of parts, functional differentiation, is not used by Waltz; only the distribution of capabilities becomes important for Waltz's conception of an international political system.

This system of similarity except for capabilities, it will be argued, is more appropriate for the international political system than for the economic system, for the units in the former carry out similar tasks. It is useful to divide the economy into functional units, each of which carries out different tasks in the operation of a modern industrial economy.

Waltz uses the term "distribution of capabilities" to describe the structure of political systems, but the term "distribution of values" is more useful as a general phrase which can apply to many kinds of systems. In a statue, the mass of the bronze is distributed in space, while in an international political system the capabilities of states are distributed in an environment of anarchy. The critical condition for being able to describe a "distribution of values" is that there be a common measure among all the elements or units of the system. If there is a common measure, the observer can ascertain how the values are distributed or positioned or allocated.

As was pointed out in Chapter 1, the general definition of this common measure of capabilities in international relations is not well-specified; capability is claimed to be an aggregation of many different measures, such as leadership, economic output, and population. The definition of a Great Power can be consistent with the definition of the common measure, since a Great Power will be distinguished by having more of a common measure than other nations. In the next chapter I will attempt to describe a theoretically rigorous definition of the term "Great Power".

Since Waltz does not need to use the concept of functional differentiation in order to describe the international political system, he does not explore the conceptual tension that exists between "functional differentiation" and "distribution of values". When two units have different functions, it may be difficult to detect a common measure; two things which have different functions by definition have something which is not similar. For example, what is common between a legislative branch, which passes legislation, a judicial branch, which uses the legislation to adjudicate disputes, and the executive branch, which is supposed to enforce the legislation? American historians often write about the difference in the relative power among the branches; for example, the late nineteenth century was alleged to have been a time of Congressional dominance over the President. But this sense of relative capabilities is rarely given a common measure.

Many other systems besides the international political one are characterized by functional differentiation. For example, an organism is composed of many functional elements, as is an ecosystem. The components are distributed, but they are distributed according to the ordering principles of time and space; the common measure would therefore be in terms of time and space. Similarly, the economic system, it will be argued, is functionally distributed and ordered in time and space, as well as according to the capability to output economic value.

In ecosystem theory, the problem of reconciling functions with a common measure has been at least partly resolved by viewing the ecosystem as a system for converting energy in a sequence of stages (Campbell et al, 1134-38). The sequence is generally specified to start at the sun. In the next stage, primary producers such as plants capture solar energy. The primary consumers such as plant-eaters (herbivores) then convert the stored energy of the plants into their own forms of energy. Finally, secondary consumers in the form of carnivores receive solar energy indirectly by eating herbivores. A recycling stage of decomposers such as bacteria and fungi feed on all of the other stages.

Each stage (or trophic level, as it is called) serves a function in the ecosystem, and each stage can be measured for its intake of energy. For instance, a common finding is that only 10% of the energy of one stage is transferred to the next; this is why there are very few carnivores in a forest or grasslands. On the other hand, the carnivores serve a very important function; they help keep the herbivores in check, which allows the foundation of the ecosystem, the plants, to survive.

In much the same way, we can look at the economy as a set of stages of output of economic value, each of which serves a particular function. The chapters concerning economic systems will elaborate on this idea.

A General Model of Systems

I have now specified most of the main elements of a theory of systems. A conceptual diagram of a system might therefore consist of the following:

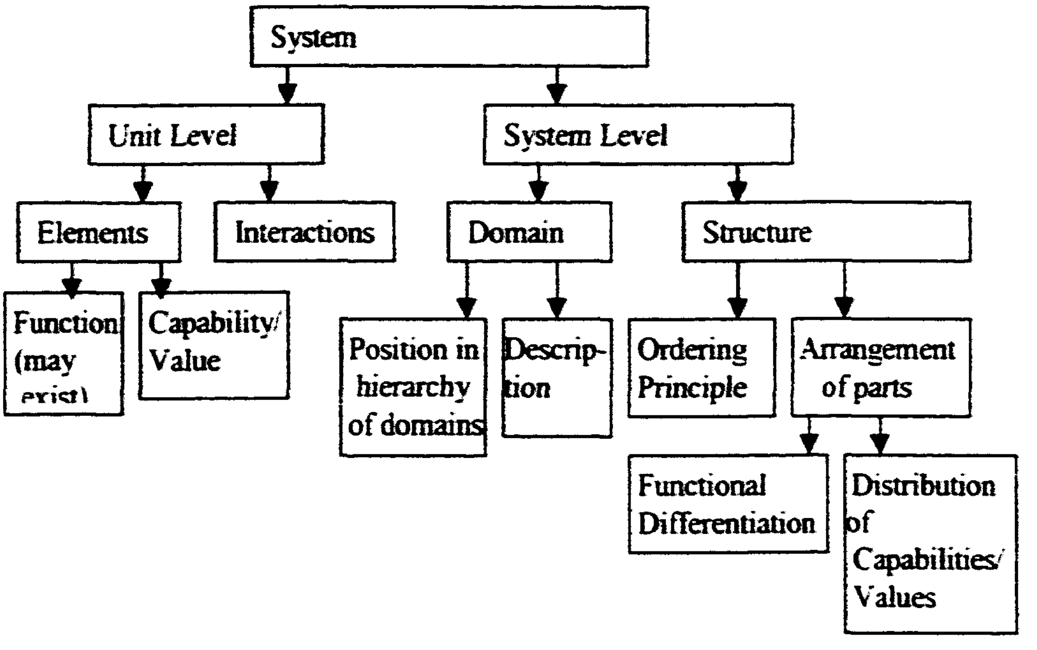


Fig. 11. Model of a system.

The theory of systems as embodied in figure 11 consists of a series of levels. On the first level, the system can be examined at either a unit level or a system level.

On the unit level, we are concerned with knowing which set of elements is in the system. The function served by an element, if there is one, is the property of each element. The capability or value that the element possesses is also a property of each element. We need not specify more than this for each element, because an element is itself a system, the description of which will give a fuller account of the element.

There is a set of interactions among the elements. As will be explained later, the most important interactions among elements are involved with feedback processes. In addition, there are always a certain set of elements which have particular kinds of interactions with outside systems; these elements and their interactions may be termed *interfaces*. For example, the foreign policy apparatus of a state is the primary political interface of a polity.

The system level is divided between the domain and the structure. The domain consists of two parts: a description of the system as a whole; and a link to the larger system of which the current system under study is a part.

The structure itself is divided into two parts, the ordering principle and the arrangement of the units. The arrangement of the units is then divided into a functional differentiation and a distribution of capabilities/values.

At the *element* level of the system, the function and value of the element must be specified so that these functions and values can be used to ascertain the functional differentiation and distribution of values that constitute the *structure* of a system. For example, the various functions of the organs of the body are specified as the functions of a particular set of elements. Using this information, the functional differentiation of the structure can be described.

The aggregation of the capabilities/values of all of the elements of a system constitutes the capability/value of the system as a whole. This value becomes the value of the system when it is considered as an element in the domain at a higher level. Thus, the aggregate output of all firms in an industry becomes the value of the industry when the industry becomes an element in the domain of the entire economy. It may not be possible to aggregate values, however.

The function of the element on one level is the same as the domain of the system at a lower level. Thus the function of a legislature within the state is to make laws, while the domain of the system called Congress or Parliament is as a law-making institution.

Thus, by specifying the various aspects of the system at all the levels of a hierarchy of domains, one can also specify how the systems fit together. Much of the specification of a system depends on how the functions and capabilities/values are defined.

Sequences and the Distribution of Causal Capability

The system has now been specified as a collection of ordered elements. In order to understand dynamic processes such as the rise and decline of Great Powers, however, it is necessary to understand some of the basic processes that characterize systems. The first step in this understanding involves exploring the role of sequences in a system, partly because production involves sequences, as will be seen in chapter 6.

Sequences play a central role in the processes of most systems. A sequence is the manifestation of an ordering in time within a system, such as the notes in a melody or the stages of an assembly line. Martin Johnson writes that "physical science is interested in the changing or the flux of world, not in any static picture, and is in fact a study of a sequence of events whose basic pattern is a time-order" (Johnson 1951, 413).

Waltz cautions that the structure of a system must be carefully separated from the interactions of the elements, or else the system level and unit level may become confused, and the effects of the structure become unclear. A sequence, as on an assembly line or ecosystem, usually involves some sort of interaction among elements in the movement of substance from one stage to another. This interaction properly belongs at the unit level. But the *necessity* of the interaction is determined by the way in which the stages are organized; that is, the structure is separate from the interactions.

For example, in a large factory, there may be a machine shop which produces parts and an assembly line which puts together the parts; this was the design of Ford's first factories. The way in which the parts are moved from the machine shop to the assembly line has changed in the 20^{th} century, from relatively nonmechanized handling equipment to sophisticated cranes and monorails. But the need to move the parts from one stage to another has remained constant, because the process of production requires that parts be made before they are put together. As Waltz argues, the structure illuminates why, even while the attributes of the units change, certain processes of a system remain the same. Sequences help to explain this constancy and continuity of processes.

Sequences often imply the existence of a differentiation in the ability to cause change within a system. That is, there may be a *distribution of causal capability* among units. Let us say that the following sequence exists:

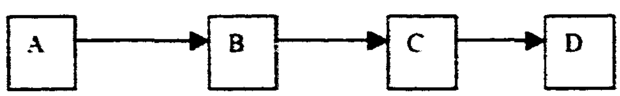


Fig. 12. Example of sequence of production.

Let us further say that this is a sequence of production in which A produces B, B produces C, and C produces D. If A changes for the better, A units will be able to produce better B units, which will mean that B units will be able to produce better C units, and C units will output better D units. Therefore, a change in A has led to an improvement in *four* sets of elements, not just one. The change in one has reverberated, or been transmitted, throughout the system. However, if D changes for the better, this change will only effect D. A, B, and C will remain as they were before. Similarly, if B changes, C and D will change, and if C changes, C and D will change. So a change in A is worth 4 units, B is 3 units, C two units, and D only one unit. Because of the position of the units in the sequence, a change will have a different effect, depending on the changed unit's position. As will be shown in more detail in the following chapters, this kind of production sequence characterizes the economic system and the domestic political system.

Differentiation of causal capability is particularly important if we have, not a one-dimensional sequence, but a two- or three-dimensional one, such as the following:

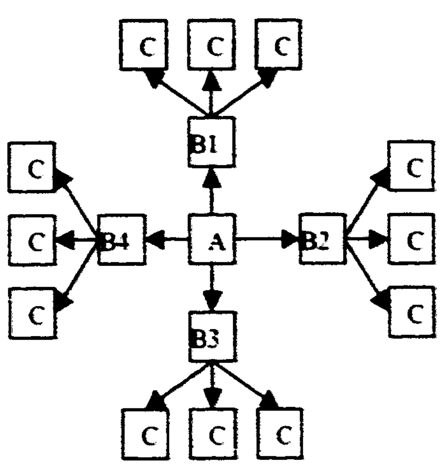


Fig. 13. Two-dimensional sequence.

In this system, a change in A will lead to a change in all Bs and then to a change in all Cs, whereas a change in a single B, say B2, will only lead to a change in B2 and its connected Cs. This sort of amplification of change is characteristic of economic systems and can be seen in the operation of ecosystems as well. For instance, when the dominant plant-type became flowering plants (angiosperms), this change effected herbivores, and through herbivores, carnivores as well.

Is the distribution of the capability to change elements within the system a part of the specification of the structure? This causal capability depends on the unit's position within the system, not on the attributes of the unit itself. For instance, it will be argued that the machine tool industry has an importance in the economy which is much greater than can be ascertained by the monetary value of its output. This is not because machine tools are magical or more complex than other goods; it is because of their position in the structure of the economy.

This distribution of causal capability cannot even be specified in an absolute way, as can the capability in the distribution of capabilities. For instance, in figure 13, the unit A can be described absolutely according to a measure, and relatively as compared to other units, using the same measure, such as dollars of output. But the capability to cause change to other units can only be ascertained if the *position* of unit A is known; if analyzed as an isolated unit, in fact, unit A has *no* causal capability. Causal capability is *only* a relative capability, knowable from the structure of the system.

The distribution of this causal ability would seem to be a part of the structure. Waltz emphasizes that structures help to explain the lack of change in a system, but structures may help to explain change as well. The existence of a differentiation in causal capability leads to nonlinear processes within a system.

There has been much interest in many of the physical sciences in the nonlinear effects of particular causes. Much of this work has taken place under the label of chaos theory, which is a popularization of more descriptive terms such as nonlinear dynamic processes. Maruyama has drawn attention to mutual causal systems, in which "the elements within a system influence each other either simultaneously or alternatingly," leading to a situation in which "processes of mutual causal relationships ... amplify an insignificant or accidental initial kick, build up deviation and diverge from the initial condition" (Maurayama 1963, 164). Growth, whether of an organism, population, economy or a state, is a nonlinear process of change. It is therefore important to investigate the role of structure in nonlinear processes. When there is an uneven distribution of causal capability in the structure of a system, some element or elements have a greater capability to change the system than other units, so that a small change in one element may cause a disproportionate, or nonlinear, change in the system as a whole.

In neoclassical economic thinking, causal relationships are linear. No element in the system has greater causal capability than other elements. By contrast, I will show in chapters 6 through 8 how an analysis of production reveals differences in causal capability among elements of an economic system.

Waltz's assumption of the importance of Great Powers has a certain nonlinear aspect. Out of a multitude of states, Waltz and others claim, there are only a few which are the focus of international attention. Great Powers have a certain "position" in the international system, but this position is more abstract than a position in a sequence or in space. Great Powers can be seen, however abstractly, as being in the position of Unit A in figure 13; change in the capabilities of Great Powers affects, not only the Great

Powers, but all of the other states as well. The distribution of this capability is of a dualistic variety; either a state is or is not a Great Power. In a system which contains a functionally differentiated sequence, the distribution of the capability to change elements is more varied than in the case of the international political system.

In a system that does not contain a sequence, then, it may be the case that one set of elements can be marked off as having a much greater effect on the system than other elements. To take an example from astronomy, when inquiring into the dynamics of a galaxy, only the stars are considered, as the planets and various other bodies are too small to make much of an effect.

In either a sequential or nonsequential system, this difference in capability to change elements may translate into an ability to change the structure itself. It will be argued in the next chapter that the Great Powers are those states that have the capability to reorder territorial allocation among states, the effect of which is to change the structure of the international political system.

For the purposes of simplifying the theory of systems, it will be assumed that functionally differentiated systems may include a varied distribution of causal capabilities among the units. In a nonfunctionally differentiated system, however, there may be only a dualistic distinction, between those elements that can cause extensive change in the system and those that can not. This dualism is based on the distribution of capabilities/values, where the difference in *values* is so great that a fundamental difference in causal capability occurs. For functionally differentiated systems, however, the distribution of causal capability is based on differences in *functions*.

The distribution of causal capability is based on either functional differentiation or distribution of values, but is different than either. Thus, the arrangement of parts of a structure can be decomposed into three elements: first, a differentiation of function; second, a distribution of capabilities/values among units; and third, a distribution of causal capabilities among units.

Generation and Allocation

In order for there to be a sequence in a system, it is necessary for there to be a functional differentiation of the elements within a system; it may be more or less difficult to establish a common measure of the units in order to describe a distribution of capabilities/values. I will call such systems *heterogeneous*.

If a system does not have a sequence, then it probably does not have a functional differentiation, and the specification of a common measure may therefore be easier. I will call systems with no functional differentiation *homogeneous*.

This dichotomy between functionally differentiated and homogenous systems suggests a fundamental difference between two types of systems. In a *generative* system, there is a functional differentiation which gives rise to a sequence of stages through time. This sequence involves the transformation of inputs which results in the creation of something new as the output.

We can find examples of generative sequences in many kinds of systems. A factory uses certain materials and intermediate goods as inputs. The factory then outputs intermediate goods of a different kind or finished goods. When organisms ingest materials and energy, they transform them into different kinds of materials and forms of energy within their bodies. When a carnivore in an ecosystem consumes another animal, such a process takes place at the end of a chain of energy and material transfers within the ecosystem. When a law is enforced in a country, that enforcement is the end result of a sequence of processes involved in the creation and enforcement of laws. All of these processes involve transformation, generation, and creation.

An *allocative* system, on the other hand, is a system that allocates the substance that the generative system generates. The allocative system does not create anything new; it moves and distributes that which has already been created.

Most systems have an allocative aspect. The retail sector is used to distribute the final goods that are produced by factories, and the financial sector allocates the capital generated by the producing sectors of the economy. A biological example would be the circulatory system in animals, which distributes the sugars transformed by the digestive system throughout the body. Within the polity, the power to control the law-making process is allocated among all members of the population in a democracy, but such control is limited to only a few people in a dictatorship. In all of these processes, the allocative system does not create, but it fulfills the equally important function of distributing the output of the generative system.

An allocative subsystem has a distribution of values and causal capabilities but little or no functional differentiation. The specification of elements in an allocative system involves only values, and not functions.

A generative subsystem has a functional and causal differentiation, and may or may not have a distribution of values. The description of elements in a generative subsystem incurs the need to specify functions. The concept of a value in a generative system is primarily one of specifying the total output of the subsystem which is generated, not one of judging the relative contribution of each element to the output. For instance, many industries contribute to the final output of the economy, and it may be difficult to attribute a precise quantity to each industry's role.

Since all parts of the generative system are often devoted to an end product, the intermediate stages can only be judged by the output of the whole, not by the elements' individual outputs. By contrast, as discussed in chapter 3, neoclassical theory posits that factors receive as income that which they contribute to the production process.

Some systems contain both generative and allocative systems within them; it may be said that such systems are *complete systems*, and are composed of two elements, allocative and generative *subsystems*. For example, an economy has both a production subsystem which generates goods and services, and an allocative subsystem which distributes this output. An organism has both a transformational subsystem which synthesizes chemicals, and a pulmonary-circulatory-waste subsystem which moves the synthesized products around and out of the body. As pointed out, an ecosystem is both a set of trophic levels, transforming different kinds of organisms into other kinds of organisms, and is a system which allocates energy and materials. A political system both creates laws and allocates control over the making of those laws. Generally, in order to understand the operation of complete systems, their generative and allocative subsystems must also be understood.

Sometimes a system can be seen as complete on one level, and then be viewed mainly as allocative or generative at the next level up in the hierarchy of domains. For example, a political system may be seen to be complete, but as part of a larger system of political economy, its allocative aspect might be emphasized.

Let us diagram a complete system as follows:

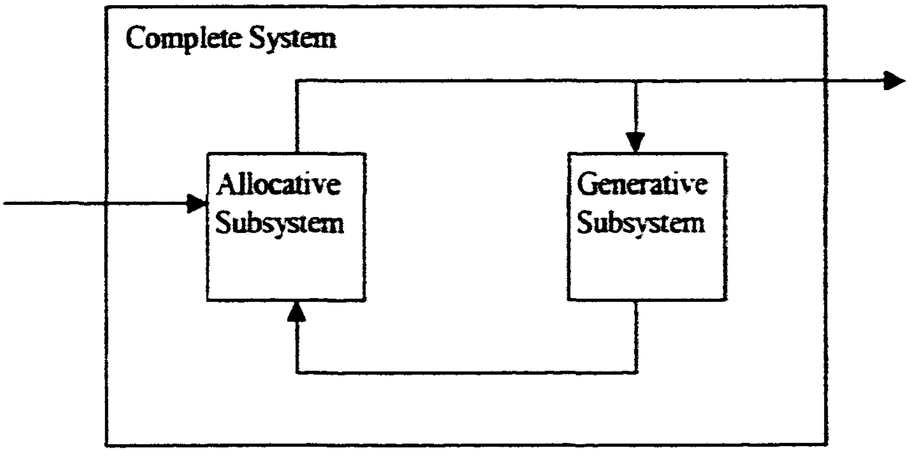


Fig. 14. A complete system.

The generative subsystem outputs a substance which the allocative subsystem directs back to the generative subsystem. The next chapters will explore the operation of this process for economic systems, political systems, and systems of political economy.

The diagram shows an arrow leading into the allocative subsystem and an arrow leading out from the allocative subsystem. All systems discussed in this study are *open* systems; that is, they receive inputs from other systems and send output to other systems. In this simplification of reality, only the allocative subsystem has control over flows into and out of a system.

The structure of a complete system is ordered in time, and is usually not a sequence but a *cycle*. Substance includes new elements in the system as well as the system's output. This substance is generated by the generator, then moved to the allocator, which transfers output back to the generator, and so on. The allocator, by distributing the output of the generator among all elements of the system, can therefore play an important role in changing the structure of the system.

The generator, on the other hand, is the source of the growth of a system. The generator cannot change the structure of the system of which it is a part, but the generator, by changing the aggregate value of the system of which it is a part, can change the structure of the system at the level *above* itself.

For instance, consider the following:

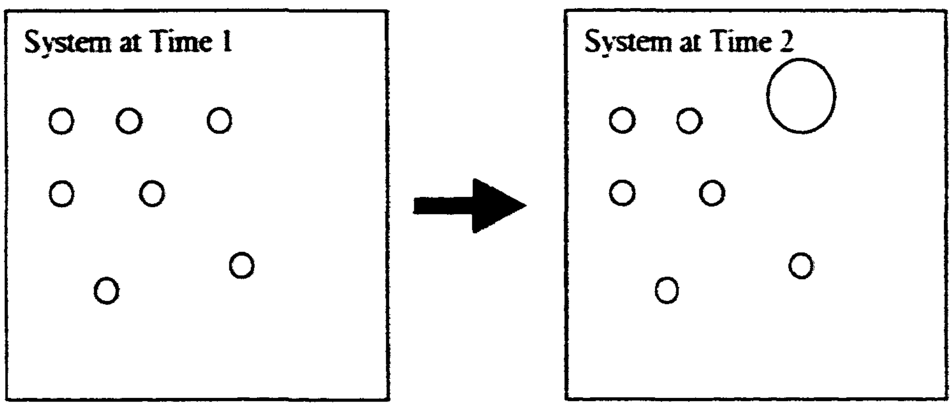


Fig. 15. Generating a change in structure.

The system at time 1 might represent an international political system in which all of the states have roughly similar capabilities. But say that one state has a capability generator which results in the state growing to such an extent that it then becomes much more powerful than the other states, as in the system shown at time 2. The internal structure of the state may not have changed, but the change in the total value of the state has changed the structure at the level above the state, the international political system.

The change in the total capability of the most powerful states, which leads to a change in the structure of the international political system, is the process of the rise and decline of Great Powers. The rise and decline of Great Powers can thus be seen within the context of the general theoretical framework presented in this chapter.

Feedback Processes

A cycle may exist within a complete system made up of allocative and generative subsystems. A generative subsystem may also have cycles within it, such that parts of a sequence loop back to previous stages. This situation known as feedback. Feedback also characterizes allocative subsystems. These feedback processes explain much of the change and stability that occurs within systems.

There are two main types of feedback processes. In a negative feedback process, an increase or decrease in a value will lead, eventually, to a compensating decrease or increase in that value, respectively, and the system will be *stable*. In a positive feedback loop, an increase or decrease in a value will lead to a greater increase or decrease of the value in the following time period, and the system will be *dynamic*, or changing.

This study will focus on the operation of positive feedback loops, because this study is attempting to explain the causes of change in the relative power of Great Powers, not stability in the international political system (for a survey of positive feedback, see DeAngelis et al 1986 and Milsum 1968). The next chapters will therefore discuss the negative and positive feedback loops that characterize political systems, economic systems, and systems of political economy.

Allocative and generative subsystems have different feedback processes. An allocative system has nonfunctionally differentiated elements, and the structure is specified by the distribution of capabilities/values. When a unit has a greater value than its neighbor in an allocative subsystem, there is a tendency for the unit to control the neighbor; the allocative units are vying for control, and they allocate values, including other units, to themselves. An example of a mechanical allocative subsystem would be a Newtonian gravitational system. Where the units are large enough – such as a star or planet – the sheer quantity of mass contained by the unit means that other units, of smaller size, will tend to be pulled within the gravitational field of the larger unit, and will be absorbed. Thus, when solar systems are forming, the proto-star pulls most of the mass of the solar system into itself. A positive feedback loop develops, wherein a certain amount of mass leads to the probability that an even larger amount of mass will be in the gravitational pull of the object.

The same phenomenon can be seen to occur in an international political system, which can be viewed as an allocative system. The larger the polity, relative to its neighbors, the better the probability that the polity will be able to absorb its neighbors. As Waltz (and others) have pointed out, however, this process is countered by the tendency for states to form a balance of power. A balance of power is an example of a negative feedback process forming in an allocative system.

Negative feedback processes form in allocative systems, in general, when a balance is achieved among the units so that no unit is large enough relative to the others to be able to absorb another unit. To return to the solar system example, the planets are at just the point in terms of mass, distance, and speed where they are large enough, far enough away from the sun, and revolving around the sun at the right speed so that they are not pulled into the sun's gravitational field.

Feedback processes in *allocative* systems therefore involve the aggregation of units into other units, in the case of positive feedback, and the countering of this effect, in the case of negative feedback.

Feedback processes in *generative* systems, on the other hand, involve the creation of substance at an exponential rate, in the case of positive feedback, and the necessity of the simultaneous, balanced growth of all units of a system, in the case of negative feedback.

For example, the foundation of the ecosystem (or community) is the ability of the organisms to reproduce, a positive feedback process. Organisms are capable of reproducing at an exponential rate. An exponential rate of growth is to be distinguished from a linear rate of growth. During a linear rate of growth, the original population will increase by a particular percentage, or will be multiplied by a particular number, in a certain period of time. For instance, in the realm of industry, if one can make 10 widgets in one hour, in 10 hours one can make 100 widgets.

In an exponential growth situation, on the other hand, the original population, numbering X, increases by an exponential, say N, denoted X^N. If we have 1 bacterium, and bacteria split once every minute, then at the end of 10 minutes we have 2^{10} bacteria, which equals 1,024. During a linear growth rate, the widgets only increase by a factor of 10; during an exponential growth process, the bacteria increase by over a factor of 1,000.

There is a large difference between 10 units and 1,024 units. In the aforementioned case of linear growth, there is only one generator, or producer, of units. In the second case of exponential growth, each new unit is also a generator. In order to produce exponential growth in the first case, each widget would have to turn into a factory, generating new widgets which then turned into factories, and so on.

As will be explained in a later chapter, this production of a producer does indeed take place in the generative subsystem of an economic system, because machinery such as machine tools generate the parts, or other substances, that can then be used for their own reproduction. There is therefore a positive feedback process inside the generative subsystem of an economy.

In an ecosystem, as it has long been observed, if any organism was to have all of its progeny survive for a long enough number of generations, the earth would eventually become covered, miles deep, with the descendants of the original pair of organisms. The negative feedback loop in an ecosystem is the necessity of many or all of the units of an ecosystem to expand at approximately the same rate as the exponentially growing units.

For example, in order for a deer population to grow exponentially, their food source would have to grow exponentially, which means that the rain and minerals that the plants need would probably have to grow at an impossible rate, and the ground available to the plants would have to grow exponentially as well. This process of balanced exponential growth can occur for a short time in situations in which, for example, the ecosystem has been wiped out by a volcanic explosion, or a better-adapted group of organisms invade a previously isolated area. But in the normal situation, what is called the *carrying capacity* of an ecosystem limits the growth rate of various of the elements.

The observation of unbalanced growth processes was one of the motivations for the development of the neoclassical economic notion of diminishing returns, which was examined in chapters 2 and 3 of this study. Ricardo explained the progressive deterioration of production on a particular piece of land as the diminishing return to additions to the labor force. From the systemic viewpoint of the framework proposed in this study, however, we can look at the same phenomenon and describe diminishing returns as the operation of negative feedback in a generative system.

Instead of focusing on diminishing returns, the neoclassical model can be recast by describing the land and labor of Ricardo's example as two different functional sectors within an economic system. That is, there are two functions called labor and land in an economy. For production to be maximized, both functional sectors must grow in some logical relation to each other; increases in labor must be accompanied by increases in land in order for the balanced growth of production to take place. For an economy as a whole to grow, all sectors of the economy must grow together in a balanced way.

In the realm of biology, the processes of the ecosystem may lead, in the long-run, to the occurrence of *coevolution*, in which the success of one species is contingent on the success of another; this is the generative negative feedback process in evolution.

There are also allocative feedback processes in an ecosystem. The competition among species is an allocative feedback process. In this situation, the competition must be seen as occurring within a particular niche, or in a particular functional area of an ecosystem, in which the different species are attempting to allocate or share the same resources.

For example, several carnivores may compete to kill a particular kind of herbivore, a task for which the various species of carnivore are well-designed. In such a situation, there may develop a "balance of power" among several species, which would constitute an allocative negative feedback process, or one species may get the upper hand and dominate its competitors, an allocative positive feedback process.

Natural selection is both the struggle among species *within* a niche, and the coevolution of species *across* niches. The struggle among species involves both negative and positive feedback in an allocative way, while coevolution involves a generative negative feedback process, because the species must evolve together. Both arenas for natural selection, however, are driven forward by the explosive reproductive potential of organisms, a generative positive feedback process.

In the same way, firms in one industrial sector struggle for domination in an allocative process, but firms across industrial sectors cooperate with one another other in a generative process. In both situations, because of the nature of industrial technology, growth can be sustained and nonlinear.

Because the international political system is allocative, only a struggle among units takes place, not a cooperation among units across sectors. Historically, this struggle occurred among states in Europe with different political (and economic) systems. When some better-adapted political economic forms had developed within Europe, the Europeans were able to invade and dominate states with different systems of political economy. Waltz refers to this process as a systems process of competition. In addition, some states more or less voluntarily followed the European example (such as Japan), a process Waltz refers to as socialization.

Where do these processes fit into the general model of a system? Are they part of the unit level or the system level? The structure determines the *type* of the system, whether allocative or generative. If the structure does not include a functional differentiation, then the system will be allocative. If the structure includes a functional differentiation, then the system will be generative.

However, feedback processes are not *part* of the structure, yet they occur at the systems level. They may be thought of as emergent properties, characteristics of the system that are not identifiable from looking at the units in isolation. The feedback processes involve interactions of the elements, which then effect the structure, which then provides the conditions under which the elements can in turn effect the structure. As Carlsnaes has pointed out, we can still separate the structure and the elements (or agents, as he puts it) if we conceive of systemic processes as the alternation of the effects of unit-level and system-level causes (Carlsnaes 1992; see also Archer 1985). Feedback processes involve the interaction of the elements and the structure. Therefore, feedback processes constitute a third level of a system, in addition to the unit level and the systems level.

In order to develop a systems theory, Waltz warns, one must define systems change. My theory includes mechanisms for systems change. It has been proposed that, in an allocative system, positive feedback can account for structural change; as some units become stronger and stronger, the distribution of capabilities changes, and thus the structure changes. Another way for the distribution of capabilities to change, it has been proposed, is for the capabilities of the generative subsystems of the units of a system to change at different rates, as in the example of the rise and fall of Great Powers.

In a generative system, a change in the functional differentiation of the elements will be a change in the structure. Perhaps the most important change in functional differentiation occurs when the first stage of a sequence becomes reproductive. That is, when the first stage of a sequence is able to reproduce itself, the entire generative subsystem then becomes capable of exponential growth; if there is not a reproductive stage in a sequence, growth can only be linear.

The functions of a generative subsystem may change for reasons internal to the subsystem. Since each element in the subsystem is also a system, the change in nature of an element at one level is caused by the change in the structure of a system at the level below. But the function of the element may also change; for instance, the lung of air-breathing animals evolved from the air sac of fishes. The change in the functional position of an element in a structure may therefore involve both change in its internal structure as well as change in the domain of the system which is the element. These changes in social systems are often conscious *innovations*; in biological systems, changes in generative systems are often *mutations*.

The negative feedback processes serve to explain continuity and stability, as Waltz has claimed. The political theory of balance of power can be seen as a negative feedback process. It shows why variation in actions of individual units, states, results in less change than one might expect from simply examining the actions themselves. But positive feedback processes can illuminate another facet of systems, the fact that structures of systems create the conditions to actually *accelerate* change.

When a small subset of elements of a system has a relatively large impact on the system because of its potential to exponentially grow or to absorb its neighbors, then we need a systems approach to understand how this can be. Thus, by using a model of systems as enunciated here, we can understand both stability and change in systems.

Conclusion: A Theory of Systems

A theory of systems such as the one presented here should itself be a system. There are several elements of the theory.

First, each system defines a *domain*. Systems in the abstract are linked to systems above and below in a *hierarchy of domains of inquiry*; a domain of inquiry may be divided into subdomains according to certain criteria.

Second, the systems are linked vertically because they are composed of *elements*, each one of which is itself a system.

Third, there is a *structure* in a system, which in turn is composed of an *ordering principle* and *arrangement of parts*. The arrangement of parts are characterized by a combination of one or more of the following: a *functional differentiation*; a *distribution of capabilities/values*; and a *distribution of causal capability*.

Fourth, a *complete system* may be said to be composed of a *generative* subsystem and an *allocative* subsystem, which either have a functional differentiation or no functional differentiation, respectively.

Finally, there exist *positive feedback* and *negative feedback processes*, which operate differently according to whether or not the system is generative or allocative.

The following diagram shows the general model of systems as explained in this chapter:

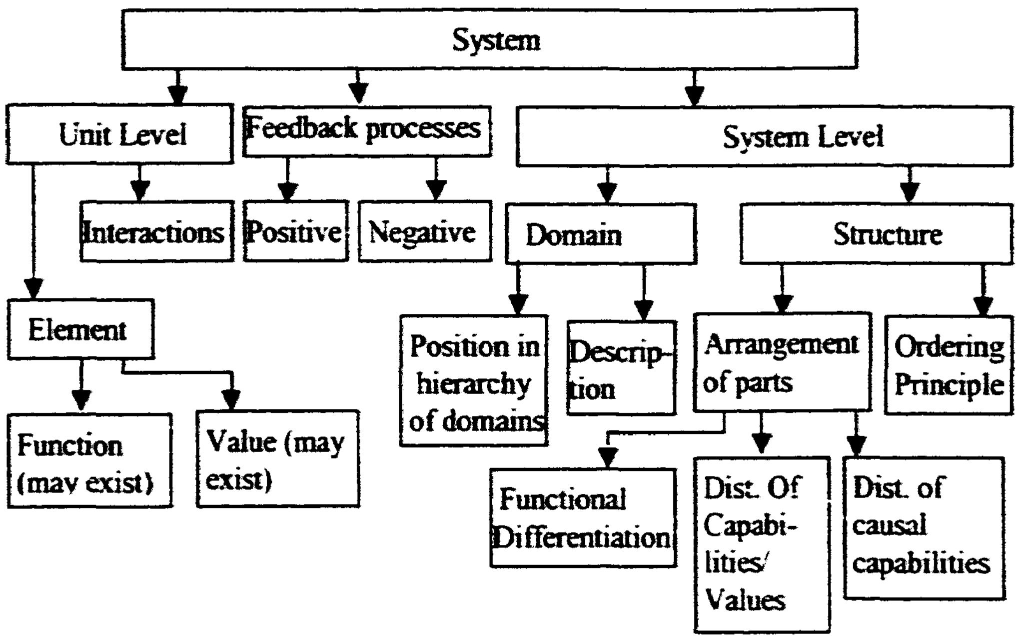


Fig. 16. Complete model of a system.

There can be said to be a structure to this theory, because each element serves a different function. There is no allocative subsystem in this theoretical system, so the theory is a generative system.

This theory of systems helps to generate theories of particular systems. In the next chapters, this theory of systems will be used to generate a theory of economic systems (and within it, a theory of production and capital systems), a theory of political systems, and a theory of systems of political economy.

These theories, in turn, will be used to generate hypotheses. A theory of a particular system is used to generate hypotheses that can be validated or refuted.

Thus, chapters five through 10 of this study have a generative structure, illustrated by the following diagram:

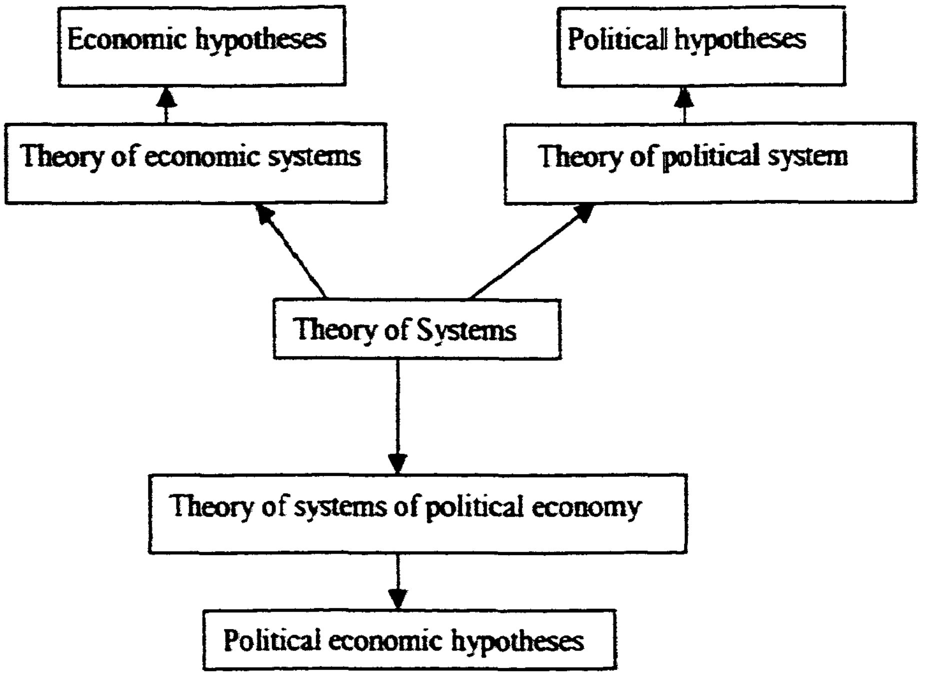


Fig. 17. Structure of chapters.

This study has a two-dimensional sequential structure, in which the theory of systems is most important, the theories of particular systems are second in importance, and the hypotheses have the least capability to influence the theory as a whole. This system of theories and hypotheses can be referred to as a paradigm, or as a theoretical framework.

Thomas Kuhn (Kuhn 1970) developed the concept of a paradigm in order to explain change in scientific theories. His used the concept in many ways (one scholar famously counted over twenty uses [Masterman 1970]), but the core of his concept seems to have been that a paradigm is a network of theories and hypotheses that hang together in a kind of *gestalt*, or totality. The term has since been used, popularly, to characterize changes in ideas ranging from advertising slogans to investment strategies. I will use the term *theoretical framework* instead, for the purpose of identifying a theoretical system which has a theory of systems, theories of particular systems which are consistent with the theory of systems, and hypotheses which are generated by using the theories of particular systems.

Since there is a theory of systems embedded in the theoretical framework, a logical consistency among the parts of the theory is easier to maintain. The framework generates itself, instead of being constructed in an ad hoc manner.

The diagram of the paradigm shows three stages of a sequence: a theory of systems, or metatheory; theories of particular domains, or theories; and hypotheses. This tripartite sequence is a useful one for explaining generative systems.

The last stage of a tripartite generative sequence involves the production of the output that is being generated by the system as a whole. For example, the GDP (gross domestic product) of a national economy, the enforcement of laws in a state, or the leaves on a tree, can be seen as the output of the generative subsystems in an economy, state, or biological community, respectively. This stage can be called the ***production*** stage, because the final output is being produced.

The middle stage of the sequence involves the production of the elements which participate in the last, production stage. Thus, the production of production machinery, the creation and regulation of bureaucratic "machinery", and the organs involved in tree growth are the middle stage of the economic, political, and biological community systems, respectively. This stage can be called the *generator* stage, because the generators of the output are created at this point in the sequence.

The first stage is the part of the sequence in which the objects which create the generators are produced. In addition, if there is a reproductive aspect of the system, this is where reproduction takes place; at the *metagenerator* stage, the metagenerators create the generators and may reproduce themselves. For example, a particular subset of machinery, to be called reproduction machinery in the chapters on economic systems, both creates more reproduction machinery and is used to generate production machinery. In a state, the political elites create the bureaucratic machinery. The political elites may reproduce themselves, as in a dictatorship (literally in a kingship) or they may simply be regenerated, as in a democracy. In a biological community, the reproductive apparatus of trees provides the machinery which will generate more reproductive organs as well as the mechanisms of tree growth.

We can diagram these sequences in the following way:

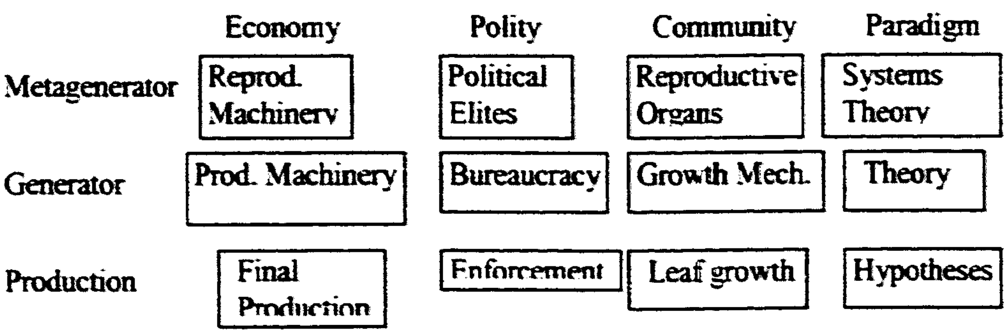


Fig. 18. Examples of tripartite sequences.

Thus, there is a consistent model which can be used in the next chapters to characterize the economic, political, and political economic systems. This model is consistent within itself, because the theory can also be conceived of as a system. By specifying these systems, certain conclusions will be reached in chapter 10 concerning the causes of the rise and decline of Great Powers. Throughout chapters 5 through 10, hypotheses will be proposed based on the discussion of the various systems.

Thus, the constructive parts of this study will follow a tripartite organization as well: first a theory of systems is presented; then, a set of theories of particular systems is articulated; and finally, a set of hypotheses will be generated.

By constructing an abstract framework in this chapter, I will be able to propose theories and hypotheses concerning the definition of a Great Power, and most importantly, technological change in production. These theories and hypotheses will not be ad hoc, as I claim the theories and hypotheses of the scholars reviewed in chapter 1 through 3 were prone to be. The theoretical framework as proposed in this chapter will be useful for understanding the processes of the rise and decline of Great Powers in the following chapters.

CHAPTER 5

A THEORY OF POLITICAL SYSTEMS

Systems have been defined, and therefore I can use my general theory of systems in order to construct theories of particular systems. The goal of this chapter is to construct a theory of political systems for two main reasons: first, in order to define a Great Power in a theoretically consistent way; and second, to be able to construct a theory of a higher level of system, specifically, a system of political economy. A theory of systems of political economy will then be used to generate hypotheses concerning the subject matter of this study, the rise and decline of Great Powers.

Defining the Political Domain

The process of rise and decline of Great Powers is a phenomenon which falls within the domain of the social sciences. One could analyze this process in terms of psychology, cultural studies, economics, sociology, political science, or many other fields. It was previously asserted that it is sometimes useful to disaggregate domains into subdomains. How are the subdomains to be chosen, and how can these subdomains be defined?

Rise and decline clearly involves political and economic factors. The power of Great Powers is manifested politically, and the strength or weakness of the industrial sectors has been of great importance since the 19th century. Many scholars have written of other influences; for example, Joseph Nye (Nye 1990, 188-201), among others, has argued for the importance of "soft power", that is, the ideological and cultural influence of one country over another.

Since the process of rise and decline is very complex, this study will restrict itself to the two most obvious causal forces, politics and economics. In order to understand the interaction of the two, it is necessary to model the two subdomains, economics and politics, as well as their combination, political economics – a total of three systems. If the domain of culture were added, for instance, it would be necessary, not only to understand the three subdomains, but the three combinations (culture-politics, culture-economics, and politics-economics), and then the combination of all three – for a total of seven systems. The complexity of the project would increase in a nonlinear way.

By restricting the inquiry to the subdomains of politics and economics, this study will be able to restrict the discussion mainly to material factors. There will be little recourse to the causal importance of incentives, demands, or desires. The theories as developed here will not exclude such considerations from future research; the theories will serve as the material skeleton on which these future studies might be constructed. Any studies which wished to concentrate on cultural or other factors would benefit from a useful modeling of the material basis of human affairs, and any discussion of that material basis should include the domains of political and economic systems.

If these two subdomains are to be chosen, then it must follow that there is some complete domain which can be divided into two subdomains. If the complete domain involves the material aspects of human social reality, then there must be some way to characterize the whole of material reality which can easily be split in two.

To some extent, any attempt to make such an abstract division of reality is metaphysical, that is, is itself based only on introspection and an artificial imposition of categories on an underlying reality. However, one can not proceed with any scientific research without making certain distinctions. Physics has used a categorization of material reality since Newton, and the important consideration is that the categorization has been useful. Newton divided reality into force, matter, time and space, and Einstein changed the categorization to *energy*, matter, time, and space. Einstein's categorization was usefull for constructing his theories.

Similarly, this study will use Einstein's categories as a starting point for the task of dividing human material reality. Einstein aggregated his four categories into two larger categories, time/space and matter/energy. The relation of time and space was the subject of his theory of relativity, while the relation of matter and energy was summed up in his famous equation, $e = mc^2$. This categorization is also suggestive for the social sciences (without implying that there is a strict analogy between physics and social sciences). It will be useful to investigate a sphere of inquiry which is mainly concerned with the human use of space, and a sphere which is mainly concerned with the human use of matter/energy.

Since this is a study of change, however, time must be an integral element of any domain under discussion. As argued in the previous chapter, systems often contain sequences, and sequences are ordered in time. Therefore, it will be useful to include time in both spheres, space and matter/energy.

If one subdomain involves space through time, and the other involves matter/energy through time, then the political subdomain can be initially defined as "the human control of space through time", and the economic subdomain can be initially defined as "the human transformation of matter/energy through time".

Economics is often defined as the production and distribution of goods and services. In the previous chapter, instead of the terms 'production' and 'distribution', the terms 'generation' and 'allocation' were used to characterize the different aspects of a system. The production of goods and services involve the transformation of matter/energy into other forms of matter/energy. Therefore, an improved definition of the economic domain would be "the human transformation of matter/energy into different forms and the allocation of those forms, through time".

The subject of the political domain, accordingly, should be restricted to space. In terms of social reality, the term "territory" is equivalent to the concept of space. Territory is one way in which humans (and other animals) experience space socially, that is, in relation to one another. Except for occasional activities such as the creation of land by the use of dikes in Holland, space is not created. Instead, space is *controlled*. But the idea of controlling space makes no sense except in the sense of controlling the objects that are contained *within* the space. In the political domain, the main objects of control will be assumed to be people.

In order to keep the model simple, the type of control to be assumed will be the control of people in space, and more particularly, the control of the *position* of people in space. The most important type of control, according to this line of reasoning, is to put people in a particular position in space.

This control manifests itself in two major ways in society. First, prisons are used to restrict the position of a person in space. The placement of a person in prison is the most obvious manifestation of the working of a political system, according to my definition of the political domain.

The second manifestation of control of humans in space is to control their existence within the space. There are three main ways of enforcing such control: first, the person can be killed; second, the person can be expelled from the territory; and third, the person can be allowed to enter the territory.

Under what circumstances a person should go to prison and for how long, whether a person should be put to death or expelled, and who should be let into a society, are questions that are at the core of the meaning of a political community. Thus, any definition of the political domain should include these issues, and the simplest definition of such a domain could end with such a definition.

In order to keep the definition simple, then, the political domain will be defined as "the generation of control of a population within a particular territory through time, and the allocation of that control". The generator of control will be called the state; the population, over which control is generated, is a generator of people. There are therefore two generators in the domestic political system: the state and the population.

The State

My definition of the political domain, despite its simplicity, includes much of the meaning that scholars have attributed to the concept of the state.

A state has been necessary in order to manifest control over a territory. Max Weber famously claimed that "a state is a human community that (successfully) claims the monopoly of the legitimate use of physical force within a given territory" (Weber 1946, 78).

Many scholars have accepted some version of this definition. For Charles Tilly, who traced the development of the modern state,

> An organization which controls the population occupying a definite territory is a state insofar as (1) it is differentiated from other organizations operating in the same territory; (2) it is autonomous; (3) it is centralized; and (4) its divisions are formally coordinated with one another. (Tilly 1975, 70)

Poggi, a political sociologist, agrees with this definition (Poggi 1990, Chapter 2), as do Weiss and Hobson (1995), and Michael Mann (1985, 67). Similar definitions are used by Skocpol (1985) and many others.

Michael Mann claims that "the definition of the state concentrates upon its institutional, territorial, centralized nature…only the state is inherently centralized over a delimited territory over which it has authoritative power" (Mann 1985, 70). The idea of space is paramount: "Unlike economic, ideological or military groups in civil society, the state elite's resources radiate authoritatively outwards from a centre but stop at defined territorial boundaries. The state is, indeed, a *place* – both a central place and a unified territorial reach" (Mann 1985, 70, italics in original).

Tilly, Mann, Poggi and others agree that one of the main functions of the state is to control the violence which occurs within the territory of the state. As Poggi argues, "Since all human beings are potentially violent and intrinsically exposed to each other's violence, it is in the interest of individuals to vest in an artificially constituted sovereign all capacity to exercise violence, as that sovereign's exclusive, unchallengeable prerogative" (Poggi 1990, 13).

Some forms of violence are more important than others: "Whoever is in a position, credibly to threaten others with physical annihilation, has at his disposal a sanction potential which is incomparably superior to all other sanctions…Having it, on this account, constitutes the very core of the political experience" (Narr, quoted in Poggi 1990, 10).

Thus part of the control of space, or territory, involves the potential elimination of a person from that space. The most important forms of violence are those that impinge on the position of a person in the territory.

The ability to control violence, and to threaten violence in order to control space, implies a capability on the part of the state to *generate* violence. In the modern (and even ancient) state, this state-sanctioned violence is enforced by agents of authority such as police, internally, and the military, externally (or internally as well). These *enforcement agents* or *means of violence*, in turn, are controlled by a group of people ordered in a hierarchy, called a *bureaucracy*. For instance, in the Federal branch of the United States government, this bureaucracy is comprised of the President at the top, the Attorney General at one level down, followed by various deputies, until finally the actual wielders of authority will be various kinds of U.S. Marshalls, Immigration and Naturalization Service officials, and prison officers. Alongside this hierarchy there also exists a hierarchy of courts which try and sentence people who have been accused of braking the law.

The *state elites* make the laws that the bureaucracy enforces; the bureaucracy enforces these laws using the means of violence, which are composed of enforcement agents and corresponding technology. The state elites not only make the laws, but they shape and create the bureaucracy. They are metagenerators, in the sense defined in the previous chapter; they create the generators (in this case, the bureaucracy), and they may also regenerate themselves.

Part of Weber's analysis of the workings of the state can be seen as an attempt to divide the concept of the state between state elites and the bureaucracy. The division is manifested in his concept of "legitimation".

For Weber, it was important that the state have *legitimate* means of coercion. This sense of legitimacy, he claimed, changed through time. At first, traditional polities dominated states, and rules were followed because tradition required adherence to customs. In the second stage, charismatic leaders upset the traditional order, and were obeyed because of the personal qualities of the charismatic leader. Finally, in the modern era, "The bureaucratic state order is especially important; in its most rational development, it is precisely characteristic of the modern state" (Weber 1946, 82).

Bureaucracy, like the machine, has made the modern world more rational and organized, if less magical (as Adorno and others have commented). Control emanating from the state is now legitimate because orders flow from a bureaucracy. Each person in the bureaucracy is important, not because of his or her intrinsic qualities, but because of his or her *position* in the structure of the bureaucracy.

The bureaucracy, then, has a structure, just like any other system, and the bureaucratic office is ordered according to its position on an organization chart; the officeholder is expendable. Since the source of legitimation is the bureaucracy, Weber's definition of the state can be reformulated as "a set of organizations that claims the monopoly of the *bureaucratic* use of physical force within a given territory".

The bureaucracy, however, receives its legitimation from an "artificially constituted sovereign", or state elites, to use Poggi's conception of sovereign (Poggi 1990, 13), just as the enforcement agents receive legitimacy from the bureaucracy. There is a sequence of the generation of control, as befits a generative system. First, the state elites create the laws which specify in which cases coercion is to be imposed, and then the bureaucracy uses the laws created by the state elites to create control over territory using the means of violence. Laws are the guidelines by which control is enforced.

The sequence within the state can be diagrammed in the following way, in which the arrows indicate direction of control:

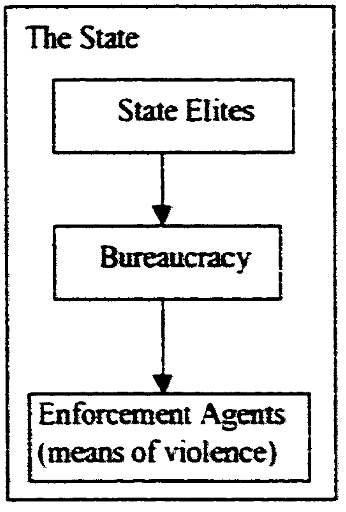


Fig. 19. Structure of the state.

The state, then, is a generative subsystem with a tripartite structure, as introduced in the previous chapter on systems. That is, there is a production of output, called the means of violence, which is generated by generators, that is, by the bureaucracy. In turn, this bureaucracy, and the laws it implements, is created by a metagenerator, the state elites. The state elites can change their own structure (say, by changing the workings of a particular branch of government). The state elites, as a group, may regenerate themselves; a King is literally reproduced, while an oligarchy generally chooses the next dictator.

One generative subsystem of a domestic political system is the state. The structure of the state contains a distribution of causal capability. That is, each stage of the sequence has differing abilities to affect other stages. The first stage, that of the state elites, is the most important, because state elites affect the other two stages. The importance of the elite stage is reflected in the historical struggle to establish democracy; if the state elites are most important, then they must be controlled by the general population if the people of a polity are to have control over the use of violence within their territory.

For Weber, the control of these metagenerators is the essence of the political domain: "The state is considered the sole source of the 'right' to use violence. Hence, 'politics' for us means striving to share power or striving to influence the distribution of power, either among states or among groups within a state" (Weber 1946, 82). Control over the state or among states is *allocated*, or distributed, among units, either to the population or to states, respectively.

The product of the state, the means of violence, is used to control the population. Thus, the state, which is comprised of the state elites, bureaucracy, and means of violence, is one element in the domestic political system, and the population is another element in the domestic political system. The population is a generative system, as is any population of organisms.

The state controls *all* of its output, that is, the state monopolizes the means of violence. As Waltz points out, the domestic political system is hierarchical. The means of violence, or enforcement agents, are legitimized by their association with the bureaucracy, which itself is legitimized by its association with the sovereign, the state elites.

Most states attempt to use some kind of ideological means of control in addition to coercive means of control, and the main goal of this ideological output is to convince the population that the state is legitimate. In addition, when citizens voluntarily obey laws, the cost of enforcement is greatly reduced, and a state which is felt to be legitimate has a greater capability to elicit voluntary compliance than a state in which the citizens do not feel loyalty.

In a democracy there is a cycle of legitimation and control, because the population which is subject to the enforcement of the bureaucratic means of violence, does itself control the state elites which direct the bureaucracy. In a dictatorship, the population exists only as the receiver of political power, and has no political power of its own.

The polity, by which I mean the domestic political system, is composed of a state which generates control over space, a population which generates itself, and a method of allocating control over the state. Thus there are two generative subsystems in a polity, and an allocative subsystem which consists of *rules* for choosing state elites. In most modern states, these rules are summarized in a part of a constitution. The part of the constitution specifying electoral rules, or an equivalent set of rules in a nonconstitutional system, is therefore the allocative subsystem of a domestic political system.

The state elites are either chosen by other state elites, in the case of a dictatorship, or they are chosen by the population, in the case of a democracy. Of course, there are many cases in between these two, but for the purposes of keeping the model simple, this bifurcation of types will serve the purposes of this study.

