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**AN EXAMINATION OF SOME SAMPLE PATH PROPERTIES OF U.S.  
ECONOMIC TIME SERIES**

*City University of New York*

Ph.D. 1986

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**AN EXAMINATION OF SOME SAMPLE PATH  
PROPERTIES OF U.S. ECONOMIC TIME SERIES**

by

**BRUCE D. MCNEVIN**

**A dissertation submitted to the Graduate Faculty  
in Economics in partial fulfillment of the  
requirements for the degree of Doctor of  
Philosophy, The City University of New York.**

**1986**

This manuscript has been read and accepted for the Graduate Faculty in Economics in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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For Joan, whose faith and encouragement made it  
all possible.

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## Chapter 1 - Introduction

To a large extent, business cycle analysis is not so much an analysis of the periodic behavior of economic variables, as it is an analysis of the systematic nature of economic time series. Many economic texts<sup>1</sup> make a point of noting that the term "business cycle" is misleading in that it implies periodicity. The observed "cycle" is more accurately described as a sequence of phases: expansion peak, contraction, trough; movement of a non-periodic, recurrent nature. Insofar as the idea of true periodic movement in economic variables is set aside, the behavior of interest in the analysis of economic time series is to be found in the relationships among series over the cycle, as well as in the recurrent characteristics of individual series at different phases of the cycle.

One apparently recurrent characteristic of cyclically sensitive economic time series is asymmetric behavior during the expansion and contraction phases of the cycle. Early statistical analyses of the business cycle made note of the fact that expansions were often long and gradual while contractions were short and abrupt. In his pioneering work on business cycles, Wesley Mitchell observed that "Business contractions seem to be a briefer and more violent process than business expansion."<sup>2</sup> A similar observation was made several years later by Keynes (1936).<sup>3</sup> An example of this asymmetric behavior is shown in Figure 1, which contains a plot of the Durable Manufactures component of the Industrial

Production Index, quarterly, 1948, 1-1983,4. Momentarily ignoring the effects of the positive trend in the series, an examination of Figure 1 illustrates Mitchell's point. The expansions tend to contain more observations than the contractions, and, the observations during the contractionary period appear to be farther apart than the observations during the expansionary period.

As a further illustration, consider Table 1 which is a reproduction of the data which formed the basis of Mitchell's observation.