The two types of polity can be diagrammed thus:

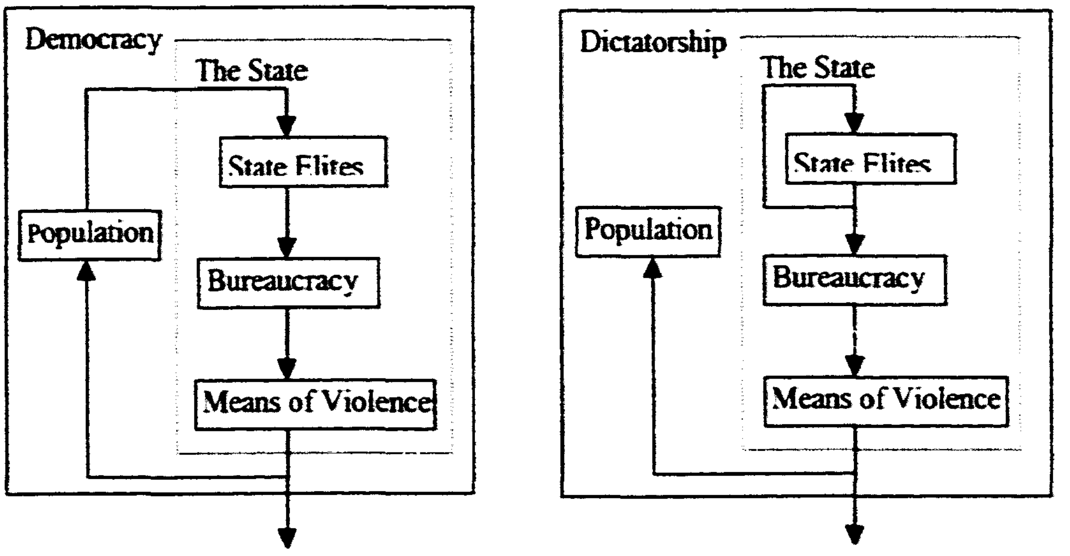


Fig. 20. Two types of polity.

The arrows in figure 20 indicate sources and targets of control. In a democracy, the objects of enforcement, that is, the people of the polity, choose state elites. In a dictatorship, only the state elites choose the state elites. The arrows pointing out of the political system indicate that the means of violence include the military, which is used to project power towards other political systems.

A change of the structure of a domestic political system is a change from a democracy to a dictatorship or from a dictatorship to a democracy. A change in the elements themselves would result from a change of their structure. For instance, the state elites might be organized according to the United States Constitution, or they might be structured as in a British parliamentary system. Structural change at the level of the state elites usually takes place as a change in the appropriate sections of a constitution, in a constitutional system. An example of the bureaucracy changing its structure would be the separation of the United States Federal Department of Health, Education and Welfare into the departments of Health and Human Services, on the one hand, and Education, on the other. Such changes may be set into a constitution in constitutional systems, but may also simply be mandated by state elites without a change to the constitution.

In addition to a structure, political systems also contain feedback processes. As shown by Tilly (1985, 181), the original development of the modern state occurred as the result of a positive feedback process among the factors of war making, state making, protection, and extraction. As the state centralized power, there was a tendency for the state to expand its power throughout the society, culminating in dictatorship. On the other hand, there is a negative feedback process also inherent in the domestic political system, such that the population as a whole may constantly push back the expansion of the state, in order to overthrow a dictatorship. Tilly has also written extensively about processes of rebellion and revolution. In general, negative feedback is manifested by the tendency for balances to appear within the polity in the form of coalitions.

At this point in this study, the definition of political system is so narrow that I have not even considered the issue of revenue extraction, raised by Tilly and his associates. Taxation and other interactions of the state with the economy will be dealt with in chapter 9, where most hypotheses concerning the state will appear.

However, based on the model as drawn here, it is possible to hypothesize that *a dictatorship will impose greater violence on the population than a democracy will.* This will constitute the first hypothesis about political systems. In a dictatorship the population is at the very bottom of a hierarchy and has no power; the state will therefore have little constraint on its behavior. The structure of the political system will enable great violence to be let loose on the population.

In a democracy, on the other hand, the population has control over the choice of the state elites. The population therefore has the power to prevent, or decrease, the execution of state violence on the citizens of the polity. This hypothesis will be used in chapter 10 as an explanation of Douglass North's observation that property rights, or distributed power, is essential in order to guarantee the security that makes economic growth possible.

By restricting the definition of the political domain to the control of space through time, then, it is possible to utilize many of the concepts employed by scholars of the state, and at the same time construct a parsimonious conception of the state and of a domestic political system. In addition, my theory of a political system mirrors the theory of systems elaborated in the previous chapter. My theory of systems has aided in the generation of a theory of political systems.

There have been other attempts to model political systems. David Easton attempted to construct such a theory in the 1950s. For Easton, "The study of politics is concerned with understanding how authoritative decisions are made and executed for a society" (Easton 1957, 49). His domain is much larger than the one specified in this chapter, and thus his construction of a system either had to be more complicated or more abstract; he chose abstraction. His system seems to be a combination of a thermodynamic and cybernetic system: first, the actual transformative element is a "black box", that is, its elements and processes are not specified; second, the focus is on the system as an allocative system; and third, negative feedback is the only process given consideration.

The political system as specified in this study, by contrast, is more narrowly defined, includes positive as well as negative feedback, and involves generative processes. My theory of political systems is thus more appropriate than Easton's theory for understanding the rise and decline of Great Powers.

Power and Capabilities

While Easton conceived of politics as the allocation of values, another tradition sees politics as a "struggle for power" (Morgenthau 1973, 31), in Hans Morgenthau's phrase. This formulation of politics transforms the problem of defining a political system into a problem of defining power: "When we speak of power, we mean man's control over the minds and actions of other men. By political power we refer to the mutual relations of control among the holders of public authority and between the latter and the people at large" (Morgenthau 1973, 32). Because the definition of political power often involves the state, the state becomes involved in a definition of the political system. The definition of the state as discussed in this chapter will be used to help construct a definition of political power.

As David Baldwin (Baldwin 1979) has advised, power is so varied that it is often helpful to specify the domain and scope of the kind of power to which one is referring. The kind of power explored in my definition of the political system involves control over space, which entails particular kinds of coercion and violence in association with legitimation. Thus, the term "political power" as used in this study does not need the broad definition often associated with the word "power".

For instance, Robert Dahl's definition of power as "the ability to get people to do what one wants them to do when otherwise they would not do it" (Waltz 1979, 191) is often paraphrased in various ways. The main idea is that someone's behavior is changed from what it would have been in the absence of an action. This idea includes the possibility that the person may have been convinced that the action should not even be considered (Lukes 1986), or that the choice is not part of the agenda (Bachrach and Baratz 1970). In any case, the definition of power in terms of behavior is very general, and is very difficult to either quantify or use for comparative analysis.

These kinds of definition of power do, however, point to power as a type of force that is pushing against something. Something is being moved when otherwise it would not have been moved, be it a choice, the opinion of a nation, or a crowd. In order to move something, human or mechanical, it is necessary to have some capabilities, or resources, at one's disposal.

The definition of power as used in physics can be used to understand the nature of capabilities used within a political system in order to project power. In physics, power is the ability to do a particular amount of work in a particular period of time. Work, in turn, is the ability to apply a particular amount of force over a particular distance. So power, in the physical sense, is the ability to apply a particular amount of force over a particular distance in a particular period of time.

Similarly, military capability may be defined as "the capability to project a particular amount of armed force over a particular distance in a particular period of time". Armed force may be quantified as either men or munitions, or as a combination of both. In addition, the ability to use armed force is often dependent on the amount of time taken to project armed force.

In physical terms, we say that dynamite has greater power than rain, because dynamite can blow a hole in the ground in seconds, while rain may take millennia to cut a gorge. Both might eventually do the same amount of work (given enough dynamite), but the time frames would be much different. Similarly, the German blitzkrieg of World War II was effective because of the speed with which the armed forces moved; the blitzkrieg led to a large projection of power. The Maginot line of the French, on the other hand, while capable of much force, and was not able to project power for a great distance beyond the Line itself, although within the range of the artillery the Line was powerful.

Distance is an important factor in the measurement of power. Usually, as Gilpin pointed out, the ability to project power decreases sharply with distance (Gilpin 1981, 56). In addition, a country such as the United States that can project armed force around the world is considered much more powerful than a country that can only project power across its borders.

Capabilities are useful for understanding how *powerful* a nation might be, but being powerful does not answer the question of what *power* is. Waltz (1979, 192) defines what it means to be powerful, but seeks to define power in terms of capabilities, not intentions: "An agent is powerful to the extent that he affects others more than they affect him", which implies that the more powerful agent has more capabilities. Another example of Waltz equating power and capabilities is his statement that "power is a means, and the outcome of its use is necessarily uncertain. To be politically pertinent, power has to be defined in terms of the distribution of capabilities; the extent of one's power cannot be inferred from the results one may or may not get". If power is "defined in terms of the distribution of capabilities", then the definition of power is synonymous with the definition of capabilities.

Physicists make a distinction that may be of help in understanding the nature of power. In physics, a distinction is made between potential energy and kinetic energy, or between potential power and dynamic power. If a person is holding a rock in his or her hand, the rock has a *potential* energy. All of the potential energy will turn into kinetic energy, only if there is no resistance (such as friction) on the way down to the ground. Otherwise, much of the potential energy may turn into heat, and the energy which is felt on the ground will be less than the original potential energy. In international relations, as well as domestically, the attempt to project power is constantly being resisted; instead of realizing all of the potential power expended, much of the power or energy expended in international actions is dissipated before any work or goals can be accomplished.

Waltz's view of power as capabilities is similar to the concept of *potential* power in physics. The capabilities of a state in the international arena are of a potential nature. What the results of the projection of power will be cannot be determined from the relative power of the state vis-à-vis other states. The absolute capabilities of a particular state can be determined without reference to the system of which the state is a part, but the outcome of the projection of power can only be understood in the context of the system of states in which the projection of power takes place.

There is therefore a difference between *the power to achieve a goal* and *being powerful*. Usually, power is meant to signify the power to do something or achieve a goal; for instance, the power to make someone do what they would not have otherwise done. Capabilities are used in the effort to accomplish a goal, but they do not guarantee the ability to achieve the goal. Capabilities are a measure of how powerful something is, not a measure of the power to accomplish a goal, although more relative capabilities are usually a better indication of probable success than less relative capabilities.

This study is concerned with the material capabilities of Great Powers. Therefore, I will concentrate on capabilities which indicate how powerful a state is, not on the power of a state to accomplish a goal. If the distribution of capabilities is understood, then the discussion of whether or not a state (or other social system) achieved its goals can be more easily accomplished, often in terms of the reasons why the distribution of capabilities did or did not lead to a particular outcome.

When a political system possesses a certain amount of political power, then, it possesses a certain quantity of political capabilities. Similarly, when a military possesses a certain amount of military power, it possesses the capability to project a certain quantity of armed force over a particular distance in a particular period of time. But this does not mean that the military possesses the power to achieve the goal of covering this distance; the outcome, like the difference between kinetic and potential power, will depend on the resistance the military forces encounter.

The term "distribution of power" will be synonymous with the term "distribution of capabilities". But these capabilities will only be a means to obtaining an end. Since their distribution constitutes a structure, the distribution of capabilities only enables or constrains the actors. The actors themselves must use the capabilities they control, and as a result of their interactions, the actors arrive at a particular outcome. Structures reveal how powerful the actors are, relatively; the units of the system, the actors, determine through their interactions which actors are able to achieve which goals.

The possession of political power implies the capability to control a certain amount of space and the population within that space, and to manifest control within a certain period of time. Since the domain of the political system is the control of space and the population within that space, then political power involves a measure of that control, in terms of distance and time, over that population and space. Therefore, *political power is the capability to control a certain population within a certain territory in a particular period of time.*

Political power is different than military power. Military capability can be a part of the political power of a state, but there are other capabilities as well. Domestically, the ability to control a population within a particular territory is usually at least somewhat dependent on the ideological capability of the state to bind the population to the state. In other words, the state tries to *legitimize* its monopoly of the means of violence by recourse to certain ideological instruments, such as propaganda, or the use of Weber's types of legitimacy, whether traditional, charismatic, or bureaucratic-rational.

Thus, domestically, the state has two sources of political power, military capabilities and ideological capabilities. Both of these capabilities imply a space over which control exists; ideological binding of the population to the state almost always involves reference to the particular territory of the polity. On the other hand, I will keep economic capabilities out of the definition of political power, in order to distinguish political power from political economic power, which will be dealt with in chapter 9.

This study will focus on the military part of political power, not the ideological. The link between economic output and military output is simpler to explain than the link between the economy and ideology. In addition, this study is concentrated on the material aspects of reality, not the psychological. In order to simplify my models, then, ideology will usually not be considered.

The state tries to monopolize political power within its territory. The state monopolizes the capability to project armed force over a distance in a particular period of time, and tries to monopolize the capability to ideologically bind the population to itself. In other words, the state monopolizes the bureaucratic (legitimate) means of violence, and the means to argue for its legitimacy. If both of these sources of political power should fail, then a revolution may occur, and the structure of the state may be changed (Skocpol 1985).

The state monopolizes direct sources of political power within the polity. The difference between a democracy and a dictatorship involves the different distributions of capability to indirectly control the state by controlling the choice of state elites. In a fully democratic polity, the distribution of capability to choose the state elites is equal among all members of the population. In a dictatorship, this indirect power is restricted to a few individuals.

In either case, a lock-in of structure is possible. That is, there may be positive feedback processes which keep the domestic political system stable. In previous discussions of positive feedback, I have highlighted their dynamic aspects. Positive feedback processes may also "lock-in" a system to a stable situation. In the case of a dictatorship, the centralization of control over the choice of state elites leads to the greater and greater accumulation of control over all units of the state apparatus, until the state is completely dominated by one or a few people. This state of affairs is maintained because no other sources of power are allowed to emerge by the state elites, and a "lock-in" occurs.

In a democracy, the ability of the state elites to control their succession has been very much constrained, and because the choice now resides within the population, it is very hard for the state elites to wrest this choice from the population. A different kind of "lock-in" occurs.

Because of these positive feedback processes, changes in state structure are quite rare; they usually occur because of war and the consequent weakening as the state, as Skocpol (1985) has shown. The change in political structure is related to the definition of the possession of political power: the state is no longer able to control the population within a particular territory in a particular period of time, that is, the state in a revolutionary situation has lost political power.

The International Political System

My definition of political power is also appropriate for use in describing the international political system. Since the international political system is an allocative system, and does not include a generative subsystem, its domain is the allocation of territory and the territories' population among polities. The international political system is composed of domestic political systems, or polities, as its elements. There is no functional differentiation among the elements, and therefore there is no generative subsystem.

The definition of the structure of the international political system should include a specification of the common measure with which to compare the values, or capabilities, of the units. This specification should be based on territory and its associated population, since political power is defined as the control of the population within a space through time, and each polity controls a particular territory. The political means of control over a territory involve military and ideological power. Since this study is concerned with material aspects of reality, I will minimize or ignore the role of ideological power in the international political system. Therefore, the armed force which is contained within the territory of the polity will be the common measure to be used in comparing units in the international political system.

In chapter 9, a fuller definition of power will be given which will include economic considerations, which are obviously important in a discussion of the rise and decline of Great Powers. At that time, a discussion of the international political economy will take place. I am giving a narrow definition of the political realm in order to be able to construct an understanding of the political economic realm which encompasses, but is separate from, the political realm.

Besides a distribution of capabilities based on military capability, the international political system also includes a distribution of causal capabilities. There are a set of states which have a greater capability to change the allocation of territory and the concomitant resources among polities than other states. In order to simplify the model, it will be assumed that there are only two possible types of states; those that can change the allocation of territory, and those that can not.

Great Powers are those polities that, collectively, control the change in the allocation of territory and the associated resources among polities. This is a testable hypothesis that flows from the logic of my theory of political systems, and constitutes the second hypothesis about political systems

For example, the Great Powers' capability to control territorial reallocation is very evident at the end of systemic wars. A systemic war may be defined as a war in which all of the Great Powers of an international political system participate on one of two conflicting sides. After such wars, the victorious Great Powers divide territory according to their own best interests. This redivision took place at the end of the Napoleonic Wars during the Congress of Vienna, after World War I in the Versailles Treaties, and toward the conclusion of World War II in the meetings of the Allied leaders (Holsti 1991).

The capability of the Great Powers can sometimes be seen in the midst of a systemic war as well. For example, by 1943, the five Great Powers had basically taken control of all the territory of the globe: the Germans controlled continental Europe; the British took advantage of their Empire; the Americas fell within the sphere of influence of the United States; the Soviets retained control of central Eurasia; and the Japanese had conquered East Asia. The division of the world was almost as complete during World War I.

My definition of a Great Power is based on my theory of political systems, as opposed to the ad hoc definitions of scholars as reviewed in chapter one. I defined a political system in terms of the control of space, and that definition in turn was based on a discussion of the division of domains of inquiry, all of which flowed from my general theory of systems. The Great Powers are defined in terms of the concept of space, and also in terms of a particular aspect of systems, the distribution of causal capability, that in turn emerged from my general theory of systems. As will be seen in chapter 9, the definition of Great Powers as presented here will be profitably merged with the discussions of economic and production systems to construct a hypothesis about rise and decline, and the statistical appendix of this dissertation is presented as an attempt to validate that hypothesis. Thus, it is hoped, the labor expended in order to understand systems is being repaid by the presentation of a theoretically rigorous definition of a Great Power.

An international political system also includes feedback processes. Waltz, as well as many others before him, has been impressed by the recurrence of balances of power within the international political system. A balance of power is an example of a negative feedback process within an allocative system. That is, the units of the system are so arranged as to withstand the operation of a positive feedback process within the system. *A balance of power is a reaction to a positive feedback process in an international system*; this is the third hypothesis about political systems

When the structure of the international system is arranged in such a way that a stronger polity has the political power to overwhelm and conquer a weaker polity, then the structure can be said to *enable* change within the system. This change may become self-reinforcing, because once the stronger power has added the weaker power's territory and armed force to its own territory and armed force, the stronger power will now have a greater capability than before to conquer other polities (see Cederman 1994, Liberman 1993). This process of accumulation can snowball, until all of the weaker polities are contained within the orbit of the state of the imperialistic polity.

This process can be referred to as the *accumulation* of power, as opposed to the *balance* of power. The following diagram shows a simple example:

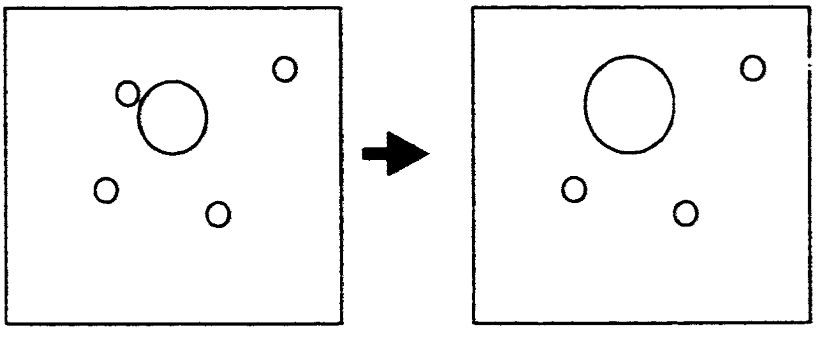


Fig. 21. The accumulation of power.

The structure of the system in this example is such that a large polity exists next to a small polity. Assuming no coalition of small polities against the big polity, the big polity is able to conquer the small polity, and now becomes even bigger, allowing it to conquer yet more small polities, and so on.

This snowballing capacity to conquer is an example of a positive feedback process in an allocative system. *Most polities have been created as a result of this* *positive feedback process of conquest*; this is the fourth hypothesis about political systems.

Many of the major states today can be viewed as a verification of this hypothesis. For example, the small Mark of Brandenburg eventually became the Kingdom of Prussia, and then expanded to become the Empire of Germany. The Hohenzollerns slowly but surely, and with great persistence, added smaller polities to their territory. Also in Europe, the French state arose as a series of military campaigns against lesser lords, and the Spanish "reconquered" much of the Iberian peninsula piece by piece from the Moors, via a snowball effect. The Duchy of Muscovy was able methodically to assimilate the other principalities of Russia as a result of the power it gained from its association with the Mongols.

Asia has also seen the accumulation of power throughout its history. The original unification of China resulted from the growing power of one province, the Ch'in. In Japan, the revolt that became the Meiji restoration started in remote provinces. India was conquered by the British a small piece at a time, as the Indian princes did not form a balance of power to stop them.

In the Americas, the Spanish were aided in their conquest of the Aztecs by other American groups; when the Spanish eliminated the Aztecs, the former allies became easy targets of Spanish expansion. Similarly, the peoples of North America did not join forces against the European invaders, allowing Britain, Spain and France to expand their colonies. After its war of independence, the United States expanded against weaker adversaries, who did not coalesce against it, allowing the United States to become stronger and stronger.

Thus, the process of positive feedback can be used to explain the formation of polities, and in particular to explain the formation of Great Powers. Systemic wars usually involve some aspect of state formation by accumulation of power, as when Hitler sought to obtain "lebensraum" (living space) through serial conquest of Western Europe, then Eastern Europe, and finally the attempt to conquer all of the Soviet Union. The process of positive feedback in the international system has led throughout history to changes in the structure of the international political system.

A major motivation for the initiation and continuation of wars can be explained using my theory of political systems, for two reasons. First, state elites of a more powerful polity may perceive that they will not be challenged by a group of lesser powers in an attempt to conquer a smaller power. Second, once an imperialistic polity captures the territory and resources of another polity or polities, the greater power of the imperialist polity may make further conquest more desirable for their state elites, leading to a positive feedback process of more and more conquest. The structure of the international political system may encourage imperialistic behavior; an imperialist may find itself with large territories without initially intending such an outcome. For example, Great Britain has been described as having acquired its empire "in a fit of absent-mindedness".

Balances of power have constantly recurred. In particular, the concept of balance of power explains why no Great Power has been able to conquer the entire planet, and why systemic wars rarely lead to state formation: for example, in his attempt at lebensraum, Hitler was thwarted. If the process of the accumulation of power continued indefinitely, eventually one polity would become strong enough to overwhelm any other state, and the international political system would be transformed into a world empire. Throughout history, states have formed alliances to stop the transformation of an international political system into a hierarchical political system.

However, attempts to accumulate power have also occurred continuously throughout history. The combination of the two concepts, snowballing conquest and balance of power, are therefore more powerful as an explanatory framework than either one by itself. By using the concept of the snowballing accumulation of power, it is possible to explain both state formation and balance of power.

Conclusion

My theory of systems has been used to generate a theory of political systems in the present chapter. My theory of political systems includes a parsimonious definition of political power, the polity, Great Power, democracy, and dictatorship. In addition, the main concepts of Waltz's theory of international political systems have been retained.

Several testable hypotheses have been generated: first, a democracy will visit less violence on its citizens than a dictatorship; second, Great Powers control the reallocation of territory among states in the international system; third, a snowballing accumulation of power in international political systems explains much of the history of state formation and its attendant wars; and fourth, balances of power form in reaction to the accumulation of power.

By divorcing the economic domain from the political, many important problems have been ignored. Hypotheses addressing the growth or stagnation of industrial power cannot be addressed in a theory focusing on politics, as defined in this chapter. These issues require a discussion of the interaction of the political and economic realms. Before doing so, it is necessary to construct a theory of economic systems. This will be the task of the next three chapters.

CHAPTER 6

A THEORY OF ECONOMIC SYSTEMS, PART 1:

THE CATEGORIES AND STAGES OF PRODUCTION

The theory of economic systems as developed in the next three chapters will be used as the foundation for the theories and hypotheses concerning the rise and decline of Great Powers. The central focus will be on the dynamics of production and the technologies of production. The general theory of systems will be used in order to analyze the processes, in particular, of production, and to construct theories of economic, production, and capital systems. In this way, theories and hypotheses concerning the rise and decline of Great Powers will be constructed, it is hoped, that will have greater explanatory power than those theories reviewed in chapters two and three.

Defining the Economic System

In the previous chapter, the domain of material social reality was divided into two mutually exclusive domains, the political and the economic. The political domain was assumed to be the sphere of space, and the economic domain was assumed to encompass matter and energy. Both political and economic phenomena involve the procession of time. Therefore, the domain of political systems involves the social experience of space through time, while the domain of economic systems encompasses the social experience of matter and energy through time.

In a previous chapter I proposed that a system can usually be divided into two subsystems, a generative subsystem and an allocative subsystem. The generative subsystem *produces* output, while the allocative subsystem *distributes* that output among the units of the system. In the case of the economic system, the generative subsystem involves in the generation of forms of matter/energy, and the allocative system distributes those forms of matter/energy (I will usually use the term *system* when referring to both complete systems and subsystems).

Only cosmological processes such as supernovas or stars generate different types of atoms, and except for the nuclear energy industry, energy is not created by humans. Instead, humans (and all life) *transform* one configuration of matter/energy into another configuration during processes of production.

In making an automobile, for instance, many transformations occur. The iron molecules that exist in iron ore are extracted by blast furnaces, using massive amounts of coking coal. The resulting array of iron molecules are not created; instead, iron's naturally occurring form as part of rock is transformed into something more useful, smelted iron. The smelted iron is then treated in steel-producing machinery, generally using electrical energy, by adding various kinds of molecules to its structure, including carbon and chromium. The resulting steel is output in the form of certain shapes, such as slabs or rolls of sheet metal. These intermediate steel goods are then transformed by a large metal-forming machine tool into the shape of the hood of a car, for example, during which time the machine tool uses an electric motor. The final automobile includes thousands of pieces that began as completely different configurations of matter and energy, moved through various intermediary states, and finally became parts of an automobile after being put together on an assembly line.

Thus, in an economic system, matter/energy is transformed from one configuration to another through time. While the original matter and energy still exist – according the laws of thermodynamics, energy does not spontaneously disappear or appear – the *structure* of the element, such as the slab of steel or the hood of the car, is made to change. The *substance* of the element may change, such as the change from iron to steel. All of these processes involve two inputs: *energy*, such as the coking coal or electricity in the example above; and the *design*, or *information*, needed to guide the transformations that occur within the economic system.

As seen in the example above, the economic system uses part of its own output to transform one configuration of matter/energy into another configuration. The economic system uses production technologies such as the blast furnace, steel-making machinery, and metal-forming equipment. Thus, the full definition of the economic system should be the following:

> The economic system transforms one set of configurations of matter/energy into a different set, through time, using certain previously produced configurations called production technologies. A configuration has a certain structure composed of a certain set of substances. Production technologies transform the structure and substance of a configuration, and generate the forms of energy and information processing needed to effect this transformation. The economic system then allocates these configurations, called goods and services.

This definition is useful for investigating the phenomenon of the long-term causes of growth because *production* is the focus of the definition. Allocation is important in the process of production as well, but the term "economic growth" describes the increase of the output of goods and services, which is a function of production. My definition of an economic system has three major implications for the nature of economic systems: 1) production is the central activity in an economic system; 2) there are several *categories* of production within an economic system; and 3) there are several *stages* of production within an economic system.

The first implication of my definition is that the economic system is based on the capability to produce goods and services. Neoclassical economists refer to this capability, in the most general sense, as *capital*; as shown in Chapter 3, capital has always been a problematic concept in economics because capital cannot be considered exogenous, or outside of, the economic system, and because production has not been a central concern in neoclassical economics. Neoclassical economic thinking tends to bypass this problem by focusing on other concepts. Instead of ignoring capital, my definition proposed above places capital at the center of the functioning of the economic system.

Distribution is also critical; both production and distribution are necessary functions within an economy. For the purposes of this study, however, I am claiming that production is more important than distribution.

As Friedrich List wrote, "*The causes of wealth* are something totally different from wealth itself. A person may possess wealth, i.e. exchangeable value; if, however, he does not possess the power of producing objects of more value than he consumes, he will become poorer. A person may be poor; if he, however, possesses the power of producing a larger amount of valuable articles than he consumes, he becomes rich.

"*The power of producing wealth* is therefore infinitely more important than *wealth itself*", and "this is still more the case with entire nations (who cannot live out of mere rentals) than with private individuals" (List 1885, 133, emphasis in original). Further, "the forces of production are the tree on which wealth grows, and...the tree which bears the fruit is of greater value than the fruit itself" (List 1885, 46).

Capital, or the means of production, constitutes the "power of producing wealth", or "the power to create wealth", the title of this dissertation. The means of production are used in the generation of output in the economic system. The generative subsystem of the economic system will be referred to as the *production system*. The production system is synonymous with the term *the means of production*.

Manufacturing, plus some utilities, mining, and construction, compose what I am referring to as the production system. Many authors have written about the importance of production, usually in terms of manufacturing, or more specifically, machinery. Most have only asserted that manufacturing is very important without constructing an argument to support the claim. Like the definitions of Great Power and the explanations of technological change reviewed earlier, the assertions concerning the importance of manufacturing and machinery have been ad hoc, not based on a theoretical framework.

For instance, A DRI study simply stated that "beginning with our industrial revolution shortly before the Civil War, the growth of manufacturing industry has been the principal vehicle of U.S. economic growth" (Eckstein et al. 1984, 1), and further, "without a strongly advancing manufacturing industry, the U.S. economy is hardly likely to maintain its progress in the decades ahead" (Eckstein et al. 1984, 4), although no justification is given for this statement. Eric Green states that "a country cannot expect to be a world economic power unless it nourishes the industrial network on which national power is based" (Green 1996, 37). John Wilkinson argued that economists should refocus their efforts onto the problems of production (Wilkinson 1983).

In the early 1800's, Freidrich List proclaimed the advantages of manufacture: "The sciences and industry in combination have produced that great material power which in the new state of society has replaced with tenfold benefits the slave labor of ancient times, and which is destined to exercise on the condition of the masses, on the civilization of barbarous countries, on the peopling of uninhabited lands, and on the power of the nations of primitive culture, such an immeasurable influence – namely the *power of machinery*". Further, "the power of machinery, combined with the perfection of transport facilities in modern times, affords to the manufacturing State an immense superiority over the mere agricultural state" (List 1885, 201, italics in original).

Thus, machinery in particular, has been seen as a critical technological capability. John Hobson, who provided much of Lenin's argument for a theory of imperialism, conceived of "The Evolution of Capitalism" as "A study of machine production", (the title and subtitle, respectively, of his book). He claimed that "the chief material factor in the evolution of Capitalism is machinery. The growing quantity and complexity of machinery applied to purposes of manufacture and conveyance, and to the extractive industries, is the great special fact in the narrative of the expansion of modern industry" (Hobson 1902, 5-6).

The German economic historian W.G. Hoffman noted that the "process of economic growth which has been fostered by the increasing use of capital goods and improved techniques of production has affected all sectors of the world's national economies" (Hoffman 1958, 1). In addition, "the expansion of a modern industrial country is generally characterized by a continual increase in the output of manufactured goods which is closely associated with a steady expansion in the volume of capital goods available in the economy" (Hoffman 1958, 31). The term "capital goods" covers both production machinery and the output of that machinery, and Hoffman was one of the few economists who studied the global capital goods industries thoroughly.

In a massive study on mechanization, published in 1934 for the National Bureau of Economic Research, F.C. Mills introduces the volume with the remark that "the machine has been the foremost factor making for economic and social change in the western world during the past hundred and fifty years", and after listing some of the changes, says that "all this is commonplace enough. That the machine has worked great changes in human life is no discovery of the past few years. For more than a century social observers have commented on the progress of machine industry" (Jerome 1934, xxi). Unfortunately, the rest of the study is content to simply describe the levels of mechanization, without trying to prove what, at the time, was obvious to most observers. The same is true of the other writers quoted in this section – they may have been correct about the importance of machinery, but there is no theoretical framework presented to help support their assertions.

Perhaps Thomas Carlyle brought the effects of production technology to their poetic extreme: "...He can use Tools, can devise Tools : with these the granite mountain melts into light dust before him ; he kneads glowing iron as if it were soft paste ; seas are his smooth highway, winds and fire his unwearying steeds. Nowhere do you find him without Tools; without Tools he is nothing, with Tools he is all" (quoted in Vowles and Vowles 1931, 1).

Unlike the previous authors, Alfred Chandler, the business historian, has constructed a useful framework for understanding production. Chandler asserts that "in production an increase in output for a given input of labor, capital, and materials was achieved technologically in three ways: the development of more efficient machinery and equipment, the use of higher quality raw materials, and an intensified application of energy". Further, "Mass production industries can then be defined as those in which technological and organizational innovation created a high rate of throughput and therefore permitted a small working force to produce a massive output" (Chandler 1977, 241). In addition, "In modern mass production, as in modern mass distribution and modern transportation and communications, economies resulted more from speed than from size. It was...the velocity of throughput and the resulting increase in volume that permitted economies that lowered costs and increased output per worker and per machine...Central to obtaining economies of speed were the development of new machinery, better raw materials, and intensified application of energy, followed by the creation of organizational designs and procedures to coordinate and control the new high-volume flows through several processes of production" (Chandler 1977, 244).

Chandler's focus on speed suggests a definition for productive power, or production capabilities. As explained in the previous chapter, power in the physical sense measures the speed at which a particular mass moves a particular distance. Chandler implies that the power of a production system is its ability to process and output a certain quantity of goods in a certain period of time. As Chandler states, "...the two decisive figures in determining costs and profits were (and still are) rated capacity and throughput, or the amount actually processed within a specified time period" (Chandler 1990, 24).

Speed is an important dimension of industrialization, according to the economist and historian of technology Nathan Rosenberg: "Industrialization, quite simply, requires the development of highly specialized kinds of skills and knowledge which are essential to the solution of the technical problems involved in machine production. In all of this there is an essential learning process and, historically, much of this learning took place within the confines of a small number of firms engaged in machine production. Furthermore, the rapidity of industrialization was substantially determined by the speed with which technical knowledge was diffused from its point of origin to other sectors of the economy where such knowledge had practical applications" (Rosenberg 1972, 97).

Thus, a production system which is becoming more powerful would be experiencing an acceleration of output along with a rapid diffusion of innovation throughout the economic system. A relatively powerful economy would be able to produce a relatively large amount of goods and services in a particular period of time, and improvements in these capabilities would move through the entire economic system at great speed.

The first implication of my definition of an economic system, therefore, is that for the purposes of ascertaining national rise and decline, it is useful to conceive of production as the most important activity in an economic system. In addition, productive power can be defined as the capability to generate a certain quantity and quality of goods and services in a certain period of time, and the capability to diffuse a certain set of innovations throughout an economic system in a particular period of time.

Categories of Production

The second implication of my definition of an economic system is that there are categories of production which consist of the creation of structure and substance, the generation of forms of energy, and the processing of information . Categories of production are the kinds of processes that people must use in order to produce goods and services.

Unlike the neoclassical world-view, production as defined here is not a homogeneous process. Neither is production viewed as an infinitely decomposable process. By restricting processes of production to four categories, production can be modeled in such a way as to capture its most important aspects while remaining comprehensible.

An element, such as a configuration of matter/energy, is also a system; it is itself composed of elements, or substance, and has a structure. An element, in order to be changed from one configuration of matter/energy to another, must undergo a change in structure and/or a change in substance. Thus, a transformation involves the change of two systemic aspects of an element: the structure of the element must change; and the nature of the element, in terms of its substance, must change.

There are certain categories of production technology that are used to effect these changes of structure and substance. To use the previous example of the production of an automobile, a metal-forming machine will change the shape, or structure, of a piece of steel so that it is usable as the hood of a car. This kind of production will be defined as *structural production*, since it involves the change from one structure to another. The metal-forming machine tool is defined as a piece of *structural production machinery*. In the example of automobile production, the steel-making machinery changes iron to steel; this kind of production will be defined as *material production*, since it involves the change from one type of material to another. The steel-making machinery is defined as a type of *material production machinery*.

There are many types of production machinery that are used in each category of production. In the automobile example, for instance, the blast furnace was used as another type of material production machinery, in order to transform iron ore into smelted iron. The assembly line is an example of another kind of structural production machinery. The process of assembling the car is an example of structural production because the assembly process creates a new system, called an automobile, by putting together the various car parts into a particular structure.

Thus, two categories of production are structural and material production. In order for these forms of production to take place, however, two other categories of production are required, energy-converting production and informational production.

The third category of production involves energy. In order for change of any kind to occur in the world of material reality, energy must be converted from one form to another. Any movement not involving momentum requires force, and this force requires the conversion of energy. Iron ore does not spontaneously change substance to smelted iron, and a metal-forming machine tool does not magically bend steel to form the hood of an automobile. A force must be applied, and this force must be manifested as a type of energy conversion, in the form of coking coal (and other energy sources) for a blast furnace, an electrical lance producing heat in a steel crucible, or the electrical-to-mechanical energy conversion of an electric motor in a machine tool. Thus, *energy-converting production* is accomplished using *energy-converting production machinery*, such as an electric lance or an electric motor.

Often, energy comes from a machine outside the factory, as in the case of electricity. In this case, production machinery is still being used to generate a form of electricity or other energy. The spatial placement of the production machinery is not as important as the fact that it is being used to generate something for application in the factory, or more generally, for application at a production site (which includes construction sites, mines, and farms).

In this study, transportation will be categorized as energy-converting production. The main activity which takes place in transportation is movement from one point in space to another, and this movement always involves, first and foremost, the conversion of energy. One of the ways in which energy is manifested is in the form of movement; work, as was explained in the discussion of physical power, is a measure of the distance an object moves. Moving an object from one position in space to another, a task which transportation machinery achieves, is a manifestation of work in a mechanical sense. Besides the components such as wheels, hulls, and wings which are used to effect this movement, forms of transportation are defined by association with their energy source, whether automobiles with an internal combustion engine or jets with a turbine engine.

Transportation does not generally involve a change in the substance or structure of an object. A machine shop is used to fabricate parts for a car; a ship is then used to transport the parts to a car factory in another country. The ship is changing the position of the parts in space, but the structure and substance of the parts stay the same.

Within a factory, certain kinds of machinery called *materials handling equipment* are used to move unfinished items from one piece of structural or material production machinery to another. On the one hand, these classes of machinery could be considered as transportation equipment, since they do not, themselves, change the substance or structure of the objects, just as the ship does not change the car parts. On the other hand, materials handling equipment can be classified as being part of the process of the generation of structure, as in the case of an assembly line, or as part of the process of the generation of substance, as in the case of an overhead rail used to transport a bucket of molten steel in a steel factory. To some extent, the exact boundaries of the categories of production are arbitrary, and I will consider materials handling equipment to be types of structural or materials production machinery, not energy-converting machinery. Once machinery is used on the outside of the factory, such as in the case of a cargo ship or truck, however, I will consider such machinery to be energy-conversion production machinery.

Transportation, as well as other energy-converting production, can be part of the final output of the production system. That is, energy-converting production is not always in the service of structural and material production, but may be part of final production itself, such as airline travel. Energy is also manifested in the change in the movement of molecules that occurs in heating or cooling, which may be used both for production (as in a blast furnace) or in final production (as in a kitchen oven). Finally, energy is manifested in the generation of light and other forms of electromagnetic energy (such as radio and TV broadcast); I will categorize light as a form of energy-conversion, but the rest of the electromagnetic wavelengths will be part of the domain of the next category of production, information.

The fourth category of production involves information. In order for production of any kind to take place, there must be a preexisting design which must be generated by a person or a group of people. This design will specify the process of production to be taken to create the desired object, and expresses the system as a whole. The design is used to help bring together all of the other categories of production – structural, material, and energy-converting – *through time*, in order to create a new set of configurations of matter/energy. In the automobile example, engineers create the designs and fabrication processes which are then carried out by operating managers and production workers. Computers and process instruments are used to help coordinate and monitor automobile production.

This production of a system as a whole does not involve, itself, any material manifestation, which is created by changing the structure and/or substance of the new element using the application of energy. Instead, the production of the system as a whole involves the processing of *information* (using, of course, production machinery). The fourth and final category of production is therefore *informational production*, and involves the use of *information production technologies*, such as computers for design or instrumentation for monitoring the production process.

In the realm of biology, information production technologies can be found at the cellular level. The biologist Mahlon Hoagland explains that "life's information – the 'ideas' governing how it operates – is encoded in genes, which are, in turn, decoded by machinery that manufactures parts that work together to make a living creature. Like the computer that builds itself, the process follows a loop: Information needs machinery, which needs information"(Hoagland and Dodson 1995, 81).

Human production involves designs, not genes. For example, in the automobile example, engineers, using either a drafting table and tools or a computer-aided design station, produce blueprints for various car parts, and specifications for the kinds of materials to be used in those parts. Other engineers specify the series of steps that must be taken, through time, to put the car together. Skilled production workers and operational managers receive the blueprints and use them to construct the parts of the car. Quality control personnel, as well as the production workers and foremen, use gauges and other industrial instruments to obtain information on how the production process is progressing, and to determine to what extent the original designs are being fulfilled.

Information production, like energy-converting production, may also be a part of final production, not just a way to change structure and substance. Media such as books and other printed matter, radio, and TV, or communications technologies such as the telephone and internet, involve the generation of information which is desired in its own right.

The definition of the economic system thus implies a four-fold division of categories of production: structural, material, energy-converting, and informational. Each category of production requires a set of production technologies. In the industrial era, the vast majority of these production technologies are types of machinery, and thus I will usually refer to production technologies as production machinery.

This four-fold categorization is simple enough to be comprehensible but complex enough to characterize the different functions that must be performed by the generative subsystem of an economic system. Each category of production can be seen as a function within the generative system. Thus, each category of production can be seen as an element of the economic system, each element serving a separate function. The set of these functions describes one aspect of the functional differentiation of the structure of the generative subsystem of the economic system.

This generative subsystem of the economic system will be labeled the ***production system***. The allocative system, which distributes the output of the production system, will be labeled the ***distribution system***. The following diagram shows the structure of the economic system as it has been elaborated up to this point:

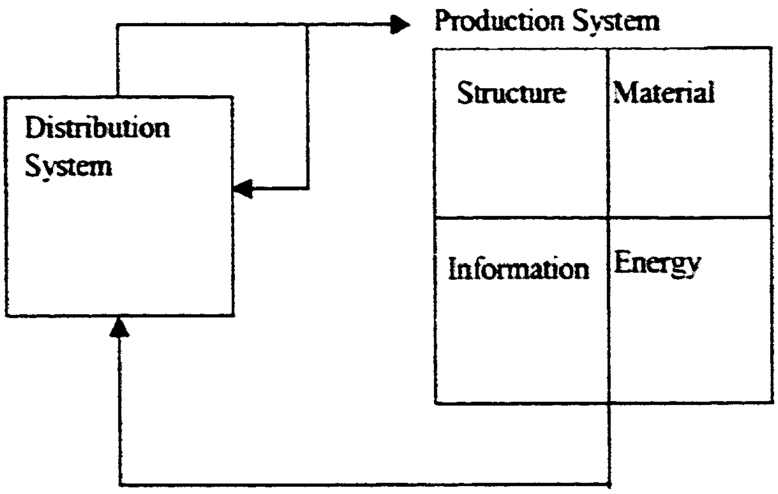


Fig. 22. Categories of production and economic system.

The economic system is composed of two subsystems, the distribution subsystem and the production subsystem (I will usually refer to these as systems, not subsystems). The production system, at this point in the argument, is composed of four elements, each of which has a function or purpose within the system of production. The output of the production system is received by the distribution system, which then allocates the output to the four elements of the production system and back to the distribution system.

One advantage of this categorization is that the categories emanate from the theory of systems. The production categories can be mapped to the categories used to describe a system.

First, the structural production function can be mapped to the structural level of the system. Just as a system is characterized by the organization of its parts, any produced good has been put together from a set of parts which themselves have been structured in a particular way (in the systems theory, the systems level includes structure and the domain of the system).

Second, the material, or substance, production function can be mapped to the elemental view of the system. The elements are the substance of the system, as the structure is the arrangement of the elements of the system. Similarly, the production elements, such as the steel molecules in a sheet of steel, are the substance while the structure, such as the shape of the sheet of steel as the hood of a car, is the arrangement of the steel crystals.

Third, the function of energy conversion can be mapped to the level of processes of change in the theory of a system. Energy conversion is required to effect change, just as positive and negative feedback processes change systems.

Finally, the information or design function is analogous to the system as a whole. The system encompasses the elemental, process, and structural levels. In the same way, the information function knits together the structural, material, and energy-converting functions of production.

The following diagram shows the mapping:

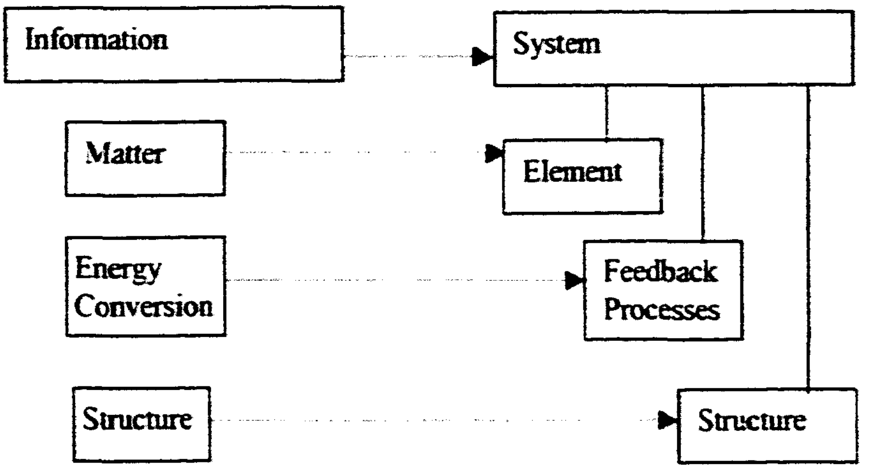


Fig. 23. Mapping categories of production to systems.

The boxes on the left of figure 23 represent the production categories, and the boxes on the right represent the systems categories, while the dotted arrows represent mapping from the production to the systems categories. In a general system, there is a hierarchy among the elements, as shown on the right-hand side of the diagram. The categories of production conceptually divide all aspects of production among themselves, but do not imply any hierarchical ordering. Thus, my four categories are not ad hoc, but are based on my general theory of systems.

Since the categories of production map to the aspects of a system, then a production machine is also a system. A production machine, first, is made of parts, which consist of certain materials; second, it is put together in a certain structure; third, it relies on the production of forms of energy, usually in the form of a motor or engine; and finally, a production machine encompasses a design which puts together substance, structure, and energy, and it may also contain within itself the ability to gather information and change its actions accordingly.

Production is a mutually symbiotic interaction of the four functions specified above. Each category of production is necessary in order for the other categories of production to take place; none could exist without the others.

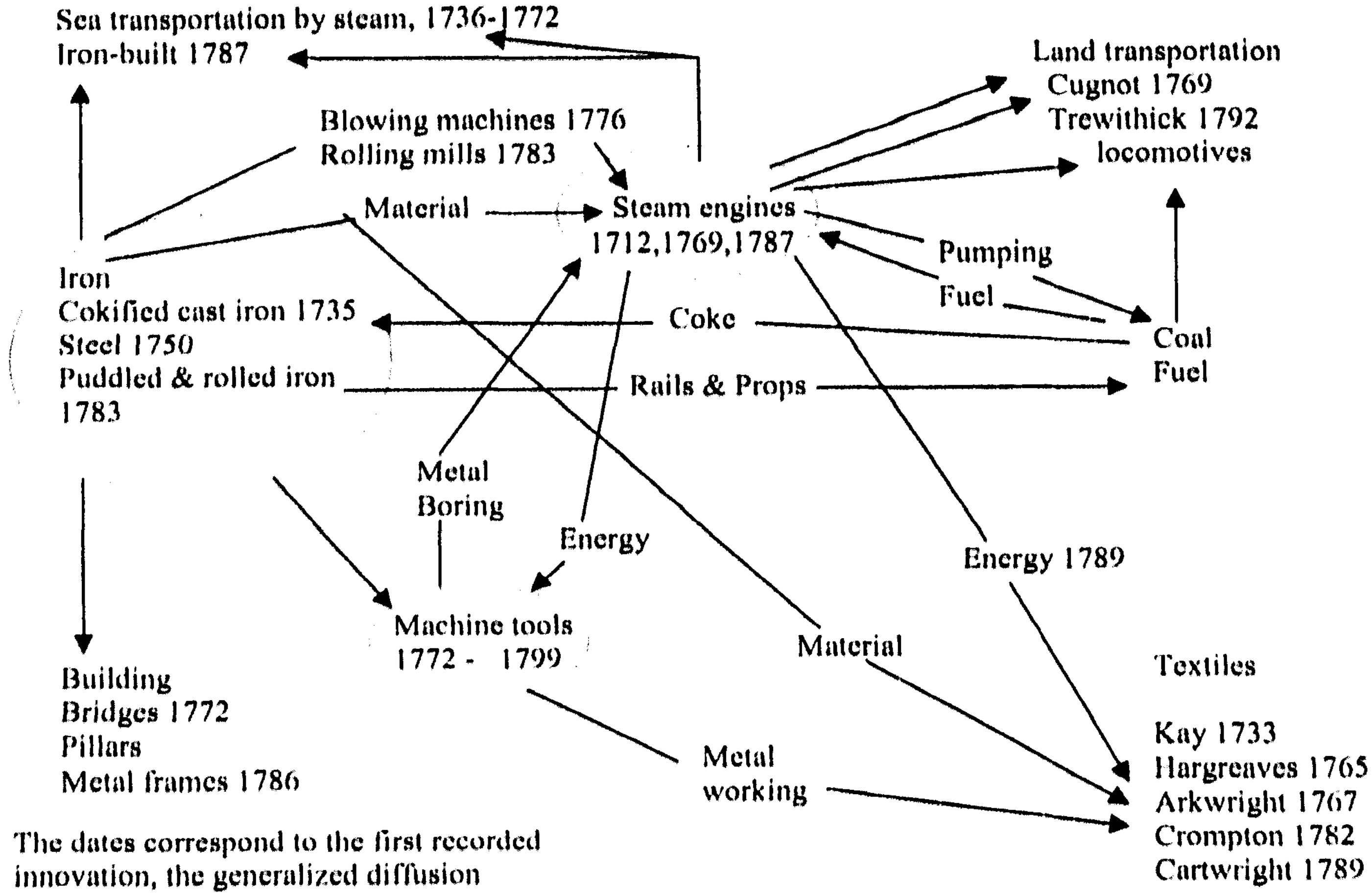
Since the functioning of one element is contingent on the functioning of the other elements, a negative feedback process occurs. Growth of the production system as a whole will be constrained unless all four categories of production are growing in some sort of balanced way. When one element attempts to grow beyond the capabilities of the other elements, the growth of the one element is stopped, restrained, or even reversed. The necessity of balanced growth leads to a kind of stability of the relative size of each functional sector.

Improvement in the techniques and quantity of production in one category reverberate to the other categories of production. *There is a positive feedback process of technological change among the four categories of production*; this is the first hypothesis about economic systems. This process is one in which an improvement in one category will cause improvement in other categories, and the improvement in the other categories will then lead to improvement in the first category, and so on.

Many scholars have offered similar lists of categories of machinery as being important for technological innovation, economic growth, and historically, the commencing of the Industrial Revolution. In none of these discussions of categories, however, is a theoretical framework proposed that would justify the inclusion of particular categories, as I have done. The lists are ad hoc.

For example, Bertrand Gille devised a diagram of the interrelation of technologies that existed at the beginning of the industrial revolution. The following is a reproduction, from Chesnais (Chesnais 1981, 55):

Simplified Diagram of the Technological System of the 1st half of the 19th century



The dates correspond to the first recorded innovation, the generalized diffusion comes later

Fig. 24. Gille's structure of production.

I have added the dotted circles, to show the material production machinery, in the case of iron and steel technologies, energy-converting production technology, in the case of steam engines, and structural production technology, in the case of machine tools. There are many positive feedback loops in this schema – for instance, from machine tools through metal boring to steam engines, and back through energy-conversion to machine tools.

Chesnais, building on this work of Gille, claims that "each system has particular nodes from which one can trace the development of strong influences on the course of technological development in many sectors, industries or branches other than those where the original innovations appeared. Innovations at the central point in the system will induce a chain of innovations at other points of the industrial system. Some of these are complementary to the initial one and, when they occur, have feedback effects and help the new 'technology system' establish its hold over wide areas of industrial ... production. The principal nodes in technology, around which the most important clustering of a systemic type takes place, have always been located in the capital goods and in the intermediate product industries: machine tools, electric and electronic equipment, and the various branches of the chemical industry." (Chesnais 1981, 55-56)

For Robert Brady, several production technologies are needed in modern manufacturing, most of which can be fit into my categories, as I indicate in parentheses: "low-cost metal" (material); "machine tools" (structural), "low-cost bulk overland-freight facilities" (energy-converting); "the ability to reduce friction", e.g., lubricants and bearings (structural); machinery which "is powered by an indefinitely flexible motive force", e.g., engines and motors (energy-converting); "systems of interchangeable parts" (structural); "automatic-control devices" (informational); and "feedback control" (informational), all depending, according to Brady, on standardization, which involves informational production (Brady 1961, 108-109).

Victor S. Clark stated that for the period from the Civil War to World War I, "the great expansion of manufacturing and its concentration in large establishments are due to the wider use of power and the improvement of machinery…Throughout the period covered by this volume, therefore, the manufacture of iron and steel was the nation's key industry, by which the progress, prosperity, and developmental tendencies of manufacturing in general were determined and illustrated" (Clark 1949, 351).

Shepard Clough notes that "in the expansion of industry during the years between 1875 and 1914 so many important innovations were made that designating the most strategic is exceedingly difficult. Yet there is little doubt that among the very important changes was the introduction of ways of making steel which permitted an enormous expansion in the output of this product as well as a dramatic reduction in price… Furthermore, cheap steel revolutionized the use of tools. It made possible great feats of drilling into the earth's crust in search of new riches". He also lists other building materials and mechanical engineering innovations, such as machine tools, as being most strategic, and entitled a section, as is common in histories of this era, "New sources of power" (Clough 1968, 400-407). Similarly, Rosenberg identifies as "the major components of industrial change" in the nineteenth century, "the substitution of machinery for handicraft skills, the widespread application of new power sources to industry and transportation, and the massive utilization of iron (and later steel)" (Rosenberg 1972, 59).

For David S. Landes, "the heart of the Industrial Revolution was an interrelated succession of technological changes. The material advances took place in three areas: (1) there was a substitution of mechanical devices for human skills; (2) inanimate power – in particular, steam – took the place of human and animal strength; (3) there was a marked improvement in the getting and working of raw materials, especially in what are now known as the metallurgical and chemical industries" (Landes 1969, 1).

In general, according to the economic historian Pollard, "the essential core of the process described here was technological, consisting of a better way of producing things or the production of new things" (Pollard 1982, v). Another economic historian, W. Paul Strassmann, also claimed that "at the heart of an industrial revolution are new machines, new processes, and new materials that transfigure the economic landscape" (Strassman 1959, 1). In particular, "Industrialization depends on metallurgy, power, and machine tools" (Strassman 1959, 117).

The historian of science A. Rupert Hall asserted that "modern technology seems to spring from four major roots, which I define in the order of their historical importance: the reorganization of labor, the use of machines in manufacture, the exploitation of man-made materials, and the application of new sources of energy. Each of these roots extends far back beyond the modern historical period" (Hall 1962, 501). By "reorganization", Hall seems to mean mainly factory organization, and his "machinery" is roughly synonymous with my use of "structural" machinery. However, Hall, like the other historians quoted, does not offer a reason for choosing these categories.

For the technological historian S. Lilley, "if the telegraph and telephone changed the world by making possible instantaneous communication over the whole globe, possibilities just as revolutionary were implied in the transmission of power by electricity" (Lilley 1965, 120). After discussing these information and energy technologies, in his next chapter he focuses on "three very important aspects of machines: the materials from which they are made and the tools and methods used in making them" (Lilley 1965, 142), concluding that "the lathe, with its many variant forms, is the most important of the machine tools and the possibility of most of the nineteenth-century advances was closely tied up with its development into a robust machine of high precision" (Lilley 1965, 147; see also Robert Woodbury's book on lathes, Woodbury 1961).

The business historian Alfred Chandler claims that "modern business enterprise, as defined throughout this study, was the organizational response to fundamental changes in processes of production and distribution made possible by the availability of new sources of energy and by the increasing application of scientific knowledge to industrial technology" (Chandler 1977, 376). He identifies structural, material, and energy-converting production technologies as key to this transformation. The factory managers "concentrated on three types of technological innovation to help expand further the volume of throughput: sustained development of multipurpose machine tools, improvement of metals in cutting tools to increase the speed at which machines worked, and increasing application of power to move materials more swiftly from one stage of production the next. All three intensified the use of energy and increased the amount of capital required in the processes of production" (Chandler 1977, 279).

Understanding the Industrial Revolution and the "second industrial revolution" of electricity and steel is important because all economies since the nineteenth century have depended on the base laid down by these eras of production innovation. The technologies created then have not disappeared today. There have been constant innovations in the basic industrial technologies, yet they have not received the same attention that other technologies, such as computers, have received. Social scientists should not judge the importance of a technology on the column inches a technology receives in magazines and newspapers. This study is an attempt to construct a more objective, theoretical basis for understanding the role of various technologies.

Aristotle, in a way, proposed a set of categories of production that were based on a theoretical framework. His categorization may serve as a useful way to understand many other scholars' categories. In the book *Physics*, he states that "the point of our investigation is to acquire knowledge, and a prerequisite for knowing anything is understanding *why* it is as it is – in other words, grasping its primary cause" (Aristotle 1996, 38-39, emphasis in original). Asking "why something is as it is", is equivalent to asking how something came to be as it is, and Aristotle is clearly interested in this process of change. His next sentence reads, "Obviously, then, this is what we have to do in the case of coming to be and ceasing to be, and natural change in general" (Aristotle 1996, 39). For something as mundane as goods and services which are the output of a system of production, then, Aristotle's inquiry is relevant – how did the goods and services come to be as they are? In other words, one way of phrasing his question, "Why is it as it is?", is to ask, "How was it produced?"

In the context of production, his answer makes more sense than he is usually given credit for. Aristotle proposes four types of "causes", but only one, philosophers tell us, is what we think of as a "cause", at least in the way "cause" has been discussed since

Hume (see Bunge 1979, 31-33). Aristotle's "causes" are not really causes in the modern sense, but categories of production, or more generally, categories of coming into being.

Aristotle states that "one way in which the word 'cause' is used is for that from which a thing is made and continues to be made – for example, the bronze of the statue" (Aristotle 1996, 39). This corresponds to one of my proposed categories of production, material production, consisting of the substance of a produced object.

Aristotle continues, "A second way in which the word is used is for the form or pattern…", corresponding to structure as defined in the chapter on systems (Chapter 4). This concept is similar to my structural category of production.

Aristotle's third type of cause is the one that survives to this day: "A third way in which the word is used is for the original source of change or rest. For example, a deviser of a plan is a cause, a father causes a child, and in general a producer causes a product and a changer causes a change" (Aristotle 1996, 39). In terms of a generative system as I have described it, Aristotle is describing a generator, or the "source of change", as he puts it. Production machinery is the "producer that causes a product".

However, I have said that *all* of the categories of production include generators. Thus, there is a generator of material and a generator of form, or structure. For Aristotle, there are the categories of substance and form, and a separate category for the generator. I am claiming that it is more useful, in understanding production in an economy, to conceive of a generator for the material *and* a generator for the structural aspects of production. There is no generator separate from form or substance.

Thus, change is a part of the material category and the structural category, instead of being a separate part of production. Several of the quoted scholars use Aristotle's method of categorization. Often, steel and sources of energy, for instance, are listed as important categories, while machinery is then put in a separate category. But machinery is part of *all* categories of production.

In order to make any change, in the Newtonian mechanical world, a force must be produced. This is Newton's answer to Aristotle: force is the "changer" that "causes a change" in the simplified model that Newton proposed. In Einstein's reformulation of Newton's categories, energy replaced force as the producer of change. Similarly, I propose that energy-conversion be the third cause of "why something is as it is". Again, a "producer" or machine is necessary in order to "cause" this kind of change.

Aristotle's most controversial "cause" was his final one: "A fourth way in which the word is used is for the end. This is what something is for, as health, for example, may be what walking is for" (Aristotle 1996, 39), in other words, there is a purpose to everything. In chapter 8 of book 2 (Aristotle 1996, 50-53), he uses this reasoning to reject the possibility that animals are the way they are because of "accident". Animals are the way they are, Aristotle reasons, because of the implementation of a consciously planned design. This idea is counter to Darwin's conception of evolution. Although evolution does not occur "by accident", since adaptations succeed because they are congruous with their environment, Darwin was able to show that there can be a design without a designer, or a "blind watchmaker", as Richard Dawkins titled his book (Dawkins 1996). However, both Aristotle and Darwin are discussing the same problem: design.

Aristotle's fourth category can therefore be conceived as the category of *design*, although we now know that, because of DNA, design can be "accidental" in the sense of not having been consciously created. I have characterized the fourth category of production as the production of information, which includes the storage, processing, and propagation of design. Machinery is used for information processing.

Many authors, such as Chandler, give causal priority to management and organization, or to computer technology, which can be seen as variations on the theme of design. But for the purposes of understanding the technological change which leads to growth, it is more useful to focus on all four categories of production – material, structural, energy-converting, and informational – simultaneously. All four categories constitute a proper list of "causes" of "why it is as it is". The approach used here is therefore multicausal, as opposed to a monocausal explanation of technological change.

Authors often claim that a single category of production is central to industrial society. It may be claimed that energy is the center of industrial life (see Smil 1999 for a guide to energy), or that we live in an age of steel (for recent surveys of materials, see Amato1997 and Sass 1998). It may be asserted that the computer has led to another industrial revolution (for a recent survey of information technologies, see Lebow 1995). Some scholars declare that transportation technology shapes history (for a good history of transportation technology, see Hugill 1993). Machines which shape and structure goods, such as machine tools, are not usually classed with these same technologies (with the occasional exception of the assembly line). This study will consider all four categories of production to be of similar importance, and I will discuss the importance of structural technologies such as machine tools in more depth in the next section.

Thus, the second implication of my definition of an economic system is that the processes of production can be usefully divided into four categories. In order for an economic system to grow, the technologies of all four categories of production must grow in a balanced way. Furthermore, innovations in any one category reverberate throughout the other categories as well, setting up a virtuous cycle of technological advance.

Stages of Production

The first implication of my definition of economic systems is that production is central to the functioning of economic systems. The second implication is that there are four categories of production. This section explains the third implication, that there are stages of production.

As was claimed in the chapter on systems, in constructing a theory of a particular system, one needs to specify an ordering principle for placing functions along a particular dimension. In the case of categories of production, there is no ordering in the sense of a series of numbers; the categories of production constitute an unordered set. The ordering principle is that the elements are part of a set of functions, or functional set.

My definition of economic systems implies, in addition to categories, *stages* of production. While categories of production comprise simultaneous processes, stages constitute the sequences of different kinds of production necessary to produce goods and services.

Two stages of production are the production machinery stage and the production stage. First, production machinery is created, and second, the production machinery is used to generate final goods and services. This sequence is a model of the economy at a very high level of abstraction. In the real world, there are very long sequences and cycles involving production machinery, output, production machinery, output, etc.

For instance, one such simplified sequence was given above in the description of the production of an automobile, and is shown here in diagrammed form:

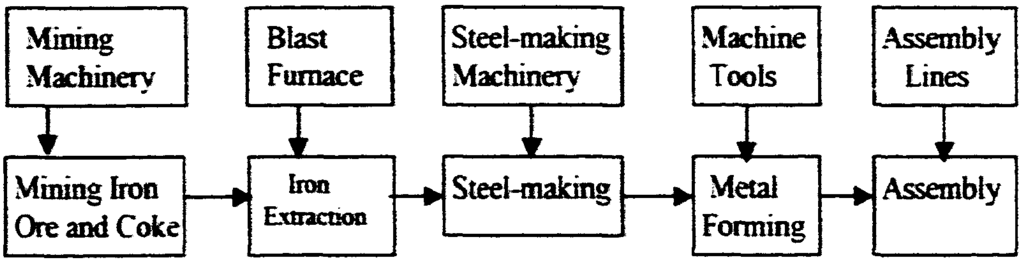


Fig. 25. Automobile production and production machinery.

The production machinery in this case consists of the mining machinery, the blast furnaces, the steel-making machinery, the machine tools, and the assembly lines. All of these classes of machinery must be produced before they can be used. The stage at which these machines are built I am calling the *production machinery stage* of the sequence of production. Once these machines are constructed, they are then used in the *production stage* to produce, in the automobile example, the iron ore, coke, steel, metal parts, as intermediate goods, and then the automobiles, as final goods.

At all times all stages of the sequence are active. That is, in the case of the automobile, there are always blast furnaces, steel crucibles, metal-forming machine tools, and assembly lines in operation. This process is referred to as *pipelining*: something is always in the production pipeline. In order to claim that production machinery is produced before final goods are produced, I must abstract from reality, and observe that in production, the generator must exist before the final output exists.

The generator *causes* the output to exist. The existence of a cause assumes a sequence in time, that is, the effect of the cause occurs *after* the cause. In the case of production, production technology causes the provision of goods and services; therefore, production technology exists prior to the goods and services.

The production system is a generative system, which includes a sequence and a functional differentiation. Along one dimension of functional differentiation, as explained in the previous section, there exist categories of production. Along a second dimension, we have a sequence of production composed of stages. The first stage *produces* production machinery, and second stage *uses* production machinery to produce goods and services.

This sequence corresponds to the general generative systemic structure of a generator and output, as proposed in the chapter on systems. There is another possible stage in such sequences, the metagenerator stage. That is, there is a stage that must exist in order to generate the generator.

Such a stage exists in all human societies. Humans are unique in being able to use tools to make tools. Many other animals make tools. For instance, chimpanzees strip leaves from a twig and use them to capture termites, or they find appropriate rocks with which to crush shelled nuts. Since the earliest humans, predating our species ***homo sapiens***, "metagenerator" stones have been selected for use in order to create various stone-based cutting tools; certain "hammer" stones were used to produce tools. But these hammer stones were not a reproductive technology. That is, the stones used to make stone cutters were not used to make more stone metagenerators.

Similarly, there have been various simple technologies for creating fires, and fires were (and still are) used both as energy-converting production technologies and material production technologies. But these devices, such as setting a spark using flint, could not be used to help create more flints.

With the development of iron technologies, however, a reproductive aspect appeared in human technology. It was now possible to use an iron hammer to help create another iron hammer.

The industrial revolution created the production technologies which enabled human production systems to become fully reproductive. *It is because of the ability of the metagenerative production machinery to be mutually causative and reproductive that economic output has increased exponentially since the advent of the Industrial Revolution*; this is the second hypothesis about economic systems. By using the systems theory as developed in this study, it is possible to give a formal definition of the Industrial Revolution: the Industrial Revolution was *a change in the structure of the system of production from containing a partially reproductive metagenerator to a fully reproductive metagenerator*.

Carrol Pursell has summarized the interactive nature of the metagenerative technologies of the industrial revolution:

> The increasing availability of cheap iron, both cast and wrought, made it possible to move from the wood technology of time immemorial to modern iron technology. This was not a simple progression from one development to another. Immediate and critical feedback reinforced the change and made it irreversible through a ratchet effect. The use of coke had, for example, made iron cheaper and available in larger quantities. As a result, it became economically feasible to use steam engines in many more industries. When John Wilkinson, who cast the iron cylinders for Boulton and Watt's great engines, installed one to power his blast furnace, the increased blast further improved the quality, quantity, and cheapness of iron that he then used in

> improved engines. The steam engines were widely used to drain coal mines, and this application made coal cheaper and more readily accessible. This in turn encouraged the greater use of steam engines that drew on coal for fuel. And so it went....The rolling mill developed by Cort offers another case in point...Another example can be taken from the extremely important field of machine tools. To be most useful, iron had to be worked into useful shapes. The only machines that could possibly accomplish this were themselves made of iron. Thus each improvement in metallurgy made it easier to cut and work iron, and this in turn made it possible to produce more and better iron products...(Pursell 1995, 56-58: for similar quotes, see [Rosenberg 1982, 246] and [Strassman 1959, 206-208]).

This trend of mutually causative metagenerative technology has continued throughout the last two centuries. Because of the development of steel, the construction of electricity-generating turbines was enabled. With ample electricity, fine steels were created by using electric lances. In addition, electricity allowed for an increased productivity and precision in the use of machine tools, which in turn created the opportunity for the development of better steel-producing and electricity-producing technologies.

More recently, the expansion in power and use of computers has led to breathless descriptions of the present era as ushering in a "new economy" or as being the most important period of technological innovation in history. By using my theory of production, however, it is possible to understand the present period of technological change: the *informational production technologies* have caught up with the structural, material, and energy-conversion technologies.

The metagenerator for all computer-based technologies is a set of machinery called semiconductor-making equipment. These technologies, which are based most fundamentally on optical technology, are used to create the semiconductors that are then inserted into most pieces of equipment today, including production machinery. An improvement in semiconductor-making equipment leads to more powerful semiconductors, which are then used to create better semiconductor-making equipment. Before the advent of the transistor, vacuum tubes were not used in the construction of vacuum-tube producing equipment; the information production technologies were not used to reproduce themselves. Semiconductor-making machinery, like machine tools, help to reproduce themselves.

These reproductive metagenerative technologies can be labeled *reproduction machinery*, to focus attention on the ability of these classes of machinery, collectively, to cause exponential growth of output. This exponential growth is the result of two kinds of positive feedback. First, the technologies help each other; there is mutually causation, and an amplification of innovation. This is a general feature of the four categories of production, as explained in the previous section.

Second, reproductive machines can collectively reproduce themselves. This positive feedback process is particular to the reproductive stage of production, as opposed to the mutually causative aspect of the categories of production. Since machinery can produce output much faster than humans can produce the same output by hand, the total production emanating from reproductive machines can expand explosively. The reproduction machinery industries contain great productive power.

We can see this self-production in several technologies. Machine tools produce the metal pieces that are used in all machinery. This means that machine tools make the parts for making more machine tools.

The reproductive potential of reproductive technologies, furthermore, can be most easily observed within the machine tool industry, although machine tools are not the only kinds of machinery which help to reproduce themselves. Many scholars have written about the importance of machine tools and the more general category of metal-working technology. These scholars have also noted the way in which machine tools create the machines which create goods and services, without setting this insight into a general theoretical framework, as I am attempting here.

For example, a long-time editor of the trade journal *American Machinist*, not surprisingly, believed that "machine tools are the foundation for almost all manufacturing." He goes on to back up this assertion: "Once we leave the work of artisans behind, virtually every man-made device is produced either by machine tools or by machines and equipment produced by machine tools. Thus an automobile is an assembly of metal parts made by machine tools, plastic parts produced by machines made by machine tools, fabric processed on textile machines made by machine tools, rubber processed and molded by equipment made on machine tools, and glass processed by equipment produced by machine tools...Machine tools have often been called the only machines that can reproduce themselves" (Ashburn 1988, 19).

According to Corcoran, "It is said that machine tools are the master tools, the tools that make tools. Virtually every product is built on a machine tool or on a machine made by a machine tool. Accordingly, technological change within the machine tools industry translates into technological change in manufacturing processes themselves" (Corcoran 1990, 227). The economic historian Habakkuk (1967, 105) states that "A large part of American industrial progress in the nineteenth century was due to the rapidity of technical advance in machine tools". In a well-known article entitled "Do machines make history?" Robert Heilbroner states that "until a metal-working technology was established – indeed, until an embryonic machine-tool industry had taken root – an industrial technology was impossible to create" (Heilbroner 1994, 58).

The technological historians Derry and Williams (1960, 363) assert that "in the twentieth century the rapid development of the motor-car, and subsequently of the aeroplane industry opened immense new fields for the application of machine-tools. Although never a large industry in terms of the number of people employed, the machine-tool industry has long been of the most fundamental importance to technological progress of every kind".

A United Nations report on global machinery industries states that, historically, "the pace of development of machine tools governed the pace of industrial development" (UNIDO 1984, 57); the authors also claim that the entire industrial machinery sector plays this role (UN 1984, 3). Currently, "in terms of a country's development, machine tools play a crucial role" (UN 1984, 57).

According to a report commissioned by the National Academy of Engineering and the National Research Council, "The machine tool industry is of great strategic importance to the processes of economic growth and industrial development. Virtually every major manufactured product is produced on machine tools or on machines built by machine tools" (Machine Tool Panel, 1), and "Machine tools are crucial elements in heightening industrial productivity".

The following is a reproduction of a diagram found in their study. It shows the tripartite structure of production that starts with machine tools (reproduction of figure 2, page 6):

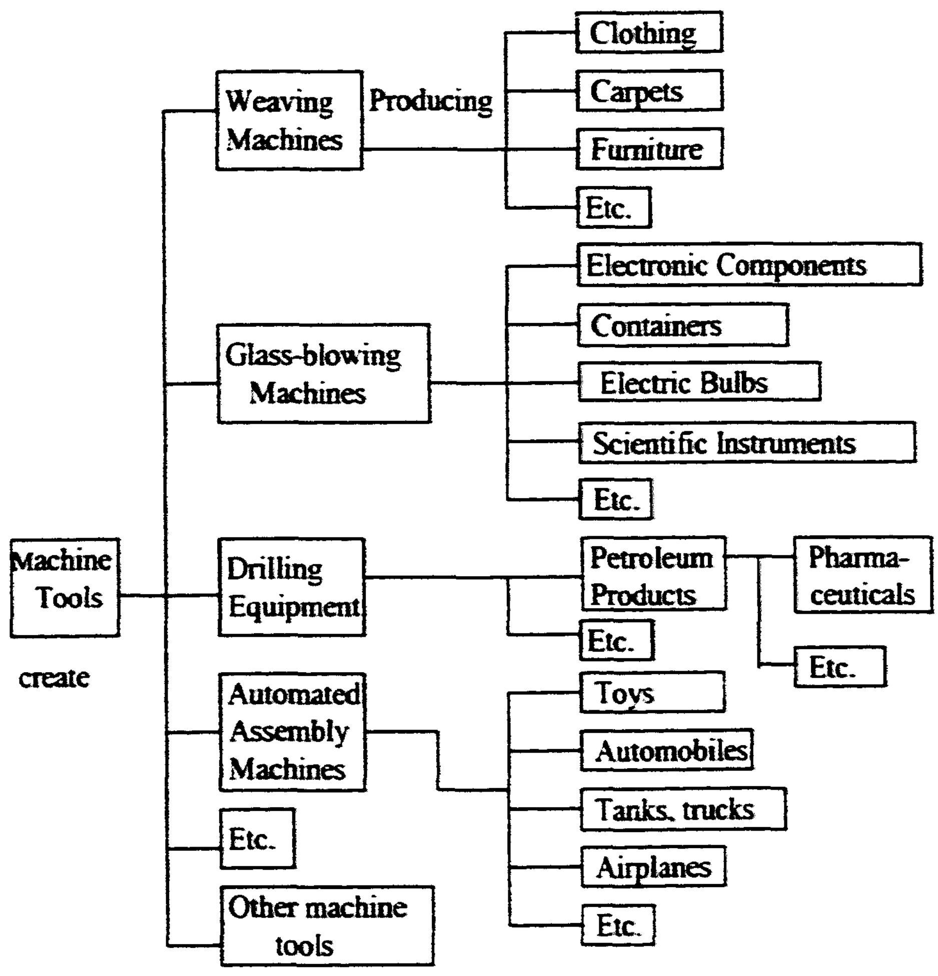


Fig. 26. Position of machine tools in production system.

Thus, machine tools create the production machinery that produces the goods people use. In a similar vein, the National Advisory Committee on Semiconductors (1990, 3) points out that the global semiconductor equipment and materials industry generates revenue of $19 billion, which is used in the global semiconductor industry, valued at $50 billion. Semiconductors, in turn, are used by the global electronics industry, which output $750 billion of goods in 1990.

Max Holland, summarizing his chronicle of the decline of the U.S. machine tool industry, states that "political primacy, economic wealth, and preeminence in machine tool production have always coincided because 'mother machines' are the heart of any industrial economy. The correspondence between the rise of the American tool industry, which began before the turn of the century and reached a peak in the early 1960s, and American politico-economic power was not mere happenstance. In like manner, the tool industry parallels the decline of the American economy since then" (Holland 1989, 264). This association of production competence and national power will be pursued in the chapters on systems of political economy (Chapters 9 and 10).

Any writer on the machine tool industry, as can be seen, makes statements along the lines of the technological historian Rolt:

> It is impossible to study the history of technology without becoming aware of the crucially important part played in that history by machine tools and their makers. It is scarcely an exaggeration to say that man's tools have governed the pace of industrial revolution. We should never have heard of James Watt, George Stephenson, Gottlieb Daimler, Rudolph Diesel or the Wright Brothers but for the tools which could alone give their ideas a practical shape...All down the ages the rate of man's material progress has been determined by his tools, because all tools represent extensions of the human hand, being designed to magnify its cunning or its power...The most versatile of all tools is the human hand, but it is feeble and fallible. The aim of all tool-makers from first to last has been to overcome these defects by enhancing the power of the hand and reducing its fallibility...the tool-makers attacked human fallibility by 'building the skill into the tool'. (Rolt 1965, 11-13)

While the structural production machine that dominates the public imagination is the assembly line, as Womack, Jones and Roos point out in their book on the automobile industry, "the key to mass production wasn't – as many people then and now believe –

the moving, or continuous assembly line. *Rather it was the complete and consistent interchangeability of parts and the simplicity of attaching them to each other*" (Womack, Jones and Roos 1990, 27, emphasis in original). This interchangeability, according to these authors, was made possible by machine tools, prehardened metals, and auxiliary technologies such as gauges (corresponding to structural, material, and informational production technologies, respectively).

Speaking of the nineteenth century, Rosenberg writes that

> the machine tool industry, then, played a unique role *both* in the initial solution of technical problems and in the rapid transmission and application of newly-learned techniques to other uses. In this sense the machine tool industry was a center for the acquisition and diffusion of the skills and techniques uniquely required in a machinofacture type of economy. Its role was a dual one: (1) new skills and techniques were developed here in response to the demands of specific customers, and (2) once acquired, the machine tool industry served as the main transmission center for the transfer of new skills and techniques to the entire machine-using sector of the economy" (Rosenberg 1972, 98).

Thus, machine tools add to the productive power of a nation because they increase the speed of diffusion of innovations throughout an economic system. Rosenberg stressed the role of machine tools in spreading innovation. Speaking of the metal-shaping activities in general, he wrote that "it is because these processes and problems became common to the production of a wide range of disparate commodities that industries which were apparently unrelated from the point of view of the nature and uses of the final product became very closely related (technologically convergent) on a technological basis – for example, firearms, sewing machines, and bicycles" (Rosenberg 1976, 16), as well as automobiles. The point in terms of this study is that one set of production technologies not only was critical to the production of several categories of final goods, but that the skills learned in the production machinery industries spread, in a give-and-take fashion, throughout large portions of the economic system: "We suggest that the machine tool industry may be regarded as a center for the acquisition and diffusion of new skills and techniques in a machinofacture type of economy. Its chief importance, therefore, lay in its strategic role in the learning process associated with industrialization" (Rosenberg 1976, 18).

As Strassmann commented on Rosenberg's article, "But interindustry economics anoints none as king, not even machine tools" (Strassmann 1963, 444). There are important technologies within all four of the categories of production, although machine tools are the least known of them.

Steel-producing equipment is made from steel; therefore, this type of equipment helps to make more of its type of machinery. Electricity is used, by machine tools, to make the high-precision parts of electricity-producing turbines; the turbines help to make more turbines. Finally, semiconductors are used to produce the parts that make up semiconductor-making equipment, and thus every advance in semiconductor-making technology is self-reinforcing.

These technologies not only are used to make more of themselves, but collectively they are employed to make more of one another. The steel is used to make machine tools, and the electricity powers the machine tools that produce more machine tools. One of the greatest benefits of semiconductors has been to automate machine tools; computerization has led to large-scale automation of steel production. New metal alloys are used to produce more reliable electricity-generating turbines and material for semiconductors.

The historian of technology Basalla points out that Samuel Butler, the author of the utopian novel Erewhon, wrote that "the propagation of mechanical life depends on a group of fertile contrivances, called machine tools, that are able to produce a wide variety of sterile machines" (Basalla 1988, 16). Butler was calling attention to the fact that some technologies, in this case machine tools, are "fertile", which means that they are reproductive.

These reproductive machines not only make more of themselves, they are used to produce the production machinery that produces the final, consumed output. For example, machine tools, steel from steel mills, electricity from electrical systems, and computers are used to produce the following: construction machinery that builds the physical structures in the economy; the textile machinery that is used to make clothes; the food machinery that is used to process much of the food we eat; and the planes and trains that we use to travel.

I will use the term "production machinery" for machinery that is used to produce final output. Thus, reproduction machinery and production machinery are separate categories. The general term "machinery" will be used to refer to both reproduction and production machinery. Machines bought by consumers will be referred to as "consumer machinery", but for the purposes of this study, will not be included in the general term "machinery". When a truck is used to transport parts between factories it is classified as production machinery; when the same kind of truck is bought by a factory worker for personal use, that truck is classified as consumer machinery. Each machine is classified according to its use as either reproduction machinery, production machinery, or consumer machinery.

Most of the machines that are classified as a type of reproduction machinery can also be used as production machinery. Thus, most of the electricity generated by turbines is not used to make more reproduction or production machinery but is used for production of final output or home use. Most steel is used for final production, particularly in construction. Many machine tools are used in the auto industry. Sometimes the same machine may be used for different stages of the production process. A production machine takes on a particular function depending on what it is being used for during a particular period of time.

While certain classes of machinery, such as machine tools, can be used as both reproduction machinery and production machinery, there are certain classes of production machinery that never participate in reproductive processes. As Strassmann pointed out in terms of the nineteenth century, "Textile machines benefit as much as machine tools and motors from advances in metallurgy and power engineering…The fact that they borrow innovations from other industries without selling commodities to these industries means that they cannot expand and innovate with the increased scale of operations of these industries per se. During the nineteenth century the demand for metals, power equipment, and engineering tools grew at a much faster rate than the demand for textiles because of the strategic importance of these industries in the Industrial Revolution. The complementarity of innovations here was, in fact, the essence of that revolution" (Strassmann 1959, 214). The reproduction machinery industries as well as the production machinery industries gain from innovation in reproduction machinery, but the reproduction machinery industries do not gain from innovations in purely production machinery industries.

Thus, particular industries such as machine tools, steel, and electricity may be considered wholly within the reproductive sectors when the focus of study is the technological capability of a production technology to cause change throughout the system of production. In terms of modeling the economy as a production system, it will be more useful to split these industries into two or three pieces in order to show exactly how each stage is constituted in terms of types of machinery.

Thus, production in the industrial age has the following structure:

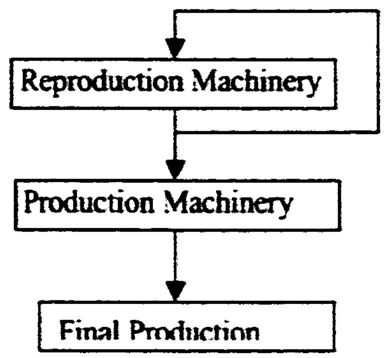


Fig. 27. The stages of the production system.

This is a sequence of stages of production. Reproduction machinery is used to produce more reproduction machinery and to produce production machinery. Production machinery is used to produce the goods and services that people use, including physical structures such as buildings and roads. This sequence of functions is ordered in time.

Because this sequence is similar to the tripartite generative sequence I proposed in the chapter on systems, I will refer to these stages as a tripartite sequence of production. There are similar tripartite sequences of production in the biological realm. For instance, the science writer Colin Tudge wrote of the co-discoverer of DNA, "Francis Crick has summarized molecular biology in what he calls the 'central dogma': 'DNA makes RNA makes protein'" (Tudge 2000, 72). In the discipline of economics, there have been two main efforts which are similar to my tripartite schema as presented here, one by a Marxist and another by a nonMarxist.

The Feld'man model is based on a model of Karl Marx. Marx developed a theory of economic production which included production machinery and production stages of production (the following is based on Domar 1957, 225). In Marx's Department (or Category) 1, the goods are made that are used to make the goods in Department (or Category) 2, which is the consumption sector. The Soviet economist Feld'man built on this basic idea to construct a model which Stalin later used as a basis for the Five Year plans. In the model, as Domar says, "in a growing economy some capital is used to make more capital" (235). As Domar shows in his article, investment in Category 1, that is, capital goods, can lead to exponential growth.

Feld'man stated that "the increase of the rate of growth of production depends on the increase of the capital of sector A as compared with the increase of the capital of sector B (consumers' goods sector). With expanding reproduction, sector A must supply sector B not only with producers' goods required to continue production at the current level of output, but also with additional fixed and circulating capital necessary for expansion of reproduction…This gives rise to the idea of dividing the capital of sector A into two sections, of which one (A_2) supplies sector B with the means of production required to sustain output at a given level, and the other (A_1) supplies all industries in both sectors with additional capital to enable reproduction to expand." (Feld'man 1964, 175-176). This is similar to my tripartite structure, where A_2 is similar to my production machinery sectors and A_1 is similar to the reproduction machinery sector. The difference is that A_1 also provides extra *production machinery* to the final production sectors, while in my conception of an economic system the reproduction sectors do not supply machinery to the final production sectors, but only to the production machinery sectors.

Using Feld'man's ideas, Stalin wrote that "a fast rate of development of industry in general, and of the production of the means of production in particular, is the underlying principle of and the key to the industrialization of the country, the underlying principle of and the key to the transformation of our entire national economy along the lines of socialist development…It involves the maximum capital investment in industry" (Stalin 1964, 266).

Stalin used this reasoning as part of a plan that resulted in rapid industrial growth as well as the starvation millions of peasants, among many other deprivations. However, he grasped the importance of the "production of the means of production". His use of the term "means of production" corresponds to my use of the term "production machinery", and the producers of the means of production therefore correspond to my use of the term "reproduction machinery".

As K.N. Raj notes, "The theoretical implication that it might be useful in certain contexts to break down the capital goods sector in the Marxian scheme of reproduction into two sub-branches, one devoted to the manufacture of capital goods for producing capital goods (which for convenience has been termed the 'machine-tool sector' by Dobb) and the other manufacturing capital goods directly for the consumer goods sector, has been reflected to some extent in subsequent planning literature" (Raj 1967, 217). Maurice Dobb (Dobb 1960), whom Raj referred to, used a tripartite disaggregation of the economy similar to the one used in this study, but he tried to make his model compatible with Marxist economic traditions.

The nonMarxist economist Adolph Lowe adopted a tripartite classification similar to my scheme, although he was more concerned with equilibrium than growth. After distinguishing between the consumer-goods and equipment industries, "among the equipment-goods industries I propose to distinguish between those that produce equipment to be applied in the production of consumer goods, and others that produce equipment for the equipment-goods industries themselves" (Lowe1987, 34); in other words, he distinguished between production machinery and reproduction machinery, respectively.

Lowe points out that in order to find a sector that makes itself, the problem of "infinite regress" must be solved (Lowe 1987, 36): that is, once having found the equipment which makes the equipment which makes goods, is not there also a sector that makes the equipment that makes the equipment that makes the equipment, and on and on? Solow (1962, 207) invokes this "infinite regress" to dismiss the possibility of identifying a separate equipment-making equipment sector.

Lowe solves this problem by considering reproduction in organisms, specifically wheat, and concludes that "the primary condition for the economic reproduction of wheat is its physical capacity for self-reproduction". He therefore finds that:

> "The lesson is obvious. Only if we succeed in discovering in the realm of fixed-capital goods certain instruments which share with wheat the capacity for physical self-reproduction can our problem be solved. In other words, we have to look for a type of equipment which is technically suited to produce other equipment as well as its own kind. What we find, as a matter of fact, is not one single instrument, but the comprehensive group of instruments which are classified as machine tools. They are for industrial production what seed wheat or the reproductive system in animals represents for agricultural production.

> They form an indispensable part of input whenever an equipment good, including machine tools themselves, is to be reproduced". (Lowe 1987, 37, see also Lowe 1965, 270)

I would only amend this statement to say that there is a class of machinery, including machine tools, which, as a set, reproduce themselves. In fact, Lowe uses machine tools, steel plant, blast furnaces, and extraction machinery as examples of his equipment-making equipment sector (Lowe, 1987, 38).

Many authors have commented on both the categories and stages of production, without putting them into a broader framework. This study is an attempt to provide the larger framework within which to understand the insights of these scholars and the long-term processes of the economy. Understanding production as a functionally-differentiated system composed of a structure makes possible the construction of hypotheses which are theoretically-based and hold greater explanatory power for understanding the rise and decline of Great Powers than the various ad hoc statements exhibited in this and previous chapters.

Thus, there are two dimensions in the ordering of the elements of the system of production. Along one dimension, production technologies fit into categories of production. Along another dimension, technologies can be characterized according to their position in a sequence of stages of production. The next chapter (Chapter 7) will discuss the structure of the production system that results from the combination of these two orderings, and Chapter 8 will include a discussion of the other subsystems within the economic system, the capital subsystem and the distribution subsystem.

CHAPTER 7

A THEORY OF ECONOMIC SYSTEMS, PART 2:

THE PRODUCTION SYSTEM AS A WHOLE

In the previous chapter, two important aspects of technological change were discussed: first, change in the technologies of one or more categories of production reverberate to other categories of production; and second, the change to a fully reproductive production technology allows for exponential growth. Great Powers that are more successful in encouraging and harnessing the beneficial effects of these technological changes will rise relative to Great Powers that are less successful.

The present chapter will further explore the sources of technological change and their effects on the performance of Great Powers. The importance of reproduction and production machinery will be highlighted, and the benefits that emerge from the interaction of all production system functions taken as a whole will be discussed.

This chapter will also lay the groundwork for rigorous modeling of the economy. The concepts which are discussed in this chapter can be used to construct a sophisticated computer simulation of the production system, although such a simulation is beyond the scope of this study. The capability to create a simulation is important for validating and refuting hypotheses that arise from my theory of economic systems.

The Structure of the Production System

The two dimensions of the ordering principles of the structure of the production system can be combined into a two-dimensional diagram, to be called a *production matrix*:

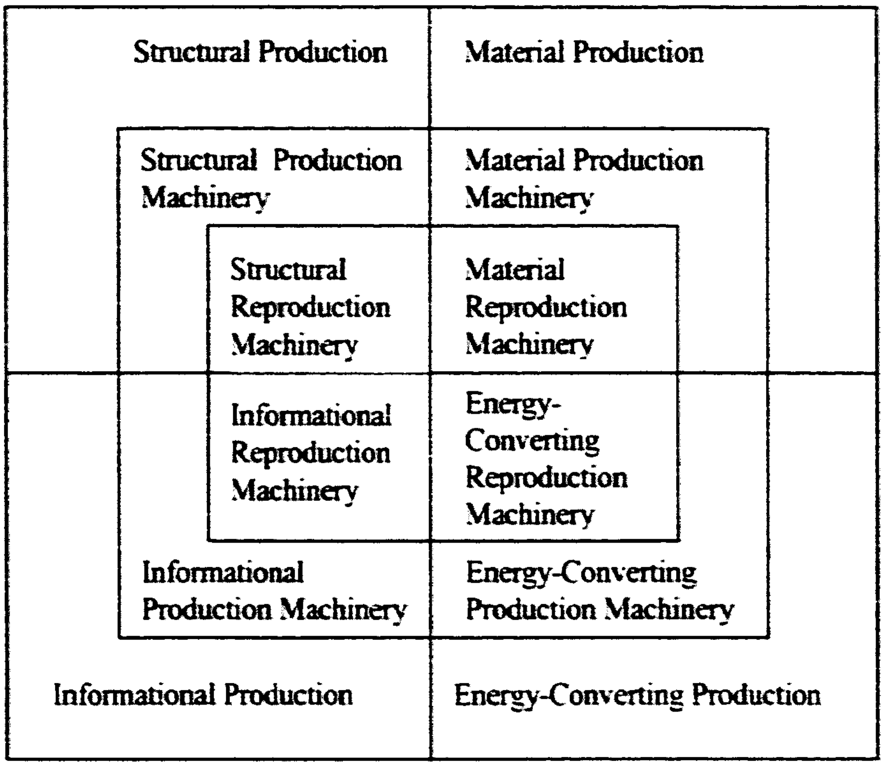


Fig. 28. Structure of the production system.

Each stage of production is composed of four categories of production.

There are twelve functional sectors of the production subsystem of the economic system. These functional sectors are the *elements* of the production system; they are arranged in a structure which is characterized by two ordering principles, categories and stages of production. These sectors will be referred to as *production system niches*, or simply *niches*.

The production matrix is an attempt to disaggregate the economy while retaining comprehensibility. In a similar way, Nathan Rosenberg has stressed the necessity of disaggregating technology:

> "Not only do technologies change over time, there are, in fact numerous technologies that coexist in a society at any moment. This heterogeneity renders distinctly suspect all attempts to speak about technology and its consequences in highly aggregated ways. It is not possible to come to grips with the complexities of technology, its interrelations with other components of the social system, and its social and economic consequences, without a willingness to move from highly aggregated to highly disaggregated modes of thinking. One must move from the general to the specific, from 'Technology' to 'technologies'. One must even be prepared to 'dirty one's hands' in acquiring a familiarity with the relevant details of the technology itself" (Rosenberg 1976, 2).

By dividing the production subsystem of the economy into twelve niches, I have attempted to strike the proper balance between aggregation and disaggregation. It should be possible to construct a useful explanation of the working of the economy, while retaining comprehensibility.

The functional sector can be called a niche in the sense used in ecological theory. The term "niche" has been difficult to define rigorously. As one biology text puts it, "an organism's niche is its ecological role – how it 'fits into' an ecosystem" (Campbell, Reece and Campbell 1999, 1115). More generally, Webster's dictionary defines an ecological niche as "the position or function of an organism in a community of plants and animals" (Webster 1989, 964). In the same way, a production system niche is the position or function of certain production technologies in the structure of the production system.

I have stressed the role of machinery in the discussion of the production system. However, there are two other factors of production which must be fit into a conception of a niche. The discussion of these factors includes a discussion of the interactions among the elements of the system. These extra factors, physical structures and intermediate goods, along with machinery, are the inputs and outputs which make up the interactions among the elements of the production system.

The first extra factor is the category of physical structures (national income accounts refer to these as structures, but for clarity I will refer to them as physical structures). Buildings, transportation infrastructure such as roads, electrical and communications networks and water and sewer systems, among others, fall under this term. Production machinery must have physical structures in order to function. For instance, machinery must be housed in a factory building. Trucks require roads, and electrical use usually requires an electric grid. Generally, when economists refer to "fixed capital", they are referring to "plant and equipment", which means machinery and physical structures.

Machinery is the active part of fixed capital, while physical structures are the passive part. That is, physical structures *enable* machinery to be agents of production, just as structures within a system enable or constrain actions by agents. Since most of the technological change which has led to the economic growth of the last two hundred years has been the result of change in the technology of machinery, this study will focus on machinery, not physical structures. But each niche still contains physical structures which are necessary for production. Like machinery, physical structures can be classified according to the category of production in which they participate. Thus, roads are part of the process of transportation, which I have classified as energy-converting production. A building creates position in space, therefore buildings are classified as part of the structural aspect of production.

According to the model adopted here, physical structures are only created in the final production stage. The machinery niches use some of the output of the final production stage in the form of physical structures. The machinery niches, in turn, move machinery in the following manner: first, the reproduction machinery stage generates reproduction machinery to be used in both the reproduction and production machinery stages; then, the production machinery niches move only production machinery to the final production niches. Unlike the machinery stages, the final production stage generates physical structures for all production system niches.

The second additional factor of production is the category of intermediate goods, or what economists call "circulating capital". These are the goods, such as steel, chemicals, electricity, metal and plastic parts, natural resources, and myriad other items, which are used by machinery to generate output. Each niche, in the machinery and final production stages, contains a set of intermediate goods which are used by that stage to generate goods. However, intermediate goods do not move between stages, in my model.

The final production niches output everything that humans use to live. Humans use machinery in all four categories of production, among which are the following: first, tools and utensils for structural production; second, stoves and ovens for material production; third, the energy-conversion of refrigerators, lights, air conditioners and transportation machinery in the form of automobiles; fourth, computers, telephones, televisions and stereos as information production. Economists refer to these types of goods as consumer durable goods.

Humans also use physical structures, in the form of the infrastructure that final production niches also use, again in the four categories; buildings and furniture for structural production; water and sewage systems for material production; roads, railways, airports and the electrical grid for energy-converting production; and telephone and internet infrastructure for informational production.

People use intermediate goods, which economists usually refer to as nondurable goods, as well as services. The nondurable goods and services can also be categorized: first, housing services such as real estate or hotels, can be seen as structural; second, food in general is part of the material production of the human being; third, cars, transportation services, utilities such as gas and electric power, and household goods such as light bulbs can be considered as energy-conversion production; and fourth, the telephone services, printed and broadcast media can be classified as informational production.

This human use of goods and services thus is similar to the categories of production within the production matrix. Human life can be thought of as a sphere of production. People use machines, structures, and intermediate goods, just as the production system niches use the same factors. Thus, the realm of the use of goods and services by people can be labeled ***human production***.

Data for human production can be obtained from the U.S. national income accounts in the form of personal consumption expenditure (PCE) data, which measures the expenditure of consumers by category. This table is an example of what I will call the *expenditure view* of the economy. The following table presents a rough guide to the 1994 figures for the U.S., which I have categorized into structural, material, energy-conversion, and informational expenditures:

Table 4. US Expenditures in Categories of Production

Structural Production	%	Material Production	%	Energy Conv Production	%	Informational Production	%
Housing	15	Food & Tobacco	16	Transportation	11	Recreation	8
Hospitals	8	Drugs	2	Gas & Electric	3	Education	2
Household Operations	5	Clothing & Shoes	6			Religious & welfare	3
		Personal Care	1			Doctors, Dentists & other services	7
		Cleaning	1			Telephone	2
		Water	1			Jewelry & Watches	1
Total %	28		27		14	Total	23

This table was constructed using the U.S. Statistical Abstract 1997, table no. 702 (Bureau of Economic Analysis 1997, 454). The total was 4,925 billion dollars for PCE, and the total of the four categories is 92% of PCE. The remaining 8% of PCE consists of financial and legal expenses. These constitute parts of the distributional system and the state.

The following diagram illustrates the factors of production which emanate from each stage of production:

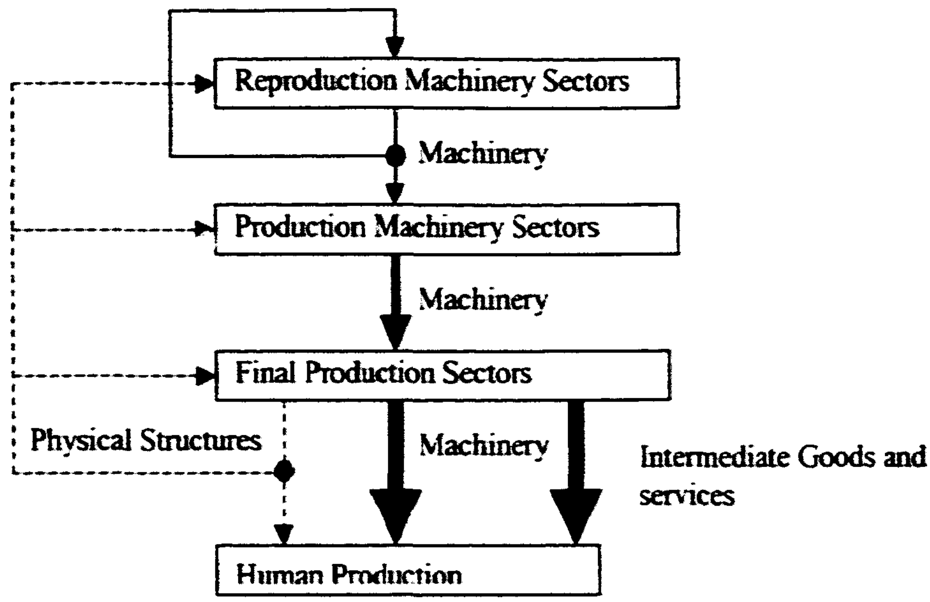


Fig. 29. The stages and capital factors of production.

The thin arrows represent reproduction machinery, the medium width arrow represents production machinery, the dashed arrows represent physical structures, and the very large arrows represent consumer durables and nondurables.

All parts of the production system have now been accounted for. There are machinery niches, which contain physical structures and intermediate goods as well as machinery. The final production niches contain the production of all physical structures, as well as the production of machinery and intermediate goods for human use.

In the diagram on the following page, I have divided the production of machinery, physical structures, and intermediate goods for humans among the twelve production system niches proposed in the preceding diagram of the production matrix, using the names of industries as specified in the United States national income accounts (using Standard Industrial Classification Manual 1987):

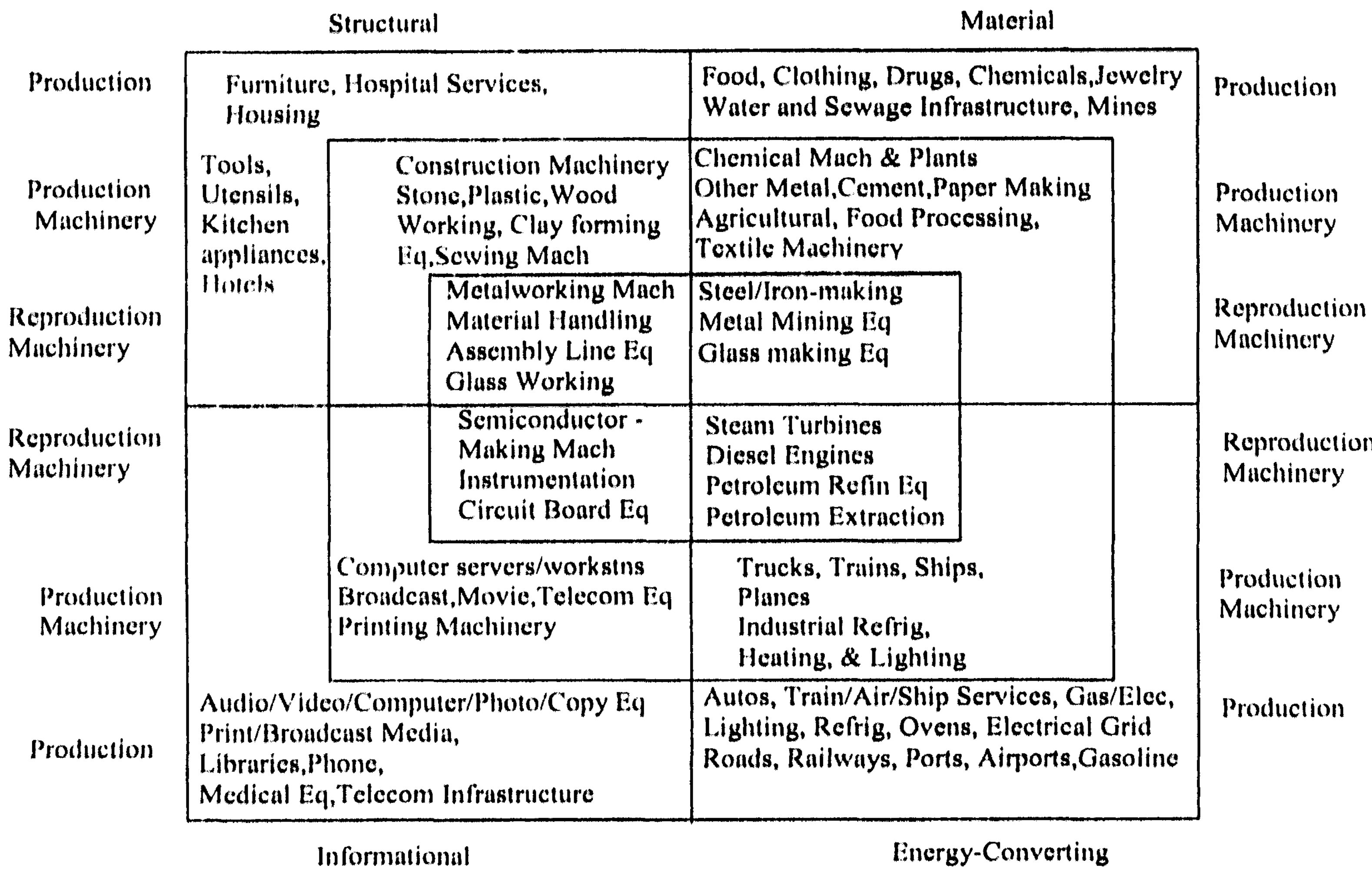


Fig. 30. Detailed structure of production system.

The labels on the outside of the large box indicate the categories and stages of production. A full specification of the lists of industries associated with each production system niche is included as Appendix 1 of this chapter.

These production system niches are themselves composed of a number of industries, or groups of industries. An industry, in theory, is composed of a number of firms. A homogenous group of firms within one industry is the domain of neoclassical economic theories. Neoclassical economists conceive of an economic system as a market composed of identical firms, within one industry. This study is focused on production system niches, however, not firms.

The following is a diagram of the hierarchy of domains as proposed in this study:

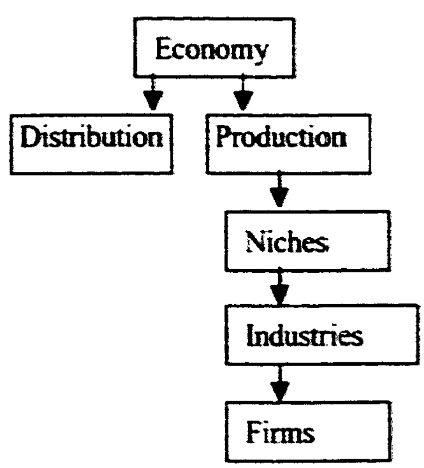


Fig. 31. Hierarchy of economic system.

In order to understand the working of the economic system it is best to focus on the level of the niches. It is necessary to be aware of particular industries, because in the national accounting systems, data are categorized according to these industries. The level of the firm, while useful for understanding the determination of prices and other phenomena, is not as important when exploring the national processes of production.

The ordering principles of the production system have now been specified. The elements are ordered according to two dimensions, categories of production and stages of production. The resulting twelve elements, called production system niches, are arranged into a structure as described above, according to their functional differentiation.

The Distribution of Capabilities within the Production System

A structure of a system is composed of ordering principles, a possible functional differentiation, a distribution of capabilities, and a possible distribution of causal capability. The ordering principles and functional differentiation have been specified. Since each niche can be represented as having a money value, there is also a distribution of capabilities which must be examined. There are three ways to describe this distribution empirically: an expenditure view, a capital asset view, and a value-added view.

The expenditure view has been used, in table 4, to describe personal consumption expenditures (PCE). In national accounting, expenditure in an economy is divided into a number of categories. The standard division includes the following: 1) personal consumption expenditures, which as the name implies covers the spending of people for their own use; 2) fixed private investment, which includes additions to the reproduction and production machinery niches, as well as physical structures; 3) government spending, which includes wages to employees but also includes investment in physical structures; and 4) net imports, that is, the trade balance.

The production matrix can be presented by showing the distribution of capabilities in terms of expenditure. The distribution of expenditure in the various niches gives an indication of the demand in that niche, that is, it shows the ability of the niche to call forth spending. The machinery niches have a very small ability to bring forth spending in comparison to the final production niches themselves, because the machinery niches are very small in comparison to the rest of the economy.

The second kind of measure of capability is called *value-added*. In national accounting systems, value-added is used as a measure of the money value that is added at a particular point in the process of production. This figure is calculated by subtracting the price of the material inputs from the price received for the outputs. For instance, in the steel industry, a particular amount of money is spent on iron, other materials, energy, and machinery. The value-added is the revenue of the steel industry minus these inputs. Generally, the value-added equals the income received by the various people who participate in the production. The value-added is therefore synonymous with profit plus wages, plus occasional other charges, such as rent.

The value-added approach is useful for explaining the detailed interactions of the various industries in an economy. In particular, a system of *input-output tables* has been constructed by the United States and other governments, which shows the inputs which each industry uses, as well as the destination of the outputs of each industry (Leontief 1986). The standard input-output table, however, only includes flows of intermediate goods in its most detailed sections. The expenditure view can also be represented in a standard input-output table, but is separated from the detailed flows of intermediate goods. The twelve niches of my production matrix can be modeled in terms of value-added input (Lawson and Teske 1994), not including expenditure:

Table 5. Intermediate Goods Input-Output Table of the U.S., 1987, in billions

	Struct Final Prod	Struct Mach Prod	Mat Final Prod	Mat Mach Prod	Energy Final Prod	Energy Mach Prod	Info Final Prod	Info Mach Prod	Total
Struct Prod	294.6	13.5	109.3	2.5	103.5	28.0	118.2	10.5	680.0
Mat Prod	194.4	9.9	438.3	1.7	41.1	22.0	68.1	6.2	781.6
EnergyProd	80.5	6.5	87.0	1.6	317.5	41.3	63.0	19.2	616.5
Info Prod	62.5	1.3	23.0	.3	23.3	6.2	187.8	18.2	322.6
Total	632.1	31.1	657.6	6.1	485.4	97.6	437.1	54.1	2,401.1

Note: Struct stands for Structural, Mat for Material, Energy for Energy-Converting, Info for Informational, Mach for Machinery, and Prod for Production

As the U.S. Bureau of Economic Analysis advises, "for the distribution of industries *producing* a commodity, read the *column* for that commodity. For the distribution of commodities *produced* by an industry, read the *row* for that industry" (Lawson and Teske 1994, 106, emphasis added). In order to find the inputs for an industry, we look at the column; in order to ascertain which industries used a particular kind of commodity, we look at the row.

For example, machine tools have been categorized in the table as structural machinery production. Structural machinery production industries used over 13 billion dollars of goods from the material production niche, the greatest part consisting of steel and other iron products. Another example is the final material production industries, which according to this table used over 438 billion dollars worth of products from the material production industries. For example, the steel industry uses some of its own products, as well as products from other material production, such as chromium.

This table only uses industries which I have categorized as involving production, excluding distribution and state systems. Much greater detail for the production system niches is possible using the 1987 U.S. Input-Output accounts (Lawson and Teske 1994).

This input-output table constitutes the *interactions* of the elements of the production system. It does not reveal the structure, which I have described in terms of the categories and stages of production, because interactions occur at the elemental level of a system, not at the structural level.

The advantages of the value-added approach are that 1) the internal functioning of the production system can be studied, and 2) the proper relative money value of each industry can be ascertained. In the expenditure view, on the other hand, the steel industry disappears, except for the plant and equipment that is invested in it, because all final products that use steel come from industries other than the steel industry. The steel is subsumed in the production of automobiles, for instance. By using a value-added view, we can see that the value of the product of the automobile industry is only partly added by the automobile industry, and that most of the value of the cars has come from various other industries, such as steel, that are never seen in the expenditure view.

Like the expenditure view, the value-added view also shows that the machinery niches are relatively small. In the table above, the machinery industries are always smaller than their associated final production industries. The value-added view shows the ability of an industry or niche to *generate* output, and thus it is the more important than the expenditure view, because the role of the production system is to generate goods and services. Reproduction and production machines *directly* generate relatively little value.

The machinery production niches, however, *indirectly* generate almost *all* output. The third view of capabilities, in terms of capital assets, gives a better measure of this phenomenon. In this view, we see the means of production of each niche, both in terms of structures and in terms machinery (for discussion, see Katz and Herman 1997). This is the value, appropriately depreciated by the U.S. Department of Commerce, of the assets used during production. The previous table showed the value of the goods and services that is generated by the assets shown in the following table.