Figure 1  
Industrial Production Index  
Durables, Quarterly, 1948-1983

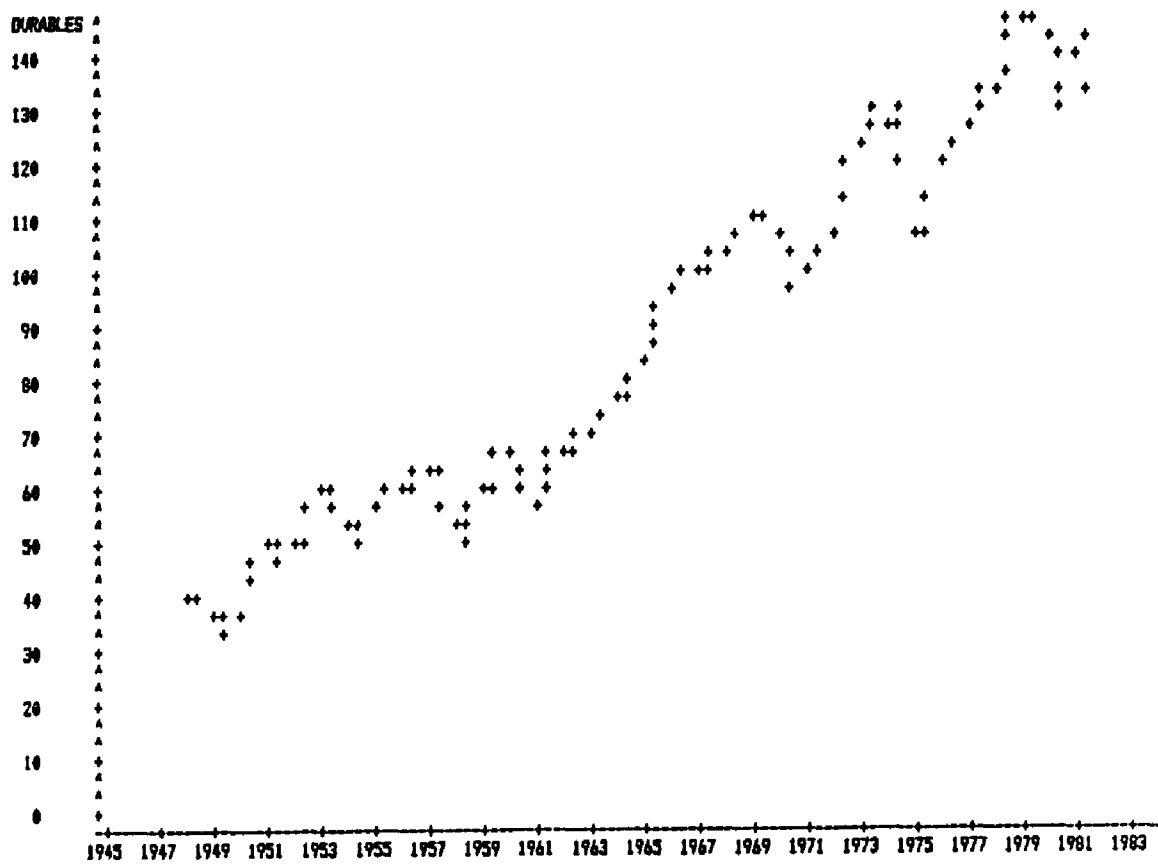


Table 1

**Number and Average Magnitude of Advances and Declines  
in Month-to-Month Changes in Five Indexes of  
Business Conditions**

	<u>No. of Advances</u>	<u>No. of Declines</u>	<u>Aver. Magnitude of</u>	
			<u>Adv. Pts</u>	<u>Dec. Pts</u>
AT&T Business Index	256	228	2.5	2.7
Frickey, clearings	222	215	4.0	4.2
Snyder, clearings	231	213	2.0	2.2
Snyder, deposits	241	264	3.0	2.8
Persons, trade	121	107	2.8	3.3

Source: Wesley Mitchell, Business Cycles.

The number of month-to-month increases generally exceeds the number of decreases, and there is some tendency for the average monthly decline to exceed the average monthly increase. Barring criticism of his analytic approach, Mitchell's observations certainly suggest a systematic difference between the expansionary and contractionary phases of the indexes he examined.

At this point, it is important to note that the asymmetry being discussed is not the result of a positive trend in the time series. A positive trend applied to a symmetric series will lengthen the expansions and shorten contractions, thereby giving the appearance of asymmetry. The asymmetry at issue, while apparent in the original series, will exist after the series is detrended. Figure 2 contains a plot of the detrended Durable Goods component of the IPI, where the trend is assumed to be log linear. Note

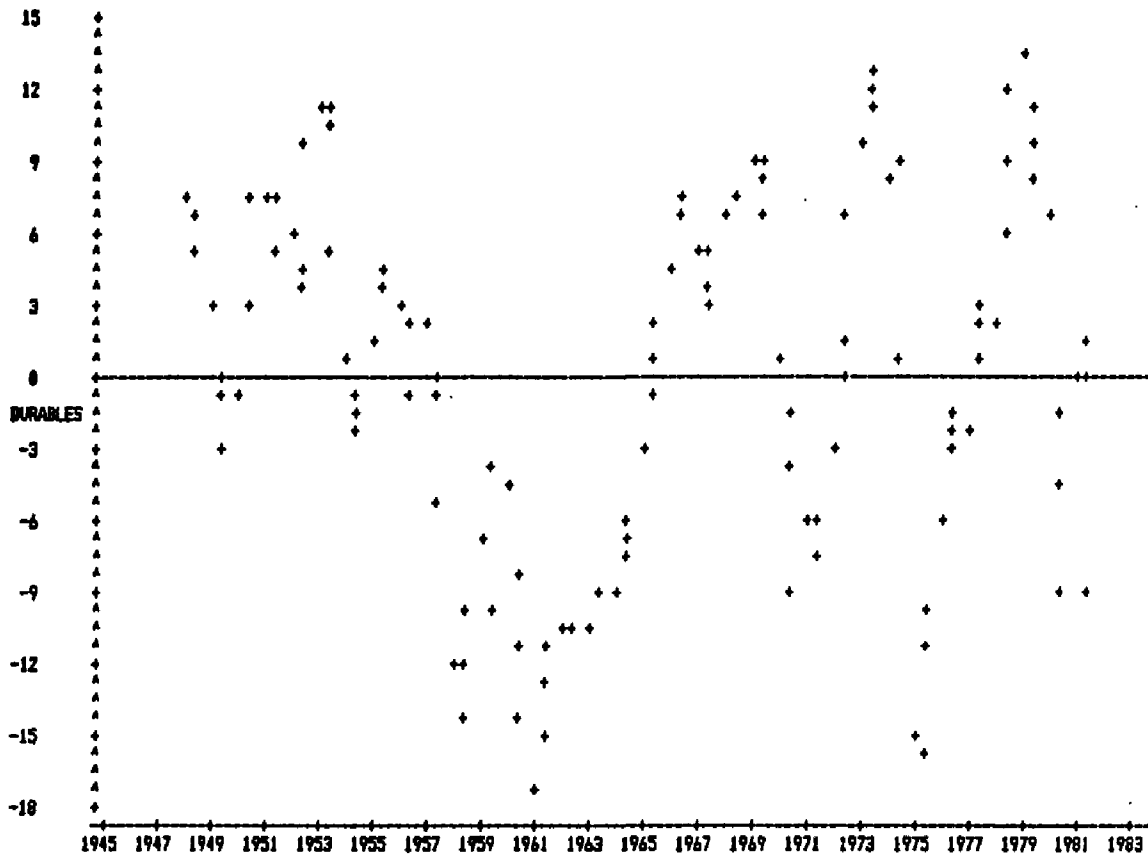
that the series still exhibits the same basic asymmetric character as it did before it was detrended. The issue of detrending is very important, and will be discussed further in Chapter 3.