The following table shows the main assets used in each niche, in millions of dollars (from Bureau of Economic Analysis 1998):

Table 6. Capital Assets Input-Output Table for the U.S. (in millions)

1987 Machinery and Physical Structures	Structural Production	Material Production	Energy Production	Information Production	Total
Structural Reprod Mach	78,328	41,077	35,526	22,039	176,970
Structural Prod Mach	93,423	59,372	94,067	27,118	273,980
Structural Phys Structure	203,104	181,833	91,683	644,820	1,121,440
Material Reprod Mach	0	10,077	17,289	0	27,366
Material Prod Mach	5,268	191,337	1,425	963	198,993
Material Phys Structure	1,078	611,937	29,844	10,159	653,018
Energy Reprod Mach	160	2,022	45,503	1,684	49,369
Energy Prod Mach	20,138	68,405	246,034	27,450	362,027
Energy Phys Structure	19,267	36,540	1,607,741	37,814	1,701,362
Information Reprod Mach	2,635	2,190	21,842	13,524	40,191
Information Prod Mach	6,635	29,228	33,331	235,205	304,399
Information Phys Struct	0	0	0	163,518	163,518
Total	430,036	1,234,018	2,224,285	1,184,294	5,072,633

Thus, to determine how much material production machinery is used for structural production, for instance, one would look at the row labeled "material prod mach", and move to the column labeled "structural production", to find the figure of 5,268 million dollars. While the standard, intermediate goods input-output table shows the *interactions* of the elements of a production system, this table shows the *capabilities* of the elements, and therefore indicates the distribution of capabilities in terms of productive power.

The capital assets input-output table, Table 6, should be combined with the intermediate goods input-output table, Table 5. Each stage of production should have its own table for fixed capital, which interacts with its own table for intermediate goods. Thus, each stage will have a capital input-output table which interacts with its own intermediate goods input-output table. For example, the reproduction machinery stage will have its reproduction machinery assets, which use its own intermediate goods to produce reproduction machinery, both for itself and for the next stage, the production machinery stage. The production machinery stage will have its own assets, made up of reproduction machinery, which uses its own intermediate goods. The output of this stage, production machinery, will be used in the final stage, final production. The final production stage will have its own capital assets, made up of production machinery, as well as its own intermediate goods. Finally, the final goods for human consumption will emanate from the final production stage. Figure 32, comprising the next page, shows this combination schematically.

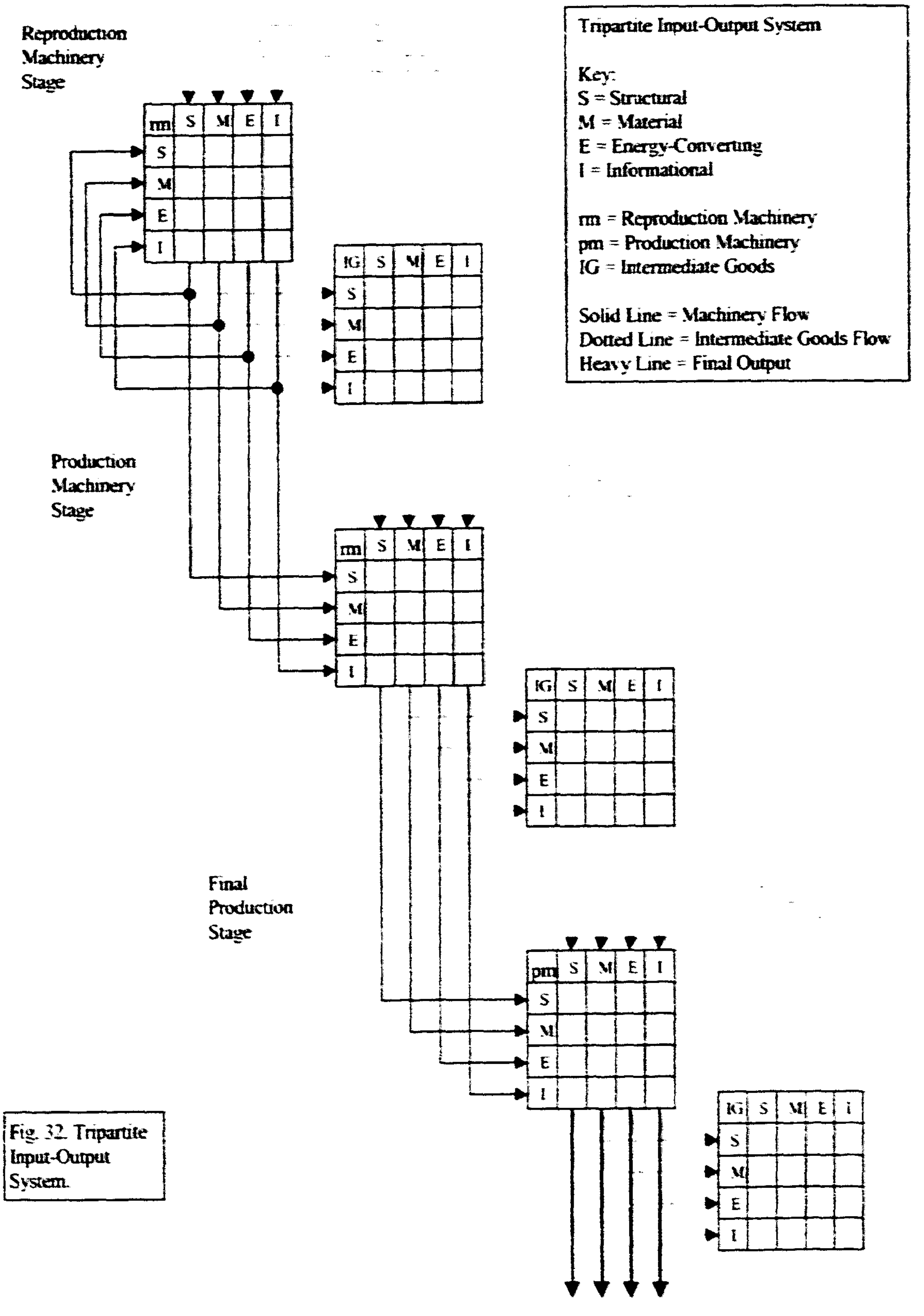


Fig. 32. Tripartite Input-Output System.

In the reproduction machinery stage, we have a capital assets table which shows, in its rows, the machinery (and physical structures) which are used by each of the industries in the columns. The intermediate goods table, similarly, shows the commodities in the rows, distributed to the industries that use the commodities, in the columns. This intermediate goods table works the same as Table 5. However, unlike the standard input-output table, the commodities used by each industry move to the capital assets input-output table, because all production requires machinery (and structures). The commodities therefore come out of the top of the intermediate goods table, into the top of the capital assets table.

The output of the reproduction capital assets table – which is the output of the particular niche – comes out of the bottom of the capital assets table. The output will either be in the form of more intermediate goods, in which case they move to the intermediate goods table, or the output will consist of machinery. Machinery either moves back to the reproduction machinery capital assets table (since this is a reproductive stage), or the machinery moves to the production machinery stage.

This movement of machinery out of a capital assets table and into another one is referred to as machinery *investment*. These investments, or *capital flows* as they are termed in the national income accounts, are also measured by government agencies (see, for example, [Bonds and Aylor 1998], for investment data).

The production machinery stage works in much the same way as the reproduction machinery stage. The difference is that in the production machinery stage the machinery output moves only to the final production stage, not back to the originating stage, as in the reproduction machinery stage.

The final production stage is similar to the other stages. Output can move to the intermediate goods table, or output moves out of the production system altogether, to the human production sphere. For simplicity, I am not showing that the structures generated in the final production stage are fed back to all three stages.

The advantage of this tripartite input-output table is that it can be used to create computer simulations of the production system. Neoclassical economists use analytic mathematical methods in order to model the economy. These methods are useful when the phenomena to be modeled are aggregated. When the phenomena are disaggregated, as they are in this study, then the interactions of the various elements, iterated through time, should be observed. Computer simulation is designed for just such tasks. Thus, a computer simulation using a tripartite input-output model is useful as a tool for validating or refuting hypotheses that are proposed to account for the behavior of production and economic systems.

Thus, depending on which phenomena one wishes to investigate and the methods used to investigate the phenomena, different views of the distribution of capabilities of a production system are warranted. The tripartite input-output model will be most useful for exploring the actual workings of the economy, as it combines the value-added and capital-assets views. The production matrix is useful as an overview of functional differentiation, and to model expenditure.

Since the production system is generative, the functional differentiation of the structure of the production system is more important than is the distribution of capabilities for explaining the growth, stagnation, or decline of the production system. The distribution of capabilities is useful for understanding the interactions of the different functions and production system niches, for tracking changes, and for testing hypotheses. However, the arrangement of the functions is the central focus of concern.

The same prioritization between function and capability occurs in much of biology. The internal workings of a cell, organism, or ecosystem must be based on a solid understanding of the physical weight, appearance, and other measurable characteristic of the various biological elements. But the focus of study is how these various elements interact to create the living cell, organism, or ecosystem. Computers are needed to simulate the simultaneous functioning of many elements in biological systems, because of the complexity that results from functional differentiation (for an ecological example, see [Ford 1999]). A similar need arises in order to simulate a production system.

In order to focus on the workings of the production system, one would use the various measures of expenditure, value-added, and capital-assets to illuminate that functioning. In terms of the distribution of capabilities, the distribution of expenditure, value-added, and capital-assets shows that the machinery niches have lesser capabilities in terms of the ability to call forth spending or to project power on the basis of assets than the niches which they make possible, the final production niches. Therefore, the machinery niches are always vulnerable in an industrial system. As will be asserted in the next chapters, the machinery niches have fewer resources with which to control their fate than do other parts of the production system and system of political economy as a whole. However, the machinery niches have a large capability to affect the growth of the production system.

Systems sometimes include a distribution of causal capability among their elements, and this distribution of causal capability may be very different from the distribution of capabilities. Because of their position in the structure of the production system, the machinery production niches are more important in causing change than the final production niches. When one or more of the reproduction machinery technologies change, the capabilities of the production machinery sectors also change, and therefore the possibilities and productivities in the production sectors will also change. A change in a final production niche will only affect the affected production niche. Any changes in the final production niche will only be possible because of preceding changes in the production technologies used to generate that production.

Therefore, *there is an ordering of the capability to cause technological change within the production system which reflects the sequence of stages of production, from reproduction machinery as the most powerful source of technological change, to production machinery as less powerful, and to the final production stage as least powerful*; this is the third hypothesis about economic systems. Technological power can be defined as the capability of a part of the economic system to propagate, directly and indirectly, greater ability to generate value-added throughout a particular economic system, in a particular period of time.

However, since "the benefits of innovation were difficult to identify comprehensively because such benefits were frequently captured by industries other than the one in which the innovation was originally made" as Rosenberg (1982, 77) pointed out in terms of the past two centuries, the machinery industries have not, historically, received as income from other parts of the economic system the income that the machinery niches have made possible for the rest of the economy. There is therefore a potential that machinery niches will receive less than ideal economic support for their activities.

Recently, some economists have become interested in general purpose technologies, or GPTs, "characterized by the potential for pervasive use in a wide range of sectors and by their technological dynamism. As a GPT evolves and advances it spreads throughout the economy, bringing about and fostering generalized productivity gains…Advances in GPT technology lead to new opportunities for applications. Such positive feedbacks can reinforce rapid progress and economic growth. The problem is that these complementary innovative activities are widely dispersed throughout the economy, making it very difficult to coordinate and provide adequate innovation incentives to the GPT and application sectors" (Bresnahan and Trajtenberg 1995, 84-85). In other words, some parts of the economy have a greater impact on the economy as a whole than other parts, but it may become difficult to steer investment back into these critical niches.

The concept of GPTs does not seem to include technologies that are used only in production, such as machine tools, but only technologies, such as electricity and semiconductors, that are used in *all* parts of the economy: "Most types of machinery have such a limited variety of uses that they do not come close to qualifying as GPTs…We rule out machine tools because their range of use is restricted to manufacturing…From the point of view of the economy as a whole, they do not quite fulfill our criteria of widespread use" (Lipsey, Bekar, and Carlaw 1998, 47). Thus, the concept of GPTs will not be used in this study.

Other scholars have also argued that production machinery is critical for economic growth, although they do not support their statements. For example, Chudnovsky and Nagao (1983, xi) state "All advances in productivity are connected with the volume and efficiency of the tools, instruments and machinery with which mankind carries on its productive activities". They later claim that "capital goods production has thus been the dynamic agent in accelerating the technological transformation of society" (xii). Boucher (1981, 101) states that "it is the writer's belief that the most pervasive influence on productivity advance is the improvement in design of the tools of production". For Fransman, "The machine sector lies at the heart of the processes involved in the generation and diffusion of technical change" (Fransman 1986, xi). The main theoretical basis for this claim seems to be the Feld'man model, which was discussed in the previous chapter.

In an important economic article, J. Bradford De Long and Lawrence H. Summers (Secretary of the Treasury in the last Clinton years) tried to show the importance of production machinery using statistical techniques. They came to the conclusion that there is "a clear, strong and robust statistical relationship between national rates of machinery and equipment investment and productivity growth. Equipment investment has far more explanatory power for national rates of productivity growth than other components of investment, and outperforms many other variables included in cross-country equations accounting for growth" (De Long and Summers 1991, 446).

De Long and Summers also suggest that "the private return to equipment investment is below the social return, and that the social return to equipment investment is very high" (De Long and Summers 1991, 482). In other words, the machinery niches do not receive as income that which they contribute to the rest of the economy. According to De Long and Summers, in fact, "The social rate of return to investment is 30 percent per year, or higher" (De Long and Summers 1991, 485), even though the rates of return for the machinery industries are far below 30 percent.

There is an inherent contradiction between the causal capability of machinery industries and their relative capabilities as measured by expenditure or revenue generation, and because of this discrepancy, industrial economies are in constant danger of suboptimal technological change; this is the fourth hypothesis about economic systems. The machinery industries may be underfunded, while the richer and larger niches will command the attention of the financial and state systems.

Structure, Rise, and Decline

Because of the distance of the machinery niches from the larger centers of economic power, as an industrial economy declines, its competence will deteriorate from the center out. That is, competence in reproduction machineries will be the first to decline, followed by competence in production machinery, until finally all productive capabilities are depleted. By contrast, a country that is rising will first increase its abilities in the final production niches, then it will upgrade its competence in production machinery, and finally a rising country will become a world leader in reproduction technologies.

Thus, *nations rise economically by moving up the stages of production in terms of competence, from production to production machinery to reproduction machinery. Nations decline by moving down those same stages of production, first losing competence* *in reproduction machinery, then in production machinery, and lastly in final production.* This is the fifth hypothesis about economic systems.

This sequence of rise or decline of a production system is linked to the size of the economic system. The economic system must be large enough to support a full complement of machinery industries. As Rosenberg has put it, "An economy may be sufficiently large to make possible all the economies of specialization available to the producers of consumer goods without being nearly large enough to generate optimum conditions for the producers of capital goods" (Rosenberg 1976, 143). In order for a particular class of machinery to be produced, the machinery industry must be a minimum size. Unless the industry reaches this minimum size, sufficient economies of scale may not be possible, or the skill base may not be available to support the industry. This minimum size can only be achieved if the niches which the machinery producer is supplying are also at a minimum size; there is no market for textile machinery if there is no textile industry. The minimum size of the final production niches that enables most or all of the production machinery sectors to persist can be referred to as the *minimum market size* of the production machinery niches. The minimum size of the production machinery niches that enables most or all of the reproduction machinery niches to survive will be referred to as the minimum market size of the reproduction machinery niches. This concept of minimum market size will be important in the chapter 10, in which it will be hypothesized that a Great Power must have a minimum market size for production and reproduction machinery industries.

As the final production niches decline, they reach a level *below* the minimum market size for the production machinery niches, at which point many of the production machinery industries disappear or start a process of severe decline. Since the reproduction machinery industries, such as the machine tool industry, are sensitive to the decline of *production* machinery industries, production machinery industries may persist, but the decreasing production machinery niches may decline to below the minimum market size for the reproduction machinery industries. Therefore, one would expect that initially reproduction machinery industries would decline and collapse, followed by production machinery industries, until finally production industries would decline in a situation of general economic decline. A reverse process would occur in a sequence of rise: first, final production would develop; second, production machinery industries would be established as a result of the growth of the final production industries; and third, reproduction machinery industries would become fully functional as a result of the growth of the production machinery industries to a minimum market size.

The most important benefit of economic "common markets" is that they provide minimum market sizes for all niches of a production system. I will refer to these as *global regional production systems*. This advantage of size was the case for the United States throughout most of its history, and has been one of the consequences of the European Union.

When all production system niches are present within an economic system, then that production system may be said to be *complete*. *A complete production system is greater than the sum of its parts; both the stages and categories of production participate in a mutually self-reinforcing, positive feedback process of production and technological change. There is a negative feedback process within a complete production system* *because there must be a balanced pattern of growth among all niches.* This is the sixth hypothesis about economic systems.

To anticipate an argument from Chapter 10, most types of production and reproduction machinery must reside within the national economy in order for the national economic system to reap the greatest benefits from those industries. This is a consequence of the above hypothesis. The addition of a new niche or set of niches to an economy has greater effects than simply the addition of the value-added of those industries; in other words, my argument directly contradicts the doctrine of comparative advantage, which concludes that nations should focus on those few industries which are their best. In the long-run, because of the complementarities of the various niches, overall competence in production increases at a greater rate than if only a few niches, no matter how well developed, exist within an economy.

A corollary of this argument is that trade *within* a global regional production system is the most important type of trade, not trade *among* global regional production systems. Intra-regional trade is necessary in order to produce the output of a complete production system. Inter-regional trade has two consequences.

First, discrepancies in productivity of industries between countries will be overcome if trade occurs. This is the perspective of comparative advantage and the benefits of exchange in general, as elaborated by neoclassical economists.

Second, the interchange of designs will be advanced by interregional trade. For all of recorded history, peoples have expanded their technological stock of knowledge and designs by trading (see Pacey 1990 and Pacey 1992). This process continues today, and is the global equivalent to a process which will be touched on in the next chapter, the importance of the interchange of ideas in processes of innovation. From the perspective of this study, the interchange of ideas is the most important function of trade.

The ability to export to other countries is important if two questions are answered affirmatively: first, "Are a significant proportion of the exports going to a global regional production system of which the national production system is a part?", in other words, the trade is intra-regional; and second, "Is the income received for these exports being used to develop other parts of the national production system, viewed as part of a wider global regional production system?" In other words, the resources received in exchange for the exports is used to develop the home industries, not simply as income for consumption or for foreign investment that will never return to the exporting country.

Developing countries and nonGreat Powers never develop machinery industries, which are referred to by Rosenberg in the following as capital goods industries:

> Many of the major innovations in Western technology have emerged in the capital goods sector of the economy. But underdeveloped countries with little or no organized domestic capital goods sector have not had the opportunity to make capital-saving innovations because they have not had the capital goods industry necessary for them. Under these circumstances, such countries have typically imported their capital goods from abroad, thus this has meant that they have not developed the technological base of skills, knowledge, facilities, and organization upon which further technical progress so largely depends. (Rosenberg 1976, 147)

Thus, economic systems need certain human assets in order to develop a full complement of production system niches. In order to understand the importance of "skills, knowledge, facilities, and organization", I turn in the next chapter to a discussion of what will be called capital systems. Once capital systems are explained, the distribution subsystem will be discussed in conjunction with the production subsystem, thus presenting a framework for understanding the economic system as a whole.

Chapter Appendix: Industries in Functional Sectors

Numbers in parentheses refer to categories from the Standard Industrial Classification 1987 of the United States

Structural Reproduction Machinery: Machine tools (3541, 3542) , Material handling (Conveyers 3535, Hoists 3536,Industrial Trucks 3537), Rolling Mill Machinery (3547), Welding Equipment (3548), Handtools (3546), Assembly Machinery (3549), Glass-working (35598 15, 35598 19)

Material Reproduction Machinery: Steel-making machinery, Mining machinery (3532), Glass making-machinery

Energy-Converting Reproduction Machinery: Turbines (3511) and Diesel Engines (35191, 35193), petroleum refining (3559801)

Informational Reproduction Machinery: Semiconductor-making Machinery (35595), Circuit-Board Equipment (35596), Process Control Instruments (3823), Analytical Instruments (3826), Lab Apparatus (3821)

Structural Production Machinery: Stone and ceramic working (3559813, 3559817, 3559822), plastic-forming (35593) , wood-working (3553) , construction machinery (3531) , sewing machines (3559888, 3559889, 3559890), clay-forming (3559827), concrete-forming (3559831, 3559835)

Material Production Machinery: chemical manufacturing (35591), textile (3552), food products (3556), paper (3554), oil and gas field machinery (3553), farm machinery (3523), cotton-ginning (3559853), cement-making (3559839), glass-making (3559843)

Energy-Converting Production Machinery: industrial heating and cooling and lighting, trucks and buses (3713, 3715), freight train (3743), cargo plane (37215), cargo ship (37313)

Informational Production Machinery: servers, telecomm equip (3661), broadcast equipment (3663), business computers, business software, printing trades machinery (3555), motion picture equipment(38613), still photography (38611), photocopy (38612), clocks (38732)

Structural Final Production: Housing, Commercial Buildings, Factory, Furniture (25), Clothing (Apparel 225 and 23), footwear leather and leather products (31)

Material Final Production: Cleaning and toilet preparations (284), Paints (285), drugs (283), food and kindred products (20), tobacco products (21), water systems, gasoline systems (gasoline 29991)

Energy-Converting Final Production: cars, buses, passenger trains and planes, heaters, cooking (3631), air conditioners, Freezers/refrigerators (3632), household wares (3634), laundry (3633), vacuum cleaners (3635), lighting (3645, 3646), roads, electrical systems, ports, airports, elevators (3534), car repair machinery (35597), commercial laundry equipment (3582), refrigeration and cooling (3585), service industry (3589), electrical grid, roads, airports, ports, canals

Informational Final Production: Computers, telecomm, audio & video (3651), print, medical equipment(3841, 3842,3843, 3844, 3845) , telecomm system, watches (38731), ophthalmic (3851)

CHAPTER 8

A THEORY OF ECONOMIC SYSTEMS, PART 3: THE CAPITAL AND DISTRIBUTION SYSTEMS

Machinery industries are critical for production, and technological change in machinery industries is the most important kind of technological change. If technological innovation in machinery industries is central to economy-wide technological change, what causes machinery innovation? In order to understand this question, this chapter will use the theory of economic systems as elaborated in the previous two chapters to explain the production and design of machinery and the sources of innovation. The full description of an economic system will then be possible, integrating the distribution system with the production system.

The Capital System

Machinery does not spontaneously change itself; a person or group of people must create a new design for a new machine. Let us call these people *engineers*. Their output is a design. Generally, engineers do not actually produce the machines that they design. They hand the designs to a set of people called *skilled production workers*. These people have the ability to translate a design into a series of production steps that result in intermediate goods, and/or a complete machine, using machinery in the process. Operational managers, such as foremen and plant managers, work with the skilled workers to implement the designs of the engineer. Operational managers will therefore be considered to be functionally similar to skilled production workers.

The following sequence characterizes machinery production and design: engineer → design → skilled production worker → machine. The engineer *generates* a design, which the skilled production worker uses to produce the output, a machine.

In order to produce his or her design, the engineer draws on a *stock of knowledge* which is produced by *research scientists and engineers*, or more simply, researchers. These researchers are also often teachers. Teachers teach students to go forth into society and use a stock of knowledge, but teachers also teach more teachers. In other words, teachers self-reproduce.

We therefore have the following simplified structure of capital production and innovation:

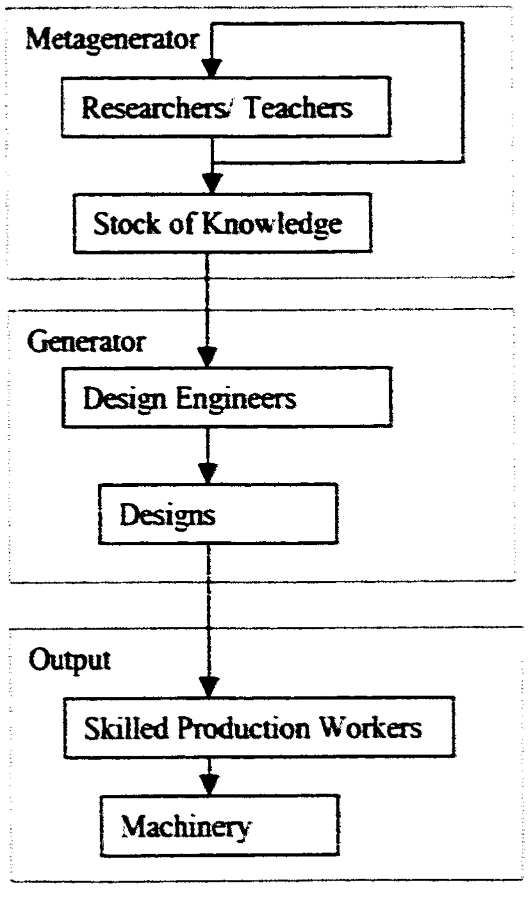


Fig. 33. The capital system.

Each stage has two elements, one human and the other a form of capital. The researcher/teachers add to the stock of knowledge, which can be thought of as a kind of capital, or asset. Using the stock of knowledge, teachers train engineers, who also use the stock of knowledge in their own work, the generation of designs. Designs are also a form of capital, or asset. Finally, skilled production workers use the designs to create machinery. This system of capital is an example of a tripartite generative system consisting of researchers/knowledge, engineers/designs and workers/machines, corresponding to a reproductive metagenerator, a generator, and an output, respectively.

This sequence reflects scholars' assessments of the requirements for development. Chudnovsky and Nagao propose, as technological requirements for competence in capital goods industries, "machine-operating skills" and "manufacturing technology", where "one basic component of this technology is the engineering knowledge of manufacturing methods and techniques, including quality control and testing", and where "another component of equal if not greater importance is the managerial and organizational know-how". In addition, "product design capacity is the ability to conceptualize and define and actually to design a product", and a "research and development capacity in the capital goods industries is clearly influenced by the claims of product design work" (Chudnovsky and Nagao 1983, 10-14).

Innovation can occur at each stage of this sequence. Innovation in an earlier step in the sequence has effects that may have an impact on processes later in the sequence. For example, a discovery made in the subfield of mechanics in the field of physics would have great import for many kinds of engineering, which would, in turn, affect all kinds of machinery production. When great strides were made in solid state physics in the 1940's with the invention of the transistor, the entire electronic revolution of later decades was made possible.

The "invention of invention", as Whitehead famously put it, was one of the great advances of the industrial age. In terms of the system of capital diagrammed in figure 33, this was equivalent to creating, or routinizing, the metagenerator stage of research. The structure of the machinery systems of the major powers changed because of the widespread adoption of research facilities (for recent studies of U.S. policy, see Branscomb 1993;Rosenbloom and Spencer 1996;Skolnikoff 1993).

My concept of a tripartite capital system as defined above is, in part, an attempt to formalize the insights of the economist Simon Kuznets. Kuznets did not formalize his ideas in a coherent way which would be useful for further research.

For Kuznets, production and innovation are inextricably mixed. According to Kuznets, "marked rises in product per labor unit ... are usually possible only through major innovations, i.e., applications of new bodies of tested knowledge to the processes of economic production. Indeed, modern economic growth is, in substance, an application of the industrial system, i.e., a system of production based on increasing use of modern scientific knowledge" (Kuznets 1959, 14-15). Kuznets goes so far as to define innovation in terms of production: "Innovation is a new application of either old or new knowledge to production process (production defined broadly)" (Kuznets 1959, 29), therefore "continuous progress and, underlying it, a series of new scientific discoveries are the necessary condition for the high rate of modern growth in per capita income combined with a substantial rate of growth in population" (Kuznets 1959, 29).

Further, "science is the base of modern technology, and ... modern technology is in turn the base of modern economic growth" (Kuznets 1959, 30). My tripartite sequence mirrors Kuznets' three steps: my stage of researchers/knowledge is similar to Kuznets' role of science; my "engineers/designs" reflects his "modern technology", in that engineering is based on science; and the product of "worker/machines", which is the output which increases in economic growth, is based, like Kuznets' "modern economic growth", on modern technology and the work of engineers.

Kuznets defines an invention as the discovery that leads to an innovation, and he defines an innovation as the invention's application. He claims that "many major inventions, if they are to become successful innovations, demand heavy capital investment – both in material goods and in the training of the labor force." (Kuznets 1959, 31). The resulting accumulation of capital is necessary because "without the heavy capital investment in buildings, roads, bridges, railways, power stations, machine tools, and blast furnaces, high levels of total and per capita product are unobtainable" (Kuznets 1965, 30). Thus, innovations must be embodied in capital.

Still, "the major capital stock of an industrially advanced nation is not its physical equipment; it is the body of knowledge amassed from tested findings of empirical science and the capacity and training of its population to use this knowledge effectively" (Kuznets 1965, 35). Kuznets calls this knowledge a "stock of knowledge", and I have used this concept as one of the outputs of the metagenerator step of the capital system, the scientists/researchers. Further, "the major source of modern economic growth, with its high rates of aggregate increase and rapid structural shifts, lies in the vast increase in the stock of useful knowledge" (Kuznets 1964, 26).

Kuznets highlights many of the themes which are present in this chapter. Innovation flows from production, is usually embodied in investment in equipment, is dependent on a stock of knowledge provided by scientists and engineers, and is central to modern economic growth.

Nathan Rosenberg has also written about the role of innovation in a manner reminiscent of Kuznets. For Rosenberg, the entire machine tool industry has a disproportionate ability to add to the "stock of knowledge": "The machine tool industry may be looked upon as constituting a pool or reservoir of skills and technical knowledge which are employed throughout the entire machine-using sectors of the economy" (Rosenberg 1976, 19). Therefore, production and especially reproduction machinery sectors have a large role to play, not only in causing technological change via their effects on later stages of production, but also on their effects on the "stock of knowledge".

Kuznets refers to "useful" knowledge, "technological" knowledge, and other kinds of knowledge. In this study, the stock of knowledge will be defined as the scientific and engineering knowledge which is useful for designing and using production machinery. This stock of knowledge will usually be available in public printed form, in research journals or books.

Engineers create the designs which are the concretization of the discoveries made by researchers. All innovation must pass through the stage of design. Skilled production workers, depending on the management of the particular factory in which they work, can also contribute important insights.

De Bresson focuses on the contribution of production workers: "There is no such thing as fixed capital stock; the stock is constantly improved, increased, and modified...Practical know-how increases the equipment's capacity...workers probably constitute the major source of all inventions" (De Bresson 1987, 64).

Thus, the process of production is also a process of innovation. The innovation that powers economic growth cannot occur without production. *Part of the cause of innovation is production*; this is the seventh hypothesis about economic systems. This hypothesis would help to explain the insight by Alice Amsden, in the case of Korea, that greater output led to greater productivity. She states that "the growth rate of output increases as the growth rate of productivity increases, and in closed-loop fashion, depending on institutional constraints, the growth rate of productivity increases as the growth rate of output increases – through investments that embody foreign designs, economies of scale, and learning-by-doing" (Amsden 1989, 323). This learning-by-doing takes place, according to the economist Kenneth Arrow, because "learning is the product of experience. Learning can only take place through the attempt to solve a problem and therefore takes place during activity" (Arrow 1962, 155). Rosenberg argued that learning-by-using is particularly important in the capital goods industries (Rosenberg 1982, 122).

By combining the processes of innovation and production, I am claiming that people in the capital system are doing more than learning-by-doing. I wish to introduce the term "innovating-by-doing", to emphasize the point that innovation is a part of the production process. "Doing" – that is, producing – is partially a question of better understanding a production process, that is, learning. Arrow (1962, 155) defines learning as "the acquisition of knowledge", which while important, is not the same as creating new innovations. As defined in this chapter, the stock of knowledge *assists* in the creation of innovations that are used to produce goods, but there is a separate output, design, which is the embodiment of innovation. As engineers (and to some extent, researchers and workers) gain expertise in the course of production, they also *create* productivity-enhancing innovations. The term innovating-by-doing is meant to focus attention on the active creation of innovations, as opposed to the more passive process of learning pieces of knowledge that already exist. Both processes are important; the difference is in the emphasis.

The capital system is both the source of the *machinery* contained within a sector, and the source of technological *changes* associated with the use of those assets. The capital system is one element in the system that constitutes a niche in the production system. As explained above, physical structures are also part of a niche, as are the intermediate goods created within the niche. In addition, unskilled labor is usually conceived of as another element.

The Production System Niche as a System

Thus we have the following diagram, showing a niche as a system, composed of a capital system, physical structure and unskilled labor. Input from other niches constitute the interaction from other elements in the system:

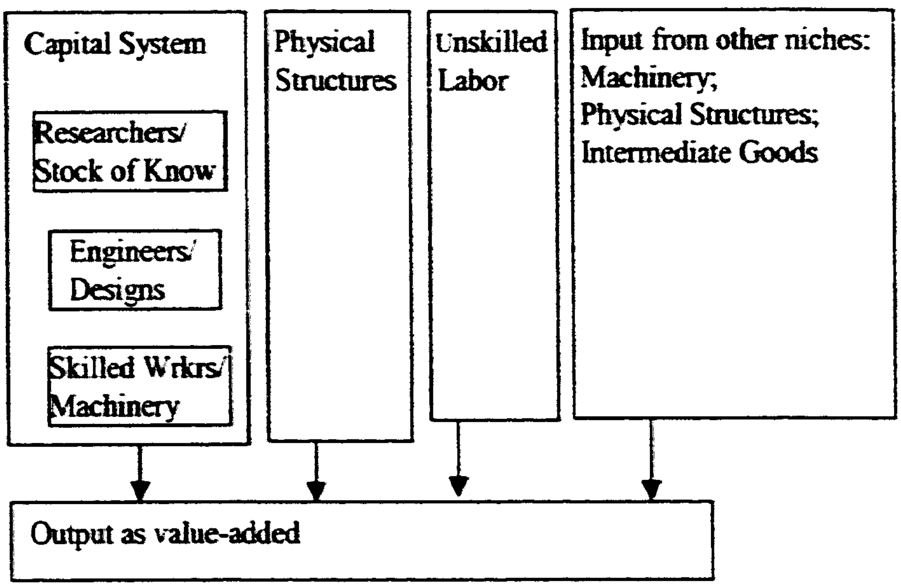


Fig. 34. The production system niche as a system.

Output moves to other niches. Output is measured in terms of the value-added that was generated by the originating niches.

This model is similar in some ways to the characterization of production as put forth by neoclassical economists, who usually reduce production to the factors of production called capital and labor (and occasionally, land). I have restricted the term "capital" to what Adam Smith called "fixed capital", by which he meant machinery and physical structures. Inputs from other niches constitute what Smith called "circulating capital", or intermediate output. Capital as shown above also incorporates a significant portion of the workforce, that is, skilled workers, engineers, and researchers. Economists recently have called this human input "human capital", and I will use the same term to refer to skilled workers, engineers, and researchers. The term "labor" is here restricted only to unskilled labor. In neoclassical discussions, labor is considered one homogenous group; homogeneity holds only in the case of unskilled labor.

Alfred Chandler offers a similar assessment of the importance of human capital to the one offered here. In describing the basic workings of mass production, he states that "organizationally, output was expanded through improved design of manufacturing or processing plants and by innovations in managerial practices and procedures required to synchronize flows and supervise the work force. Increases in productivity also depend on the skills and abilities of the managers and the workers and the continuing improvement of these skills over time" (Chandler 1977, 241). Further, "the potential economies of scale and scope, as measured by rated capacity, are the physical characteristics of the production facilities. The actual economies of scale or of scope, as determined by throughput, are organizational. Such economies depend on knowledge, skill, experience, and teamwork – on the organized human capabilities essential to exploit the potential of technological processes" (Chandler 1990, 24).

Chandler emphasizes the organizational capacity of managers. Managers (such as factory superintendents) who directly control production are considered a form of skilled production worker in my scheme. The operational manager is trying to fulfill a design, and the orders emanating from the operations manager are ideally part of the design. The operations managers and skilled production workers are part of the implementation of the design as specified by the engineers.

The role of middle managers and top managers is ignored in my conceptualization of the production process. These administrative managers, as well as the rest of the administrative overhead of the firm, are generally involved in nonproduction activities, as will be explained in the next section.

Technological change within a niche is the result of two main factors. First, *internal change* will occur within the capital system of the niche, and that change will be the result of a change made by a combination of the researcher, engineer or skilled production worker elements.

Second, *external change* will result from the first kind of change, because the inputs from another niche may enable further technological advances in a niche further down the sequence of production. This will occur when a type of production machinery is improved, or an intermediate input is better adapted for the destination niche.

If technological change is guided by researchers, engineers, and skilled production workers, why are some nations able to experience more technological change than others? First, *innovation by people depends on the level of resources directed toward the innovators, in the form of income, educational facilities, and research/work facilities*; this is the eighth hypothesis about economic systems.

Second, *innovation is encouraged by the wide distribution of access to the various forms of capital, be they the stock of knowledge, designs, or machines, or their human counterparts, researchers, engineers, and skilled production workers. In other words, the free flow of people and ideas is an important determinant of technological innovation*; this is the ninth hypothesis of economic systems. When the power to control this flow is concentrated, for example, in certain organs of a dictatorial state, then the rate of innovation will slow down. When a populace is well-educated and allowed to express and communicate their ideas, and when they are allowed to travel and visit production facilities, then innovation will flourish. As postulated in chapter 6, the speed with which innovations spread is an indication of the power of the system of production, and free access to people and ideas allows innovations to spread more quickly. Thus, a democracy will tend to encourage more innovation than a dictatorship, as will be commented on in Chapter 10.

Therefore, an explanation of technological innovation on the level of the capital system involves resources and the free flow of people. An explanation of technological innovation on the level of the production system includes two other sources. First, the structure of the economy enables or constrains innovation. There is an ordering of the innovative potential of sectors of an economy, such that reproduction machinery sectors have the greatest potential, followed by production machinery sectors, followed by final production. More generally, according to Rosenberg, "a small number of industries may be responsible for generating a vastly disproportionate amount of the total technological change in the economy" (Rosenberg 1982, 76).

Second, there is a complementarity of the various categories of production, which is also the result of the structure of the production system. Rosenberg highlights this complementarity:

> Inventions hardly ever function in isolation. Time and again in the history of American technology, it has happened that the productivity of a given invention has turned on the question of the availability of complementary technologies...Technologies depend upon one another and interact with one another in ways that are not apparent to the casual observer, and often not to the specialist ... The growing productivity of industrial economies is the complex outcome of large numbers of interlocking, mutually reinforcing technologies, the individual components of which are of very limited economic consequence

> by themselves. The smallest relevant unit of observation, therefore, is seldom a single innovation but, more typically, an interrelated clustering of innovations…The importance of these complementarities suggests that it may be fruitful to think of each of these major clusterings of innovations from a systems perspective. (Rosenberg 1982, 56-59)

In sum, "Technological progress in one sector of the economy has become increasingly dependent upon technological change in other sectors" (Rosenberg 1982, 73).

Strassmann also points out the importance of complementarity: "The interrelatedness of innovation in key industries by 1850 set the basis for an accelerated pace of mutually reinforcing changes. This pace continued through wars and depressions into the twentieth century" (Strassmann 1959, 208). The structure enables certain pathways of innovation.

To these two sources of innovation at the production system level I have elaborated three at the capital system level. First, the actual process of production itself, in the form of well-supported capital systems, encourages innovation; I called this process "innovation-by-doing". The sources of innovation in a capital system come from the researchers, engineers, and workers (including operational managers). Thus, the structure of the capital system also enables innovation.

Second, a capital system needs resources in the form of income and educational and research facilities. This support may need to come from outside the niche of which the capital system is a part.

Third, a wide distribution of access to various forms of capital, both physical and human, leads to greater technological change, implying that democracies have greater potential for economic growth than dictatorships. Thus, the structure of the political system may have an influence on national rates of innovation.

The capital system has now been described. The capital system is the most important element in the system that is the production system niche. The hierarchy of systems is therefore the following:

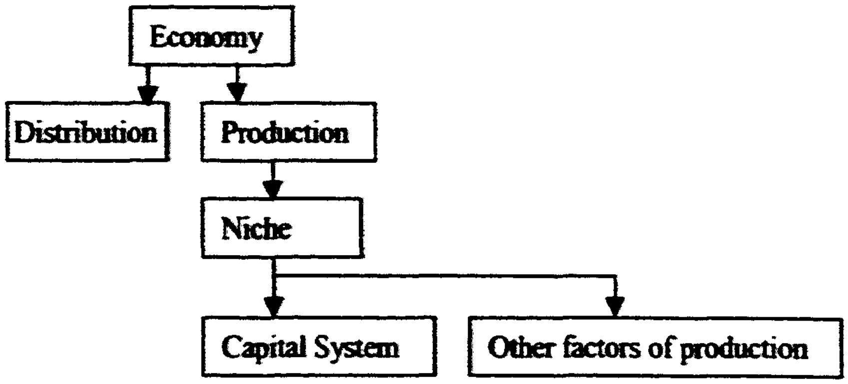


Fig. 35. The hierarchy of the economy including the capital system.

The economic system is composed of two subsystems, distribution and production. The production subsystem is composed of niches. Each niche is made up of factors of production, the most important being the capital system. In addition, niches can be further decomposed into individual industries, which may be characterized according to their factors of production.

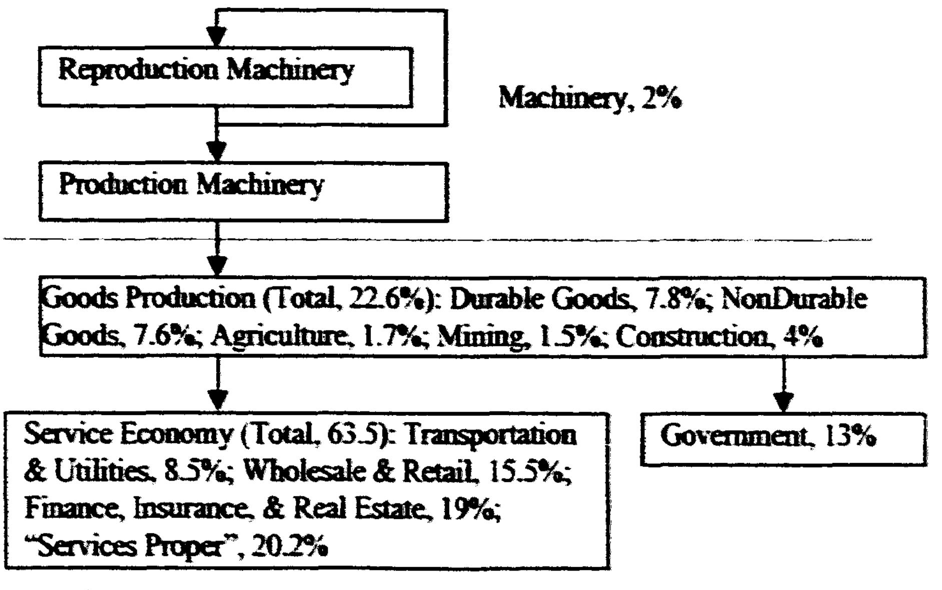
The theory of the production system has now been explained. The distribution system, and the economic system as a whole, must now be modeled.

Distribution System

Once the production system has generated its output, the distribution system receives the output and distributes it to three destinations: 1) the population, in the form of income; 2) back to the production system in the form of finance capital; and 3) into the distribution system, because the distribution system's power to allocate includes a capability to allocate a large segment of the output to itself.

The distribution system is a large part of the economy. In 1996, retail and wholesale activities constituted 15.5% of the U.S. GDP, by value-added. The same year, finance and insurance held 8.4% of U.S. GDP (Lum and Yuskavage 1997, 28). Advertising and other distributive business services may constitute another 1%, thus yielding a total for the distribution system of approximately one quarter of the economy.

We can diagram the U.S. economy as follows, where the percentage indicates the percentage of the economy as a whole (in terms of value-added in 1996):



Source for percentages: *Survey of Current Business*, "Gross Product by Industry, 1947-96", 11/97

Fig. 36. Percentage distribution of value-added in economy.

The arrows indicate the direction of production. The service economy receives 63.5% of the national product. The goods sector constitutes about 25% of the national product, including the machinery industries – which are only 2%, although about half of machinery is imported into the U.S. Note that much of what constitutes the "service" economy is dependent on goods production. The retail and wholesale sectors are retailing and wholesaling the production of the goods sector. Utilities, including transportation services, are based on production machinery, either electrical, communications, or transportation machinery. Real estate and some of the "services proper", such as hotels, rely on physical structures such as buildings. Other "services proper", such as engineering consultants or computer software, are integral parts of production processes. Repair services make up almost about 4% of the economy, and involve structural change to machinery. Health services, which make up about 6% of the economy, can also be seen as another kind of "repair", but to human "machinery", and involve the use of various classes of production machinery such as instrumentation and drug-making machinery. Thus, virtually all nondistribution service industries are based, in one way or another, on production machinery.

The retail/wholesale sectors can be divided into the same categories as the categories of production. The role of the retail/wholesale sectors is to distribute the goods and services produced by the production system. Every industry that exists in the structural, material, energy-converting, or informational final production sector that is destined for human consumption has a corresponding sector in the retail/wholesale part of the distribution system.

In addition to the entire industries which make up the distribution system, a large percentage of the personnel of most firms is devoted to the activities of marketing, advertising, sales and distribution of products and services, and to internal finance and accounting activities. According to David M. Gordon, in the U.S., 13% of employees were managerial and administrative in 1989 (Gordon 1996, 43), and received 22.4% of national income in the same year (Gordon 1996, 82). These parts of firms also constitute a part of the distribution system. I would therefore classify office buildings and automobiles, for example, as "distribution physical structures" and "distribution machinery", respectively. I claimed in the previous section that middle and upper managers should not be included in a description of human capital.

The financial sector interacts with the economy almost exclusively in terms of money, but the allocation function of the financial sector can be considered in terms of products and services instead of being measured exclusively in money terms. The benefit of using money is that a mass of different products and services can be represented with one measure. Therefore, when people participate in exchange, they do not have to worry about which of a huge number of things, or portion of things, is being traded. But sometimes it is convenient to measure the goods and services that are flowing within the economy, instead of the money. After all, the money represents goods and services. When money is exchanged, ultimately, real goods and services are being exchanged.

Thus, when finance capital is directed in investment, for example, to build a new factory, the process can be described as the redirection of a certain amount of money. It can be said that the materials that were bought with the money were used to build the factory; it can also be shown that those same materials were redirected from one part of the economy to another. One could also view the pay of the workers who built the factory and the wear and tear on the machinery used in the construction of the factory as being redirected from one production sector to another. In other words, people and machines and goods have been taken from the output of a set of production industries and allocated to another point in the production system, that is, invested. Thus, the financial system allocates the output of the production system, and directs the output according to the wishes of the decision-makers who control the output.

Therefore, the financial system can be said to mirror the production system. While the retail/wholesale sectors only mirror the categories of production (with the trivial exception of the selling of machinery), the financial system can be modeled as having the same twelve niches as the production system. These financial niches can be viewed as taking output from each production system niche – not as money, but as real goods and services. These goods and services are transferred to other financial niches, and then the destination financial niches transfer the real goods and services to their mirror production system niches.

For example, assume a new car factory is being built with financing from a bank or a stock offering, and a set of machine tools is needed. In terms of the flow of goods and services, the output of the machine tool maker is being transferred from the structural production machinery *production* niche to the structural production machinery *financial* niche. An intra-financial system transfer then takes place, as these machine tools are transferred to the energy-converting *financial* niche. Finally, the machine tools are moved to the energy-converting *production* niche (transportation is considered within the energy-converting niches).

This example is shown in skeleton form below:

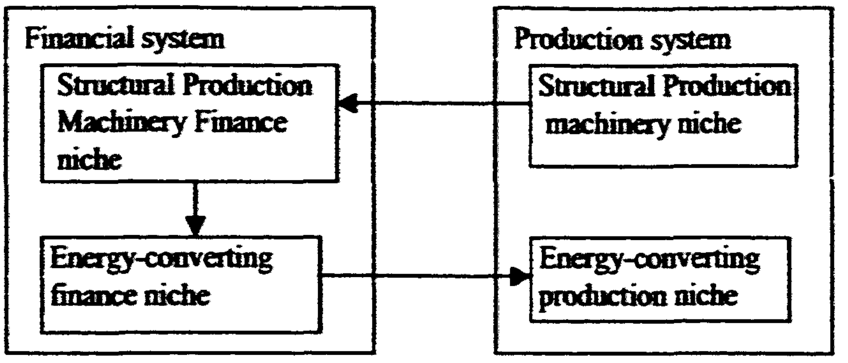


Fig. 37. Financial system interacting with production system.

The arrows follow the movement of output from one niche to another. At some point, the energy-converting production niche has to give something back to the energy-converting finance niche, and so on, but the goods sent back and forth do not have to be identical.

Generally, when finance capital is involved in this way, the providers of capital expect, not simply the receipt of an equivalent money value, but a *return* on their investment. According to the model offered here, this return on investment (ROI) is the result of the greater output of goods and services that is made possible by the provision of various resources and production machinery to the receiver of the financial asset. In the example above, the bank or stock holders receive more money value, that is, more claim to goods and services, as a result of their investment, because the car factory was able to create additional value by using the machine tools to produce automobiles. The ROI may be reinvested elsewhere, at which point the goods and services obtained may be recorded. The financial system is being modeled here as a repository, in which goods and services are flowing in, goods and services are flowing out, and some goods and services are being used up by the people and firms that make up the financial system.

A full specification of the economic system is diagrammed in the following:

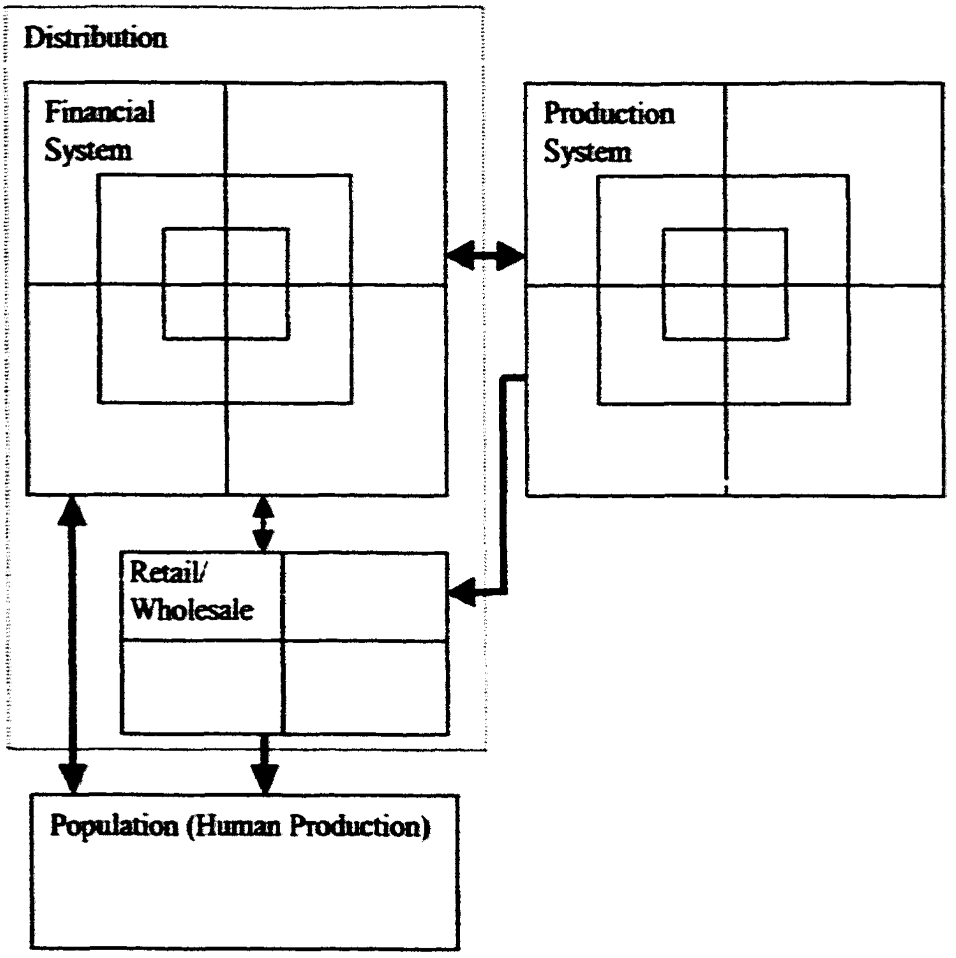


Fig. 38. The economic system.

The arrows indicate that the output emanates from a subsystem to the appropriate corresponding component. Thus, the output from the production system moves either to the corresponding niche in the financial system, or to the corresponding category in the retail/wholesale system. The different categories of goods and services move from the retail/wholesale system to the population, as do resources from the financial system; in turn, the population may send resources into the financial system, and the financial system may send resources to its corresponding niche in the production system.

The population is shown as separate from both the production and distribution subsystems. As explained in the previous chapter, the population constitutes its own production system. Humans are the objects which are being produced; like any population of organisms, the population of any nation has the potential to grow exponentially. By separating the population from the other components of the system, it will be easier to combine the economic and political systems in the next chapter, because they both share a population.

As a production system of a nation continues to grow and generate more and more output, more and more economic power accrues to the financial system because the financial system is able to control a larger and larger amount of output; this is the tenth hypothesis about economic systems. This "power" is not the same as productive power. The financial system controls a larger and larger amount of resources. I will define this power as *distributive power*, the ability to move a particular amount of previously produced goods and services a certain distance in a certain period of time. Thus, modern financial firms have a large amount of distributive power because they can move billions of dollars around the world in seconds. On the other hand, as claimed in the previous chapter, the machinery industries have little distributive power because they generate relatively little money value.

Economic power, then, will be seen to be a combination of productive and distributive power. Economic power is the capability to generate goods and services, diffuse productive innovations, and move the resulting goods and services a particular distance in a particular period of time.

It is also the case that in a rising economic system, the interaction between the financial system and production system is mutually self-reinforcing. The financial system improves the production system, in a rising economy, by directing resources back into the appropriate niches of the production system. The economy starts to decline when this mutually beneficial interaction turns into a one-way flow from the production system to the financial system.

It has been a repeated pattern throughout history that nations that develop into powerful producers eventually become financial centers, because the production of output gives rise to the expansion of the nation's financial system. Charles Kindleberger postulates that "the usual progression in the national cycle is from trade to industry to finance" (Kindleberger 1996, 212). The industrial stage may lead to decline, he feels, because the sector becomes "large, resistant to change, defensive", partly because institutions such as guilds and monopolies, which were once beneficial, have become burdensome. He is worth quoting at length:

> "The cycle in finance starts with promotion of trade and industry through short- and sometimes long-term capital lending, and ultimately moves to trading assets and preoccupation with wealth rather than output. Merchants and industrialists graduate from risk-taker to rentier status, and conserve flagging energy. Consumption out of given incomes rise, savings decline. Various interests push their concerns at the political level, and if enough do, they block effective action. Income distribution tends to become more skewed, the rich richer, the poor poorer. With greater access to the reins of political power, the wealthy are likely to resist some ethically appropriate sharing of national burdens, such as the costs of defense, reparation, infrastructure, and other public goods". (Kindleberger 1996, 213)

Carried too far, the focus of the entire economic system shifts to the financial system. This can become positive feedback process, because the finance capital accumulated in the finance center can be used to accumulate even more finance capital by controlling generators of output, both domestically and internationally. A financial "imperialism" may evolve, which may be destructive to the originating country as well as possibly distorting of the recipient country.

Eventually, the original production system which led to the creation of the financial system is depleted, and because of this neglect, the means of production begin to decline. In a sense, the goose that lays the golden eggs is starved. The entire economy then starts to decline, except for the financial sector, which may be able to retain its international role as a distributor of capital. Such is the state of the United Kingdom currently.

According to this model, in order for the economy to grow, a production-centered financial system must redirect capital back into all production niches, since a well-functioning production system requires that all niches be well-supported. This is the negative feedback character of the production system; no niches will do well unless all or most niches grow.

In particular, in a growing economic system, the financial system must be able to redirect capital into the vulnerable machinery industries. But if the machinery industries are not well-funded, the investment opportunities of the machinery sectors will seem less and less desirable, and less and less capital will be directed toward them, leading to an even weaker production sector. A vicious cycle, a form of positive feedback, will result. Neglect of production leads to declining production competence which leads to even less investment in production. The very success of the production system may lead to a decline of the production system, because of the relative rise of the financial subsystem within the wider economic system.

For the most part this imbalance takes place because of the functional differentiation between the generative and allocative subsystems of the economic system. Since the financial system reallocates resources, the generative sectors are at their mercy. The imbalance may be exacerbated by the relative imbalance in the distribution of capabilities between the two systems, particularly when the resources of the financial system become large vis-à-vis the production system. In such a case, both the distribution of capabilities *and* the functional differentiation tend to lead to depletion of the production system; in other words, at a certain point both aspects of the structure of the economic system as a whole lead toward an unbalanced situation. At this point, a positive feedback process may take over, leading to financial hegemony within the economic system.

Historically, the state is the outside force which must step in to correct an imbalance between the financial and production systems. The state that steps in is often an outside state. For instance, when Germany and Japan were defeated by the Allies, the power of the German and Japanese banks, industrial elites and military were heavily circumscribed by the United States. This helped the German and Japanese states to reorient their economies to civilian industrial production.

The United States was able to restrict its financial titans early in the twentieth century, partly through the mechanism of antitrust legislation. This was done partly because of the democratic nature of the political system. Theodore Roosevelt and other progressives were able to rally public opinion behind their efforts. These solutions were not possible for Germany and Japan for much of the first part of the twentieth century because of their authoritarian structure.

Conclusion

The production subsystem of the economic system contains the engine of growth which causes the rise of a national economy. Reproduction machinery is capable, collectively, of creating exponential growth, and both production and reproduction machinery sectors are the most important sources of technological change. In addition, the structural, material, energy-converting, and informational categories of production participate in a mutually symbiotic amplification of technological advance.

The nature of the capital subsystem of each sector is another source of innovation and growth. The researchers/teachers act as reproductive metagenerators, training engineers and generating knowledge, which the engineers then use to create better designs of production machinery and production processes. These designs are then turned over to skilled production workers and operational managers, whose competence is crucial for a well-functioning economy.

These capital-generating people need the support of high income levels, good educational facilities, and research facilities. In addition, innovation is encouraged by the free flow of information, people, and capital.

The role of the financial sectors in a rising nation is to encourage these processes of innovation and growth within the production system. In particular, because the distribution of value-added is much different than the distribution of causal capability – in other words, because the machinery industries have much less allocative power to redirect resources than productive power to generate resources – the financial sphere must compensate.

However, there is a tendency in any economic system for the financial system to accumulate resources to itself instead of redirecting resources to the production system. As the financial system gains more and more power over resources as a result of the success of the production system, the financial system is able to lock-in its hold over the economic system as a whole. The entire system is then in danger of decline, as the production system is depleted.

Thus, the rise and decline of economic systems depends on the management of the production and financial systems. The positive feedback processes of the production system encourage growth; the positive feedback processes of the financial system may encourage either rise or decline.

It is within the political economic system that the outcome of this struggle is often decided, because the state and the nature of the state is crucial to the enfolding of these processes. The interaction and combination of the political and economic systems must be considered in order to pursue a full understanding of the rise and decline of Great Powers.

A systems approach is necessary for understanding the complexity of these national economic processes. John Hobson argued for a holistic understanding almost 100 years ago. Speaking of economists at the turn of the last century, he wrote:

> Each piece of the mechanism [in an economy] is clearly described, and the reader is informed how it fits into the parts which are most closely related to it, but no simultaneous grasp of the mechanism as a working whole is attained. When we graft upon the idea of a mechanism that character of continuous self-development which transforms it into an 'organism', the synthesis of the changing phenomena is still more difficult to comprehend…To understand the

> evolution of the system of modern industry we must apply to the heaps of bare unordered facts those principles of order which are now recognized as the widest generalizations or the most valid assumptions derivable from other sciences. (Hobson 1902, 8-9)

The chapters on the theory of an economic system (Chapters 6 through 8) have been concerned with fitting the "bare, unordered facts" together in a way that is consistent with a wider array of scientific thought than is normally used by neoclassical economists. My general theory of systems has been used to construct a specific theory of economic systems, and my theory of economic systems has been used to generate hypotheses which can be tested. The political and economic domains have now been explored; the level above these systems, the level of systems of political economy, will be investigated in the next two chapters. Rise and decline are phenomena at the level of systems of political economy.

CHAPTER 9

A THEORY OF SYSTEMS OF POLITICAL ECONOMY, PART 1: DEFINING SYSTEMS AND CAPABILITIES

Now that both political and economic systems have been described, it is possible to combine the two in order to construct a theory of material social reality, encompassing systems of political economy. In this chapter, because I define political economic systems and capabilities, I will be able to propose a common standard with which to measure the relative rise or decline of particular Great Powers. In the review of previous scholarship concerning the rise and decline of Great Powers, I claimed that there was no theoretically based method for measuring rise and decline. This chapter will construct such a measure. In addition, the nature of the power of Great Powers will be broadened to include their control over global production capacity, bringing into play the chapters on production systems. Finally, discussion of the role of the state and its interaction, mainly with the production system, will lead in the next chapter to hypotheses concerning rise and decline.

Defining a System of Political Economy

In the chapter on the theory of political systems, I described the realms of politics and economics as the two subsystems of a system of political economy. The domain of the realm of political economy is a combination of the realms of politics and economics. This section will propose a method for combining these realms.

The political and economic subsystems are the two functional elements in a system of political economy. The political subsystem generates and allocates control over a population within a territory through time, while the economic subsystem generates and allocates goods and services for a population through time. Therefore, one way to define a system of political economy is as a system that generates control over, and goods and services for, a population within a territory through time. It follows that political economic power is the capability to generate control over, and to generate goods and services for, a particular population within a particular territory in a particular period of time.

These definitions sum the two subsystems of politics and economics into one system by simply adding the two definitions together. I noted in the chapter on systems, however, that properties usually emerge out of a system; these new properties are not predictable from observing the constituent elements of the system in isolation. The above definition of a system of political economy has brought out one emergent property: the population of the polity is shared by both the political system and the economic system. In addition, the above definition combines the concept of territory with the concept of an economic system. Previously, the territorial aspect of economic systems was not considered.

The two subsystems have different functions within a system of political economy. Both functions are indispensable in such a system. Most importantly, each subsystem provides support for the other subsystem. A political system, and the state within the political system, cannot exist without the economic system, and vice versa.

The two subsystems may be said to be in a state of mutual symbiosis, such that each subsystem benefits from an association with the other.

The political system is clearly dependent on the economic system to provide the resources with which to function. Therefore, another definition of a domestic system of political economy would be that it generates *goods and services* for a population within a territory over time in order to generate *control* over a population within a territory through time.

The phrase "population within the territory through time" can be used when discussing both subsystems, as seen in the paragraph above, because both subsystems share the same population, the same territory, and the same time period. Therefore I will define a *nation*, for the purposes of discussing systems of political economy, as a domestic system of political economy containing a particular population in a particular territory through time. I will therefore drop the phrase "population within the territory through time" when discussing these systems, since the phrase will be assumed.

In the formulation of a domestic system of political economy as a nation which generates goods and services in order to generate control , one function (control over space) is postulated as being dependent on the other function (transformation of matter/energy), but not vice versa. However, economic systems are not viable unless they are protected against the violence of others and unless rules of behavior are enforced; these are functions of the state. The economic system needs the state because production takes place through time; if production is interrupted before completion, virtually all output is lost. In order to guarantee producers that their efforts will not be wasted, the state must provide protection *through time*. Production also requires the interaction of the various economic niches, which requires that the state provide protection *through space*. Therefore, the state must provide protection *through space and time*. The function of the political system, as far as the economic system is concerned, is to provide protection of the economic system through space and time.

A definition of a system of political economy that would reflect this dependence on the state would be as a system that generates control through space and time in order to generate goods and services. In this formulation, one function (the economic function) is dependent on the other function (the political function), but not vice versa.

If *both* functions are dependent on the other, in other words if the two subsystems are interdependent, then the system consists of mutually reinforcing elements, which means that the system contains a positive feedback loop. One element helps the other element which in turn loops back to help the first one, and so on. Even though this process involves positive feedback, the political economic system is stable in the sense that the nation is constantly performing at a high enough level to insure that the nation will not disintegrate into two separate spheres, the economic and the political. The structure is stable in that the elements will remain the same, bonded together because of their mutual benefit to one another.

When positive feedback leads to a stable situation, this stable state is often referred to as a "lock-in" of a particular configuration of the system. Lock-in occurs, for example, in both the "vicious cycle" of poverty, in which low income leads to inferior education which leads to low income, and also in a "virtuous cycle", such as when investment leads to high income which leads to investment. In other words, positive feedback can lead both to a situation in which a stable ceiling on performance is reached, and also to a situation in which a stable floor on performance is set.

In a system of political economy, the economic and political systems can form a "virtuous cycle", a stable lock-in at a high level of performance. The economic and political systems form a *cycle* of mutual benefit. The political system protects the economic system, and the economic system provides the resources for the political system, and then the cycle repeats itself.

The following diagram shows this simple cycle:

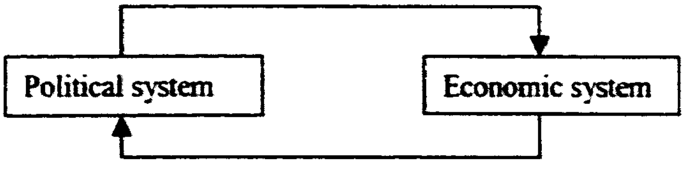


Fig. 39. Cycle of political and economic systems.

This process is nicely illustrated by Robert Gilpin in the conclusion of his discussion of "The nature of political economy" in the book *U.S. Power and the Multinational Corporation*. Gilpin writes:

> Political economy in this study means the reciprocal and dynamic interaction in international relations of the pursuit of wealth and the pursuit of power. In the short run, the distribution of power and the nature of the political system are major determinants of the framework within which wealth is produced and distributed. In the long run, however, shifts in economic efficiency and in the location of economic activity tend to undermine and transform the existing political system. This political transformation in turn gives rise to changes in economic relations that reflect the interests of the politically ascendant state in the system. (Gilpin 1975, 43).

This "reciprocal and dynamic interaction" applies to the domestic system, as well as to the international system. Instead of focusing on the influence of the "politically ascendant state", as in the above quote, my conception of a domestic system of political economy assumes the build-up of power of the "politically ascendant" element in the *nation*; the politically ascendant element in the nation is the state.

In *The Formation of National States in Western Europe*, Charles Tilly and his co-authors concentrate on the process of the ascendancy of the state that occurred in the early modern period. The state was able to draw on increased resources, and was therefore able to increase in size and scope. Once the state increased in size, it was able to extract even more resources, which allowed the state to grow even bigger. In other words, Tilly et al. are interested in the part of figure 39 in which the economic arena helps the political system, not vice versa.

Tilly stresses the importance of the extraction of resources for the process of war-making which led to the development of the modern nation-state:

> Most of the political units which disappeared perished in war. The building of an effective military machine imposed a heavy burden on the population involved: taxes, conscription, requisitions, and more. The very act of building it – when it worked – produced arrangements which could deliver resources to the government for other purposes...It produced the means of enforcing the government's will over stiff resistance: the army. It tended, indeed, to promote territorial consolidation, centralization, differentiation of the instruments of government and monopolization of the means of coercion, all the fundamental state-making processes. War made the state, and the state made war. (Tilly 1975, 42)

Besides being Tilly's most famous statement, the significance of the last sentence is that it implies a positive feedback process in the process of state formation. "War made the state" because the state was able to gather more resources, both from its original territory and any territory it conquered; "the state made war" with the extracted resources, which led to a more powerful "state", which led to more "war", and so on (Bruce Porter

(1994) bases his book "War and the State" on this cycle, and Ardant and Finer in [Tilly 1985 et al] explore the details of the extraction of resources in early modern Europe).

Douglass North, as seen in Chapter 2 of this study, focused on the second part of the political economic cycle as shown in figure 39: the effect of the political system on the economic system. For North, the advantage of a stronger state in early modern Europe was that it was able to guarantee protection and security. North emphasized security of property rights; I am emphasizing the security of the production process. In either case, the state provides security to the economic system, and the economic system provides resources to the state.

Eventually, because of this coevolution of the state and the economy, the modernizing European states exploded over the entire globe, and reshaped human society in their image. As McNeill stated, "between the fourteenth and twentieth centuries, acceleration of Europe's capacity to produce wealth became autocatalytic – a self-sustaining process, perhaps best compared to the reaction of an atomic pile when one considers the disruptive consequences of Europe's increasing wealth and power had for the rest of the world" (McNeill 1992, 121).

The theory of political and economic systems as proposed in this study combines the work of Tilly and North. The element missing from both of their interpretations is the system of production. Tilly assumes a system of production which provides output to the state. North assumes a production system which is being protected by the state. Since their causal sequences both terminate at the production system, they cannot adequately explain the mutually self-reinforcing nature of systems of political economy. Since I have proposed a theory of a system of production, I can more readily establish a theory of a system of political economy than Tilly and North, even as I use their insights. In addition, since my theory of a system of production involves an explanation of the process of technological change, I am able to better explain long-term historical change than Tilly or North. Tilly, North, and others *assume* the development of the means of production, whereas my theory *explains* economic development and provides a systemic definition of the means of production (that is, as a system of production).

Thus, it is possible to construct a definition of a system of political economy in which both functions, the political and the economic, are modeled as being mutually interdependent. The problem in writing a definition for a system made up of mutually interdependent elements is that writing is a linear form of expression, implying a linear ordering of causation. In a mutually interdependent system, on the other hand, a linear ordering of causation does not exist; instead, a cyclic ordering of causation is in force. Thus, if both elements have equal priority, a system of political economy could be defined in one of two linear ways: first, as a national system which generates control in order to generate goods and services; or 2) as a national system which generates goods and services in order to generate control.

However, if there is indeed a positive feedback loop operating in a system of political economy, then the definition needs to be cyclic, and therefore infinite, or indefinitely long. For instance, using the first definition cited in the above paragraph I could say that a system of political economy is one which generates control within a nation in order to generate goods and services in order to generate control in order to generate goods and services in order to generate control, ad infinitum.

Instead, the following definition is intended to cover the meaning of an infinite cycle, with a minimum of words: *A system of political economy is a system that generates and allocates control over, and generates and allocates goods and services for, a population within a territory through time in a mutually self-reinforcing cycle.* A system of political economy is therefore more than the sum of its two parts, because each part makes the other stronger and stronger, up to a certain stable maximum, for an indefinite period of time. A political system without an economic system would be very short lived, and an economic system without a political system would be very vulnerable.

Approximations to both situations have existed in history. There have been several empires which have been based on exploitation of the subject people's resources, sometimes to the extent of taking most of the food and the people to near-starvation levels; and there have been other cases of civilizations which were thriving economically but were destroyed by invading peoples. This latter process repeated itself several times when the peoples of the steppes swept down into the "Eurasian ecumene", as William McNeill called it, which was composed of the four major civilizations of pre-modern times, the European, Middle Eastern, Indian, and Chinese civilizations (McNeill 1963, chapter 7). Time and again, peoples from the steppes interrupted the development of the Middle Eastern, Indian, and Chinese civilizations (McNeill 1963, chapters 8 and 10), thus giving an eventual advantage to the Europeans. For example, an economic historian argues that the Seljuk Turks, through their overtaxation and sometimes ruthless exploitation, are partly responsible for the decline of the Middle East in the 12th and 13th centuries (Ashtor 1978, 296-297).

More recently, Hitler's war economy was to some extent dependent on the need to conquer in order survive. The economies of the exploited peoples, particularly to the east of Germany, were simultaneously destroyed (Kaiser 1990, 377-384). Nazi Germany had a huge productive base of its own, but the needs of the political system became disconnected from the needs of the economic system, both in Germany and in conquered countries. There was no mutually beneficial cycle; all of the benefits went to the state.

In contrast to this predatory behavior, the modernizing early modern polities of Europe were able to establish a positive feedback process between their political and economic systems – although they also exploited and destroyed extra-European societies in the process. Douglass North asserted that the construction of property rights was the key to the growth of early modern nations. Although a full exploration of early modern Europe is beyond the scope of this study, I would like to suggest that several early modern European states became less rapacious than many of their neighbors. These states did not siphon off the entire surplus of the production system, as many other states did. Some states allowed a complete economic system to develop.

A complete economic system has the following elements: 1) A complete set of the twelve production niches as specified in chapter 7, which discussed the production system as a whole; and 2) both a retail/wholesale element in the distribution subsystem, as well as a financial system.

One of the striking features of early modern Europe was the development of sophisticated financial systems (Abu-Lughod 1989; Kindleberger 1993, Chapters 2 and 3). These financial systems developed, I would suggest, because the state allowed pools of surplus capital to exist in independent hands. Without this restraint by the state, along with the imposition of the rule of law, those pools of resources would not have been available in the first place.

This restraint on the part of the state points to an important aspect of relative rise and fall of nations: The state must *manage* the economic system. The state-as-manager is a concept implied by Douglass North, since he argues that the state must provide protection of property rights. Every economic system is fundamentally shaped by the ways in which the state manages the economic system.

When the early modern states of Europe changed the standard state management practices of the time and allowed complete economic systems to develop, they became much more powerful than they would have otherwise been, because the production systems were able to thrive. I will define a *complete system of political economy* as one in which the state manages the economic system in such a way that a complete economic system exists. A complete system of political economy is composed of a complete economic system and a state which is a competent manager.

The successful preindustrial, early modern European states were able to use the resources generated by their complete economic systems (including advancing technology) to dominate the international system. The other polities of the era did not respond to the challenge of the innovating European states. The other polities did not *adapt*. The other forms of systems of political economy were therefore eventually eliminated. In addition, the technological advantage of the European states in terms of machinery helped them to dominate the international system, especially after the industrial revolution. The explanation of European domination is therefore multicausal; there were both political economic and technological causes. The European nations took advantage of mutually reinforcing systems of political economy, and they exploited the power imbalances that emerged after they developed more advanced forms of machinery and technology.

Recently, a literature has developed concerning what is called a *national system of innovation* (Nelson 1993; Freeman 1995). Many nations now engage in large-scale support of research and development (R&D). Much of this R&D is provided by independent firms, but governments have become central to research funding. It is assumed in this literature that countries must innovate in order to maintain a leadership position or in order to keep up with leading nations.

Much of this literature seems to equate innovation mainly with the laboratories staffed by scientists; as explained in my chapter on capital (Chapter 8), I consider the entire production system to be an innovation system. In addition, my conception of the capital system has the advantage of being set within the disaggregated structure of a production system, while the articles and books on national innovation usually either aggregate innovational measures or list sectoral spending without any systemic perspective.

Currently, many polities remain incomplete, in political economic terms. Even in the most powerful nations, furthermore, some parts of the economic system are provided by other nations in the form of imports. Completeness, like power generally, is relative.

A Great Power must have a complete system of political economy, or it will cease to be a Great Power; this is the first hypothesis about systems of political economy. The implication of this hypothesis is that completeness has an effect on the relative capability of a Great Power, or any other nation. Therefore, the more niches of a political economy a nation contains, the greater its political economic capability.

This relative completeness is nonlinear. That is, the more elements a nation possesses, the more capability that the addition of one more element provides. This is because the niches of a political economic system form positive feedback relationships with each other, so that the addition of one more element will reverberate within all the other elements. Once *all* niches exist within one nation, that nation will enjoy all of the complementarities that come with a complete political economic system.

Political Economic Capability

Political capability was defined in chapter 5 as the capability to control a certain population within a certain territory in a particular period of time. The Great Powers were defined as those polities which control the reallocation of territory and population in the international political system. *Military* capability, which is the single most important aspect of political capability, was defined as the capability to project a particular amount of armed force over a particular distance in a particular period of time.

Great Powers must possess the productive resources necessary to generate a large enough quantity of military power necessary to fight effectively in a war involving all Great Powers. This is the second hypothesis about systems of political economy. Paul Kennedy expresses this line of reasoning as the conclusion to "The Rise and Fall of Great Powers":

> It was as clear to a Renaissance prince as it is to the Pentagon today that military power rests upon adequate supplies of wealth, which in turn derive from a

> flourishing productive base, from healthy finances, and from superior technology. As the above narrative has shown, economic prosperity does not always and immediately translate into military effectiveness, for that depends on many other factors, from geography and national morale to generalship and tactical competence. Nevertheless, the fact remains that all of the major shifts in the world's military-power balances have followed alterations in the productive balances; and further, that the rising and falling of the various empires and states in the international system has been confirmed by the outcomes of the major power wars, where victory has always gone to the side with the greatest material resources. (Kennedy 1987, 439)

Kennedy's concept of military power is similar to my concept of military capability. His concept of "military effectiveness", on the other hand, is similar to my concept of the power to achieve goals as explained in my chapter on political systems, in Chapter 5 (Kennedy 1987, 198). In other words, according to Kennedy, military power does not always translate into the ability to achieve certain goals, but production power, in general, underlies military power, and eventually military capabilities make the difference between victory and defeat.

Wars involving all Great Powers, as referred to in the second hypothesis, are very rare, but have the potential to drastically change the nature of the international system. Great Power wars can change the set of polities which are Great Powers, and these wars can create internal changes, by changing the nature of the domestic political systems of the Great Powers. In the last four hundred years, the Thirty Year's War, Napoleonic Wars, First World War, and World War II have been wars of this potential. I will refer to these as systemic wars.

For example, in World War II, Germany could have eliminated the Soviet Union as a Great Power, and perhaps Britain as well. The systems of political economy of the conquered Powers would have been changed to match the Nazi model. Instead, democracy was imposed on West Germany, as well as Japan.

Gilpin ranks systemic wars, which he calls hegemonic wars, as the most important events in the international system: "A hegemonic war is the ultimate test of change in the relative standings of the powers in the existing system. Every international system that the world has known has been a consequence of the territorial, economic, and diplomatic realignments that have followed such hegemonic struggles" (Gilpin 1981, 198).

The capability of the production system to generate military capability is implied by the definitions of economic, political, and military capabilities, and by the logic of production. Economic capability was defined as the capability to generate goods and services, diffuse productive innovations, and move the resulting goods and services a particular distance in a particular period of time. Economic capability is used to create military capability, since military capability depends on the generation of a certain category of goods and services, military production. In turn, military capability is an important component of political capability, and so political capability is indirectly dependent on economic capability. On the other hand, as discussed previously, political capability is used by the state to manage the economic system; therefore, political capability is used to create economic capability.

This causal cycle is diagrammed below:

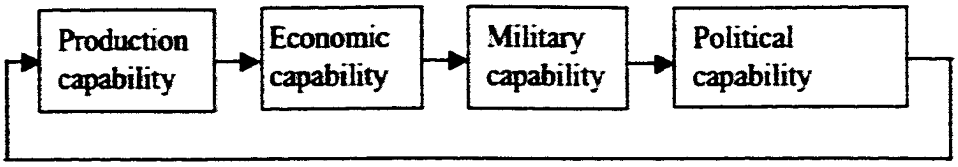


Fig. 40. Cycle of production, economic, military, and political capability.

This mutually beneficial interaction among economic and political forms of capability suggests a definition of political economic capability which is similar to the definition of the domain of political economy. Political economic capability could be defined as the capability to generate goods and services, diffuse productive innovations, move the resulting goods and services for a certain population and control a certain population, all within a certain territory in a particular period of time, in a mutually self-reinforcing cycle.

However, a capability should be a common measure that is shared among all elements. If there is one common measure, then a structure may be determined from the arrangement of elements of different capability. In order to simplify the model of a system of political economy enough to find this common measure, I will search for elements which are common to both of the political economic subsystems, the political subsystem and the economic subsystem.

The political system is based, to a great extent, on military capabilities, and military capabilities are based, to a considerable degree, on material goods such as military equipment. Military equipment is a form of machinery. Like all other machinery, military equipment is created by other kinds of machinery, and in particular, by reproduction machinery. In addition, reproduction machinery is used to create production machinery, which is used to create final output. Thus, machinery seems to be a common denominator across a domestic system of political economy. In order to explore this concept, I will propose a structure of the domestic system of political economy.

The following diagram shows the domestic system of political economy as a combination of the political and economic systems, without considering military equipment or state management of the economy:

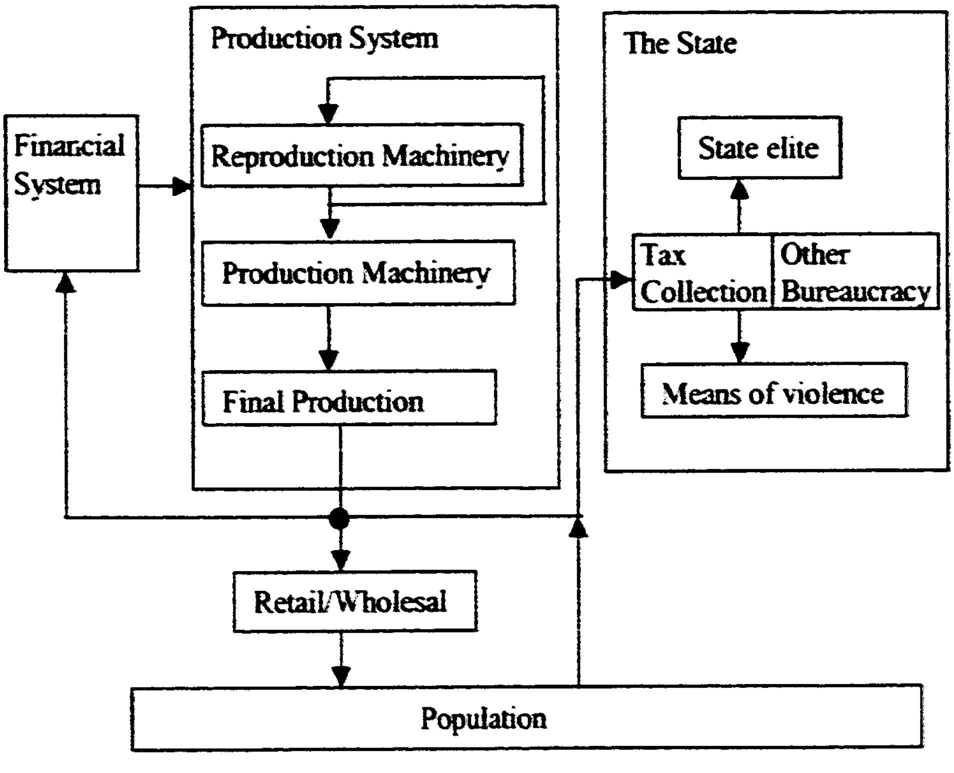


Fig. 41. Structure of domestic system of political economy.

This simplified model of a system of political economy shows some of the flows of goods and services. All elements of this system will be referred to as political economic niches, or simply niches. Like the production system, each element serves a particular function within the system, and therefore each element is similar to a niche as explained in the discussion of economic systems, in chapter 6.

All goods and services originate from the production system. After moving through the intermediary sectors of retail and wholesale, a certain percentage of this output moves to the population. Other parts of the production output are received as input by the financial and tax collection niches. Resources collected as taxes from the production system and from the population are used to provide resources to the bureaucracy (including tax collection), to state elites, and to the means of violence. In the simplified diagram of figure 41, the state returns nothing to the production system, but the financial system directs investment into the production system.

Now I will add the generation of military equipment and state management of the system of political economy:

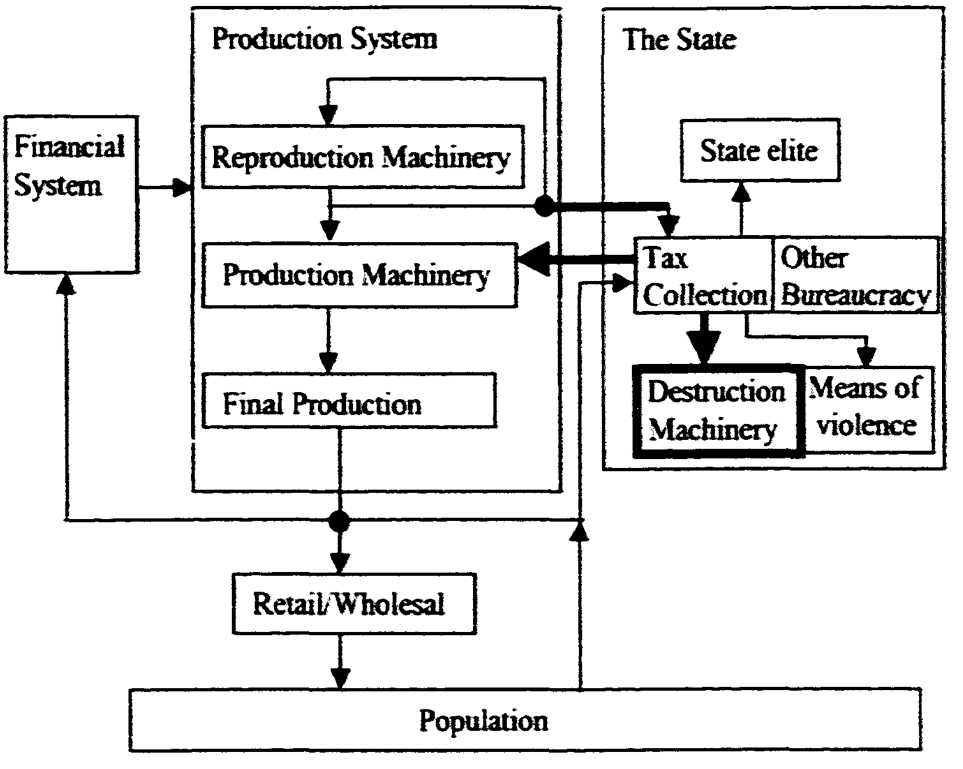


Fig. 42. State interaction with production system

In figure 42, the new additions are shown with thick lines. Reproduction machinery is sent, via tax collection, to a new element in the state system, destruction machinery (this process is shown with a thick arrow from reproduction machinery to tax collection, and then by a thick arrow from tax collection to destruction machinery). Like the production machinery niches, the destruction machinery niche uses reproduction machinery to generate destruction machinery. In return, the state sends a certain amount of resources to the production system in an attempt to guarantee that the production system will be able to fulfill the state's needs, in terms of final production and reproduction machinery (this is shown by the thick arrow from tax collection to the production system as a whole). This is part of the state management function.

Destruction machinery is the machinery used by the means of violence, both inside and outside the territory controlled by the state, in order to project military power. In the twentieth century these kinds of machinery have included tanks, missiles, fighter jets and bombers, aircraft carriers, and more mundane equipment such as guns and bullets.

Destruction machinery is the negation of production machinery; the purpose of destruction machinery is to destroy goods, services, and people, while the production and population generative subsystems create goods and services and people. Destruction machinery is useful for the protectiou of generative capabilities because only destruction machinery can repel, or destroy, destruction machinery from other states which threaten destruction of economic assets.

In modern wars, one of the most important military objectives has been to use destruction machinery in order to destroy production and reproduction machinery. For example, discussing the Allied strategic bombing of 1944, Richard Overy concludes that "bombing gradually dismembered the economic body" of Germany (Overy 1995, 125, see also 130-131).

Machines which destroy must themselves be produced. Reproduction machinery is used to produce destruction machinery in the same way that reproduction machinery is used to produce production machinery. Reproduction machinery is the most important component of the physical capital which exists in the destruction machinery niche. A tank needs machine tools, steel, electricity, and increasingly, semiconductors, in order to be built. Any powerful modern state will have a stake in the performance of its reproduction machinery industries. Since reproduction machinery is so important for military power, the Great Powers that control reproduction machinery control the capability to create military power as well.

Because of the importance of reproduction machinery for the creation of destruction machinery, and the importance of final production goods and services in order to feed and cloth the armed forces of the nation, the state has generally had a motivation to recycle resources back into the production system. This is the third hypothesis about systems of political economy.

In other words, recycling resources is a critical part of the state management function. For instance, much of the development of machine tools was financed by the U.S. Army in the mid-nineteenth century, because the Army was interested in producing guns by using interchangeable parts, which required high quality machine tools (Smith 1985). In the 1950s, the U.S. Department of Defense funded much of the early work on transistors because of their importance for military equipment (Misa 1985). As McNeill has shown, states have a long history of supporting military, and thus reproduction, machinery development (McNeill 1982).

We therefore have the following flow of production within a political economy:

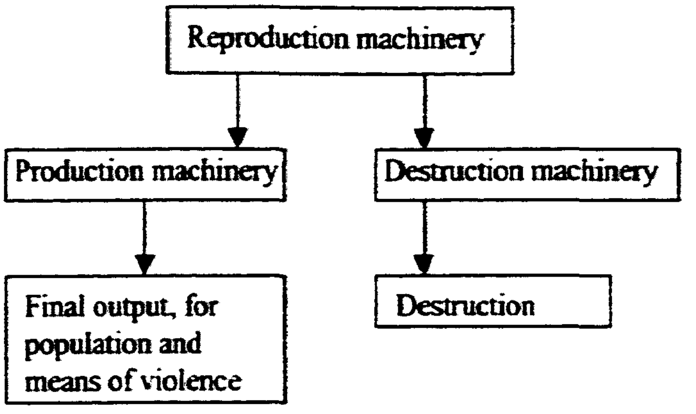


Fig. 43. Flow of production within nation.

Reproduction machinery is the common link between the two subsystems of political economy. Reproduction machinery is used to generate goods and services for the economic system, and to generate the destruction machinery used by the state to control the population within a territory. Final output is used to support the population, and also to support the people who occupy positions in the means of violence.

More generally, reproduction, production, and destruction machinery together form the material basis of a system of political economy. Reproduction machinery and *destruction* machinery are critical to the functioning of the political subsystem. Reproduction machinery and *production* machinery are the basis of the economic subsystem. Since the economic and political subsystems are mutually beneficial and reinforcing, and since the machinery industries are central to the operation of these subsystems, then the logical conclusion is that the reproduction, production, and destruction machinery niches are mutually beneficial and reinforcing.

Previously I proposed that domestic political economic capability be seen as the capability to generate control and goods and services for a nation. Since machinery is the basis of the capability to *generate control and goods and services*, then another way to define domestic political economic capability is to say that it is the capability to *control and generate reproduction, production, and destruction machinery* within a territory through time. Thus, the term "generate control and goods and services" has been replaced with the term "control and generate reproduction, production, and destruction machinery," since machinery is what is used to generate goods and services.

A more succinct way of looking at this capability is to describe the control and generation of machinery as the control over the *capital assets* of particular political economic *niches*. Within a niche, there exist various capital assets, in terms of human capital, machinery, physical structure, and natural resources; these are the components of a political economic niche (besides unskilled labor), in order of importance to the generation of political economic capability. Therefore, we can say that a particular niche in the nation has a particular political economic capability based on a common measure, the capital assets of that niche. *Political economic capability is the capability to control the capital assets of a particular political economic niche within a particular nation over a particular period of time*. What is a political economic niche?

The Domestic System of Political Economy

It was previously observed that the production system is composed of a set of twelve niches, which constitute a set of functions, each of which constitutes a combination of a category and stage of production. Each niche serves a different, but necessary, function within the production system. The wider economic system is also composed of a financial system and a wholesale/retail sector, which are part of the distribution system. In addition, the population exists as a separate entity. Within the political system, the state is a subsystem of the political system, as the production system is a subsystem of the economic system. Each of the state sectors (the state elites, bureaucracy, destruction machinery and means of violence) are on the same level in the hierarchy of domains as the production system niches, financial system, and wholesale/retail sector.

The following is a diagram of the proposed hierarchy of domains, with the domestic system of political economy at the top, consisting of the top four levels:

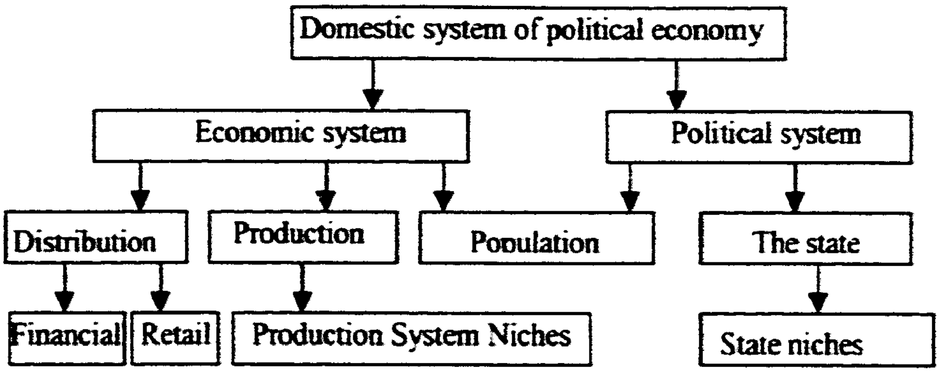


Fig. 44. Hierarchy of domestic system of political economy.

An arrow pointing downward indicates that the lower system is a subsystem of the higher system. In the next chapter on rise and decline (chapter 10), the important elements under discussion will be the financial system, production system, and the state. That discussion will ignore retail and wholesale, thus equating distribution with the financial system. Thus, the domestic system of political economy will be analyzed in the next chapter without the intervening layer of the economic system and the political system.

In terms of understanding political economy at a more general level, however, I will use the lowest level shown in the diagram above, including the financial system, retail/wholesale, the twelve production system niches, the population and the state niches. However, instead of considering the capability of each state niche separately, I will consider the state to be only one political economic niche. The state is hierarchical, and thus any assets that exist in any part of the state are indirectly controlled by the state elites. By contrast, the other political economic niches are not hierarchically related to one another.

The following diagram shows the political economic niches of a nation:

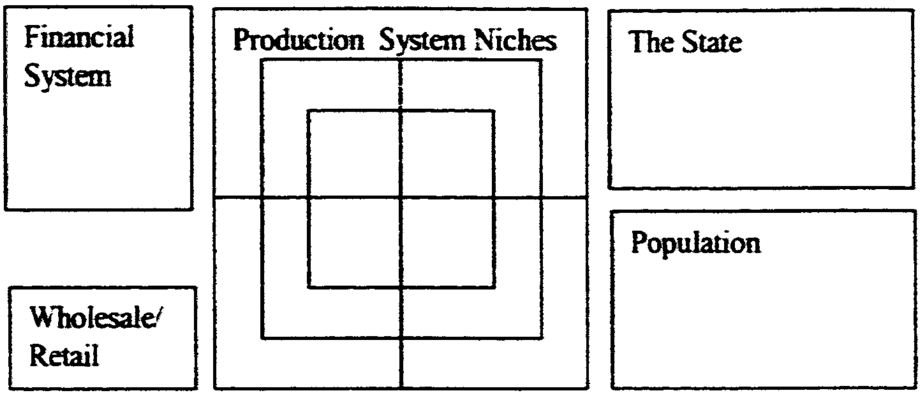


Fig. 45. Niches of a domestic system of political economy (nation).

Each niche fulfills a specific function in the domestic system of political economy. The state is considered as one niche because it is a hierarchy. The state elites have ultimate control over all state capital assets. The main assets of the state are destruction machinery, the reproduction machinery used to create the destruction machinery, and the buildings, offices and transportation equipment used by the bureaucracy, state elites, and enforcement agents. The infrastructure that the state usually builds is categorized according to its appropriate production system niche, even though the state provided the resources. Assets are categorized according to their function, not their source of funding.

Tax revenue is collected in terms of money, but the uses to which taxes are put are manifested in goods and services. As indicated above, the state takes all of its resources from the production system, either directly from production system niches or indirectly through the financial system or the population. The state's revenue is transformed into salaries for employees, assets, or resources returned to targeted parts of the production system, as shown above.

The word "nation" will be used as shorthand for a domestic system of political economy, and the term "national niche" will refer to a political economic niche. The assets that each national niche contains may be used by the people who either work in that niche or the people who control assets in that niche; one of the main uses of these assets is to influence the members of the state. If some niches have more resources than others, the larger niches will ordinarily have a greater influence within the state.

The final definitions of a system and capability of political economy have been determined. A domestic system of political economy is a system that generates control over, and goods and services for, a population within a territory through time in a mutually self-reinforcing cycle. Political economic capability is the capability to control a certain quantity of capital assets within national niches within a nation. I will also refer to political economic capability as *national power*, since I have defined a domestic system of political economy as a nation, and capabilities are the resources which are used for the projection of power.

Defining Great Powers and International Capabilities

The discussion of the domestic system of political economy can be used to construct a definition of a system of international political economy and of international political economic capability. The state is always the interface between the international and domestic systems of political economy. Therefore, a discussion of the international system of political economy, or more simply, the international system, must involve the state.

A state, in a modern nation, almost always controls all of the military assets of a nation. This control is not simply a case of formal ownership. As Seymour Melman has shown, for instance, in the U.S., the Department of Defense acts as a central office for the entire military industrial sector. The companies within this military industrial sector are owned by private individuals. But the planning and many of the production decisions that are ordinarily carried out by top management in civilian industries are instead carried out by the Department of Defense elites in the military industrial sector (Melman 1985, Chapter 3).

A state that produces military equipment, therefore, has an initial base of political economic power. That is, the state controls destruction machinery assets, as well as the reproduction machinery assets which produce destruction machinery.

Ultimately, the state can control any assets within its territory. This is because violence, in the short run, is the final arbiter of all disputes. In the long-run, on the other hand, the means of violence are dependent on the means of production. Unless the means of production can generate the physical assets of the means of violence, the means of violence will eventually become ineffective. But the state, using its means of violence, can always take physical control of any assets within its territory.

Because of this ultimate control by the state, political economic power in the *domestic* arena translates into political economic power in the *international* arena. Any assets that are within the territory controlled by a state can be considered as part of the capability of the state and of the nation in which the assets reside. Even if the assets within a nation are owned by people in different nations, the nation which *contains* the asset can *control* the asset.

This focus on the *territorial*, as opposed to the *personal* location of control is similar to the distinction drawn by national accountants between Gross *Domestic* Product, or GDP, and Gross *National* Product, or GNP. GNP measures the sum of the goods and services produced by firms which are owned by individuals which are citizens of the nation, and includes those produced in other nations which are owned by citizens of the nation being measured. GDP measures the sum of all the goods and services produced within a specific territory of a nation. GDP has become the international standard, not GNP (BEA 1991).

Therefore, international political economic power mirrors domestic political economic power. We can measure the international distribution of political economic power by adding up all of the reproduction, production, and destruction assets within the territory of each nation. This is the most aggregated measure of international political economic power. This reveals what I will call the *global aggregate distribution* of political economic capabilities.

The Great Powers of the industrial era have been those nations that among themselves have collectively controlled the change in allocation of territory because the Great Powers are those nations that have controlled, within their territories, the global reproduction, production, and destruction machinery niches. In other words, the Great Powers control most of the political economic power, or capabilities, of an international system. This control is not total, but the Great Powers collectively have a near-monopoly in these niches. The Great Powers form an oligopoly of these niches. This is the fourth hypothesis about political economy. A succinct historical discussion of this hypothesis will be offered here.

The first industrial nation was Great Britain, which virtually created many categories of machinery, most notably machine tools, steam engines, large-scale iron manufacture, and textile machinery. The two most powerful nations during the eighteenth century and through the Napoleonic Wars were France and Britain. The French Encyclopedia supervised by Diderot shows the sophistication of French production technology in the eighteenth century; Adam Smith used the Encyclopedia as the basis for his famous pin factory example concerning the division of labor (Diderot 1959 [1763]). During this historical period English inventors were taking machinery designs a step further than Diderot.

By the middle of the nineteenth century, when Great Britain was at the height of its power, British machinery output and expertise were clearly superior to all other nations, with the possible exception of the United States. By the end of the nineteenth century, both the United States and Germany were challenging British global dominance, as both the U.S. and Germany came to be important producers and exporters of machinery. Through World War I and the 1920's, the United States, Germany, and Britain, in that order, dominated the world market in reproduction and production machinery (Herrigel 1989 and League of Nations 1927). This dominance translated into a near-monopoly of production of military equipment in World War I.

By the 1930s the long-term industrial development of Japan was resulting in significant machinery output for that nation, and the harrowing short-term industrial development of the Soviet Union was setting the stage for the conflict of five Great Powers during World War II. As in World War I, the Great Powers produced virtually all military equipment in World War II (League of Nations 1945 and Hillmann 1952).

By the 1950s, Great Britain's long presence as one of the elite of the machinery-making nations came to an end, as did her global political influence. In the 1960s, Germany and Japan regained their position, so that four nations controlled the bulk of machinery output through much of the 1980s: the United States, Soviet Union, Japan, and Germany (Economic Commission for Europe, Various Issues).

During the 1980s, the Soviet production of machinery collapsed along with its political system. Germany continues to dominate machinery production on the European continent, but Italy and France have made the global region of the Euro perhaps the largest machinery production area by the turn of the millennium. Japan also continues to be a major competitor, and despite growth of total production, the U.S. economy is declining in terms of machinery production.

The Statistical Appendix to this study will examine data concerning machinery throughout the twentieth century in greater detail. The main finding of the appendix is that three or four countries, which can be identified as Great Powers, have consistently controlled approximately two thirds of the global production of most classes of machinery.

Thus, a prima facie case to be made that: 1) Great Powers control the reallocation of territory among nations; 2) they control the production of the most important types of machinery in terms of political economic power; and 3) they are also effective in fighting systemic wars. Great Powers contain states that control the territories which contain *global* production system niches. Great Powers therefore have a near-monopoly of the niches which have the greatest causal capability within a production system, the machinery niches.

In a previous chapter I claimed that the machinery niches within an economic system had a greater causal capability to enable economic growth than other niches. The largest possible economic system is the global economic system, covering the whole world. Like a domestic economic system, it has various niches, all of which must be present in order for the system to operate efficiently. A diagram of the global production system niches could indicate the percentage of assets controlled by particular nations for particular niches, or it could simply show, in money terms, the aggregate assets for particular global niches.

Those countries or sets of countries that control most or all of the assets of a niche have a near-monopoly on the political economic power contained within such a niche. The closer the niches are to reproduction machinery niches, the more political economic power a nation possesses.

The Great Powers have controlled the capability of other countries to change or maintain their level of output because Great Powers have controlled the production of the capital assets used to generate output. For example, if country A produces the machinery that country B uses to produce output, then country A controls the capability of country B to generate output, in the long-run. In other words, when country B imports machinery, the state of country B potentially controls the imported machinery since the imported machinery is now within the territory of the state of country B. However, the causal capability to change output lies with country A, not country B. The machinery-producing country controls the rise and decline in political economic capability of the machinery-importing country for three reasons: 1) the machinery-producing country can choose not to export to the importing country; 2) the importing country is dependent on the exporting country for technological changes; and 3) all machinery eventually depreciates and become unusable, and so the importing country, in the long-term, is dependent on the exporting country for the maintenance and existence of its final production niches.

This situation is shown in the following diagram:

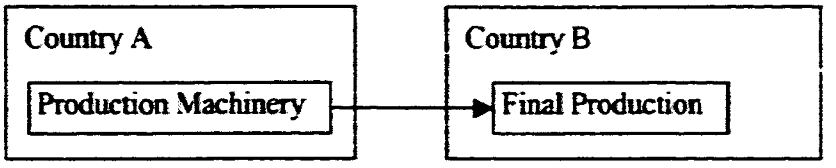


Fig. 46. Production machinery dependence.

The production machinery niches of Country A provide the production machinery which is used by the final production niches of Country B. Country A controls the production machinery niches of Country B, since Country A contains the capital assets which are used to produce the production machinery that is used to create final production in Country B.

Since the Great Powers control the reproduction, production, and destruction machinery niches within the global economy, they also control the long-term capability of all nations to produce and distribute output. Previously I claimed that there are three stages of production, from reproduction machinery to production machinery to final production. To return to my example, if the final production niches of country B are dependent on the production machinery niches of country A, then country A has potential political economic power over the final production niches of country B.

If country B imports the output of the final production niches of country A, then it can be said that the final production niches of country B are *controlled* by country A. Country A controls the capital assets which produce the final output for country B. This is a different situation than the previous example, in which Country B imported the machinery from country A, in which case country A only had the power to control the *change* in the final production niches of country B.

The following diagram shows this state of affairs:

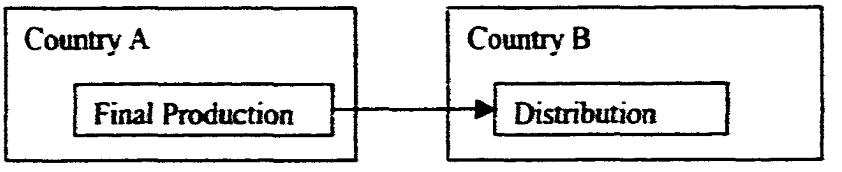


Fig. 47. Final production dependence.

Country A produces the goods and services which are then distributed in Country B.

When country B imports, for example, all of its automobiles from country A, then it can be said that country B has an automobile sector – but the automobile political economic niche (that is, the capital assets of the automobile industry) reside in the territory of country A. Similarly, if country B imports all of its machine tools from country A, it can be said that country B has a reproduction machinery niche – but that that niche is positioned within the space of country A, in terms of capital assets. If, however, country B does not even import reproduction machinery, because it produces no production machinery, then it can be said that country B has *no* reproduction machinery niches.

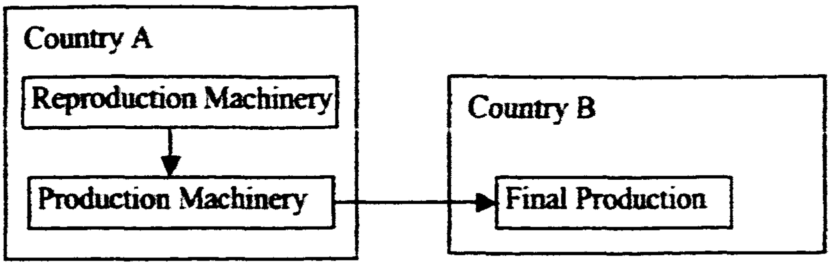


Fig. 48. Reproduction machinery powerlessness.

In figure 48, Country B has no reproduction machinery niches, its production machinery niche resides in Country A, and the capability to change the final production niches of Country B is controlled by Country A.

For example, many East Asian countries produce goods which are exported elsewhere, particularly to the United States. These countries use production machinery equipment for their final production niches which are imported, mainly from Japan. The production machinery niches of these east Asian nations therefore reside in Japan, since they import all of these machines from Japan. Since they do not produce production machinery, they have no reproduction machinery niches. These Asian nations contain final production niches within their territory, but since Japan produces the production machinery of these niches, Japan controls the change in the capital assets of the final production niches.

On the other hand, in so far as these east Asian nations produce all of the goods for various industries in the United States, these nations control such American industries. These east Asian nations hold a certain amount of political economic power over the United States, but the Japanese hold a much greater amount of political economic power over the east Asian countries, since the Japanese control the machinery niches, which hold greater causal capability than the final production sectors.

In general, if a nation imports the output of a niche, the importing nation can be said to *contain* the corresponding niche, but the exporting nation *controls* the importing nation's niche, because the exporting nation contains within its territory the capital assets used to create the output of that niche. Since capital assets are the measure of political economic capability, the exporting nation has political economic capability, or power, over the importing nation's niche. The focus is on which nation *produces* the output, not which nation *uses* the output. The user, in my model, is dependent on the producer, and has less power, in political economic terms, than the producer.

The same considerations apply to military equipment. Since most countries received their military equipment from the U.S. or U.S.S.R. during the Cold War, and since the superpowers controlled the capital assets which generated those military machines, therefore, according to my definition, the superpowers controlled the destruction machinery niches of most of the countries of the world. This control gave the U.S. and Soviet Union tremendous international political economic power.

Financial assets can be translated into control over particular classes of machinery. Much of the importance of international flows of investment capital is that such flows are translated into machinery and physical structures which nations can use to produce goods and services. Thus, by restricting the focus of international power to machinery, the most important aspects of financial flows can also be captured, and financial assets do not have to considered separately from other capital assets.

The three sets of political economic machinery niches – reproduction, production, and destruction – have an ordering of causal capability. This ordering can be used to further differentiate levels of power among nations.

Reproduction machinery niches are the most important machinery niches for three reasons. First, these classes of machines are used to make the production machinery which is used to make final production. Second, reproduction machinery is used to make destruction machinery. Third, as argued earlier, the reproduction machinery stage has the greatest capability to encourage technological change of any part of the economic system.

Production machinery industries are more important than destruction machinery industries for three reasons. First, production machinery creates final production for the population, including the people within the state and the members of the military establishment, as was pointed out above. A large part of the prosecution of a war has always involved the supply of goods to military personnel, and this supply has always been dependent on the final production niches of the belligerent countries (Van Creveld 1977). If a warring country is dependent on another country for its supplies, the supplying country has considerable power over the warring country.

The second reason that production machinery is more important as a determinant of political economic power than destruction machinery is that, as discussed above, a nation producing production machinery may have political economic power over a nation which imports from the producer of production machinery. In addition, the existence of production machinery niches within a particular nation means that other nations do not have this aspect of political economic power over the nation possessing production machinery sectors.

Third, technological developments in production machinery usually have a greater use in the destruction machinery sectors than vice versa (Melman 1983, chapters 8 and 13, Melman 1985, chapter 5, Alic et al. 1992). The use by civilian industry of military research is referred to as *spin-off*. Much research that is considered spin-off is actually research concerning reproduction and production machinery that has been financed by the military. As suggested in hypothesis 3, the state has an interest in supporting the production system. Much of the research classified as military is actually devoted to general technologies of production.

For the purposes of understanding the relative importance of various parts of the system of political economy, the source of resources is not as important as the niche which is being improved by the research. Important technologies which are considered spin-off, such as computers and machine tools, have often been part of reproduction machinery niches, since reproduction machinery is used to create destruction machinery. That same reproduction machinery can also be used to create production machinery. Breakthroughs in certain kinds of military equipment, such as tanks, is rarely applied to final production.

The spin-offs that become available to the nonmilitary sectors of the nation could have usually been obtained much more efficiently if the resources had been targeted directly to the civilian sectors. In other words, the opportunity cost of research in the military sectors is high, because the funds and human capital workers used in the military sectors have been diverted from possible civilian uses.

Thus, production machinery industries serve a number of purposes for the increase of national power. Destruction machinery industries, on the other hand, serve only one purpose, to help the nation create military power, which is also critical for national power. Economic and political economic power are differentiated largely by the addition of the capital assets of military production to the latter. Economic capability involves just reproduction and production machinery, while political economic capability involves reproduction, production, *and* destruction machinery.

Thus, *there is a distribution of political economic causal capability within the machinery sectors of the nation, from reproduction machinery niches to production machinery niches to destruction machinery industries, respectively*. This is the fifth hypothesis about systems of political economy. This ordering of causal capability is also reflected within the international system of political economy. Nations which control reproduction machinery industries are at the apex of international political economic power.

The International System of Political Economy

The international system of political economy can therefore be defined as the generation and allocation of domestic political economic niches, in terms of capital assets, among the nations of the system. Because political economic capabilities have been defined in terms of capital assets, and since capital assets are the means by which the various capabilities of the niches are generated, the international system of political economy can be said to *generate* niches.

International systems of political economy also *allocate* political economic niches among nations, as has been discussed above in reference to the control of machinery niches by Great Powers. Thus, my theory of systems of political economy is useful for understanding the detail of relations of power among particular nations, in terms of the kinds of goods that are produced, exported and imported. For instance, the discussions that have occurred over the unequal terms of trade between countries trading mainly natural resources and countries trading manufactured goods can be understood within the context of my system of political economy. Resource-providing countries control a particular kind of asset, natural resources, but these capital assets confer relatively little political economic power on the states of those countries, while for the machinery manufacturing countries the terms of trade are greatly in their favor because of the importance of machinery. Resource-providing countries often do not even control their own final production niches, in the cases in which they import most of their goods.

My system of political economy can also be used to explain the scholarship associated with Immanuel Wallerstein's concept of the World System (Wallerstein 1974, Chapter 7). According to Wallerstein, there are three tiers of power in the world-system, reflecting "a hierarchy of occupational tasks, in which tasks requiring higher levels of skill and greater capitalization are reserved for higher-ranking areas" (Wallerstein 1974, 350). The most powerful, called the core-states, control most of the surplus generated in the global economy. While Wallerstein conceives of core-states as controlling surplus that emanates from an assumed production system, my equivalent to Wallerstein's concept of core-states is the concept of Great Powers – the countries which control machinery production.