It seems reasonable to ask why a suspicion of asymmetry in economic time series warrants further investigation. That is, given some circumstantial evidence of asymmetry in an economic time series, what are its implications both theoretically and practically.

First we will consider the theoretical issues. In the most general sense, existing theories of the business cycle can be categorized as either internal theories, external theories, or mixture (internal and external) theories.<sup>4</sup> An internal theory is one which attributes economic fluctuations over time to factors operating within the economic system itself. External theories attribute the cause of cyclical fluctuations to factors outside the economic system. A slightly more detailed categorization of business cycle theories includes a subdivision of the exogenous theories according to the type of external impulse said to create the cyclical fluctuations. That is, modelling of external theories follows two basic lines. Models with exogenous variables which fluctuate cyclically (eg: sunspots) are said to have Type I shocks, while Type II shocks refer to models with disturbance terms in the equations.<sup>5</sup> In addition, models of the three basic types of theories can be either linear or nonlinear. The importance of asymmetry lies in the distinction between

Figure 2

Industrial Production Index, Durables  
Quarterly, Detrended, 1948-1983



linearity and nonlinearity. The following excerpt from an article by J. Blatt captures the essence of the issue.

"All linear theories are inherently symmetrical between ascending and descending phases, and no symmetrical theory can lead to asymmetrical results. If the theory is deterministic this becomes a theorem. An asymmetrical result is simply impossible. If the theory is stochastic, then the symmetry must hold for the expected values of all observed quantities. If an asymmetry is observed in the data, this asymmetry must be interpreted as the result of a chance fluctuation. Such enormous chance fluctuations are quite unlikely."<sup>6</sup>

Thus, evidence of asymmetry in economic time series raises serious questions about the legitimacy of linear models of the business cycle. This is an important point, since for the past 25 years or so linear stochastic models with exogenous shocks have been the most popular types of business cycle models.

Recently, nonlinear endogenous models of the business cycle have experienced a resurgence of popularity in economic literature. While these models are still in the early stages of development, they appear to have important implications for stabilization policy. As such, they may provide some very good practical reasons for wanting to know whether or not economic time series are asymmetric. As pointed out by R. Farmer, "It is important to be able to distinguish between a nonlinear world in which active stabilization policy would be necessary to maintain a stationary equilibrium from a linear world in which a laissez-faire policy might suffice."<sup>7</sup> This point will be taken up in Chapter 6.

It should be noted that an asymmetric sample path is not the only type of nonlinearity that is important from an economic point of view. In particular, economic time series may jump at certain points in time, or, shocks may emanate from asymmetric distributions. While asymmetry implies nonlinearity, the converse is not necessarily true. Asymmetry is a specific, yet important aspect of nonlinearity. Thus, while empirical evidence of asymmetry is not, in itself, satisfactory proof that the "economic world" is nonlinear, it would certainly provide crucial evidence toward drawing such a conclusion.

One additional reason for wanting to know whether economic time series are asymmetric concerns forecasting. An optimal forecast of a nonlinear time series requires a nonlinear forecasting procedure. Maraval (1983) has shown that nonlinear time series are more accurately forecast by a bilinear model than by an ARIMA model. Hinich and Patterson (1985) have found that daily stock returns are generated by a nonlinear process. This suggests the presence of information relating to the dependence of daily returns which can conceivably be used to predict stock market activity.