Unlike Wallerstein's theory, my theory explains why the most powerful states change in levels of power, and gives a clear measure of how power is distributed. Wallerstein's second tier, which he calls the semi-periphery, has been particularly difficult to define. In my theory, a semi-periphery can be defined as the nations such as the ones I discussed in east Asia – they contain final production niches, but they import their machinery. Finally, Wallerstein's periphery can be seen to be equivalent to those countries which only provide natural resources to the other two tiers, and do not even control production machinery, because they import final production goods.

My theories are a useful addition to Wallerstein's because Wallerstein, like many neo-Marxist writers (see Arrighi 1994 and Chase-Dunn 1989), does not seriously consider production as a system. For these scholars, in fact, finance seems to be virtually the entire focus of their discussion of the economy. Technological changes, and the operation of production systems, is left out of their accounts. As a consequence, change is exogenous for World Systems writers. In my theories, change is largely an endogenous set of processes.

Instead of discussing terms of trade or semiperipheral or peripheral countries, however, the central focus of this study is the role played by the Great Powers in the international division of labor. The division of labor is defined in terms of the production system, and in particular, in terms of the stages of production (that is, the reproduction machinery, production machinery, and final production stages).

The Great Powers, for the most part, control both the change in the reproduction machinery niches of all nations and the output of the reproduction machinery niches, because the Great Powers control most of the production and destruction machinery industries. Since reproduction machinery is only used to make production and destruction machines (besides more reproduction machines), if non-Great Powers are not making production or destruction machinery, then non-Great Powers are not using reproduction machinery. Therefore, only Great Powers tend to have reproduction machinery niches, and therefore Great Powers control these most critical classes of machinery.

Thus, at least in the industrial age, territory is not as important as control over capital assets. Capital assets such as reproduction, production, and destruction machinery, are used to control territory, and therefore political economic power is more important than political power.

By using the concepts of political systems and economic systems to form a new, higher domain of political economy, various properties emerge which were not evident in the discussion of political or economic systems. First, the role of destruction machinery has been included as an element in the system. Destruction machinery requires production, which is an economic system function, and destruction machinery is used to control territory, which is a political system function. Thus, destruction machinery straddles both systems, and therefore can only appropriately be understood within the context of a discussion of political economy.

Second, the state, an element in the political system, survives with the resources of the production system, part of the economic system. A full understanding of the state is not possible without considering the state as an element in a system of political economy.

Third, the national control of niches of a production system has ramifications for international behavior, because nations use control of other nation's niches in order to exert influence. Finally, as I will explain in the next chapter, political economic processes are important for understanding international dynamics and relative rise and decline of nations.

There are three ways of characterizing political economic capabilities, from the most aggregated to the least aggregated. At the highest level of aggregation, the capital assets of each nation are combined to form one number representing that nation, and the global aggregate distribution of capabilities is determined from the relative sizes of the capital assets of each nation. However, it may be difficult to form this one measure. The easiest measure would be to add the money value of all reproduction, production, and destruction machines, either together or separately. Another measure would be to count all engineers, scientists, and skilled production workers, in order to compare relative levels of human capital. Finally, an inventory of natural resources could be attempted, although such a measure would be much less important than machinery or human capital measures.

The advantage of aggregating political economic capabilities at the highest level is that the processes of snowballing accumulation of power and balance of power in the international system can be more easily explained. This task will be taken up in the next chapter.

At the next level, involving global niches, the share of each nation in each global production niche can be determined, considering the global economy as one economic system. The advantage of this approach is that the Great Powers are discernable as those nations that control the first two stages of global production, reproduction machinery and production machinery, and as those nations that also control the global destruction machinery niche.

Finally, at the national niche level, the control by a particular nation over an amount of capital assets in a particular niche of a particular nation (including itself) can be measured. The ability of other nations to change the niche can be measured by adding up the assets used in the niche which are imported from other countries. The actual control of the niche can be determined by measuring the imports from other countries into the particular national niche. The advantage of this approach is that relations of power between and among various specific nations can be ascertained, which can be particularly useful for an historical narrative.

Thus, there are aggregate, global niche, and national niche methods of measuring political economic capabilities. The fundamental level is the national niche level, that is, the amount of capital assets controlled by a particular nation over the particular niche of a particular nation. This level is fundamental because the other two measures can be considered aggregations of the national niche level. Depending on the phenomena to be discussed, the appropriate measure can be chosen.

The domestic system of political economy and the international system of political economy have been defined. Political economic capabilities and power have been defined, and three measures of the distribution of political economic power among the nations of the international system have been proposed. I now turn to the processes of rise and decline which are a part of the domestic and international systems of political economy.

CHAPTER 10

A THEORY OF SYSTEMS OF POLITICAL ECONOMY, PART 2: RISE AND DECLINE

Rise and decline is the result of two main sets of causes: an internal set and an external one. First I will inquire as to the internal causes, that is, how the structure, elements, and processes of the domestic system of political economy lead to rise or decline. Then I will explore the external causes, involving the interactions among nations in the international system.

Internal Causes of Rise and Decline

There are two main cycles of positive feedback processes within a nation that cause absolute rise and absolute decline. One I will call an *expansion* cycle, leading to absolute rise, and another I will label a *depletion* cycle, leading to absolute decline. After investigating the nature of *absolute* rise and decline, I can address the issue of *relative* rise and decline, which is the focus of this study.

In order to discuss these processes, I will construct a model of the domestic system of political economy. As alluded to in Chapter 9, I will not use national niches as the elements in the models for these cycles. Instead, I will use the level of the hierarchy of domains that exists just below the political and economic systems. The retail/wholesale sector will be ignored. Without the retail/wholesale sector, the distribution system becomes synonymous with the financial system, and thus I will use the financial system, not the distribution system, as one of the elements of the model.

The following is a full representation of the hierarchy of systems, as elaborated in the previous chapters:

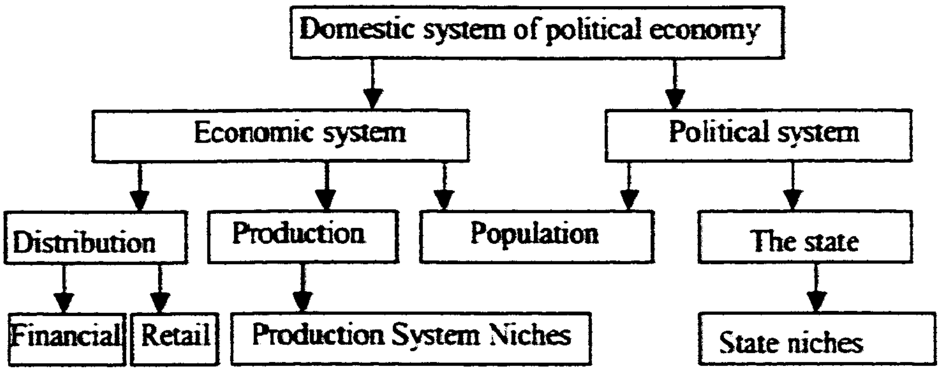


Fig. 49. Hierarchy of domestic system of political economy.

In order to explore the internal processes of rise and decline, the production system, population, financial system and state will be examined. Thus, the hierarchy of the model will be simplified into the following model:

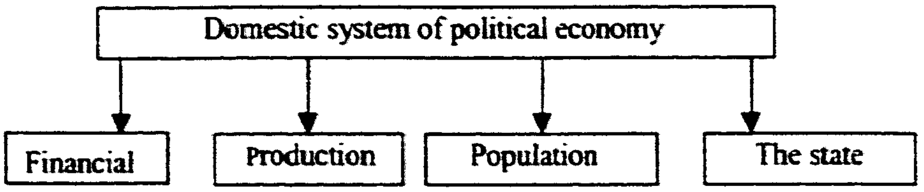


Fig. 50. Simplified hierarchy

There are three positive feedback loops which lead to growth in an expansion cycle (growth is synonymous with absolute rise in this model). First, the production system grows because of the positive feedback processes inherent within it, involving reproduction machinery and the mutual symbiosis of the categories of production. These are the processes explored in the chapters on economic systems, chapters 6 through 8.

The interaction of the financial system with the production system is also a positive feedback process in an expansion sequence. In an expansion sequence the financial system is allocating resources back into the appropriate niches in the production system, leading to greater growth within the production system. In turn, more output from the production system makes more resources available for the financial system, and in an expansion cycle, the financial system recycles this greater resource flow back into the production system; the production system then grows larger, and the feedback loop begins again.

The third positive feedback process involves the interaction of the state with the economic system, which is composed of the financial system and the production system. In an expansion cycle the state provides security, rule of law, and management of the economy; these services lead to greater growth of the production system and the financial system, both of which provide the state with greater resources, and the feedback loop begins again.

These interactions are diagrammed below:

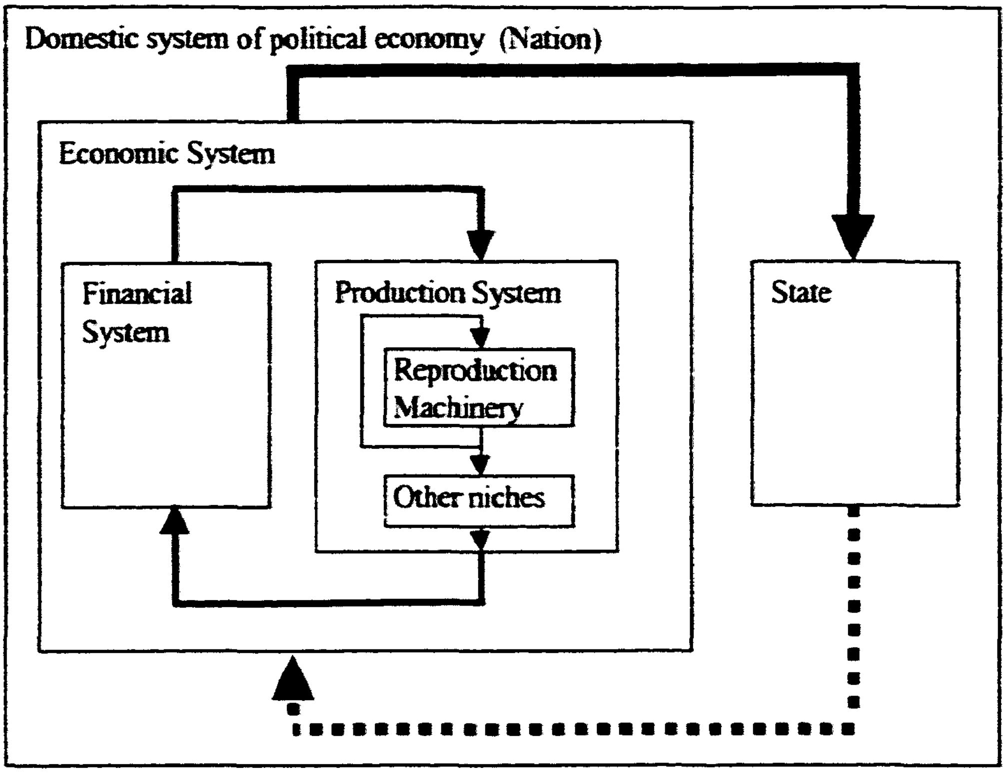


Fig. 51. Positive feedback loops during absolute rise.

Resources flow out of the reproduction machinery niches and back into the reproduction machinery niches (red line); this is the first positive feedback process (the categories of production also form a positive feedback loop, but for simplicity, this loop is not shown). Resources flow out of the production system, into the financial system, and then back into the production system (green lines); this is the second positive feedback process. Finally, resources flow out of the economic system and into the state (solid blue line); the state provides protection, rule of law, and management, as shown by the dotted blue line. The role of the population will be dealt with later.

These loops of mutual reinforcement move from the production system outward, starting with the positive feedback loops of the production system. This production system then forms a positive feedback loop with the financial system, giving rise to growth of the economic system as a whole. Finally, the economic system forms a positive feedback loop with the state, giving rise to growth of the nation as a whole. Thus, growth progresses from production system to economic system to domestic system of political economy.

These three sets of expansionary feedback loops flow in the opposite direction as well. The growth of the system of political economy gives support to the economic system, and the growth of the economic system as a whole is necessary for the growth of the production system. The following diagram is a schematic of this interaction:

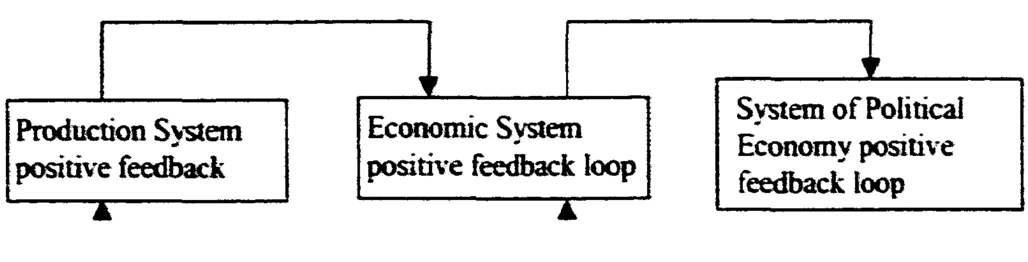


Fig. 52. Expansion cycle.

The solid lines show the primary flow of positive feedback processes, while the dotted lines show the secondary effects of positive feedback processes backward through the domestic system of political economy. There is therefore a cycle of feedback loops, which I call the expansion cycle.

Thus, in this model of an absolutely rising nation, there is an expansionary cycle of feedback loops at work. The production system, financial system, and state are all helping each other to expand. Insofar as a first step can be identified in a cycle, the production system provides the dynamic for the loops of growth. The resources of the production system are the basis of the feedback loop between the production system and the financial system, and the resulting resources of the economic system are the basis of the feedback loop between the state and the economic system. Therefore, *the most important single cause of the rise of a Great Power (or any nation) is the growth of the production system*; this is the sixth hypothesis of political economy. The financial system and state are critical causes of growth, but the production system remains fundamental.

The production system can be seen as a metagenerator within an expansionary system of political economy. In an expansionary system, the production system serves as the source of exponential growth. As shown in figure 56, it creates the generators which it then uses to create more generators. It also creates the resources used in the economic system, the second stage of this tripartite generative system, which generates the third stage, the domestic system of political economy as a whole. The entire expansionary system can be diagrammed as the following:

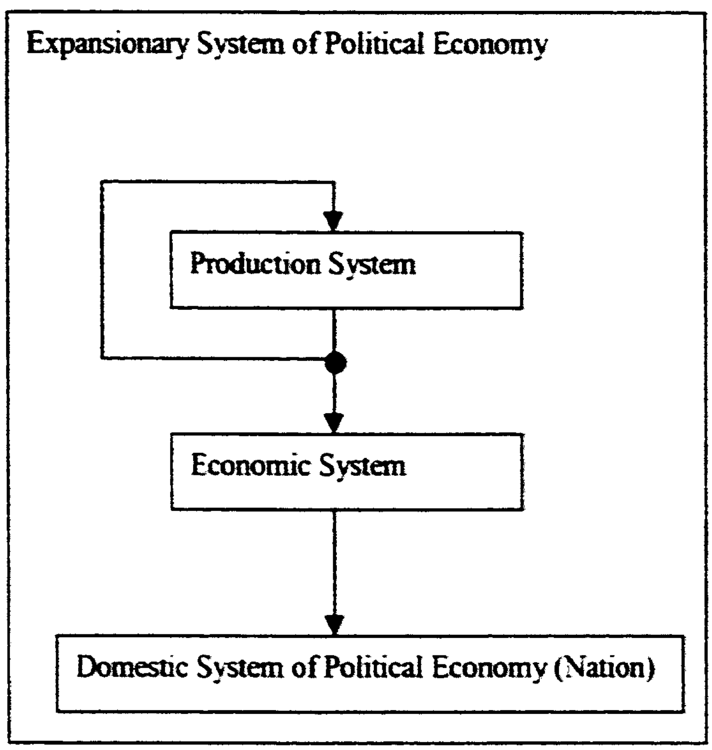


Fig. 53. Tripartite expansionary system.

In a depletion cycle, on the other hand, the cycle of mutually reinforcing positive feedback loops breaks down. The production system retains its internal cycle of growth, but the financial system fails to recycle resources back into the production system in the appropriate manner. Instead, the financial system *depletes* the production system, and retains the resources for itself. The financial system becomes parasitic, instead of being beneficial. Similarly, in a depletion cycle, the state depletes the resources of the economic system; the state extracts a relatively large quantity of resources and denies the economic system the resources it needs to grow.

There is a cycle of feedback loops in a depletion cycle. First, the production system engages in a beneficial positive feedback loop. Then, between the financial system and the production system a positive feedback loop occurs, but the financial system is the only beneficiary. Finally, the state builds up its assets in a positive feedback loop with the economy, but the economy as a whole declines.

If the financial system or the state are controlled by people whose primary motivation is short-term accumulation of power, then the state or financial system will behave in the same manner as an aggressive, powerful nation surrounded by weaker states: there will be a snowballing accumulation of power. Instead of the conquest of weaker states by an imperialist power as in an international system, a financial system or state dominated by a short-term power drive will "conquer" the resources of the nation, at the expense of the production system. This process of resource "conquest" is the hallmark of the depletion process.

Both of these cycles are ideal types (Weber in Gerth and Mills 1946, 59-61); that is, they are simplified models of reality constructed so that we can understand a complex process. In reality, various aspects of both the expansion and depletion cycles are usually at work at the same time in a nation. The financial system and state may both be encouraging the production system in some ways, and depleting the production system in other ways.

Both the financial system and state depend on a growing production system as the basis for their own growth. They will therefore have a structural motivation for encouraging the production system, not depleting it (hypothesis three of systems of political economy, in chapter 9, made the same claim concerning the state). This dependence on one part of a system in order to enable growth in another part of the system is a manifestation of a negative feedback process in a generative system. In a generative system, as explained in chapter 4, there is a range of relative component growth rates that must occur if the system as a whole is to grow.

In order for the production system to grow, the elites who control the state and financial sectors must be willing to forgo smaller short-term gains for larger long-term returns. Any investment involves a similar calculation. However, throughout history, elites have not always been prudent. They have often been unable to resist the temptation to eat their own seed corn, as the saying goes, or to kill the goose that lays the golden eggs, to cite a fairy tale. These very old cultural references have had great staying power because they sum up problems that have recurred throughout history. Humans will often sacrifice long-term riches and security for short-term indulgence. When elites are unconstrained and behave in this way for a long period of time, absolute decline occurs.

In chapter 9 I stated that "I will define a *complete system of political economy* as one in which the state manages the economic system in such a way that a complete economic system exists. A complete system of political economy is composed of a complete economic system and a state which is a competent manager." That is, in a complete system of political economy, the state is not seriously depleting the economic system. I also suggested in chapter 9 that early modern European states developed in such a way that the economic systems were allowed to thrive, instead of being strangled by taxes and over-regulation. In the next section I will put forth a hypothesis as to why this occurred, but the important point to made here is the following: *The establishment of the modern state prevented the depletion cycle from leading to absolute decline; nations with a modern state do not decline absolutely, they only decline relatively. Modern nations usually rise absolutely because of the expansion cycle.* This is the seventh hypothesis of systems of political economy. Thus, for most, although not all, Great Powers in the industrial era, relative decline occurs not because of absolute decline. Relative decline of a Great Power occurs because growth is less rapid than for other Great Powers.

Before the invention of the modern state, a domestic system of political economy had an inherent tendency to move from absolute rise to absolute decline. As discussed in chapter 2 of this study, Robert Gilpin and many other scholars have noted this rise-leads-to-decline phenomenon. This process is also still possible in the modern era, as will be explained in the next section.

This rise-leading-to-decline sequence occurred, and can still occur if safeguards are not taken, because the distribution of political economic capability within the nation changes during its absolute rise. In particular, the capital assets controlled by the financial system and state increase relative to the capital assets controlled by the production system. There is a shift in the distribution of capabilities, that is, capital assets, among the political economic niches of the nation. The structure of the domestic system of political economy changes.

This change occurs because much of the output of the production system flows into the state and financial system; it is the choice of the controllers of assets within these two systems to allocate the quantity of these assets that will be recycled back into the production system. When resources are not recycled, but remain within one of the subsystems of a nation, those resources leave the beneficial, expansionary cycle of positive feedback loops. Resources are only useful for long-term growth if they move into, and the output eventually moves out of, the production system. Isolated non-production system resources become static, that is, they can no longer add to the dynamism of the positive feedback loops of growth. As postulated previously, state and financial elites have tended to hold onto resources that should have gone back into the production system because they seek short-term fulfillment of desires for wealth and power over longer-term rewards.

Sometimes state or financial elites miscalculate in their estimates of what quantity of resources can be safely diverted from the production system. They may feel that the needs of military defense demand more diversion of resources than are beneficial for the long-term growth of the nation; it may even be the case that a nation finds itself in an environment in which it has no choice but to arm itself into a state of decline.

When the financial system and/or state become parasitic and deplete the production system, the production system loses power relative to the other subsystems. Thus, as shown in the diagram below, the production system loses political economic power to the state and financial system, thus leading to a positive feedback process (or vicious cycle) wherein the state and financial systems accumulate more and more power relative to the production system.

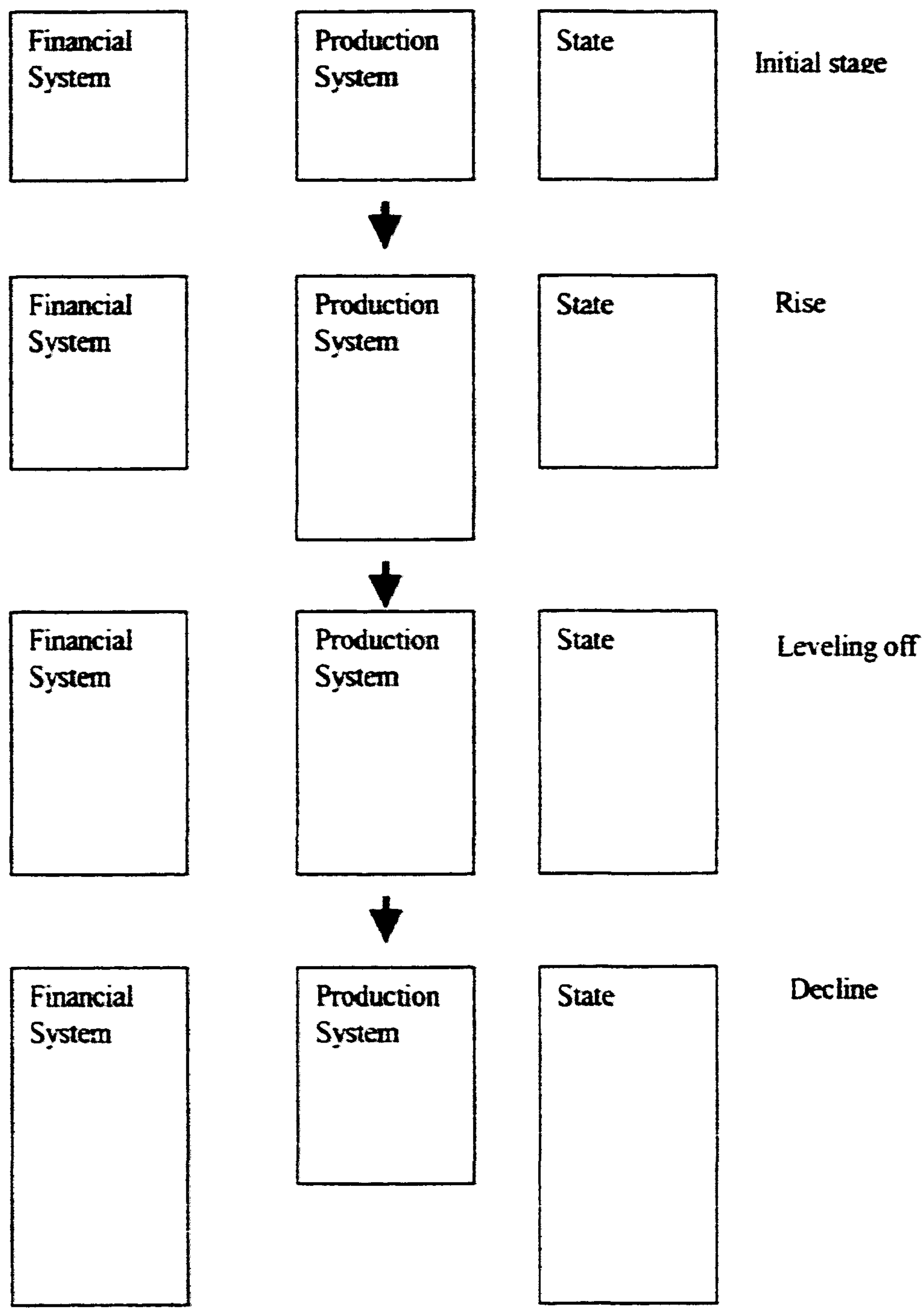


Fig. 54. Sequence of absolute decline

The sizes of the boxes indicate the relative sizes of the various systems relative to the initial stage. In the rising stage, the growth of the production system will slightly exceed the growth of the financial and state systems. In the leveling-off stage, the financial and state systems will become more powerful as a result of the growth of the production system, and will drain enough resources from the production system that the production system will stop growing. Finally, in the declining stage, the production system will shrink even as the state and financial systems temporarily expand.

The population is also the recipient of the resources which ultimately come from the production system. The population supplies the labor force for the various elements of the nation. Thus there is a beneficial positive feedback loop between the population and the other subsystems of the nation. On the other hand, the population can also deplete the resources from the economic system, when over consumption erodes savings and investment, leading to decline. However, I am focusing on production and thus will not further explore the role of consumption by the population in the processes of rise and decline. In my model, the state, financial, and production elites have a greater influence over the health of the economic system than the population as consumers.

This sequence from a supportive state and financial system to a depleting state and financial system is similar to the change from mutualism, as defined in biology, through commensalism, and finally to parasitism/predation (Campbell et al 1999, 1117-8). These terms are meant to explain the effects of the interaction of two species within an ecosystem. In mutualism, a positive feedback loop exists because both species benefit from the association with the another. This situation is similar to the process of absolute rise as postulated above. In commensalism, one species benefits, while the other is not affected. This might be the situation in my leveling-off stage of rise-leading-to-decline, in that the state and financial systems are expanding, while the production system is static. Finally, parasitism and predation involve gain on the part of the parasite or predator and loss on the part of the host or victim. In the declining stage of rise-leading-to-decline, the state and/or financial system may be said to be parasitic or predatory.

Many authors have used the image of the parasitic or predatory state in order to model state-society interactions. For example, in *War Making and State Making as Organized Crime*, Tilly states that "to the extent that the threats against which a given government protects its citizens are imaginary or are consequences of its own activities, the government has organized a protection racket" (Tilly 1985, 171). In *Plagues and Peoples*, William McNeill compares the microparasitism of microorganisms with the "macroparasitism" of humans: "A conqueror could seize food from those who produced it, and by consuming it himself become a parasite of a new sort on those who did the work" (McNeill 1976, 6). In *Embedded Autonomy*, Peter Evans inquires into the reasons for and implications of the existence of what he calls "predatory states," which "extract such large amounts of otherwise investable surplus while providing so little in the way of 'collective goods' in return that they do indeed impede economic transformation" (Evans 1995, 44). Rise-leading-to-decline can be seen as a movement from mutualism, or encouragement on the part of the state and/or financial system, to parasitism or predation by the state and/or financial system.

By constraining the state and financial systems, the modern state for the most part has broken the sequence of absolute rise leading to absolute decline as proposed above. However, some production systems may be more hampered or encouraged by their respective state and financial sectors than others. There will still be growth in the more heavily depleted nations, but they will fall behind other nations which have more vibrant economies. Thus, the *relative* rise of a Great Power will always be accompanied by an *absolute* rise in political economic power (that is, capital assets), and a *relative* decline will usually also be accompanied by an *absolute* rise in power.

The later history of the Soviet Union was a case of *absolute* decline accompanying *relative* decline. But as will be explained in the next section, this phenomenon has been rare among Great Powers in modern times. In order to understand the causes of relative rise and decline, therefore, it is necessary to compare the characteristics of absolutely rising Great Powers, and thereby determine why particular Great Powers are rising more rapidly than other Great Powers. In order to accomplish this task, the focus of study should be on the mechanisms of the production, economic, and political economic systems as enumerated in chapters 5 through 9, and how those mechanisms lead to growth. Occasionally, it will be necessary to understand how depletion can go so far as to lead to absolute decline.

Relative rise and decline is a multicausal process. The performances of the state, financial system, and production subsystems are all critical to the performance of the nation as a system. The production subsystem causes the most change in the relative performance of a nation.

The rise and decline of Great Powers must be understood within the context of the performance of the entire set of Great Powers of a particular time period. If rise and decline is usually relative, then the internal causes of rise and decline of a Great Power must be discussed within the wider international system of which each Great Power is a part.

External Causes of Rise and Decline

In different historical eras and regions of the world, various kinds of political economic structures have become dominant. Depending on the nature of the others with which a particular nation interacts, a specific national structure might be more or less successful within a particular international system. In the extreme case, a lagging polity might be conquered by another polity. Rise and decline is a relative phenomenon because all units exist within a system of other nations. These other nations set the context within which the rise and decline of a particular nation occurs; thus, there are *external* causes of relative rise or decline.

A nation with a political economic structure which is better adapted for a particular international system will tend to have greater political economic capabilities available to its state elites than a nation with an inferior structure, assuming similar size. When an imbalance among nations occurs, the stronger polity has an opportunity to exert influence over or even conquer the weaker neighbor or neighbors. It was pointed out in chapter 5 that a positive feedback process of snowballing conquest may then occur, in which an expansionary nation, because of its larger and larger quantity of capabilities, will be able to obtain yet more capabilities through conquest.

In chapter 5, I assumed that these capabilities consisted of a military force, without specifying how that military force was constructed. Now that I have included destruction machinery into the system of political economy, the description of snowballing conquest can be completed. If a conquering nation controls the capital assets of its colonies, than it can use those capital assets to further increase the production and destruction capabilities at its disposal. These new resources can be fed into the military apparatus, and more conquests can occur. The total capabilities available to the state snowballs or accumulates in a nonlinear way.

Balances of power are often used to prevent the rise of a Great Power by denying the expansionary Great Power or nation seeking to be a Great Power the resources of potential victims of aggression (see, for example, [Lustick 1997] concerning the Middle East).

Much of the process of state formation is the consequence of a snowballing process of conquest. In order to maximize the benefits of conquest, the state of the conquering nation must integrate the various niches of the conquered polity with the niches of the conquering nation, or else it will be more difficult to obtain the full benefits of the new niches. To take advantage of *external* causes of rise such as conquest, there may also be an *internal* process of management by the state.

Thus the internal and external causes of rise and decline may both be factors in the *relative* rise and decline of Great Powers. An inquiry into only the internal processes of rise and decline would lead to a focus on the *absolute* rise and decline of a country. In chapter 2, I claimed that Gilpin had basically taken an approach based on the performance of one country, and that Douglass North was interested in a permanent ranking of groups of nations in relation to each other. But because this study is concerned with the ways in which a nation compares to other nations, *through time*, the measure of interest is the change in capabilities of one nation compared to other nations. Thus, a nation which is increasing its absolute capabilities may be declining relative to other nations which are increasing their capabilities at a faster rate. It was postulated in the previous section that most cases of relative rise and decline are the manifestation of the absolute rise of both the nations that are relatively rising and the nations that are relatively declining.

Gilpin argued that the internal, social ordering of a polity is a critical factor in the relative performance of that polity, through time (as I discussed in chapter two). Different structures of domestic systems of political economy will be more or less successful, depending on the structures of the other nations which constitute the international environment. When the internal ordering, or structure, of a nation changes, the nation may become more or less successful than the other nations in its environment. Thus, a change in the national structure may be a cause of relative rise or decline (a change in structure may also have no effect). When a change in national structure leads a nation to become more successful, other nations may adopt the change as well. If enough nations, and particularly Great Powers, adopt the innovation or innovations, the environment that all nations exist within will have thereby changed; nations which were successful in the environment before the change took place may become less successful, and other nations may embark on a spectacular rise.

Therefore, a change in the structure of a nation may lead to a change in the international environment in which other nations act; eventually, the structure of the international system will change because the distribution of capabilities among nations will be affected by the internal changes going on within the nations that make up the international system. Thus, the structures of the domestic systems of political economy, or nations, *evolve through time*.

I am proposing a theory of the evolution of national structure which involves two processes: first, the *variation* of national structure, an internal, or elemental, cause of change; and second, *adaptations* which the international system encourages nations to adopt, which is an external, or systemic, cause of change. In the biological domain, of course, Darwin proposed a theory of evolution which is the model for any theory of evolution, including my model. It may be instructive to explore the broad principles he enunciated.

Darwin's theory of evolution is very powerful because he postulated both an internal and external cause of change in order to explain evolution. For Darwin, the internal cause of evolution, emanating from the individual organism, was what he called "variation" in forms, or what are now referred to as "mutations". It was well-known in the nineteenth century that variations within a species could occur through breeding of plants and animals. Darwin took advantage of this knowledge in the first chapter of "Origin of Species" (Darwin 1964 [1859]). People select the variations they prefer in the course of breeding; Darwin referred to this process as "artificial selection".

Darwin's external cause of change in evolution is "natural" selection. The environment, or ecosystem, will encourage, or "select", the organismic variations which are better adapted to that ecosystem than those organisms that are less well-adapted to that ecosystem. The natural selection process, unlike the process of artificial selection, is not consciously made. The ecosystem is self-organizing: "Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring" (Darwin 1964 [1859], 61). The ecosystem will encourage some variations and discourage others. The words "encourage" and "discourage" are not meant to imply that the system has a conscious desire; the particular configuration of the system increases or decreases the probability that a particular type of element, or in this case a particular species, will thrive or fail.

Writing about the domain of international political systems, Kenneth Waltz postulates the existence of two sets of behaviors which are indirect effects of the structure of an international system (Waltz 1979, 74-77). The first, which Waltz calls "socialization", highlights conformity in behavior among nations when they attempt to operate effectively within the international system. I would like to propose that in the long-run, one way that states behave in order to conform to the international system is to manage the adoption of successful variations. For example, the Japanese state implemented a drastic change in structure in the Meiji restoration of the late nineteenth century, in order to imitate many aspects of the successful European polities. However, this idea of following an existing model misses an important phenomenon: the states that are socializing to a particular national structure are often following the lead of some state or set of states that originally created a new "variation" in national structure. The state that originates the variation is not undergoing a process of socialization; quite the contrary, the state or nation is actually *innovating*. Thus, the effects of existing within a system are not only felt through socialization, but also through innovation.

The second indirect effect of structure on the system of states, according to Waltz, involves competition among states, which is similar to Darwin's conception of natural selection (the concept of socialization is similar to Darwin's concept of artificial selection). That is, a conscious choice is not made to socialize; those nations that are better-adapted to a particular international system succeed and others fail. Throughout history, the better-adapted nations have conquered or otherwise controlled the less well-adapted nations; most forms of political economic systems have become extinct. States must respond to the existence of various forms of domestic systems of political economy and to changes in national structure, or they risk relative decline or even elimination. Similarly, Darwin explained, "the structure of every organic being is related, in the most essential yet often hidden manner, to that of all other organic beings, with which it comes into competition for food or residence, or from which it has to escape, or on which it preys" (Darwin 1964, 77).

I am absolutely not advocating, however, the notion that success in the international system indicates superiority other than that of the generation of political economic power. Late nineteenth century "Social Darwinists" made the mistake of equating success in a particular international environment with cultural and racial superiority. Darwin was always careful to link adaptations to *specific* environments, which were constantly changing because their constituent parts were constantly changing. Darwin wrote an encyclopedia on the subject of barnacles; he was not interested in finding the eternally superior organism.

Successful variants of a domestic system of political economy have risen relative to less successful variants, depending on a particular international system in a particular period of time. This study will not give a full accounting of the variations of structure that have occurred throughout history, and their changes of fortune through time. But it is important to discuss the main features of the evolution of the domestic system of political economy during the modern period, because the characteristics adopted since early modern times are still critical today.

National evolution in the modern period

As was discussed in the previous chapter, the hallmark of the rise of the modern nation was that a complete system of political economy was constructed on the territory controlled by the state. That is, in early modern Europe, some polities included the following: 1) a state with a competent bureaucracy (and taxing authority) and a means of violence, including a destruction machinery (or technology) niche; 2) a reasonably efficient financial system; and 3) a production system with all the niches in place, using technology which was the best for the time period. The state in such a system was constrained in such a way that it did not deplete the economic system.

Such a political economic system contains a *balance* among its elements, which includes the state, the production system, the financial system, and the population. All elements must grow in power if the system as a whole is to grow in power. This is the consequence of a negative feedback process of a generative system. The shift from a potentially all-consuming state to a balance among elements of a nation was of historical importance because the depletionary cycle then became infrequent.

How was this shift achieved? The eighth hypothesis of systems of political economy is that *partial to full control by the economic system over the choice of some or* *all state elites, plus partial control of the state over the financial system, results in a situation that allows for the dominance of the expansionary cycle within a nation.* There must be some constraint on state elites by economic elites, or else the state elites will be able to deplete the economic system. In addition, there must be some form of control over the financial system, or else the financial system can also become unconstrained and deplete the production system. Thus, the *structure* of the domestic system of political economy must be constructed in such a way as to enable the elements to survey and check one another. My next task is to describe what sort of national structure is required.

In the chapter on political systems, I proposed the hypothesis that "a dictatorship will impose greater violence on the population than a democracy." This is because there is a *cycle* of control among the elements of a political system in a democracy, but only a *sequence* of hierarchy in a dictatorship, as I showed in the following diagrams:

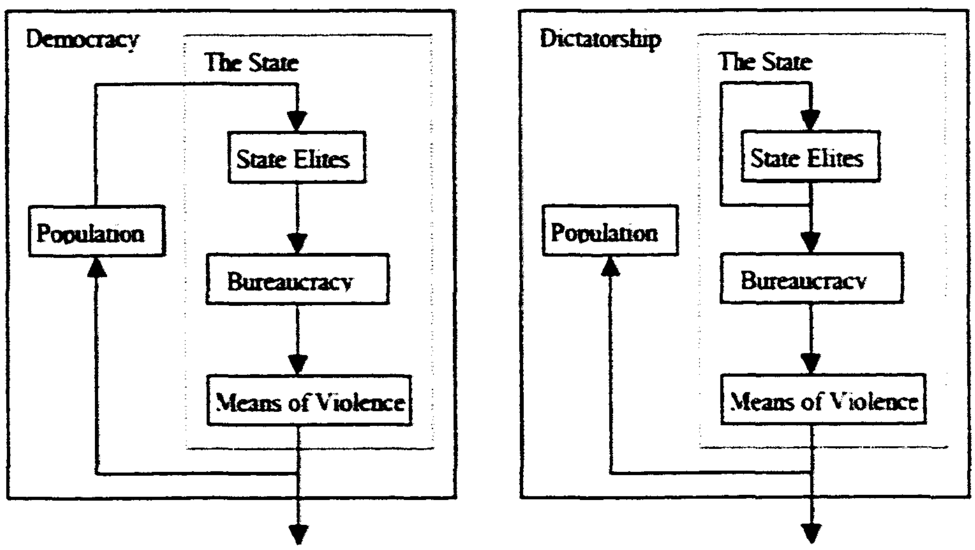


Fig. 55. Democratic and dictatorial political structures.

If I replace the box labeled "population" with a box labeled "economic system", then the following diagrams describe the two different structures:

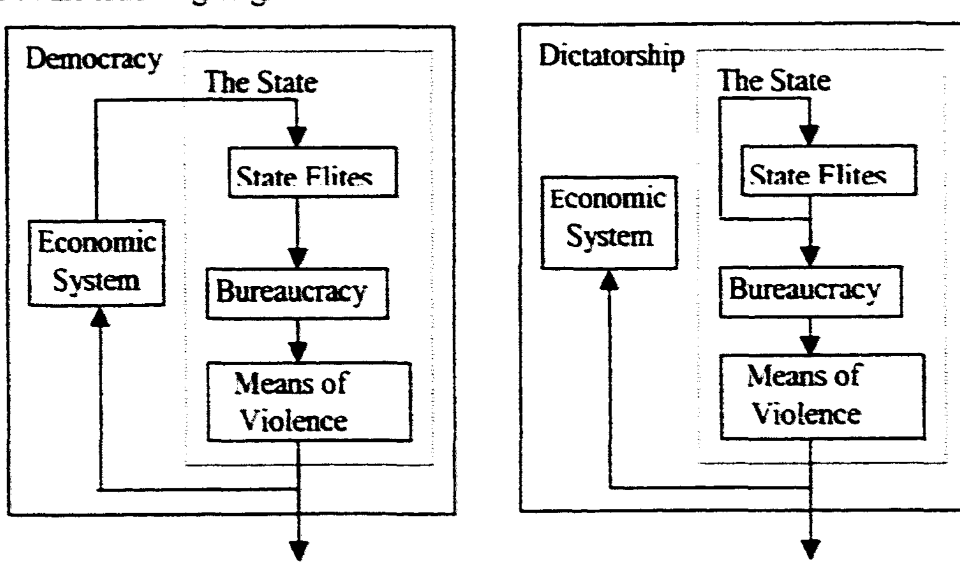


Fig. 56. Democratic and dictatorial domestic systems of political economy.

A corollary of my hypothesis that democracies wield less violence on their population than dictatorships, therefore, is that democracies (or, more formally, nations in which the economic system has partial or full control over the choice of at least some state elites) wield less violence on the economic system than dictatorships. Thus, the members of the population who are members of the economic system (which includes most adult members) would be able to resist harmful depletion of the economic system on the part of the state. In a *partial* democracy, such British parliaments before the 19th century, only the economic elites among non-state elites have some power over the choice of state elites. In a *full* democracy, all people in the nation have some power over the choice of state elites. For the purposes of the eighth hypothesis, a democracy can be of either type in order for a balance among elements to be enabled.

This line of reasoning explains more fully then property rights the phenomena accompanying economic growth as described by Douglass C. North. As I stated in Chapter 2, "States can use their power to make institutions as they wish, whether or not such institutions make economic sense, and the distribution of power over the state organizations will therefore have a critical effect on institutions. Like Gilpin, North confuses rules and property rights with distribution of power." I also stated that "often in North's writings, he stresses the importance of the security, or lack of security, of property rights." Thus, control over violence on the part of the economic system would seem to be an important cause of the security of property rights. North's examples, which included Athens, Rome, the decline of feudalism, and the early Parliaments of the Low Countries, England, France, and Spain, are all discussions of power-sharing schemes, or the lack of such power-sharing, over the state elites on the part of economic elites.

This power-sharing, which started in early Modern Europe with various forms of Parliaments, was the crucial structural change which allowed for the dominance of the expansionary cycle over the depletionary cycle. North, as pointed out in chapter 2, provides evidence for this connection. For example, speaking of England, he states that "the economic policies of the Tudors were the same as those of the continental kings. Had they been able freely to trade monopolies and other restrictive rights for revenue, the outcome for economic efficiency would have been similar [to France and Spain]. But in England the crown ran into effective opposition", in the form of a powerful parliament (North 1981, 156).

This was an evolutionary adaptation of the domestic system of political economy on the part of some European countries. During the pre-industrial period, there were various improvements and temporary regressions on the part of many of these countries; the French Revolution can be seen as a "correction" of the French political economic system, for instance, which had earlier included Parliaments. In addition, regulation over the financial systems, particularly over the currencies, was another hallmark of this period.

Therefore, the first structural, evolutionary national adaptation of the modern period was the distribution of power over state elites, and the regulation of the financial system by the state. This adaptation, along with the development of production technologies, led to a complete system of political economy, as defined at the beginning of this section.

By encompassing a complete set of production system niches, a Great Power also therefore contains reproduction machinery (or technology) and production machinery (or technology) niches. The existence of a complete system of political economy, therefore, implies that the reproduction and production niches exist, which implies that the complete nation is also a Great Power. While pre-industrial nations did not have industrial machinery, they still had technologies which were equivalent to, if less productive than, the industrial machinery technologies (see Diderot 1959, Williams 1987, Strandh 1979).

Operating simultaneously with this need for completeness in order to compete effectively in early modern times, and becoming more critical through time, was the need for a larger and larger minimal quantity of capabilities for a powerful nation, and in particular, for a Great Power. This was why Machiavelli called for Italian unity at the end of "The Prince" (Machiavelli 1979, Chapter 26). According to the historian Ludwig Dehio, continental powers such as France under Napoleon, or Hitler under Germany, were attempting to achieve the size of other "world powers", such as Great Britain, Russia, and eventually, the United States (Dehio 1962).

There is always a historically-contingent maximal size for a Great Power . The human capital workers of a production system need to be in close enough proximity to one another to be able to interact on a constant basis. Since all of the production system niches complement each other, the people who make up these sectors must be able to make this complementarity possible by interacting. As technologies of communication and transportation improve, the distances between various human capital workers in a complete system may become larger. But at some point, the distances become too large for effective production and innovation. Innovation-by-doing requires the physical presence of the innovators at the production site, and travel between sites requires time. Since all production takes place through time, the minimization of this transport time is critical to a thriving production system composed of mutually reinforcing elements.

Because production and innovation are intimately interrelated, technological progress will always depend on physical proximity among producers within different niches of production systems. Physical movement is, in turn, dependent on the ability of the state to provide protection to the people and things that are moving. This implies that *there is some territorial size for a system of political economy, which is both big enough to encompass all niches of a production system, but small enough to allow for intense interactions among the human capital workers who are responsible for the output and development of those niches*. This is the ninth hypothesis about systems of political economy. There is a range in the size of a domestic system of political economy which is both not too small and not too big, but the lower and upper limits on this range have both generally increased through time because of advances in information production technology (communications) and energy-converting production technology (transportation). The second national adaptation was to set the size of Great Powers to what has come to be known as the "nation-state", that is, a territory controlled by a state which is larger than a city but more integrated and generally smaller than an empire.

By the middle of the nineteenth century, the international environment had changed yet again. An innovating nation, Britain, had developed the world's first reproduction machinery sector, a process which is usually called the Industrial Revolution. Any polity that could not create a machinery-based production system was doomed to conquest or domination by those who did develop such technologies. Much of the international system was divided up among the imperialist powers during this time period; some, such as Japan, were socialized, that is, the state embarked on a conscious design of catching up to the other industrial nations.

The state has generally had to manage the process of industrialization in some form. As Gerschenkron argued, the later a state decided to industrialize, the more the state had to become involved in the industrialization process (Gerschenkron 1962). Thus, the production system of England required relatively little help from the central government, although some aid was provided. The young United States helped manufacturers by developing much of the machinery used for manufacture in an attempt to stock the nineteenth century arsenals. The German government, in the late nineteenth century, helped set up a network of technical institutes and apprenticeship programs. (Smyser 1993). The Japanese state became involved with the establishment of various niches of their production system. The most extreme example of state intervention was the U.S.S.R., in which the state took over the entire economy.

Thus, nations had to adapt by industrializing, that is, developing machinery and machinery-based final production sectors, or risk losing power within the international system. A nation whose production system and military is based on industrial machinery I will term "fully industrialized".

Increasingly as the nineteenth century progressed, and then to an even greater extent in the twentieth century, the state was called upon to *manage* the production system. This included industrial policies of direct intervention in the form of subsidies and protection, and also the establishment of networks of institutions that create human capital, that is, educational facilities and laboratories. Structurally, this intervention manifested itself with the recycling of resources which the economic system provides to the state in the form of revenue, which were redirected back to the production system in the form of subsidies and educational facilities.

Therefore, the third evolutionary national adaptation was to change the structure of the production system from a partially reproductive generative system, based on pre-industrial technologies, to a fully reproductive generative system, based on industrial machinery (that is, machinery which is mainly constructed out of iron, steel, or other metals, powered by inanimate power, shaped by other industrial machinery, and uses industrial machinery to process information). In addition, the states learned to manage the production system, each state doing so in its own way.

By the late nineteenth century, then, three major attributes characterized a Great Power that had good long-term possibilities for rising relative to other Great Powers and other nations: 1) a complete system of political economy, with a balance among the production, financial, state, and population sectors, usually involving some form of democratization; 2) a size which was big enough to encompass a complete system of political economy yet small enough to allow for human capital interactions, depending on the transportation and communications technologies of the times, usually involving the creation of a nation-state; and 3) a fully reproductive production system and a state which competently managed the industrial nature of the production system.

In the twentieth century, many variations in structure took place, although space limits my discussion of these variations. Four variations stand out. First, by the end of World War I, monarchy as a state structure had almost disappeared as an option for a

Great Power. That is, the choice of the most important state elite was not limited by the literal reproduction of the current monarch. This is a structural change in the state. This change may have occurred because the accelerating pace of technological change, coupled with the need for competent management of the economy by the state, meant that the choice of competent state elites needed to be more reliable than the genetic mix of the heir to the throne. However, the causes of this structural change are beyond the scope of this study.

Second, as noted by Karl Polanyi in his book *The Great Transformation* (Polanyi 1944), in the first half of the twentieth century states learned that it was necessary to increase the control and regulation of their financial systems in order to avoid the panics and depressions that marked economic life until World War II. In various industrialized countries, central banks were given the power to regulate various aspects of financial life. This was a structural change in that the state was given greater control over the financial sphere.

Third, a major variation of the modern system of political economy was attempted, which may be treated under the term "totalitarianism". A totalitarian state was one which included a fully reproductive, industrial production system, but crucially, the structure of the system of political economy was actually pre-modern, as I have defined the term. The totalitarian state did not promulgate a balance among the subsystems of the nation; instead, the state had total control over all other subsystems (finance, production, and population).

In the case of the Soviet Union, Stalin consciously created strong reproduction and production machinery niches, along with a powerful destruction machinery niche

(Davies et al. 1994). However, the destruction machinery niche soon came to receive the lion's share of the resources generated by the production system, and by the 1980's, the Soviet Union was doing something that no Great Power had done during the industrial era; it was declining absolutely (Shmelev and Popov 1989, Rowen and Wolf 1990, Nove 1992). Thus, by structuring the Soviet political economic system in such a way as to encourage a snowballing of power on the part of the state, the Soviet state brought about the operation of a depletionary cycle.

The totalitarian variation met with short and medium term success, but eventually became extinct. Another variation, which I earlier called "fully democratic," has become very widespread at the current time. Previously, I claimed that a system of political economy in which the economic system, in some form, had some control over state elites, would allow a beneficial balance of power to form. This control by the economic system occurred in the early modern period in the form of Parliaments. This extension of the right to vote for state elites and property owners was enough to engender a balance within the nation. Since then, of course, the right to vote has been extended to all adults in what I call "full" democracies.

There are three reasons why a full democracy may be more efficient than a partial democracy, although a full treatment of this issue is beyond the scope of this study. The reasons that I will cite, however, are based on hypotheses that I have proposed in previous chapters.

The first reason builds on the hypothesis that a dictatorship will visit more violence on the population than a democracy. A democracy that only caters to economic elites might therefore impose more violence on nonelites than a full democracy. In a full democracy, then, nonelites would feel more secure in increasing human capital, that is, in investing the resources necessary to acquire the skills needed for a strong production system. In addition, because the citizens of a full democracy would put constraints on the state, the state might not deplete the citizens with overtaxation to the extent that the citizens would not have the resources to invest in the creation of human capital.

Second, the state in a full democracy might be more willing to invest resources in human capital because it would be to the advantage of the voters to increase their access to educational facilities. A partial democracy, such as Wilhemine Germany, also invested in large-scale education (Locke 1984), but the democratic nature of the U.S. was important in the establishment of universal education. It may be that full democracy increases the likelihood that appropriate state resources will be directed towards the creation of human capital.

Third, as my ninth hypothesis of economic systems states, in part, "the free flow of people and ideas is an important determinant of technological innovation." There is an increased likelihood that these rights of travel and discussion will be universally applied in a full democracy than in a partial one. These three possible beneficial effects of a fully democratic political structure all indicate that full democracies may be particularly effective in increasing the creation of human capital.

Thus, the twentieth century witnessed the introduction of many variations in the nature of a domestic system of political economy. The totalitarian variation disappeared, as did the older, monarchical one, in the major countries, although they persist in smaller nations. A fully democratic political structure has become dominant, whether or not it is more efficient than a partial democracy. More research is needed to determine whether full democracies are more efficient, as well as to determine whether monarchical systems disappeared as a result of inefficiencies.

Each stage in this evolutionary process – internal balance of power, optimal size, full industrialization, and twentieth century innovations – resulted in a different environment for the Great Powers (as well as other nations). When several Great Powers created or imitated these adaptations, the others were forced either to adapt or fall out of the set of the Great Powers. Except for time periods when the totalitarian nations were experiencing absolute decline, *relative* rise and decline during the modern period depended on the relative performance of growing, expanding nations.

As proposed in the sixth hypothesis of political economy, "the most important single cause of the relative rise of a Great Power (or any nation) is the growth of the production system." What, then, determines the relative performance of national production systems?

The Relative Rise and Decline of Production Systems

In chapters 5 through 9, I proposed several hypotheses which can be used to address various questions concerning the performance of a domestic system of political economy. By using these hypotheses, it will be possible to construct a framework for understanding the relative rise and decline of production systems and therefore for better understanding the rise and decline of Great Powers.

The first factor affecting the rise of production systems is the fact that some Great Powers have more complete production systems than others. As I proposed in hypothesis six concerning economic systems:

> A complete production system is greater than the sum of its parts; both the stages and categories of production participate in a mutually self-reinforcing, positive feedback process of production and technological change. There is a negative feedback process within a complete production system because there must be a balanced pattern of growth among all niches.

Therefore, a Great Power with a relatively more complete set production system niches would have a greater potential for rise than a Great Power with fewer niches. Most nations do not possess all machinery niches, because they usually import at least some of their machinery. Therefore, a nation with a larger percentage of machinery niches would have a greater potential for rise than a nation with a smaller percentage.

The state can play a role in making a production system more complete. The state might attempt to create an entire industrial sector, by using a combination of subsidies, protection, incentives, and development of the appropriate human capital facilities. The state might also try to increase the percentage of a niche contained within the nation through a process of import substitution.

Another role the state can play is to create a larger physical space within which to embed a complete production system. Historically, states have done this either by conquering other polities, such as occurred in the takeover of North America by the United States, or by a voluntary conglomeration, as in the case of the European Union. At some point, as in the case of the United States, the vast majority of inhabitants must be not simply dominated but integrated into the production system in order to achieve optimal productivity.

The second factor in the relative rise of a production system involves the relative technological impact of various parts of the production system. I argued previously that reproduction machinery industries are the most important sectors for the long-term growth possibilities of a nation, with production machinery industries being almost as important. Yet, these machinery sectors are very small and therefore may have difficulty attracting enough investment from the financial system. The state can work with other sectors of the economy in order to encourage the machinery sectors, as the Japanese agency MITI has done (for example, Kodama 1995). The state can support human capital formation, as in the case of German technical institutes and apprenticeship programs, usually also in association with other economic sectors. Finally, the state occasionally directly invests in machinery development, as noted previously in the case of U.S. government support for machine tools.

Thus, there are several factors which affect the relative position, and potentiality of rise of a nation, based on the quality and quantity of production system niches. Because of the positive feedback of benefits among all production system niches, completeness is desirable. Because of the greater causal capability of reproduction and production machinery niches, and because of their vulnerability, particular care concerning these sectors would have a greater than average return for the resources devoted to their performance.

There is also a set of factors affecting production systems which concern the capital systems of a production system. In particular, a nation can increase the rate of growth by increasing innovational activity, particularly in the most important production system niches. As I claimed in the eighth hypothesis on economic systems, "Innovations depend on the level of resources directed toward the innovators, in the form of income, educational facilities, and research/work facilities."

Researchers, engineers, and skilled production workers (including operational managers) are the components of human capital within capital subsystems within the production system. They generally need a relatively high standard of living, because otherwise these highly educated workers would gravitate to other professions. They need a very long training period, and this time period requires support, often from the state. The laboratories, design facilities, and factories in which these people work need to be supplied with resources, and may require constant upgrading as technology progresses. All of these requirements can be measured, in terms of income received, years of schooling and training, and money spent on facilities.

Nations that provide more support for human capital development should have a larger output of technological innovation than nations that provide less support. But by following the model of the production system as elaborated in this study, it should be possible to look at the levels of support of *particular* sectors, not simply support for the economy as a whole. Following the hypotheses of the above discussion, innovational support in the reproduction and production machinery niches should result in the highest return to national investment.

Innovation requires more than support in terms of resources; part of the cause of innovation is production, or innovating-by-doing. Therefore, the relative success of a nation in constructing a full complement of niches, and in supporting the production system in general, will also be an indicator of future innovational activity. In turn, more innovations will provide an incentive to support the production system, because the promise of greater productivity will tend to bring forth greater investment, in particular from the financial system. The performance of the production system and the level of innovational activity therefore operate as a positive feedback loop. A nation with a stronger link between the worlds of production and innovation will therefore rise more rapidly than a nation with a weaker link.

This linking of innovation and production is reinforced if the free flow of information and access is encouraged, as claimed in hypothesis nine concerning economic systems. The state can constrain itself from interfering with such access, a task which totalitarian states find difficult. The state can also provide the resources for travel and communication, as the United States government provided in the case of continental transportation and communication systems, such as the railroads, interstate highway system, airport facilities, and the initial development of the internet. The production system itself can encourage access and free flow when communications and information technologies advance. The existence of a healthy means of production, the resources made available to human capital workers and facilities, and the enabling of travel and communication, can all operate in a beneficial positive feedback loop to encourage innovation-by-doing.

Thus, a rising nation or Great Power will have more powerful production systems and more innovational activities occurring within its borders than most other nations. Those borders are themselves important, because as I hypothesized earlier:

> There is some territorial size for a system of political economy, which is both big enough to encompass all niches of a production system, but small enough to allow for intense interactions among the human capital workers who are responsible for the output and development of those niches.

For the United States, the territorial size of the nation was conducive to the interaction of human capital workers, to constructing a complete production system, and to protection on the part of the national government. The European Union has reaped many of the rewards of proper size throughout its history, starting as the European Coal and Steel Community in the 1950s. Are most other nations too small? Would they benefit from merging together? These questions arise as a result of the model presented in this study, and would be a fruitful avenue of future research.

Many variations of the basic model of the modern nation exist today, involving an internal balance of power, varying sizes, varying compositions of their systems of political economy and production, and varying distributions of power within the nation. Nations continue to evolve. By using the framework as presented in this study, it should be possible to explain the trajectory of the past, the comparative positions among nations in the international system in the present, and many of the possible paths for particular nations in the future.

I have now elaborated a set of theories of particular systems with the goal of understanding the processes underlying the rise and decline of Great Powers. During the course of this presentation, I have generated many hypotheses that can be used to test the usefulness of this framework. In the next chapter I will discuss my conclusions and present my framework and hypotheses in summary form.

CHAPTER 11

CONCLUSION AND SUMMARY

This study had the goal of constructing a theory with which to understand the relative rise and decline of Great Powers in the industrial era. After reviewing the economic and political science literature, I concluded that existing theories of rise and decline are lacking for deficient major reasons.

First, a logically consistent definition of a Great Power does not exist. Even though Great Powers are the most important nations in the international system, there is no measure that can be used to distinguish between Great Powers and nonGreat Powers. By carefully constructing measures of power, I proposed methods of determining the set of nations that are the Great Powers.

Second, theories of rise and decline of nations in general rely on the concepts of property rights, diminishing returns, and technological change that are not capable of explaining the phenomena of variation among nations through time. In the case of property rights, both Robert Gilpin and Douglass North use historical examples that would indicate the greater importance of the political distribution of power within a nation.

Both Gilpin and North also continually refer to technological change as an important factor for growth, as do neoclassical economists. In the case of the concept of technological change, the problem is not that the concept does not have the potential to be a powerful explanatory variable; the problem is that technological change becomes an exogenous force that cannot itself be explained or accounted for.

Finally, both Gilpin and the neoclassical growth economists assume that the concept of diminishing returns is an important one for explaining economic phenomena. However, it is impossible to explain why something increases, as in the case of economic growth, by referring only to a concept that involves decrease, as in the case of diminishing returns. As Solow showed, technological change must be invoked in order to overcome the contradiction, but neoclassical economists have not been able to explain technological change.

Scholars are led to the door of technological change without entering the house. The reason for this reluctance is that these scholars do not attempt to explain or explore the realm of production because they focus on the nature of exchange. By contrast, this study focuses on the processes of production, and by doing so, is able to explain technological change, and thereby rise and decline, in a more satisfactory manner than before.

In order to explain production and its role in the international system, it is necessary to confront the problem of the complexity of social systems. Gilpin, North, and the neoclassical economists attempt to simplify reality by assuming a system of homogeneous elements, which can be described according to aggregate behavior. This methodology was originally inspired in the nineteenth century by the fields of classical and statistical mechanics in physics. However, the field of biology and its several subfields, as well as other historical sciences, have fruitfully applied a methodology of looking at their domains of reality as made up of a hierarchy of systems. These systems are made up of components that are not homogeneous, but heterogeneous. When a system is heterogeneous, it is necessary to disaggregate the various measures of the system. Each of these different kinds of elements in such a system often fulfill different kinds of functions within the system. I constructed a general model of systems, based on the work of international relations theorist Kenneth Waltz, that stressed the different functions that different parts of a system may perform.

Adding to Waltz's model, I proposed that some systems *allocate* the output of a system, and some systems *generate* that output. The work of economists (and Waltz) concentrate on the allocational aspect of systems. In order to understand production, however, it is necessary to concentrate on the generative aspect of systems. Systems that generate contain stages or steps in a sequence or cycle of elements, each element fulfilling a separate function in the process of generating output. By contrast, allocative systems contain similar elements which can be measured according to one standard. A system containing both a generative and allocative subsystem, therefore, includes both a set of elements which are different, and an output which can be measured and allocated according to a standard of measure.

A generative system often contains a tripartite structure, that is, there is a *metagenerator* stage that generates itself, a *generator* stage that uses a metagenerator to create generators, and an *output* stage that uses a generator to produce output. Because of the metagenerator stage, exponential growth is possible. Thus, there is a positive feedback process within generative systems that accounts for the growth of many systems. Negative feedback operates in a generative system by requiring the balanced growth of all components.

By contrast, an allocative system contains a possible positive feedback process in which one element or set of elements controls or comes to contain more and more of the other elements. In an allocative system, negative feedback operates by preventing this snowballing accumulation by any one element or set of elements.

Thus, to understand a system, one must understand the systems that are the elements of the system under consideration, one must find a measure that is common among all elements of the system, the functions (including generative and allocative functions) must be determined, and the positive and negative feedback processes must be ascertained.

In addition, some elements in a system have greater capability to cause change than other elements. The process of growth is nonlinear; that is, a change in one element may have a greater than proportional impact on the other parts of the system. When change in an element in a generative system creates greater change in the system as a whole than change in other elements, the element has greater causal capability, according to my theory of systems.

By focusing on the generative function, the concept of time becomes important, because a sequence or cycle orders elements in time. Because of the explicit integration of the concept of time in the definitions, the discussion of change within systems becomes easier. By contrast, neoclassical economists and social scientists in general are often more interested in equilibrium, which directs attention to static phenomena, than change. Since rising and declining are processes of change, a methodology in which change remains central is appropriate.

The theory of a system was used as a template to construct theories of particular systems of interest, and in particular, theories of political systems, economic systems, and systems of political economy. In turn, these particular theories of systems were used to generate hypotheses. By conceiving of reality as a hierarchy of systems, the complexity of social systems can be simplified enough to aid in comprehension, while retaining the detail required to understand the system as a whole.

In order to understand a complex social reality, there must be some criterion for dividing that reality into categories. I chose material categories, and thus the political domain encompasses control over space through time, while the economic domain encompasses the transformation of matter/energy through time. The political economic domain therefore encompasses all of material social reality.

A domestic political system contains a generative subsystem, the state, which has a tripartite structure. The state elites generate themselves, and are used to generate the bureaucracy, which generates the final output, the means of violence. Control is allocated within a polity monopolistically by the state.

An international political system, on the other hand, has no generative subsystem, and is equivalent to Waltz's conception of an international system, that is, it is an allocative system. I gave a definition of a Great Power that can be used to understand an international political system: Great Powers, collectively, control the reallocation of territory within the international political system.

An economic system, like a domestic political system, contains a generative subsystem. This subsystem generates the goods and services of an economy, while the allocative subsystem distributes those goods and services. The generative subsystem of an economic system I called a production system.

Understanding the production system is the key to understanding technological change as well as the capabilities upon which national power is based; and therefore the production system is the single most important cause of the rise and decline of Great Powers. In neoclassical economics and much of the scholarship in political science, the production system is considered to be a homogenous mass of capability, with no useful distinctions among its parts. The production system is considered to be a "black box." The intention of this study is similar to one expressed by Nathan Rosenberg, in the preface of his seminal work on technology and economics, *Inside the Black Box*: "The purpose of this book is to break open and to examine the contents of the black box into which technological change has been consigned by economists" (Rosenberg 1982, vii). This study has also examined the contents of the black box into which *production* has been consigned.

In order to undertake this endeavor, I examined the inner workings of the production system. First, I identified four categories of production – structural, material, energy-converting, and informational. Every technology can be categorized into one these categories of production. Production requires all four categories, and they are mutually beneficial. Thus, technological advance in one category reverberates throughout the other three, and then back to the first category.

Second, I identified a tripartite generative sequence within the production system. In the reproduction machinery stage, classes of machinery are produced using those same classes of machinery, such as machine tools, steel-making machinery, electricity-generating turbines, and semiconductor-making equipment. These reproduction machineries are metagenerators, as defined above. They are used in the next stage, the production machinery stage, to make production machinery, which is used in the next stage, the final production stage, to make the goods and services that people use.

The reproductive nature of reproduction machinery gives industrial economies great economic power to generate goods and services through time. Because these machines reproduce themselves, economic growth has been exponential since the start of the Industrial Revolution. They enable a positive feedback process of growth to occur. Any technological change that occurs in the reproduction machinery sectors has a greater impact than any other change in the production system. Changes in the production machinery sectors are the second most important kinds of changes in the production system.

By combining the four categories of production with the three stages of production, I modeled the production system as containing twelve production system niches, presented in a diagram called a production matrix. If a production system contains all of these niches, it reaps the benefits of the positive feedback processes within both the stages and categories of production.

The production system is composed of niches, and each niche contains, among other factors of production, a capital system. This capital system is also a tripartite generative sequence. Researchers add to a stock of knowledge, and teach more researchers. Researchers and the stock of knowledge are used in the next stage to produce engineers, who use the stock of knowledge to design machinery. Skilled production workers and operational managers use these designs to build the machinery which constitutes the physical capital, along with physical structures and natural resources, which is used to generate the output of all of the niches of the production system.

These human capital workers – researcher/teachers, engineers, and skilled production workers – are the agents of technological change. Support for their efforts, in the form of resources and access to one another, is critical if technological change is to occur. These people are constantly innovating-by-doing, creating new methods of production by being intimately involved in the production process itself.

One of the most important functions of an explanatory framework, such as the one offered in this study, is to direct the attention of scholars to particular sets of phenomena that the framework leads the scholars to conclude are among the most important phenomena. In this study, the role of human capital workers has been emphasized. These professions, and especially the engineers and production workers, are only rarely examined. In addition, the literature on technological innovation has tended not to be based on a solid understanding of the crucial role of production in the innovative process.

By constructing a systems-based framework, it was possible in this study to construct a useful measure that can be applied across all of the elements of the production system. I devised three such measures – expenditure, value-added, and capital assets measures. Using these measures, I diagrammed a tripartite input-output model, which can be used to simulate a production system. The capital assets measure is the most important measure, because physical and human capital is the generative substance of a production system.

Thus, by using my theory of systems, I have been able to construct a theory of production that both models the complexity of production and allows for comprehension and analysis. Technological change is not a homogenous entity; it is specific to its position in the system of production, and its influences and influence are dependent on the structure of the system of production.

Once the production system is specified, several aspects of the rise and decline of Great Powers become manageable. The rest of the economic system, the retail/wholesale and financial systems, are used to allocate that which the production system generates. The domestic system of political economy, or nation, is composed of an economic system, the state as specified in the theory of political systems, and the population. The economic system has the function of transforming matter/energy, and the political system has the function of controlling the space. The economy needs the state for protection and enforcement of laws, and the state needs the economy for the resources with which to operate. A nation is therefore composed of two functions, the economic and political, which are mutually reinforcing.

A critical class of machinery that is constructed by reproduction machinery is destruction machinery, or military equipment, which is used by the state to control its territory and to either project power against other nations or protect itself against military force. Destruction machinery can only exist in the realm of political economy; it is neither purely political, because it is a produced good, but it is not purely economic, because its purpose is to control space.

The concept of a domestic system of political economy is based on the concepts of its components, which are themselves systems. Since destruction machinery is critical in a political system, and reproduction and production machinery are critical in the economic system, within a system of political economy capabilities can be measured by accounting for all three kinds of machinery. The distribution of capabilities among nations can be measured in several ways, all based on the capital assets that are contained within the territory of a nation. In other words, the power of a nation is based on its human and physical capital.

The Great Powers of the industrial era have been those nations that have collectively controlled the change in allocation of territory because the Great Powers are those nations that have controlled, within their territories, the global reproduction, production, and destruction machinery niches. This is my fourth hypothesis of systems of political economy. This definition is made possible because of the theories of systems which preceded its introduction. It is therefore built on a solid theoretical base and can be measured, unlike the definitions of a Great Power catalogued in Chapter One.

By constructing a standard measure of political economic capabilities, it is possible to understand some of the processes of the international system of political economy. If the power of a nation is stronger than one of its neighbors, it may attempt to conquer that nation and integrate its production system into its own. Thus empowered, the conquering nation has a greater capability to conquer yet more nations, and so on, until a balance of power forms. This snowballing accumulation of power is the manifestation of the positive feedback process that is possible within the international system, and has accounted for much of the state formation of Great Powers throughout history.

The political economic power of a Great Power has generally risen since the advent of the modern nation. In a modern nation, there is a balance among its subsystems, that is, the state, the production system, the financial system and the population. Because of this balance, a negative feedback process operates such that the state, financial system and population are unable to deplete the nation to the point of absolute decline. Instead, decline has generally been relative. This is because, unencumbered, the growth-enhancing positive feedback processes within a nation are very powerful.

The positive feedback processes of the production system are the engine of growth upon which rise ultimately depends. The financial system forms a positive feedback loop with the production system, ideally recycling resources into the appropriate sectors of the production system. The state then forms a positive feedback loop with the entire economic system, feeding resources and management into the economic system.

This balance is made possible by at least a partial control of the economic system over the state in the form of some sort of democracy, and a management of the state over the financial system. Without this balance, the state has the power to deplete the production system to the point of absolute decline, as occurred in totalitarian systems of political economy.

Great Powers have evolved over the centuries in terms of the structure of their domestic systems of political economy. Starting with a partial democratic system, they have also had to grow in size so that all the niches of a production system can be contained within the nation, usually in the form of a nation-state. They have had to industrialize in order to survive in an industrial international system, and the state has become involved in the management and maintenance of the production system which makes industrial power possible.

As the Great Powers have evolved, so have all the other nations, which have either adapted or been conquered and dominated. The process of rise and decline continues, as the structures and processes of the production systems, capital systems, political systems, and systems of political economy are changed through constant innovation of the elements of the system.

This system of systems, as proposed in this study, provides the opportunity to model the processes of rise and decline as they occurred in the industrial era. Standards have been proposed with which to measure the relative power of nations and Great Powers, and with which to simulate the operation of particular systems, such as capital system, the production system, the economic system, and the domestic system of political economy. It is also possible to simulate the international processes of political economy using the measures and system models as developed in this study.

In order to model the complexity of the processes of rise and decline, I started by conceiving of reality as being divided among levels, as a hierarchy of domains. Each level is composed of elements which exist at level below; thus, the concept of a hierarchy of domains led to the concept of systems composed of elements. A system composed of elements, in turn, can be functionally differentiated, since the elements can encompass different functions. Once there is functional differentiation, it is possible to conceive of sequences through time composed of the functioning of different elements. Production can therefore be modeled, because production must occur in a sequence of functionally differentiated steps through time. Once production occurs, reproduction is possible, because reproduction is the production of a class of objects by a similarly produced class of objects. Therefore, a positive feedback, exponential process is possible, and therefore growth in general can be explained.

Economic growth leads to absolute national rise, and those nations and Great Powers that grow faster rise relative to those which grow more slowly. This study has proceeded through the following conceptual sequence in an effort to understand rise and decline: Levels of systems → elements within systems → functional differentiation of elements → sequence of functions → production of output → reproduction of generators → positive feedback processes → growth of systems → relative rise of elements (Great Powers) within a constantly evolving system (the international system of political economy).

The most important single cause of the rise of a Great Power (or any nation) is the growth of the production system (as I claimed in my sixth hypothesis about systems of political economy). The most important single cause of the rise of a production system is the growth of the reproduction machinery niches, the production machinery niches, and the final production systems, respectively. The growth of these stages of production must all occur within an environment of the balanced growth of the structural, material, energy-converting, and informational categories of production. The single most important cause of the growth of these niches (as well as others) is the performance of their capital subsystems, which are based on the human capital workers. In order of importance, these human capital workers are researchers, engineers, and skilled production workers (including operational managers).

The financial system is indirectly important because of the way in which the financial system redirects resources back into the production system. The state is indirectly important because of the protection it offers to the economic system as a whole and because the state manages the various subsystems of the economic system, most critically the production system. Finally, rise and decline of a particular nation or Great Power is relative to all of the other nations or Great Powers of a particular period of time. The international system is a cause of rise or decline because of the opportunities or constraints existing in its structure, and the actions taken by the leaders of nations within the context of that structure.

A framework has been established with which to explain the causes of the relative rise and decline of Great Powers in the industrial era. Further research is needed to validate the hypotheses advanced in this study, so that this framework may be used as an alternative to the theories offered by scholars in the past. Clearly, this new research should focus on the processes by which nations enhance their power to create wealth.

Summary of System Theories

This section is provided as a reference for the concepts developed in the previous chapters. In particular, this section records the particulars of the various systems and hypotheses proposed.

Part 1: Systems

Because the causes of the rise and decline of Great Powers are very complex, it was necessary to construct a theory of systems which could be used to construct theories of particular systems.

A system was described as being composed of the following (from Ch. 4):

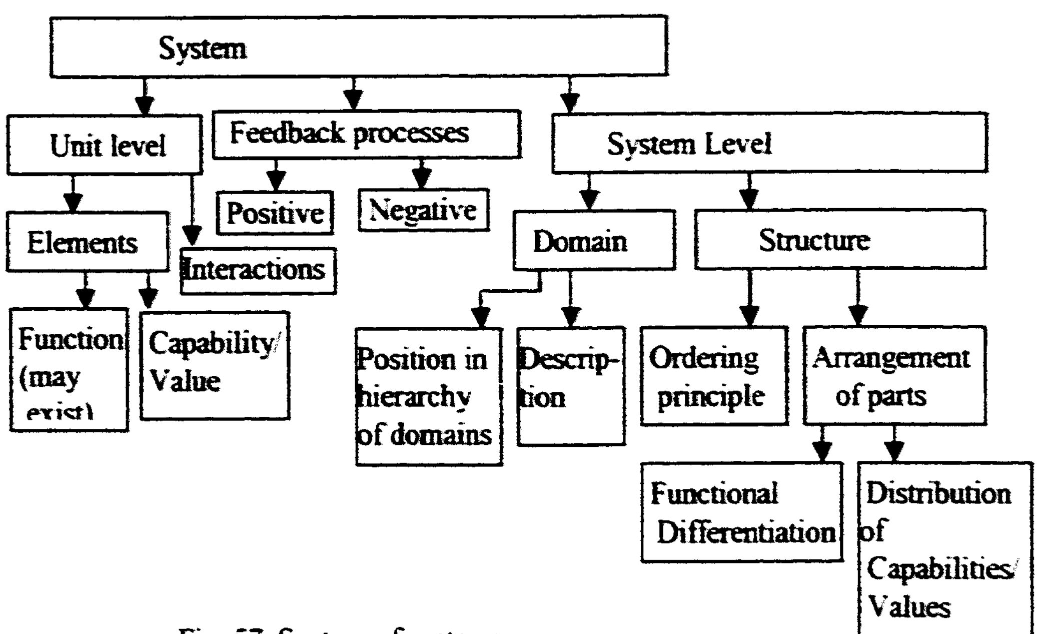


Fig. 57. System of systems.

By conceiving of reality as a hierarchy of domains, I was able to divide social reality into a system of systems, with the following structure:

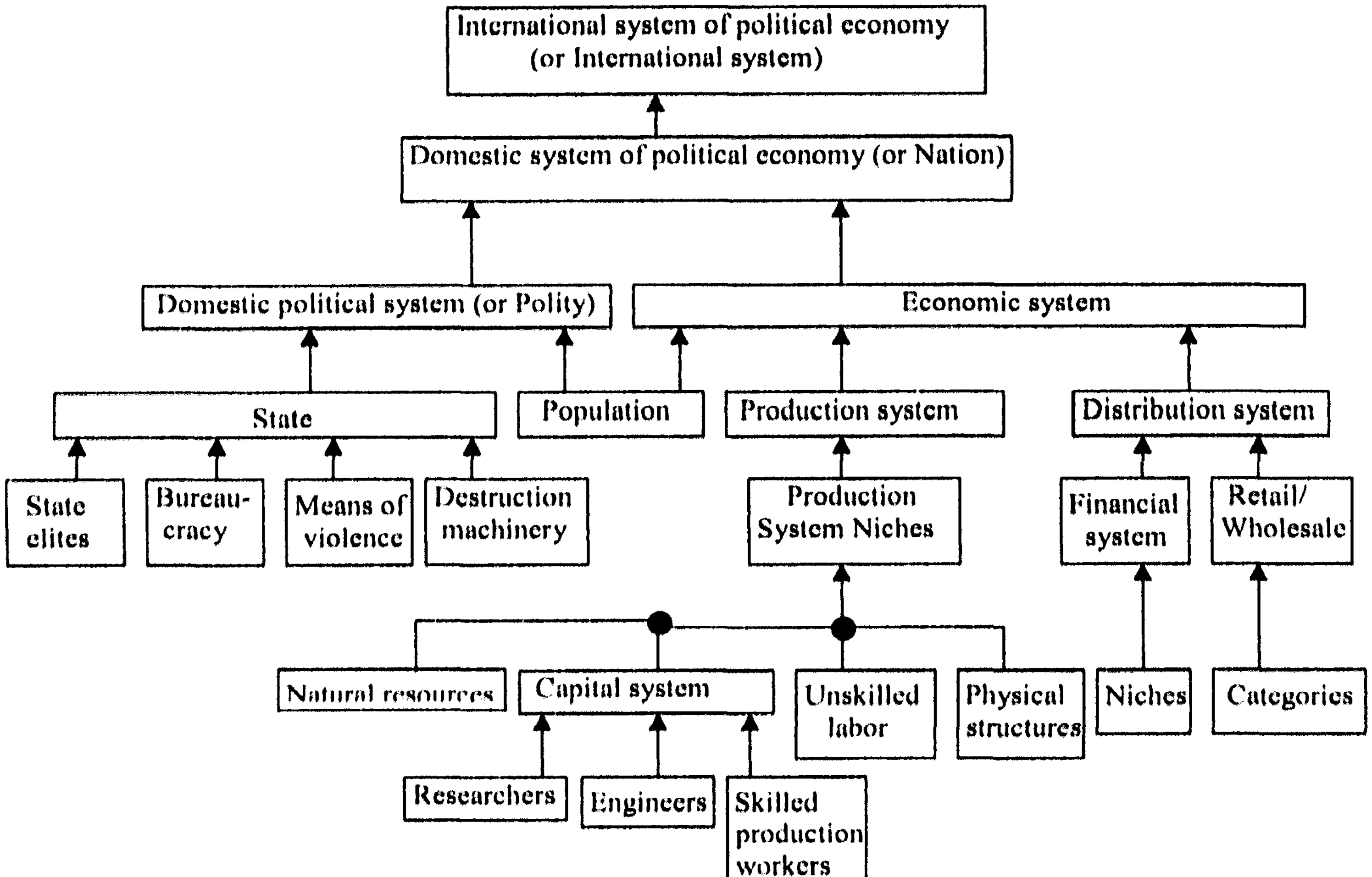


Fig. 58. Full specification of hierarchy of political economy.

There are seven levels in this hierarchy of domains. Each component, except at the top and bottom, are both systems at one level and elements of a system at the level above. The system of the international political economy is the top level, which is made up of elements which consist of domestic systems of political economy, in other words, nations. Nations are composed of two subsystems, a political subsystem and an economic subsystem; this is the level of social subdomains. Below political and economic systems we have the level of domestic political economic *systems*. Below these are *subsystems* of domestic political economy, such as the production system and the state. The next two levels are, for the most part, specific to elements of the production system: first, the factors of production compose every element of a production system; second, the capital system, which is a factor of production, is composed of human capital workers.

Since most components of the hierarchy of domains are systems, and each system, as shown on the first diagram of this chapter, is composed of many systemic elements, a large number of systemic elements have been presented in chapters five through eleven. In the next two pages, I present tables which state the various elements of most of the systems discussed in this study. I indicate the following aspects of the system: whether the system is allocative, generative or both; what kind of ordering principle or principles may be used (cycles and sequences are the two types of ordering in time, and "func set" is an abbreviation of "functional set"); in the case of a functional differentiation among elements, the types of elements are listed, and if there is no functional differentiation, only the one type of element is shown; the measure of the distribution of capabilities; the causal capability of the elements; the description of the domain of the system; the positive and negative feedback process or processes at work; and finally, the definition of power for a system, if applicable.

Table 7. Systems Presented in this Study and their Elements, Part 1

System	Allocative/ Generative	Ordering Principle	Elements (Functional Differentiation)	Distribution of Capabilities/Values	Dist of Causal Capabilities
International Political Economy	Allocative/ Generative	Anarchy Space Func Set	Nations	Control over national niches in terms of capital assets	prod/reprod/ destruct machinery (Great Powers)
International Political System	Allocative	Anarchy Space	Polities	Population within a territory	Control over re-allocation of territory (Great Powers)
Domestic Political Economy	Both	Cycle	National niches or financial, production, state	Control over human, machinery, and natural assets	Production: reprod, prod, destruction mach
Domestic Political System	Both	Hierarchy, Space, Cycle or Sequence	State,Population, Constitution	Control over choice of state elite	State monopoly
State	Generative	Hierarchy Space Sequence	Tripartite – State elites, bureaucracy, means of violence Destruction mach	State elite	State elite
Population	Generative	Sequence	People	Equal	None
Economic System	Both	Cycle	Production system, distribution system, population	Value-added or expenditure or capital assets	Production System, distribution system, population
Production System	Generative	Func Set Sequence	Tripartite – 12 niches	Value-added or expenditure or capital assets	Position in sequence
Niche	Generative	Func Set	Factors of production	Contribution to technological change	Capital System, Physical Structure, Unskilled Labor, Natural resources
Capital System	Generative	Sequence	Tripartite – Research, Engineer, Worker	Contribution to technological change	Researcher, Engineer, Worker
Distribution System	Allocative	Func Set	Financial System, Retail/Wholesale	Control over Prod System output	Financial System
Financial System	Allocative	Func Set Sequence	Mirrors Production System 12 niches	Control over Capital assets	None
Retail/Wholesale	Allocative	Func Set	4 Categories of Prod	Value-added	None

Table 8. Systems Presented in this Study and their Elements, Part 2

System	Domain Description	Positive Feedback	Negative Feedback	Power (capability/value of element)
International Political Economy	the generation and allocation of capital assets of niches among system's nations	Snowballing accumulation of power	Balance of power	Assets controlled by a nation in the particular niche of a nation (including itself), in terms of capital assets
International Political System	The allocation of territory among polities	Snowballing accumulation of power	Balance of power	Same as domestic
Domestic Political Economy	The generation and allocation of control over, and goods and services for, a nation through time in a self-reinforcing cycle	Mutual benefits of economic/political systems	Need balanced growth	The capability to control production/destruction assets (& votes in a democracy) within a national niche in a particular period of time.
Domestic Political System	The generation and allocation of control of a population within a particular territory through time	Lock-in of dictatorship or democracy	Balancing coalitions	Political power is the capability to control a certain population within a certain territory in a particular period of time
State	The generation of control of a population within a particular territory through time	Lock-in of state elite	Factions	Military power is the capability to project a particular amount of armed force over a particular distance in a particular period of time.
Population	People residing in a particular territory	Biological reproduction	Malthusian checks	
Economic System	The transformation and allocation of configurations of matter/energy through time, using production technologies.	Mutual reinforcement among subsystems.	Necessity of balanced growth of all subsystems	The capability to generate goods and services, diffuse productive innovations, and move the resulting goods and services a particular distance in a particular period of time.
Production System	The transformation of configurations of matter/energy through time, using production machinery	Exponential growth	Balanced growth among niches	The capability to process and output a certain quantity of goods (or value-added) in a certain period of time
Production System Niche	The position or function of certain production technologies in the structure of the production system.	Exponential growth of capital system	Balanced growth among factors of production	Technological power is the capability to propagate, directly and indirectly, a greater ability to generate value-added throughout a particular economic system, in a particular period of time
Capital System	The generation of machinery	Researchers as teachers	Balanced growth	Same as Production System Niche
Distribution System	The allocation of goods and services.	Accumulation of capital assets	Need prod system & state	the capability to move a particular amount of previously produced goods and services a distance in time.
Financial System	Allocation among niches	Same as distribution	Same as distribution	Same as distribution system

Part Two: Hypotheses

The theory of systems, as shown in chapter 4, yielded many systemic elements which were used to construct theories of specific systems, as shown in the previous two pages. Thus, my theory of systems was used to generate theories of specific systems. In turn, I used the theories of political, economic, and political economic systems to generate many hypotheses. The following summarize these hypotheses, which are numbered for each system:

The following are the hypotheses about political systems:

1) A dictatorship will impose greater violence on the population than a democracy.

2) Great Powers are those polities that, collectively, control the change in the allocation of territory and the associated resources among polities

3) A balance of power is a reaction to a positive feedback process in an international system

4) Most large polities have been created as a result of the positive feedback process of conquest, and many wars are caused by this process.

The following are the hypotheses about economic systems:

1) There is a positive feedback process of technological change among the four categories of production

2) It is because of the ability of the reproduction machinery to be mutually causative and reproductive that economic output has increased exponentially since the advent of the Industrial Revolution

3) There is an ordering of the capability to cause technological change within the production system which reflects the sequence of stages of production, from reproduction machinery as the most powerful source of technological change, to production machinery as less powerful, and to the final production stage as least powerful

4) There is an inherent contradiction between the causal capability of machinery industries and their relative capabilities as measured by expenditure or revenue generation, and because of this discrepancy, industrial economies are in constant danger of suboptimal technological change

5) Nations rise economically by moving up the stages of production in terms of competence, from production to production machinery to reproduction machinery. Nations decline by moving down those same stages of production, first losing competence in reproduction machinery, then in production machinery, and lastly in final production.

6) A complete production system is greater than the sum of its parts; both the stages and categories of production participate in a mutually self-reinforcing, positive feedback process of production and technological

change. There is a negative feedback process within a complete production system because there must be a balanced pattern of growth among all niches.

7) Part of the cause of innovation is production, or innovating-by-doing.

8) Innovations depend on the level of resources directed toward the innovators, in the form of income, educational facilities, and research/work facilities

9) Innovation is encouraged by the wide distribution of access to the various forms of capital, be they the stock of knowledge, designs, or machines, or their human counterparts, researchers, engineers, and skilled production workers. In other words, the free flow of people and ideas is an important determinant of technological innovation

10) As a production system of a nation continues to grow and generate more and more output, more and more economic power accrues to the financial system because the financial system is able to control a larger and larger amount of output

The following are the hypotheses about systems of political economy:

1) A Great Power must have a complete system of political economy, or it will cease to be a Great Power

2) Great Powers must possess the productive resources necessary to generate a large enough quantity of military power necessary to fight effectively in a war involving all Great Powers.

3) Because of the importance of reproduction machinery for the creation of destruction machinery, and the importance of final production goods and services in order to feed and cloth the armed forces of the nation, the state has generally had a motivation to recycle resources back into the production system

4) The Great Powers of the industrial era have been those nations that have collectively controlled the change in allocation of territory because the Great Powers are those nations that have controlled, within their territories, the global reproduction, production, and destruction machinery niches

5) There is a distribution of political economic causal capability within the machinery sectors of the nation, from reproduction machinery niches to production machinery niches to destruction machinery industries, respectively

6) The most important single cause of the rise of a Great Power (or any nation) is the growth of the production system.

7) The establishment of the modern state prevented the depletion cycle from leading to absolute decline; nations with a modern state do not decline absolutely, they only decline relatively. Modern nations usually rise absolutely because of the expansion cycle.

8) Partial to full control by the economic system over the choice of some or all state elites, plus partial control of the state over the financial system, results in a situation that allows for the dominance of the expansionary cycle within a nation.

9) There is some territorial size for a system of political economy, which is both big enough to encompass all niches of a production system, but small enough to allow for intense interactions among the human capital workers who are responsible for the output and development of those niches.

STATISTICAL APPENDIX

Introductory Discussion

This statistical appendix will attempt to prove the validity of the hypothesis, put forth in chapter 10, that "the Great Powers of the industrial era have been those nations that have collectively controlled the change in allocation of territory because the Great Powers are those nations that have controlled, within their territories, the global reproduction, production, and destruction machinery niches". I will assume the validity of a further hypothesis, that "there is a distribution of political economic causal capability within the machinery sectors of the nation, from reproduction machinery niches to production machinery niches to destruction machinery industries, respectively". Therefore, in this appendix I will present data concerning production and reproduction machinery industries, with some reference to destruction machinery industries.

The data to be used are based mostly on value added for the machinery industries, because most international data reports value-added. Some of the data are in gross output. Gross output is the final value of the machinery. Value-added is a measure of the value that is added by the machinery industries to goods that are used by the machinery industries but that do not originate with the machinery. The steel industry, for instance, creates the steel that is used by the machinery industry. When machinery is measured by gross output, the steel is included in the measure. When machinery is measured by value-added, the steel is not included.

In the following pages, I will construct a series of snapshots of the distribution of global machinery capability among nations in a particular year or series of years, using various sources. In addition, I will postulate a specific set of Great Powers for each time period discussed. At the end of the appendix, I will present graphs which will link all data points.

Three different categories will be used. Ideally, I would present data that showed disaggregated industrial output. In this way, I could construct series for machinery which was specifically reproduction, production, or destruction machinery, as described throughout this study. Instead, I will use data which are available from international agencies for the following categories:

1) For reproduction machinery, I will use data concerning machine tools. The American trade journal *American Machinist* calculated world production of machine tools starting in 1966. U.N. and other organizations regularly use the *American Machinist* data when discussing the global machine tool industry.

2) For production machinery plus reproduction machinery, I will use data, mostly from the U.N., concerning what are called the ***nonelectrical machinery*** industries. Starting with the International System of Industrial Classification, revision 2, in the 1960s, this category has the numerical label of 382. These types of machinery cover almost all of what I have labeled as the reproduction and production machinery industries. However, this category also covers military equipment such as tanks, artillery and guns, and some consumer machinery, such as

washing machines and refrigerators. To some extent, then, this category encompasses destruction machinery as well. I will refer to this category as ***nonelectrical machinery***.

3) The broadest category of machinery, which encompasses all forms of machinery, is called the metal products or engineering industries. The International Standard Industrial Classification (ISIC), Revision 1 included the categories 35 through 38 in metal products industries, and the U.N. regularly used this category in its reports. The metal products industries include metal products fabrication, non-electrical machinery, electrical machinery, transportation machinery, and precision instrumentation. These are the categories used for the data for 1948, 1953, and 1958. All of these categories became category 38 in Revision 2 of the ISIC, which will be used for the data for 1963. I will also refer to the category without metal fabrication as *general machinery*. I was able to restrict data to general machinery starting in 1970.

Data for the Soviet Union are particularly difficult to obtain. At times, as I will explain, it is necessary to calculate the Soviet share of world production of the various categories by making various assumptions and using auxiliary data sources.

The data will be presented for 1913 and 1925, 1938, World War II, 1948, 1953 and 1958, 1963, 1970 and 1975, and 1980, 1985, 1990, and 1995. The charts will use all years as data points, except for World War II, according to availability of data for particular categories of machinery.

1913 and 1925

In May 1927, the League of Nations held an International Economic Conference. As part of that conference, Dr. Karl Lange presented a memorandum on behalf of the German Machine Builders' Association (VDMA are the German initials). This memorandum discussed the state of the "mechanical engineering" industries, by which he meant the classes of machinery I have called nonelectrical machinery above. As Lange put it, however, "Owing to the inadequacy of the available statistical material, it is exceedingly difficult to compare the situation and development of the various branches of industry in the different countries" (League of Nations 1927, 58). Particularly before World War II, most international statistics dealt with easily comparable commodities such as oil and wheat. As the journal *Mechanical Engineering* put it at the time, the data "include what is understood to be the first analysis of the machinery industry of the world that has ever been published" (*Mechanical Engineering*, 1928, p.285).

The main finding of Lange's work is that the United States was dominant in world production. In 1913, the U.S. produced 50% of the world's machinery, and in 1925 the U.S. output comprised 57.6% of world production.

The following table shows Lange's findings (League of Nations 1927, 11):

Table 9. World Machinery Production in the Early 20th Century

1913 output		1925 output	
U.S.	50.0%	U.S.	57.6%
Germany:	20.6%	U.K.	13.6%
U.K.	11.8%	Germany	13.1%
Belgium	4.1%	France	2.8%
Russia:	3.5%	Russia	1.8%
Austro-Hungary	3.4%	Austro-Hungarian successor states	1.5%
France	1.9%	Switzerland	1.3%
Italy	1.3%	Italy	1.2%
Japan	.3%	Japan	1.0%
The rest	3.1%	The rest	6.1%

Thus, the U.S., Germany, and U.K. controlled 82.4% of world machinery production in 1913, and 84.3% in 1925. The U.S. could be considered a "superpower" in terms of machinery during this time period; the U.S., Germany, and U.K. were the Great Powers because they dominated the production of reproduction and production machinery.

1938

The next data point to be constructed is that of 1937-1938. This data point is more difficult in that there is no straightforward assessment of specifically machinery industries, as was carried out by Lange, for all countries. The following data sources shed light on the state of the world in 1937 and 1938.

The most comprehensive treatment of global production for the late 1930's was written by H.C. Hillmann for Arnold Toynbee's *Survey of International Affairs, 1939-*

1946 (Hillmann 1952). Both Paul Kennedy, in *Rise and Fall of Great Powers*, as well as Klaus Knorr, in *The War Potential of Nations*, use Hillmann's figures in order to judge the relative strength of Great Powers in this period. Hillmann refers to capital goods as "the optical, engineering, metal goods, shipbuilding, vehicles, chemical, and part of the heavy industries (i.e., pig-iron and crude steel)" (Hillmann 1952, 491). Thus, the category of capital goods includes both general machinery, as well as the production of chemicals and metal. The output of capital goods industries can give a better indication of machinery production than other measures, such as manufacturing or industrial strength. Hillmann gives measures for manufacturing shares of world production (Hillmann 1952, 439):

USA	USSR	Germany	UK	France	Japan	Italy
35.1	14.1	11.4	9.4	4.5	3.5	2.7

He gives the shares for capital goods as the following (Hillmann 1952, 446):

USA	USSR	Germany	UK	France	Japan	Italy
41.7	14	14.4	10.2	4.2	3.5	2.5

We have some clues as the share of general machinery production in 1938 from U.N. studies. According to *Growth of World Industry, 1938-1961* (UN 1965), the share of metal products production in 1938, not including the U.S.S.R. and Eastern Europe, shows North America with 36.7% and Western Europe with 54.3%. It should be noted that the U.S. suffered a severe downturn in production in 1938. According to a U.N. study quoted in [Woytinsky and Woytinsky 1953], Germany constituted 32.4% of European production in 1938, and the U.K. constituted 26.5%. According to the U.N. study *Patterns of Industrial Growth, 1938-1958* (UN 1960, 448-69), in 1948 the U.S.

accounted for 95% of metal products production in north America. According to the U.N. study *The Engineering Industry and Industrialization* (UN 1968, 266-267), in the 1950s the U.S.S.R. constituted two thirds of metal products production for the U.S.S.R. and eastern Europe. I will assume that these percentages were similar in 1938, and that the U.S.S.R. accounted for 14% of world production of machinery, as Hillmann says it did for capital goods.

I arrive at the following figures for share of general machinery in 1938:

U.S.	27.5%
U.S.S.R.	14.0%
Germany	13.9%
U.K.	11.4%

Since there are no data for nonelectrical machinery as opposed to general machinery, I will assume that the shares for nonelectrical machinery for 1938 reflect those for general machinery.

The U.S., Germany, U.S.S.R. and U.K. were the Great Powers in 1938. They combined to produce 66.8% of the machinery in 1938. Note again that this was at a time when the U.S. was producing much less machinery that it was capable of producing, because of the depressed state of its economy. Judging from the American share of machinery in the 1920s and the 1940s, the capacity of the machinery sector in the U.S. was probably closer to the figure given by Hillmann for the share of the U.S. for capital goods in 1937, that is, 40%.

Another indication of the influence of the U.S., U.K., and Germany before World War II is the status of those countries as the dominant exporters of machinery. In 1928, approximately the year of the Lange report, the world share of exports of machinery were the following: U.S. at 34.2%, Germany at 23.7%, and U.K. at 21.6%. In 1936, the figures were 28.2%, 29.6%, and 21.1%, respectively. Thus, these three countries accounted for 79.5% of exports in 1928, and 78.9% in 1936 (VDMA 1956). The USSR was a minimal exporter during this period.

Another indication of control over machinery production is available in the form of data concerning machine tool production. According to Hillmann, "traditionally, the world's largest producers were the United States and Germany" (Hillmann 1952, 447). He states that at the start of World War II, the U.S. and Germany had approximately the same quantity of machine tools, while the U.K. had only half as much as Germany. This is confirmed by data from Woytinsky, who claims that in 1938 44.6% of machine tool production in Europe emanated from Germany, while 19% was produced by the U.K. (Woytinksy and Woytinsky 1953, 1150). Hillmann also asserts that the USSR had one third the quantity of machine tools of Germany.

According to this line of logic, then, the share among the Great Powers of machine tools in 1938 was the following:

U.S.:	28%
Germany:	28%
UK:	13%
U.S.S.R:	9%

The total for these four Powers is 78% of world production, but this is not including Asian, or specifically Japanese, production, and is a very rough estimate.

Knorr claims that before World War II, "Great Britain, France, Italy, Japan, and, to a diminishing extent, the Soviet Union were more or less dependent on imports from [the U.S. and Germany]" for machine tools (Knorr 1956,190). Thus, the figures given above may have underestimated the level of American and German domination of world machine tool production in 1938.

World War II

For the period of World War II, there do not seem to be any world-wide comparisons of machinery output. However, Knorr compiled a table of machine tool production for the years of World War II. In 1942, according to Knorr, the U.S. produced 307,000 machine tools; Germany produced 166,000 tools; the U.K. produced 96,000 tools; and Japan produced 55,000. The only year for which data were available for the USSR was 1940, at which time 50,000 machine tools were produced (Knorr 1956, 190). Both Knorr (Knorr 1956,193) and Hillmann (Hillmann 1953, 446) argued that machine tools in particular were, and would continue to be, critical to any country's war efforts.

The output of destruction machinery during World War II was prodigious. According to Harrison (Harrison 1988, 172), the volume of combat munitions produced by the belligerents in 1944, the year of largest production, was the following (in 1944 dollars):

USA	$44 billion
Germany	$17 billion
USSR	$16 billion
UK	$11 billion
Japan	$6 billion

Since the five above-mentioned countries were the only effectively operating major nations at the time,and controlled most of the territory of the world either directly or indirectly, these five countries constituted the Great Powers of 1940 to 1945. They also controlled the reproduction, production, and destruction machinery industries of the global political economy.

1948

At the end of World War II, the machinery industries of Japan, and particularly Germany, were in ruins. The U.S. was by far the largest producer of machinery. In 1950, according the U.N. study *The Engineering Industry and Industrialization*, the industrialized countries constituted 82.9% of world production of general machinery and the developing countries 2.4% (UN 1968, 266-267). Thus, the world except the Soviet Bloc constituted 85.3% of the world total in 1948. The U.S.S.R. and eastern Europe (the Soviet bloc) constituted 14.7%, with the Soviet Union producing 10.1% of world general machinery. The U.N. study *Patterns of Industrial Growth* provides the totals for general machinery by region (UN 1960, 449), and the percentages of most countries for each region (UN 1960, 455 and 459). It does not discuss the percentages of the Soviet Union or Eastern Europe. I assume that the world except for the Soviet Bloc constitutes 85.3% of the world total in 1948, as provided in *The Engineering Industry and Industrialization*.

The following shares for general machinery result from my calculations:

U.S.:	49.5%
U.K.:	12.4%
U.S.S.R.:	10.1%
France:	3.7%
Germany:	3.2%
Japan:	.8%

I rate the U.S., U.K., and U.S.S.R. as Great Powers in 1948, who together constitute 72%.

In order to calculate shares of nonelectrical machinery, I assume that the Soviet Union also has 10.1% of nonelectrical machinery, since there is no available data from

U.N. studies for the Soviet Union for this period. [Woytinsky and Woytinsky 1953] quote a U.N. study which shows comparative output for nonelectrical machinery for most countries. There list does not include the Soviet Bloc, Asia, Africa, or Latin America. Using the U.N. study *The Engineering Industry and Industrialization* for the Soviet Bloc figure of 14.7% (UN 1968, 266-267) and *Patterns of Industrial Growth* for the other countries (UN 1960, 448-69), it appears that the list the Woytinsky's use constitutes 81.5% of world nonelectrical machinery production. This yields the following shares for nonelectrical machinery in 1948:

U.S.:	55.2%
U.S.S.R:	10.1%
U.K.:	8.4%
France:	4.2%
Germany:	3.8%

The Great Powers of 1948, the U.S., U.S.S.R., and U.K., controlled 73.7% of world production of nonelectrical machinery.

According to data provided by [Woytinsky and Woytinsky 1953], the U.S. constituted 30.4% of the combined machine tool production of Europe and the U.S. in 1949. This figure is lower than expected because there was a significant post-war slowdown in the machinery industry in the U.S., because surplus military machine tools were released to industry. Using the 1947 share of machine tool production with the 1949 data for Europe, the U.K. looks to have 18.4% of combined U.S. and European production. Germany was destined to overtake the U.K. in machine tool production by about 1952, however (Woytinsky and Woytinsky 1953, 1150).

1953 and 1958

The 1950s were dominated by the U.S, in terms of machinery, with the U.S.S.R. attempting to catch up. During this time, the U.K. was barely a Great Power, and Germany reasserted its Great Power status.

For 1953, it is necessary to interpolate the USSR data. According to *The Engineering Industry and Industrialization*, the USSR produced 10.1% of engineering industry value-added in 1950, and 17.8% in 1958 (UN 1968, 266-267). This constituted 68% of the category of USSR and Eastern Europe. In 1953, according to the U.N. study *The Growth of World Industry, 1938-1961*, the USSR and Eastern Europe constituted 18.3% of world engineering production (UN 1965, 317). Assuming that the USSR produced 68% of this total, then the USSR engineering production constituted 12.4% of world production in 1953.

According to *Patterns of Industrial Growth*, West Germany's output constituted 22.4% of Western European production (including West Berlin and Saar), while the U.K.'s output constituted 36.9% (UN 1960, 448-69). Since *The Growth of World Industry, 1938-1961* reports that Western Europe produced 24.7% of world engineering production in 1953 (UN 1965, 317), then West Germany and the U.K. account for 5.5% and 9.1% of production, respectively. The U.S. accounted for 95% of North America's production, which was 51.8% of production, so that the U.S. itself accounted for 49.3% of global production in 1953.

The output of the Great Powers, in 1953, was therefore the following:

U.S.:	49.3%
U.S.S.R:	12.4%
U.K:	9.1%

The Great Powers in 1953 accounted for 70.8% of world engineering production.

The data for 1958 are more straightforward. According to *The Engineering Industry and Industrialization*, the following were the shares for engineering industries for the Great Powers (UN 1968, 266-267):

U.S.:	36.9%
U.S.S.R:	17.8%
U.K.:	8.7%
W. Germany	8.3%

The Great Powers' share for 1958 constituted 71.7% of world engineering production.

Because of the paucity of data for the U.S.S.R. in the 1950s, I will assume the same world percentages for the U.S.S.R. for non-electrical machinery as for machinery as a whole. Only data for western Europe is available on a comparative basis from the OEEC, the predecessor of the OECD (OEEC 1961); I therefore used U.S. census of manufactures data for category 35, which is approximately (although not completely) compatible with the OECD definition of non-electrical machinery. The available data for the 1950s are in terms of deliveries and shipments, not value-added as in other years. The U.S. data are available for value-added. In order to estimate deliveries for the U.S. data, I used the OECD study, *The Engineering Industries in OECD Member Countries, 1963-1970*, and for 1963 found that value-added was 58% of shipments for the U.S. (OECD 1973, 16 and 22). Assuming this relationship in 1953 and 1958 using the U.S.

Census of Manufactures (US 1961, 35-2), I arrived at rough estimates of shipments with which to compare with those from Europe.

I assumed that the output of the U.S. plus Europe constituted the same share of world production for non-electrical machinery as for general machinery: 76.5% in 1953, and 65.2% in 1958. The following shows the major producers for non-electrical machinery for 1953:

USA:	54.1%
USSR:	12.4%
U.K.:	8.3%
W. Germany:	4.7%

The West German share of world machinery was 5.5% in 1953, indicating that shares of non-electrical and industrial machinery were similar. I would rate the U.K. as barely a Great Power in 1953, as both its nonelectrical and industrial machinery shares were approximately 9%. The share of the Great Powers (U.S., U.S.S.R, and U.K) in 1953 was 74.8%.

Using the same methodology as for 1953, the following are the shares of largest producers of nonelectrical machinery in 1958:

U.S.:	36.5%
U.S.S.R:	17.8%
U.K.:	7.8%
W. Germany:	6.5%
France:	4.2%

I would rate the U.S., U.S.S.R, U.K., and Germany as Great Powers, although Germany (with 8.3% of general machinery) and the U.K. (with 8.7%) are clearly in a secondary tier of Great Powers. These four nations together produced 68.6% of world nonelectrical machinery output.

1963

For 1963, we have broad coverage by one U.N. study of the entire world machinery sector, contained in The Growth of World Industry, 1960-1968 (UN 1971, 496-503). The following are the major producers:

U.S.:	35.3%
U.S.S.R.:	22.0%
U.K.:	6.7%
W. Germany:	6.6%

The statistic for the U.S.S.R. however, is inconsistent with other data. In the *Handbook of Industrial Statistics, 1988*, the Soviet Bloc as a whole is given the following percentages of world share for the components of general machinery in 1965: for nonelectrical machinery, 17.5%; for electrical machinery, 7.4%; and for transportation equipment, 7.4% (UNIDO 1988, 45). Assuming the U.S.S.R. constitutes about 75% of each figure, then the U.S.S.R. could not possibly constitute 22% of world production of the category which combines these subcategories. However, I will use the 22% figure, because of its use with a broad comparative study, and urge future research to clear up this inconsistency.

I would rate the U.S. and the U.S.S.R. clearly, and West Germany just barely as Great Powers in 1963, but not the U.K. This is because of the distribution of nonelectrical machinery.

For the U.S.S.R., I am using a figure published *Handbook of Industrial Statistics, 1988*, which states that in 1965 the "Centrally Planned Countries", which refers mainly to the U.S.S.R. and eastern Europe, produced 17.5% of world nonelectrical machinery production (UNIDO 1988, 45). Since in future years the U.S.S.R. accounted for approximately 75% of the nonelectrical machinery production for this area, I will assume that the U.S.S.R. accounted for 75% of this region's output in 1965 as well.

The O.E.C.D. constituted almost all of what is described as the "Developed market countries" in *Handbook of Industrial Statistics, 1988*, which produced 79.3% of nonelectrical machinery production in 1965 (UNIDO 1988, 45). I applied these percentages to 1963, and used *The Engineering Industries in OECD Countries, 1963-1967* (OECD 1973, 22) for value-added. As several countries, such as Italy, did not have data, I added 7% to the OECD total, since the proportion of the excluded countries in the value-added tables was 7% of the value of shipment of nonelectrical machinery in the O.E.C.D.

Here are the resulting percentages for major producers in 1963:

U.S.:	43.9%
U.S.S.R:	13.2%
W. Germany:	11.1%
U.K.:	6.1%
Japan:	4.9%

Because the U.K. has only 6.1% of nonelectrical machinery production, and 6.7% of machinery production, I do not categorize the U.K. as a Great Power in 1963. Germany, even though it has the same percentage as the U.K. of machinery, has 11.1% of nonelectrical machinery production. Therefore, I would rate Germany to be barely a

Great Power, but a Great Power nonetheless. These Great Powers controlled 63.9% of machinery production in 1963, and 68.2% of nonelectrical machinery production.

Starting in 1966, I have a continuous series concerning machine tools, compiled from various issues of the trade journal *American Machinist*. In 1966, as quoted in the U.N. study entitled *World Non-Electrical Machinery*, the U.S. produced 30.6% of world machine tool output, Germany 16%, and the U.S.S.R. 14.5% (UNIDO 1984, 79). Thus, Germany had regained its position as a major producer of reproduction machinery. The three Powers produced 61.1% of world production.

1970 and 1975

For 1970 and 1975, the *Handbook of Industrial Statistics, 1988* contains data for nonelectrical machinery (ISIC 382) as well as for the other types of machinery: electrical, transportation, and instrumentation machinery (UNIDO 1988, 302-30). However, it only contains partial data concerning the U.S.S.R.

In 1970, there are no data for the U.S.S.R, but there are two pieces of information about the share of the Soviet Bloc as a whole: in 1965, the Soviet Bloc's output constituted 17.5% of nonelectrical world production, and in 1975 it constituted 27.6% (UN 1988, 45). Interpolating between the two numbers, I estimate that the Soviet Bloc produced 22.5% of world production in 1970. Value-added figures are available for the other Soviet bloc countries, except the German Democratic Republic (GDR) only has gross output. I took approximately half of the GDR's gross output to arrive at value-added. I filled in the required number for the Soviet Union so that 22.6% of world production was accounted for by the Soviet Bloc. The following is the result, for nonelectrical machinery for 1970:

U.S.:	37.8%
U.S.S.R:	15.8%
Japan:	10.0%
Germany:	9.8%
U.K:	6.0%
France:	5.6%

I would rate the U.S., U.S.S.R., Japan and Germany as Great Powers, accounting for 73.4% of world production of nonelectrical machinery in 1970. Japan has entered the ranks of the Great Powers.

Using the same methodology for the Soviet Union (and GDR) as with nonelectrical machinery, I used the *Handbook of Industrial Statistics, 1988* to calculate data for electrical, transportation, and instrumentation machinery (UNIDO 1988, 302-30). Adding these to nonelectrical machinery, I arrived at the following shares for world general machinery production:

U.S.:	39.9%
U.S.S.R:	9.9%
Japan:	10.3%
W. Germany:	9.6%
U.K:	5.8%
France:	4.8%

The total for the U.S., U.S.S.R., Japan, and Germany was 69.7%.

For machine tool production, W. Germany actually takes the lead with 18.9% of world production in 1970, the U.S. output 18.5%, Japan output 14.2%, and the U.S.S.R. output 13.7%. These Powers totaled 65.3% of world production of machine tools.

For 1975, much the same methodology is performed as for 1970. Soviet Bloc production for the different machinery categories was taken into account, and the figures for the Soviet Union and GDR were thereby calculated. In 1975, unlike 1970, the Soviet Union has gross output figures available in the *Handbook of Industrial Statistics, 1988*.