The arguments given above certainly provide ample reason for a systematic investigation into the question of whether or not economic time series have asymmetric sample paths. Work by Neftci (1984) and Delong and Summers (1984) have provided convincing evidence of asymmetry in the employment sector of the U.S. economy. Delong and Summers

(1984) were unable to find any evidence of asymmetry on the production side of the economy and hence concluded that asymmetry is a phenomenon peculiar to the employment sector of the U.S. economy. Chapter 4 contains an empirical investigation aimed at determining whether or not the Delong and Summers contention is justified. That is, it is an examination into the extent and location of asymmetry in U.S. production series.

As noted earlier, another interesting aspect of the behavior of economic time series concerns the relationship among two or more series during different phases of the business cycle. The best known example of this being the relationship between the Index of Leading Economic Indicators and the Index of Coincident Indicators, where the former is constructed of economic time series generally regarded as leading general economic activity which is represented by the latter. One apparently recurrent aspect of the relationship between these two Indexes is that the Leading Indicator series clearly leads the Coincident Indicator series at the peak, but the two series tend to coincide at the trough.<sup>8</sup> In Chapter 5 a non parametric test, along the lines of the test developed by Neftci to test for asymmetric sample paths, is developed to determine whether such "two series asymmetry" exists. The procedure is then applied to employment and production series, at the industry level, to test the validity of a hypothesis proposed by Delong and Summers (1984) regarding the reason

for asymmetry in U.S. unemployment series. Their hypothesis will be discussed in detail in Chapter 5.

Finally, although the presence of asymmetry should conceivably be systematic in the sense that if it exists at all it should exist in the 19<sup>th</sup> century as well as the 20<sup>th</sup> century, a chapter has been included which discusses and tests for the possibility that the degree of asymmetry in economic time series may have changed over time. The original motivation behind the examination of this issue was the observation by Zarnowitz (1985) that the length of cyclical expansions relative to contractions has increased over time. Also, the Farmer (1985) paper has fueled an interest in this topic because of its emphasis on the need for an active stabilization policy in a nonlinear world.

As indicated above, this dissertation is largely an investigation into the extent and location of asymmetry in U.S. economic time series. The next chapter contains a brief survey of the existing literature on asymmetry. Then there is a discussion of the statistical framework used to test for asymmetric sample paths in individual series. The chapter following that presents the results of tests for asymmetry in U.S. production series. Chapter 5 examines the issue of "two series asymmetry" mentioned above. Chapter 6 contains an examination of the issue of whether asymmetric sample path properties have changed over time. The last chapter contains a summary and conclusion.

## Notes to Chapter 1

1. For instance, see Spencer (1983). 0-5.
2. Mitchell (1927) p. 3333.
3. Keynes (1936) p. 314 noted that "an upward tendency often takes place suddenly and violently, whereas there is, as a rule, no such turning point when an upward is substituted for a downward tendency."
4. See Samuelson (1980) Chapter 10.
5. See Hansen (1984) p. 419.
6. Blatt (1981) p. 470.
7. Farmer (1985) p. 2.
8. See Samuelson (1980), Chapter 10.

## Chapter 2 - Literature Survey

This chapter contains a selective survey of the literature relating to asymmetry. However, since the topic has not attracted much attention, it may very well be more comprehensive than intended. The discussion concentrates on four studies, outlining the methodology and results of the Mitchell (1927), Blatt (1981), Neftci (1984), and Delong and Summers (1984). It is presented chronologically to give the reader a sense of development of the literature.

As pointed out in Chapter 1, empirical observations of asymmetry in economic time series date back to the work of Mitchell (1927). Referring back to Table 1.1, we see that Mitchell's analysis was essentially descriptive in nature. That is, he provided data on the length and magnitude of the expansionary and contractionary phases of various series, and came to the conclusion that asymmetry exists on the basis of the observed differences in the data. Mitchell did not employ any method of statistical inference to determine if, in fact, there was a significant difference between the upturns and the downturns. Nevertheless, his data suggest asymmetry, and his observations are frequently included in discussions of the stylized facts of the business cycle.<sup>1</sup>