The value-added calculated is generally compatible with these gross output figures. The shares for nonelectrical machinery were as follows:

U.S.:	27.3%
U.S.S.R:	21.7%
Japan:	9.6%
Germany:	9.6%
France:	6.4%
U.K:	5.2%

The four Great Powers constituted the producers of 68.2% of world nonelectrical machinery production.

The shares for general machinery were as follows, in 1975:

U.S.:	28.8%
U.S.S.R:	12.1%
W. Germany:	9.9%
Japan:	9.8%
France:	5.8%
U.K:	5.1%

The four Powers produced 60.6 of world general machinery production in 1975.

The U.S. regained a slim lead in machine tool production in 1975, with 17.9% of production to W. Germany's 17.6%. The U.S.S.R. had 14.5%, while Japan slipped temporarily with 7.7% of world machine tool production in 1975.

1980, 1985, 1990, and 1995

The data for the 1980s and 1990s is presented for almost all countries in the statistical annex of the *Industrial Development Global Report, 1997*, as compiled by the U.N. Industrial Development Organization (UNIDO 1997, 117-243). The problem, once again, is the Soviet Union.

For 1980 and 1985, I took one half of the gross output value for the Soviet Union and used that figure for the value-added figure. This led to a conflict with the earlier methodology; that is, the value-added for the Soviet Bloc did not add up to the percentage given for Soviet Bloc as a whole elsewhere in the report (UNIDO 1988, 45). I stayed with the value-added as one-half of gross output because gross output seems to be a more basic piece of data than percentage for the Soviet Bloc. Value-added almost never rises above 50% of gross output.

For 1995, Russian data are actually available. However, by 1995 Russian output only constitutes 0.5% of world general machinery production, 1.1% of nonelectrical machinery production, and an equally small proportion of machine tool production (the figure is not even listed by *American Machinist* for 1995). For 1990, I turned to *World Engineering Industries and Automation, 1994-1996*, a publication of the U.N. Economic Commission for Europe (UN 1996). This publication uses the exchange rate of .572 dollars per ruble (UN 1996, ix). Using this exchange rate, I used data for metal products (that is, general machinery plus metal fabrication) and for nonelectrical machinery in rubles to calculate that the U.S.S.R. in 1991 only produced 3.9% of general machinery and 3.6% of nonelectrical machinery (UN 1996, 145-6). The data for 1990 are of similar magnitudes.

Starting in 1990, Germany includes both West and East Germany, adding about 2% to Germany's share of world production.

I have also included a calculation of what I list as the "Euro Big 4". This includes Germany, France, Italy, and the U.K. While the European Community, then the European Union, has been discussed as a potential political unit, it may be useful to consider the four biggest industrial countries within Europe. These are the countries which have the greatest potential to work together as a political unit. These four countries together would constitute the second most powerful Great Power.

With these considerations in mind, the following are the estimates for world production of general machinery for 1980-1995:

Table 10. World General Machinery Production, 1980-1995

	1980	1985	1990	1995
U.S.	29.2%	36.0%	29.1%	28.6%
Japan	11.8%	15.4%	22.0%	23.3%
Germany	10.4%	8.6%	15.4%	14.4%
U.S.S.R	11.9%	10.2%	3.9%	0.5%
U.K	5.7%	3.8%	4.9%	3.7%
France	5.2%	4.8%	4.8%	4.1%
Italy	3.1%	2.0%	3.0%	2.2%
China	2.1%	2.1%	1.3%	2.1%
Great Powers	63.3%	70.2%	66.5%	66.3%
Euro Big 4	24.4%	19.2%	28.1%	24.4%

The Great Powers in 1980 and 1985 are the U.S., U.S.S.R., Japan, and Germany.

The Great Powers in 1990 and 1995 are the U.S., Japan, and Germany.

For nonelectrical machinery and machine tools, the data are the following:

Table 11. World Nonelectrical Machinery Production, 1980-1995

	1980	1985	1990	1995
U.S.	26.6%	29.2%	25.6%	26.4%
Japan	10.1%	13.6%	22.4%	25.5%
Germany	8.9%	8.6%	16.5%	15.3%
U.S.S.R	22.0%	20.5%	3.9%	0.5%
U.K	5.4%	3.8%	5.3%	4.3%
France	4.1%	3.0%	4.4%	3.3%
Italy	2.4%	2.2%	3.6%	3.0%
China	3.4%	2.7%	1.8%	2.5%
Great Powers	67.6%	71.9%	64.5%	67.2%
Euro Big 4	20.8%	17.6%	29.8%	25.9%

Table 12. World Machine Tool Production, 1980-1995

	1980	1985	1990	1995
U.S.	26.6%	12.5%	8.7%	11.7%
Japan	14.3%	24.4%	28.0%	23.5%
Germany	17.6%	14.6%	22.4%	22.6%
U.S.S.R	11.4%	13.9%	11.7%	—
U.K	—	2.0%	4.3%	2.7%
France:	—	2.0%	3.0%	2.5%
Italy	—	5.1%	9.5%	8.5%
China	—	2.1%	3.0%	4.9%
Great Powers	61.2%	65.4%	59.1%	57.8%
Euro Big 4	—	23.7%	39.2%	36.3%

Conclusion

It is extraordinary that only three or four countries, throughout the twentieth century, have controlled approximately two-thirds of the global production of critical machinery categories – general machinery, nonelectrical machinery, and machine tools. While research is needed to further refine these measures, the theoretical framework as elaborated in this study has made possible an objective standard with which to determine the set of Great Powers in a particular time period, and to show the source of the international influence which those Great Powers are able to project.

The following charts summarize the data presented above. General machinery, nonelectrical machinery, and machine tools are presented in pairs. The first chart of each pair shows the Great Powers in line graph form, in order to be able to compare each Great Power individually. The second chart of each pair presents all of the Great Powers together, in order to show the dominance of the Great Powers in terms of global production.

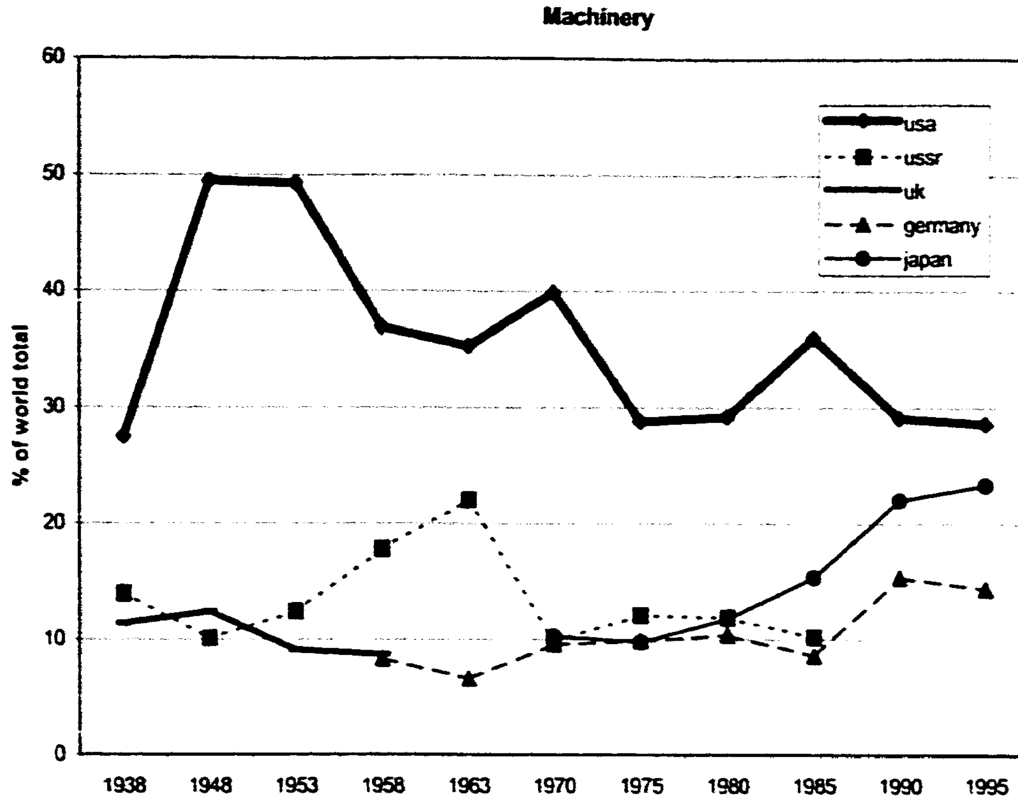


Fig. 59. General machinery by individual Great Power.

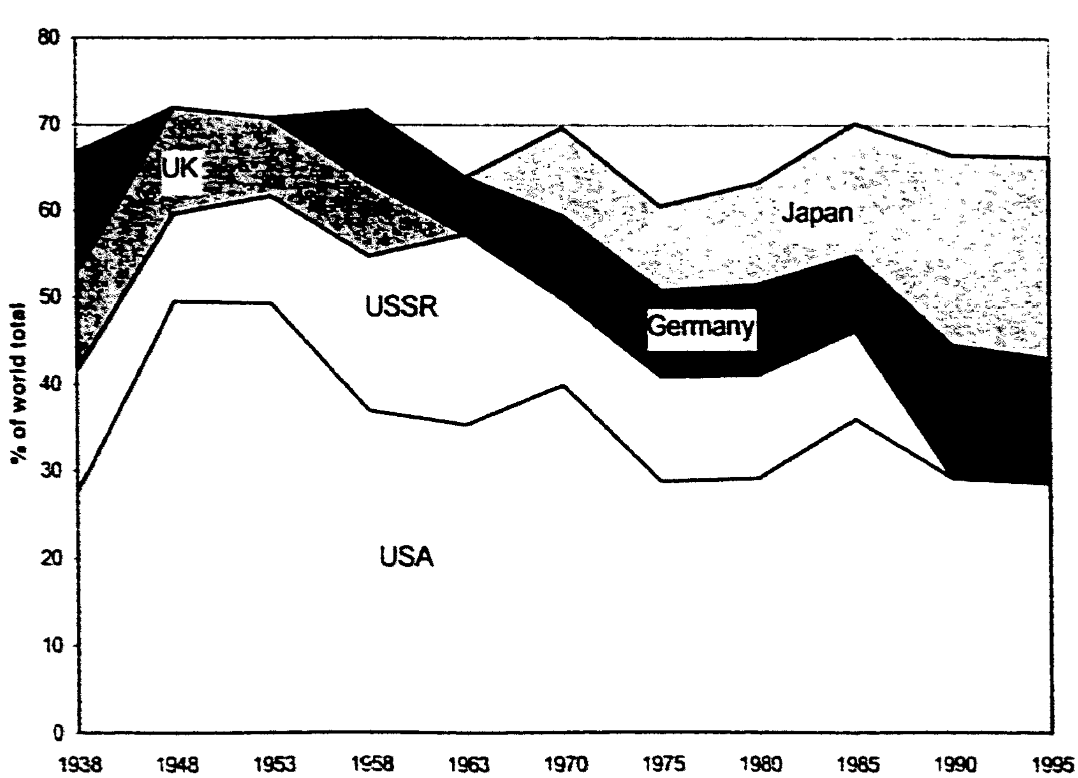


Fig. 60. General machinery of Great Powers collectively.

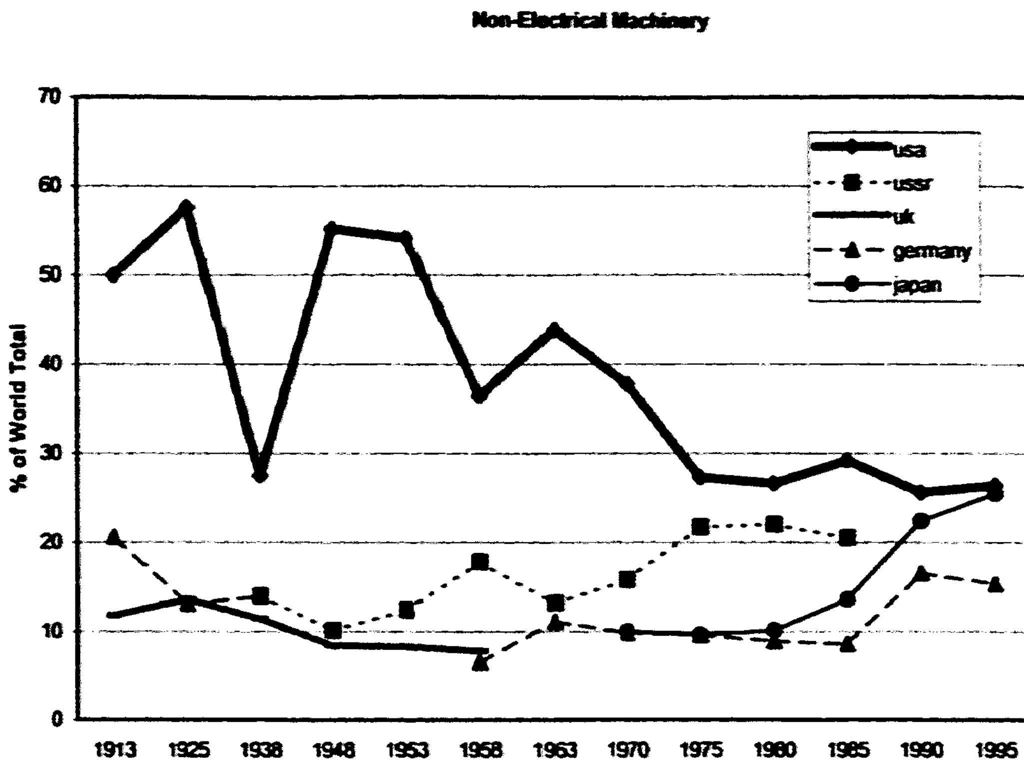


Fig. 61. NonElectrical machinery by individual Great Power.

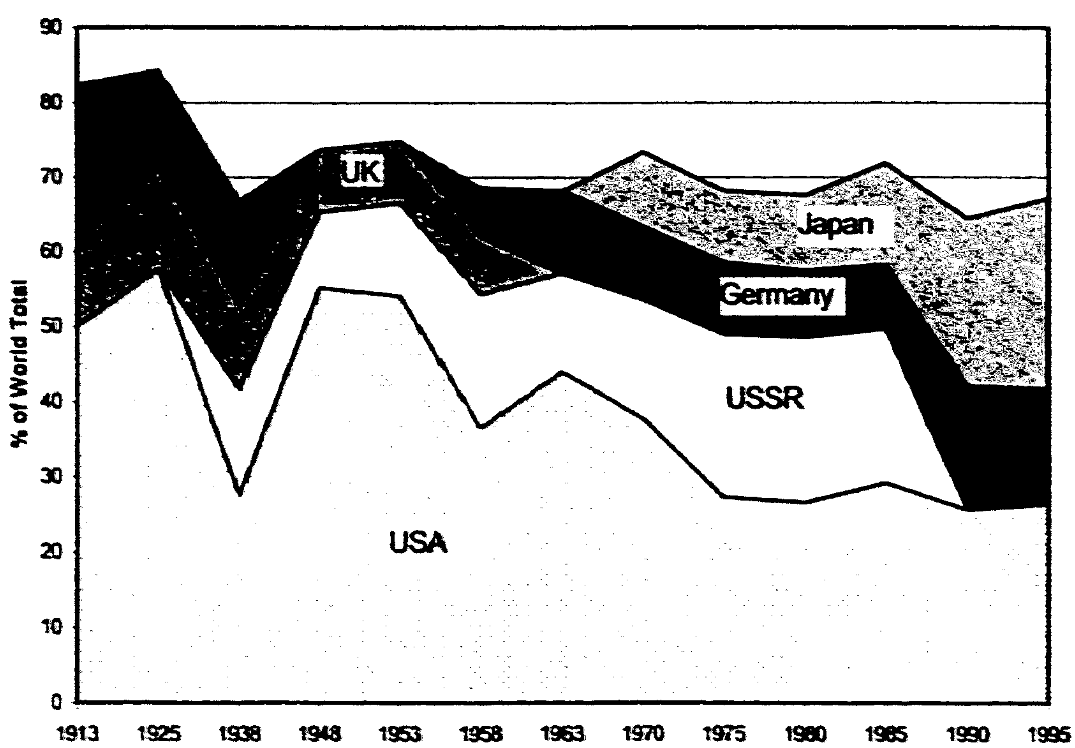


Fig. 62. NonElectrical machinery of Great Powers collectively.

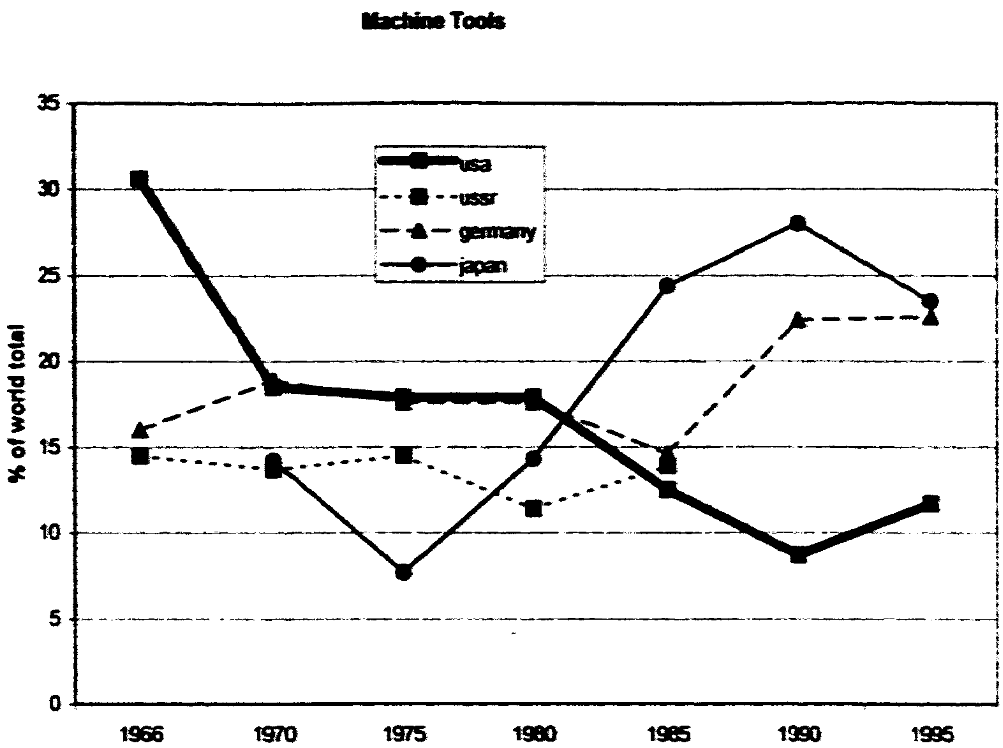


Fig. 63. Machine tools by individual Great Power.

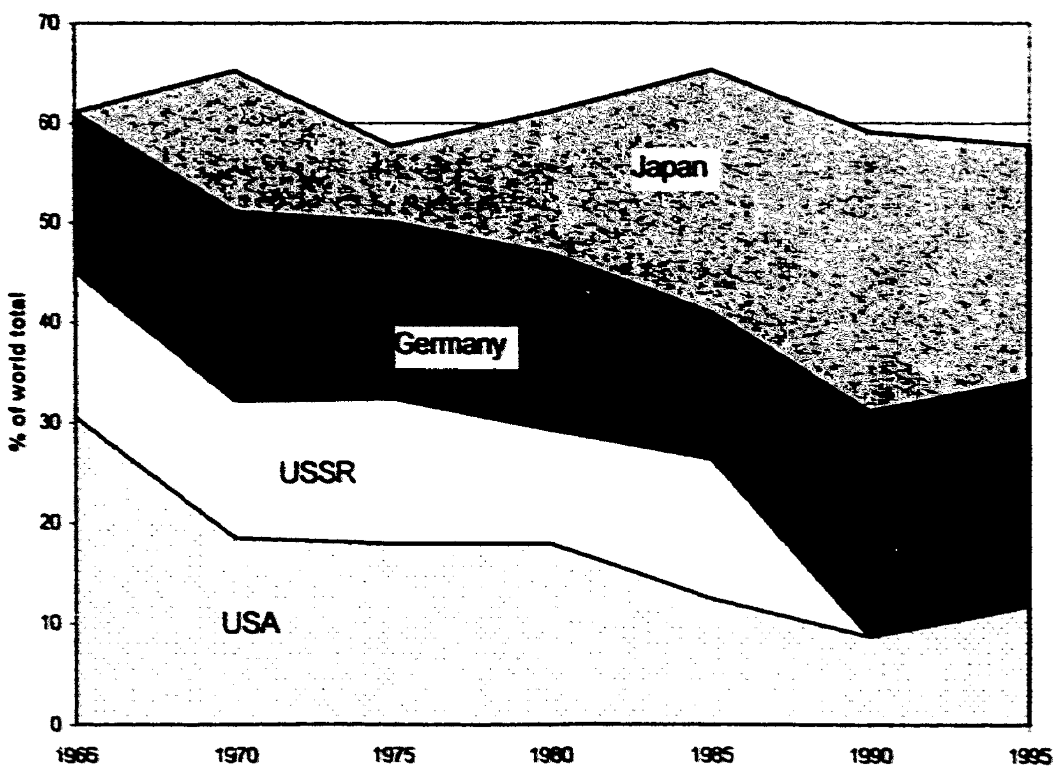


Fig. 64. Machine tools of Great Powers collectively.

BIBLIOGRAPHY

Abramovitz, Moses. 1989. *Thinking about Growth, and other essays on economic growth and welfare*. Cambridge: Cambridge University Press.

Abu-Lughod, Janet L. 1989. *Before European Hegemony: The World System A.D. 1250-1350*. Oxford: Oxford University Press.

Alchian, Armen A. 1989. Property Rights. In *The New Palgrave The Invisible Hand*, ed. John Eatwell, Murray Milgate, and Peter Newman. London: The Modern Library.

Alic, John, Lewis Branscomb, Harvey Brooks, Ashton Carter and Gerald Epstein. 1992. *Beyond Spinoff: Military and commercial technologies in a changing world*. Cambridge: Harvard University Business School Press.

Amato, Ivan. 1997. *Stuff: The materials the world is made of*. New York:Basic Books.

Amsden, Alice H. 1989. *Asia's Next Giant: South Korea and Late Industrialization*. Oxford: Oxford University Press.

Angyal, Andras. 1939. The Structure of Wholes. *Philosophy of Science* 6 (January): 25-37.

Archer, Margaret. 1985. Structuration Versus Morphogenesis. In *Macro-Sociological Theory: Perspectives on Sociological Theory*, ed. S.N. Eisenstadt and H.J. Helle. Newbury Park, CA: Sage Publications.

Aristotle. 1996. *Physics*. Oxford: Oxford University Press.

_______. 1998. *The Metaphysics*. Introduction by Hugh Lawson-Tancred. London: Penguin Classics.

Arrighi, Giovanni. 1994. *The Long Twentieth Century: Money, power, and the origins of our times*. New York: Verso.

Arrow, Kenneth J. 1962. The Economic Implications of Learning by Doing. *Review of Economic Studies* 29 (June): 155-73.

Arthur, W. Brian. 1997. *Increasing Returns and Path Dependence in the Economy*. Ann Arbor: University of Michigan Press.

Ashburn, Anderson. 1988. The Machine Tool Industry: The Crumbling Foundation. In *Is New Technology Enough?: Making and Remaking U. S. Basic Industries*, ed. Donald A. Hicks, Washington, D.C.: American Enterprise Institute.

Ashtor, Eliyahu. 1978. Underdevelopment in the Pre-industrial Era: The Case of Declining Economies. *Journal of European Economic History* 7 (Fall): 285-310.

Bachrach, Peter and Morton Baratz. 1970. *Power and Poverty: Theory and Practice*. New York: Oxford University Press.

Baldwin, David A. 1979. Power Analysis and World Politics: New Trends versus Old Tendencies. *World Politics* 31 (January): 161-74.

Basalla, George. 1988. *The Evolution of Technology*. Cambridge UK:Cambridge University Press.

Baumol, William J., Richard Nelson, and Edward Wolff. 1994. *Convergence of Productivity: Cross-national studies and historical evidence*. Oxford: Oxford University Press.

Bertalanffy, Ludwig Von. 1968. *General Systems Theory*. New York: Braziller.

Blaug, Mark. 1996. *Economic Theory in Retrospect*. 5th ed. Cambridge: Cambridge University Press.

Boucher, Tom. 1981. Technical Change, Capital Investment, and Productivity in U.S. Metalworking Industries. In *Aggregate and Industry-Level Productivity Analyses*, ed. Ali Dogramaci and Nabil R. Adam. The Hague:Martinus Nijhoff

Brady, Robert A. 1961. *Organization, Automation, and Society*. Berkeley:University of California Press.

Branscomb, Lewis M. 1993. *Empowering Technology: Implementing a U.S. Strategy*. Cambridge: MIT Press.

Braudel, Fernand. 1979. *The Perspective of the World*. Berkeley: University of California Press.

Bresnahan, Timothy F. and M. Trajtenberg. 1995. General purpose technologies 'Engine of growth'? *Journal of Econometrics* 65: 83-108.

Buckley, Walter, ed. 1968. *Modern Systems Research for the Behavioral Scientist: A Sourcebook*. Chicago: Aldine Publishing.

Bull, Hedley. 1977. *The Anarchical Society: A Study of Order in World Politics*. New York: Columbia University Press.

Bunge, Mario. 1979. *Causality and Modern Science*. 3rd ed. New York:Dover.

Bureau of Economic Analysis. 1997. *United States Statistical Abstract*. Washington, D.C.: U.S. Department of Commerce.

________________________. 1998. *Fixed Reproducible Tangible Wealth of the United States, 1925-96 (CD-ROM)*. Washington, D.C.: U.S. Department of Commerce.

Campbell, Neil A., Jane B. Reece, and Lawrence G. Mitchell. 1999. *Biology*. 5th ed. New York: Addison-Wesley Publishing Company.

Carlsnaes, Walter. 1992. The Agency-Structure Problem in Foreign Policy Analysis. *International Studies Quarterly* 36: 245-70.

Cederman, Lars-Erik. 1994. Emergent Polarity: Analyzing State-Formation and Power Politics. *International Studies Quarterly* 38: 501-33.

________________. 1997. *Emergent Actors in World Politics: How States and Nations Develop and Dissolve*. Princeton: Princeton University Press.

Chandler, Alfred D., Jr. 1977. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge: Belknap Harvard.

_________________. 1990. *Scale and Scope: The dynamics of industrial capitalism*. Cambridge : Belknap Harvard.

Chase-Dunn, Christopher. 1989. *Global Formation: Structures of the World-Economy*. Cambridge :Blackwell.

Chesnais, Francois. 1981. Schumpeterian Recovery and the Schumpeterian Perspective -- Some Unsettled Issues and Alternative Interpretations. In *Emerging Technologies: Consequences for Economic Growth, Structural Change, and Employment*, ed. Herber Giersch.

Chudnovsky, Daniel and Masafumi Nagao. 1983. *Capital Goods Production in the Third World: An Economic Study of Technology Acquisition*. London: Frances Pinter.

Clark, John Bates. 1927. *The Distribution of Wealth: A Theory of Wages, Interest and Profits*. New York: MacMillan Company.

Clark, Victor S. 1949. *History of Manufactures in the United States, Volume III, 1893-1928*. New York: Peter Smith.

Clough, Shepard B. 1968. *European Economic History: The Economic Development of Western Civilization*. Revised Ed. New York: McGraw-Hill.

Cobb, Charles W. and Paul H. Douglas. 1928. A Theory of Production. American Economic Review 18 (March): 139-72.

Corcoran, William J. 1990. The Machine Tool Industry under Fire. In *The Promise of American Industry: An Alternative Assessment of Problems and Prospects*, ed. Donald L. Losman and Shu-Jan Liang, New York: Quorum Books.

Darwin, Charles. 1964. *On the Origin of Species*. 1st ed. Cambridge:Harvard University Press.

Davies, R.W., Mark Harrison, and S.G. Wheatcroft. 1994. *The Economic Transformation of the Soviet Union, 1913-1945*. Cambridge: Cambridge University Press.

Dawkins, Richard. 1996. *The Blind Watchmaker: Why the evidence of evolution reveals a universe without design*. 2nd ed. New York: W. W. Norton.

De Long J. Bradford and Lawrence J. Summers. 1991. Equipment Investment and Economic Growth. *Quarterly Journal of Economics* 106 (May): 445-502.

DeAngelis, D.L., W.M. Post and C.C. Travis. 1986. *Positive Feedback in Natural Systems*. Berlin: Springer-Verlag.

DeBresson, Chris. 1987. *Understanding Technological Change*. Black Rose Books.

Dehio, Ludwig. 1962. *The Precarious Balance: Four centuries of the European power struggle*. Charles Fullman, trans. New York: Alfred A. Knopf.

Demsetz, Harold. 1967. Toward a Theory of Property Rights. *American Economic Review* 57 (May): 347-59

Denison, Edward F. 1967. *Why growth rates differ: Postwar experience in nine Western countries*. Washington:D.C. The Brookings Institution.

Derry, T.K. and Trevor I. Williams. 1960. *A Short History of Technology: From earliest times to A.D. 1900*. New York: Dover.

Diderot, Denis. 1959. *A Diderot Pictorial Encyclopedia of Trades and Industry*. New York: Dover.

Dobb, Maurice. 1960. *An Essay on Economic Growth and Planning*. New York: Monthly Review Press.

Domar, Evsey D. 1957. *Essays in the Theory of Economic Growth*. Oxford: Oxford University Press.

Easton, David. 1957 (1990). The Analysis of Political Systems. In *Comparative Politics: Notes and Readings*, eds. Roy C. Macridis and Bernard E. Brown. 7th ed. Pacific Grove, CA: Brooks/Cole.

Eckstein, Otto, C. Caton, R. Brinner and P. Duprey. 1984. *DRI Report on U.S. Manufacturing Industries*. New York: McGraw-Hill.

Economic Commission for Europe. Various Issues. *Bulletin of Statistics on World Trade in Engineering Products*. New York: United Nations.

Evans, Peter B., Dietrich Rueschemeyer and Theda Skocpol, eds. 1985. *Bringing the State Back In*. Cambridge: Cambridge University Press.

Evans, Peter. 1995. *Embedded Automation: States and Industrial Transformation*. Princeton: Princeton University Press.

Fel'dman, G. A. 1964. On the Theory of Growth Rates of National Income, I. In *Foundations of Soviet Strategy for Economic Growth: Selected Soviet Essays, 1924-1930*, ed. Nicolas Spulber. Bloomington, Indiana: Indiana University Press.

Ford, Andrew. 1999. *Modeling the Environment: An introduction to system dynamics modeling of environmental systems*. Washington, D.C.: Island Press.

Fransman, Martin. 1986. Introduction. In *Machinery and Economic Development*, ed. Fransman, Martin, New York: St. Martin's Press

Freeman, Chris and Luc Soete. 1997. *The Economics of Industrial Innovation*. 3rd ed. Cambridge MA: MIT Press.

Galbraith, John Kenneth. 1945. Germany Was Badly Run. *Fortune* (December): 173-200

George, Alexander L. 1979. Case Studies and Theory Development: The Method of Structured, Focused Comparison. In *Diplomacy: New Approaches in History, Theory, and Policy*, ed. Paul Gordon Lauren. New York: Free Press.

Gerschenkron, Alexander. 1962. *Economic Backwardness in Historical Perspective*. Cambridge MA: Belknap Harvard.

Gerth, H.H. and C. Wright Mills. 1946. Intellectual Orientations. In *From Max Weber: Essays in sociology*, eds. H.H. Gerth and C.Wright Mills. Oxford: Oxford University Press

Gilpin, Robert. 1975. *U.S. Power and the Multinational Corporation*. New York: Basic Books.

__________. 1981. *War and Change in World Politics*. Cambridge UK: Cambridge University Press.

Goldstein, Joshua S. 1988. *Long Cycles: Prosperity and War in the Modern Age*. New Haven CT: Yale University Press.

Gordon, David M. 1996. *Fat and Mean: The corporate squeeze of working Americans and the myth of managerial downsizing*. New York: Free Press.

Green, Eric Marshall. 1996. *Economic Security and High Technology Competition in an Age of Transition: The Case of the Semiconductor Industry*. New York: Praeger.

Habakkuk, H.J. 1967. *American and British Technology in the 19th Century: The Search for Labour-saving Inventions*. Cambridge UK: Cambridge University Press.

Hall, A. Rupert. 1962. The Changing Technical Act. *Technology and Culture* (Winter): 501-15.

Harcourt, G. C.. 1969. Some Cambridge Controversies in the Theory of Capital. *Journal of Economic Literature* 7 (June): 369-405.

Harrison, Mark. 1988. Resource mobilization for World War II: The U.S.A., U.K., U.S.S.R., and Germany, 1938-1945. *Economic History Review* 41: 171-92.

Heilbroner, Robert. 1994. Do machines make history?. In *Does Technology Drive History?: The dilemma of technological determinism*, ed. Merritt Roe Smith and Leo Marx, Cambridge MA: MIT Press.

Helpman, Elhanan. 1998. *General Purpose Technologies and Economic Growth*. Cambridge MA: MIT Press.

Herrigel, Gary B. 1989. Industrial Order and the Politics of Industrial Change: Mechanical Engineering. In *Industry and Politics in West Germany: Toward the Third Republic*, ed. Peter J. Katzenstein. Ithaca, NY: Cornell University Press.

Hillmann, H.C. 1952. Comparative Strength of the Great Powers in *Survey of International Affairs 1939-1946*. eds. Arnold Toynbee and Frank T. Ashton. Oxford: Oxford University Press.

Hoagland, Mahlon and Bert Dodson. 1995. *The Way Life Works: The Science Lover's illustrated guide to how life grows, develops, reproduces, and gets along*. New York: Times Books.

Hobson, John A. 1902. *The Evolution of Modern Capitalism*. London: The Walter Scott Publishing Co.

Hoffmann, W. G. 1958. *The Growth of Industrial Economies*. Manchester, UK: Manchester University Press.

Holland, Max. 1989. *When the Machine Stopped: A Cautionary Tale from Industrial America*. Cambridge: Harvard University Business School Press.

Holsti, Kalevi J. 1991. *Peace and War: Armed Conflicts and International Order, 1648-1989*. Cambridge: Cambridge University Press.

Holte, John. ed. 1993. *Chaos: The New Science, Nobel Conference XXVI*. Lanham, MD: University Press of America.

Hugill, Peter J. 1993. *World Trade since 1431: Geography, Technology, and Capitalism*. Baltimore: Johns Hopkins University Press.

Jerome, Harry. 1934. *Mechanization in Industry*. New York: National Bureau of Economic Research.

Jervis, Robert. 1997. *System Effects: Complexity in Political and Social Life*. Princeton: Princeton University Press.

Johnson, Martin. 1952. The Meanings of Time and Space in Philosophies of Science. *American Scientist* 412-21.

Jones, Charles I. 1998. *Introduction to Economic Growth*. New York: W. W. Norton.

____________. 1995. Time Series Tests of Endogenous Growth Models. *Quarterly Journal of Economics* (May): 495-525.

Kaiser, David. 1990. *Politics and War: European conflict from Philip II to Hitler*. Cambridge MA: Harvard University Press.

Katz, Arnold J. and Shelby W. Herman. 1997. Improved Estimates of Fixed Reproducible Tangible Wealth, 1929-95. *Survey of Current Business* (May): 69-84.

Kennedy, Paul. 1987. *The Rise and Fall of the Great Powers: Economic Change and Military Conflict from 1500 to 2000*. New York:Random House.

Kindleberger, Charles P. 1993. *A Financial History of Western Europe*. 2nd ed. Oxford: Oxford University Press.

__________________. 1996. *World Economic Primacy: 1500-1990*. Oxford: Oxford University Press.

Knorr, Klaus. 1956. *The War Potential of Nations*. Princeton: Princeton University Press.

Kodama, Fumio. 1995. *Emerging Patterns of Innovation: Sources of Japan's technological edge*. Boston: Harvard Business School Press.

Kravis, Irving B., Alan Heston and Robert Summers. 1978. *International Comparisons of Real Product and Purchasing Power. UN and World Bank.* Baltimore: John Hopkins University Press.

Kuhn, Thomas S. 1970. *The Structure of Scientific Revolutions*. 2nd ed. Chicago: University of Chicago Press.

Kurth, James R. 1979. Political Consequences of the Product Cycle: Industrial History and Political Outcomes. *International Organization* 33 (Winter): 1-34.

Kurz, Heinz D. 1990. Debates in Capital Theory. In *The New Palgrave Capital Theory*, ed. John Eatwell, Murray Milgate, and Peter Newman. London: W. W. Norton.

Kuznets, Simon. 1959. *Six Lectures on Economic Growth*. New York: Free Press.

____________. 1964. *Postwar Economic Growth: Four Lectures*. Cambridge:Harvard University Press.

____________. 1965. *Economic Growth and Structure: Selected Essays*. New York: W. W. Norton.

Lakatos, Imre and Alan Musgrave, eds. 1970. *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.

Landes, David S. 1969. *The Unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present*. Cambridge UK: Cambridge University Press.

Laszlo, Ervin. 1996. *The Systems View of the World: A Holistic Vision for Our Time*. Cresskill, NJ: Hampton Press.

Lawson, Ann M. and D. A. Teske. 1994. Benchmark Input-Output Accounts for the U.S. Economy, 1987. *Survey of Current Business* (April): 73-115

League of Nations. 1927. *International Economic Conference, Geneva, May 1927: Mechanical Engineering: Volume 1*. Geneva: League of Nations Economic and Financial Section.

_____________. 1945. *Industrialization and Foreign Trade*. USA: League of Nations Secretariat, Economic, Financial and Transit Department.

Lebow, Irwin. 1995. *Information Highways and Byways: From the telegraph to the 21st century*. New York: IEEE Press.

Leontief, Wassily. 1986. *Input-Output Economics*. 2nd ed. Oxford: Oxford University Press.

Levy, Jack. 1983. *War in the Modern Great Power System 1495-1975*. Lexington: University of Kentucky Press.

Liberman, Peter. 1993. The Spoils of Conquest. *International Security* 18 (Fall): 125-153.

Lilley, S. 1965. *Men, Machines, and History*. Revised and Enlarged Edition. New York:International Publishers.

Lipsey, Richard G., Cliff Bekar, and Kenneth Carlaw. 1998. What requires explanation? In *General Purpose Technologies and Economic Growth*, ed. Elhanan Helpman. Cambridge: MIT Press

List, Friedrich. 1885. *The National System of Political Economy*. Trans. S.S. Lloyd. New York: Augustus M. Kelley.

Locke, Robert R. 1984. *The End of the Practical Man: Entrepreneurship and Higher Education in Germany, France, and Great Britain, 1880-1940*. Greenwhich, CT: JAI Press, Inc.

Lowe, Adolph. 1965. *On Economic Knowledge: Toward a Science of Political Economics*. New York: Harper & Row Publishers.

__________. 1987. *Essays in Political Economics: Public Control in a Democratic Society*. New York: New York University Press.

Luard, Evan, ed. 1992. *Basic Texts in International Relations*. New York: St. Martin's Press.

Lukes, Steven. 1986. Introduction. In *Power*, Steven Lukes, ed. New York: New York University Press.

Lum, Sherlene K.S. and Robert E. Yuskavage. 1997. Gross Product by Industry, 1947-96. *Survey of Current Business* (November): 20-34.

Lundestad, Geir. 1994. *The Fall of the Great Powers: Peace, Stability, and Legitimacy*. Oxford: Oxford University Press.

Lustick, Ian. 1997. The Absence of Middle Eastern Great Powers: Political "Backwardness" in Historical Perspective. *International Organization* 51 (Autumn): 653-83

Machiavelli, Niccolo. 1979. *The Portable Machiavelli*. London:Penguin Books.

Machine Tool Panel, National Academy of Engineering and National Research Council. 1983. *The Competitive Status of the U. S. Machine Tool Industry: A Study of the Influences of Technology in Determining International Industrial Advantage.* Washington, D.C.

Maddison, Angus. 1983. A Comparison of Levels of GDP Per Capita in Developed and Developing Countries, 1700-1980. *Journal of Economic History* 43 (March): 27-41.

____________. 1995. *Monitoring the World Economy 1820-1992.* Paris: OECD.

Mann, Michael. 1985 (1990). The Autonomous Power of the State. In *Comparative Politics: Notes and Readings*, eds. Roy C. Macridis and Bernard E. Brown. 7th ed. Pacific Grove, CA: Brooks/Cole.

Maruyama, Magorah. 1963. The Second Cybernetics: Deviation-Amplifying Mutual Causal Processes. *American Scientist* (June): 164-79.

Masterman, Margaret. 1970. The Nature of a Paradigm. In *Criticism and the Growth of Knowledge*, Lakatos, Imre and Alan Musgrave, eds. Cambridge: Cambridge University Press.

Mayr, Ernst. 1997. *This is Biology: The Science of the Living World.* Cambridge: Harvard University Press.

McNeill, William H. 1963. *The Rise of the West: A history of the human community.* Chicago: University of Chicago Press.

______________. 1976. *Plagues and Peoples.* New York: Doubleday.

______________. 1982. *The Pursuit of Power: Technology armed force and society since A.D. 1000.* Chicago: University of Chicago Press.

______________. 1992. *The Global Condition: Conquerors, Catastrophes, & Community.* Princeton: Princeton University Press.

Mechanical Engineering. 1928. The Machinery Industry of the World. *Mechanical Engineering* 50 (April): 285-90.

Melman, Seymour. 1983. *Profits without Production.* New York: Alfred A. Knopf.

_____________. 1985. *The Permanent War Economy: American capitalism in decline.* Revised ed. New York: Simon & Schuster.

Mill, John Stuart. 1965 (1848). *Principles of Political Economy.* New York: A.M. Kelley.

Milsum, John H. Editor. 1968. *Positive Feedback: A General Systems Approach to Positive/Negative Feedback and Mutual Causality*. Oxford: Pergamon Press.

Milward, Alan S. 1977. *War Economy and Society: 1939-1945*. Berkeley CA: University of California Press.

Misa, Thomas J. 1985. Military Needs, Commercial Realities, and the Development of the Transistor, 1948-1958. In *Military Enterprise and Technological Change: Perspectives on the American Experience*, ed. Merritt Roe Smith. Cambridge MA:MIT Press

Modelski, George and William R. Thompson. 1996. *Leading Sectors and World Powers: The Coevolution of Global Politics and Economics*. University of South Carolina Press.

Mokyr, Joel. 1990. *The Lever of Riches: Technological Creativity and Economic Progress*. Oxford: Oxford University Press.

Morgenthau, Hans J. 1973. *Politics among Nations*. 5th ed. New York: Alfred A. Knopf.

Nagel, Ernest. 1961. *The Structure of Science: Problems in the Logic of Scientific Explanation*. New York: Harcourt, Brace & World.

National Advisory Committee on Semiconductors. 1990. *Preserving the Vital Base: America's Semiconductor Materials and Equipment Industry*. Washington, DC:U.S. Government Printing Office.

National Machine Tool Builders Association. Various Issues. *Economic Handbook of the Machine Tool Industry*. McLean VA: National Machine Tool Builders' Association.

Nelson, Richard R. 1993. *National Innovation Systems: A Comparative Analysis*. Nelson Richard R.. Oxford: Oxford University Press.

North, Douglass C. 1981. *Structure and Change in Economic History*. New York: W. W. Norton.

______________. 1990. *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.

Nove, Alec. 1992. *An Economic History of the USSR: 1917-1991*. Final Edition. London: Penguin Press.

Nye, Joseph S., Jr. 1990. *Bound to Lead: the Changing Nature of American Power*. USA: Basic Books.

O'Neill, R.V., D.L. DeAngelis, J.B. Waide, and T.F.H. Allen. 1986. *A Hierarchical Concept of Ecosystems*. Princeton: Princeton University Press.

OEEC 1961. Organization for European Economic Co-operation. 1961. *The Engineering Industries in Europe*. Paris :Organization for European Economic Co-operation.

OEEC 1973. Organization for Economic Co-operation and Development. 1973. *The Engineering Industries in OECD Member Countries, New Basic Statistics, 1963-1970, Volume II*. Paris: OECD.

Olson, Mancur. 1982. *The Rise and Decline of Nations*. New Haven CT: Yale University Press.

Organization for Economic Co-operation and Development. 1985. *Purchasing Power Parities*. Paris: OECD.

Organski, A.F.K. 1968. *World Politics*. 2nd ed. New York: Alfred A. Knopf.

____________ and Jacek Kugler. 1980. *The War Ledger*. Chicago: University of Chicago Press.

Overy, R. J. 1995. *Why the Allies Won*. New York: W. W. Norton.

Pacey, Arnold. 1990. *Technology in World Civilization*. Cambridge: MIT Press.

___________. 1992. *The Maze of Ingenuity: Ideas and idealism in the development of technology*. Cambridge: MIT Press.

Pack, Howard. 1994. Endogenous Growth Theory: Intellectual Appeal and Empirical Shortcomings. *Journal of Economic Perspectives* 8 (Winter): 55-72

Penn World Table. Robert Summers and Alan Heston, eds. 1991. The Penn World Table (Mark5): An Expanded Set of International Comparisons:1950-1988. *Quarterly Journal of Economics* 106: 327-68.

Phillips, D.C. 1976. *Holistic Thought in Social Science*. Stanford: Stanford University Press.

Poggi, Gianfranco. 1990. *The State: Its Nature, Development, and Prospects*. Stanford: Stanford University Press.

Polanyi, Karl. 1944. *The Great Transformation: The political and economic origins of our time*. Boston: Beacon Press

Pollard, Sidney. 1982. *Peaceful Conquest*. 2nd ed. Oxford: Oxford University Press.

Porter, Bruce D. 1994. *War and the rise of the state: The military foundations of modern politics*. New York: Free Press.

Pratten, Clifford F. 1980. The Manufacture of Pins. *Journal of Economic Literature* 18 (March): 93-6.

Pursell, Carroll. 1995. *The Machine in America: A social history of technology*. Baltimore: Johns Hopkins University Press.

Quigley, Carroll. 1961. *The Evolution of Civilizations*. Indianopolis: Liberty Fund.

Raj, K.N. 1967. Role of the Machine Tools Sector in Economic Growth. In *Socialism, Capitalism and Economic Growth*, ed. C.H. Feinstein. Cambridge UK: Cambridge University Press.

Ricardo, David. 1970. *The Works and Correspondence of David Ricardo*. P. Sraffa, ed. Cambridge: Cambridge University Press.

Rogoff, Kenneth. 1996. The Purchasing Power Parity Puzzle. Journal of Economic Literature 34 ,(June): 647-68.

Rolt, L.T.C. 1965. *A Short History of Machine Tools*. Cambridge: MIT Press.

Romer, Paul M.. 1986. Increasing Returns and Long-Run Growth. *Journal of Political Economy* 94: 1002-1037

___________. 1990. Endogenous Technological Change. Journal of Political Economy 98: s71-s102

Rosenberg, Nathan. 1972. *Technology and American Economic Growth*. Armonk NY:M.E. Sharpe.

______________. 1976. *Perspectives on Technology*. Cambridge UK: Cambridge University Press.

______________. 1982. *Inside the Black Box: Technology and economics*. Cambridge UK: Cambridge University Press.

Rosenbloom, Richard S and William J. Spencer. 1996. *Engines of Innovation: U.S. Industrial research at the end of an era*. Cambridge MA: Harvard University Business School Press.

Rostow, W.W. 1990. *The Stages of Economic Growth: A Non-Communist Manifesto*. 3rd ed. Cambridge: Cambridge University Press.

Rostow, W.W. 1990. *Theorists of Economic Growth from David Hume to the Present: With a Perspective on the Next Century*. New York: Oxford University Press.

Rowen and Wolf, eds. 1990. *The Impoverished Superpower: Perestroika and the Soviet Military Burden*. San Francisco, CA: ICS Press.

Samuelson, Paul. 1975. *Economics*. New York:McGraw-Hill.

Sass, Stephen L. 1998. *The Substance of Civilization*. New York: Arcade Publishing.

Shmelev, Nikolai and Vladimir Popov. 1989. *The Turning Point: Revitalizing the Soviet Economy*. New York: Doubleday.

SIC. 1987. *Standard Industrial Classification Manual 1987*. Washington, DC: U.S. Government Printing Office.

Singer, J. David and Melvin Small. 1966. The Composition and Status Ordering of the International System: 1815-1940. *World Politics* 18 (January): 236-81.

__________________________. 1972. *The Wages of War, 1816-1965: A Statistical Handbook*. New York: John Wiley and Sons.

__________________________. 1993. *National Material Capabilities Data, 1816-1985*; 1st ICPSR Release.

Singer, J. David, Stuart Bremer, and John Stuckey. 1972. Capability Distribution, Uncertainty, and Major Power War, 1820-1965. In *Peace, War, and Numbers*, ed. Bruce M. Russett. 1972. Beverly Hills CA: Sage Publications.

Skocpol, Theda. 1979. *States and Social Revolutions: A Comparative Analysis of France, Russia, and China*. Cambridge: Cambridge University Press.

___________. 1985. Bringing the State Back In: Current Research. In *Bringing the State Back In*, eds. Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol. Cambridge UK: Cambridge University Press.

Skolnikoff, Eugene B. 1993. *The Elusive Transformation: Science Technology and the Evolution of International Politics*. Princeton: Princeton University Press.

Smil, Vaclav. 1999. *Energies: An Illustrated Guide to the Biosphere and Civilization*. Cambridge, MA: MIT Press.

Smith, Adam. 1994. *The Wealth of Nations*. Edwin Canaan Edition. London: The Modern Library.

Smith, Merritt Roe. 1985. Army ordnance and the American system of manufacturing, 1815-1861. In *Military Enterprise and Technological Change: Perspectives on the American Experience*, ed. Merritt Roe Smith. Cambridge MA:MIT Press

Smyser, W. R. 1992. *The German Economy: Colossus at the Crossroads*. 2nd ed. New York: St. Martin's Press.

Solow, Robert. 1957. Technical Change and the Aggregate Production Function. *Review of Economics and Statistics* 39 (August): 312-320.

__________. 1962. Substitution and Fixed Proportions in the Theory of Capital. *Review of Economic Studies* 29 (June): 207-18.

__________. 1988. Growth Theory and After. *American Economic Review* 88: 307-317.

__________. 1994. Perspectives on Growth Theory. *Journal of Economic Perspectives* 8 (Winter): 45-54.

Spiegel, Steven L. 1972. *Dominance and Diversity: The International Hierarchy*. Boston: Little, Brown and Company.

Stalin, Josef. 1964. Industrialization of the Country and the Right Deviation. In *Foundations of Soviet Strategy for Economic Growth: Selected Soviet Essays, 1924-1930*, ed. Nicolas Spulber. Bloomington Indiana: Indiana University Press.

Statistical Abstract. 1997. *Statistical Abstract of the United States 1997*. Washington, DC:U.S. Government Printing Office.

Stern, Nicholas. 1991. The Determinants of Growth. *Economic Journal* 101 (January): 122-33.

Strandh, Sigvard. 1979. *The History of the Machine*. New York: Dorset Press.

Strassmann, W. Paul. 1959. *Risk and Technological Innovation: American Manufacturing Methods during the Nineteenth Century*. Ithaca NY:Cornell University Press.

______________. 1963. Discussion. *Journal of Economic History* 23 (December): 444-6.

Temple, Jonathan. 1999. The New Growth Evidence. *Journal of Economic Literature* 37 (March): 112-56.

Tilly, Charles. 1975. Reflections on the history of European state-making, in *The Formation of National States in Western Europe*, Ed. Charles Tilly. Princeton: Princeton University Press.

Tilly, Charles. 1985. War Making and State Making as Organized Crime. In *Bringing the State Back In*, eds. Peter B. Evans, Dietrich Rueschemeyer and Theda Skocpol. Cambridge UK: Cambridge University Press.

Toynbee, Arnold J. 1947. *A Study of History*. Abridged Version. Oxford: Oxford University Press.

Tudge, Colin. 2000. *The Variety of Life: A survey and a celebration of all the creatures that have ever lived*. Oxford: Oxford University Press.

UN 1960. Statistical Office of the United Nations, Department of Economic and Social Affairs. 1960. *Patterns of Industrial Growth: 1938-1958*. New York: United Nations.

UN 1965. United Nations. 1965. *The Growth of World Industry, 1938-1961, International Analyses and Tables*. New York: United Nations.

UN 1968. Economic Commission for Europe. 1968. *The Engineering Industry and Industrialization*. New York: United Nations.

UN 1971. Statistical Office of the United Nations, Department of Economic and Social Affairs. 1971. *The Growth of World Industry, Volume 1, General industrial statistics, 1960-1968*. 1969 edition. New York: United Nations.

UN 1996. Economic Commission for Europe. 1996. *World Engineering Industries and Automation: Performance and prospects, 1994-1996*. New York: United Nations.

UNIDO 1984. United Nations Industrial Development Organization. 1984. *World Non-Electrical Machinery: An Empirical Study of the Machine-Tool Industry*. New York: United Nations.

UNIDO 1988. United Nations Industrial Development Organization. 1988. *Handbook of Industrial Statistics 1988*. Vienna: United Nations Industrial Development Organization.

UNIDO 1997. United Nations Industrial Development Organization. 1997. *Industrial Development Global Report 1997*. Oxford: Oxford University Press.

US 1961. U. S. Department of Commerce, Bureau of the Census. 1961. *United States Census of Manufactures: 1958, Volume II, Part 2, Major Groups 29 to 39*. Washington, DC: U.S. Government Printing Office.

Van Creveld, Martin. 1977. *Supplying War: Logistics from Wallenstein to Patton*. Cambridge UK: Cambridge University Press.

VDMA 1956. Verein Deutscher Maschinenbau-Anstalten. 1956. *Statistisches Handbuch fur den Maschinenbau*. Frankfurt:Maschninenbau-Verlag GmbH.

von Ranke, Leopold. 1833. *Theory and Practice of History*. Translated Iggers and von Motlke. Indianapolis: The Bobbs-Merrill Company.

Vowles, Hugh P. and Margaret W. Vowles. 1931. *The Quest for Power: From Prehistoric Times to the Present Day*. London: Chapman & Hall.

Wallerstein, Immanuel. 1974. *The Modern World System I*. New York: Academic Press.

Wallis, John J and Douglass C. North. 1986. Measuring the Transaction Sector in the American Economy, 1870-1970. In *Long-Term Factors in American Economic Growth*, eds. Stanley L. Engerman and Robert E. Gallman, NBER, Studies in Income and Wealth, Volume 51. Chicago :University of Chicago Press.

Waltz, Kenneth N. 1979. *The Theory of International Politics*. New York: McGraw-Hill.

Weber, Max. 1946. *From Max Weber: Essays in Sociology*. Eds. H. H. Gerth and C. Wright Mills. New York: Oxford University Press.

Webster. 1989. *Webster's New Universal Unabridged Dictionary*. New York: Barnes & Noble Press.

Weiss, Linda and John M. Hobson. 1995. *States and Economic Development: A Comparative Historical Analysis*. Cambridge UK: Polity Press.

Wiener, Norbert. 1954. *The Human Use of Human Beings: Cybernetics and Society*. New York: Da Capo Press.

Wight, Martin. 1978. *Power Politics*. Eds. Hedly Bull and Carsten Holbraad. Leicester: Leicester University Press.

Wilkinson, Frank. 1983. Productive Systems. *Cambridge Journal of Economics* 7: 413-29

Williams, Trevor I. 1987. *The History of Invention: From stone axes to silicon chips*. New York: Facts on File.

Womack, James P., Daniel T. Jones, and Daniel Roos. 1990. *The Machine That Changed the World: The story of lean production*. New York: Harper Perennial.

Woodbury, Robert S. 1961. *History of the Lathe to 1850: A Study of the Growth of a Technical Element of an Industrial Economy*. Cambridge MA: MIT Press.

Woytinsky, W.S. and E.S. Woytinsky. 1953. *World Population and Production: Trends and Outlook*. New York: Twentieth Century Fund.

Wright, Quincy. 1965. *A Study of War*. Chicago: University of Chicago Press.