The discussion in the introductory chapter pointed out that one of the more important aspects of asymmetry is that it represents a type of movement which cannot be derived from a linear model of the business cycle. It is this point which led Blatt (1981) to investigate the issue of

asymmetry. Blatt was concerned with showing that "Frisch type" models, which were so popular among economists during the 1960's and 1970's, are inconsistent with real world observations. Frisch type models encompass a broad class of models with three basic characteristics. First, the time path generated by the model must be locally stable. Second, in the absence of random shocks, the time path must be smooth. Third, deviations from the trend caused by random shocks must be small enough to allow a linear approximation. Models of this type will be symmetrical between ascending and descending phases. Blatt's test is constructed as follows:<sup>2</sup>

Consider a time series :  $S: Y_0, Y_1, Y_2, \dots, Y_N$   
 where  $Y_t, t = 0, 1, 2, \dots, N$  are deviations from  
 a trend

The reflection of this time series is as follows:

$S^1: -Y_0, -Y_1, -Y_2, \dots, -Y_N$

Thus, when  $Y_1$  is a positive value, its reflection,  $-Y_1$  is a negative fluctuation of equal size. For a given series, Blatt used a technique developed by the NBER to identify the turning points. For each cycle in the series, he calculated the slope of the ascending phase, denoting it  $m_+(k)$ , where  $k$  represents the  $k^{\text{th}}$  cycle in the series. The measurement of the slope was approximated by calculating the slope of a straight line connecting the peak and trough of

the ascending phase of the cycle. Similarly, he found the slope of the descending phase, denoted  $m_-(k)$ . Having identified the ascending and descending phase slopes for all of the cycles, he defined the following sets:

$$\text{Set A: } m_+(k) = a_k$$

$$\text{Set B: } m_-(k) = b_k$$

Set A is a set of ascending slopes for a particular time series and set B is the set of descending slopes. For the reflection series, the following sets of ascending and descending slopes are defined:

$$\text{Set A': } m_+(k) = a_k$$

$$\text{Set B': } m_-(k) = b_k$$

Note that the set of ascending (descending) phase slopes for the reflection series is the same as the descending (ascending) phase slopes for the actual series. For the actual series the probability of the realization of the ascending and descending phase slopes is  $P(A, B)$ , while for the reflection series it is  $P(A', B')$ .

According to Blatt, if the time series being examined has the reflection property, then  $P(A, B) = P(A', B')$ . This is his "fundamental symmetry theorem."

This theorem is applied as follows:

$$\text{Let } p(n) = \text{the average } m_+(k) \text{ over } n \text{ cycles}$$

$$r(n) = \text{the average } m_-(k) \text{ over } n \text{ cycles}$$

The symmetry theorem yields the following corollaries:

(1)  $p(n)$  and  $r(n)$  have the same expected value for "Frisch type" models.

(2) The statistic  $x = \frac{p(n) - r(n)}{p(n) + r(n)}$  has an expected value of zero for "Frisch style" models.

Table 2 contains Blatt's results.

Table 2  
Results of Blatt's Test for Asymmetry

<u>Series</u>	<u>No. of Cycles</u>	<u>p(n)</u>	<u>r(n)</u>	<u>x</u>
Deflated clearings	13	0.64	1.93	-0.502
Frickey's clearings	9	0.69	1.65	-0.420
AT&T Index	9	1.12	1.79	-0.236
Pig Iron Production	15	2.49	4.02	-0.235
Electricity Output	2	0.48	0.69	-0.179
Railroad bond yields	16	2.62	0.65	-0.024

Source: J Blatt, On the Frisch Model of Business Cycles.

Table 2 indicates that the average ascending phase slope is smaller than the average descending phase slope for every series but electricity output. Also, none of the  $x$ -statistics are equal to zero, although Blatt does not say if they are significantly different from zero. Blatt only did a test for statistical significance on pig iron. In this case he was able to reject the hypothesis of symmetry at the 2% level of confidence. Blatt viewed his results as strong proof of asymmetry,<sup>3</sup> and argued that statistical

tests for significance were not necessary. However, the construction of his test statistic raises questions about the validity of his results.

According to Blatt, the expected value of  $p(n)$  and  $r(n)$  should be equal, and consequently the expected value of  $x$  should be zero. These corollaries will hold, provided the sample selection process is random. However, Blatt's technique of dividing the series into cycles and then splitting each cycle into an ascending and descending phase is nonrandom in nature. As a result the expected value of the  $x$ -statistic is probably non-zero. The apparent bias in the Blatt test points to the need for an alternative methodology.

The work by Neftci (1984) on asymmetry and economic time series takes a very different approach from that of Blatt. Neftci uses the theory of finite state Markov processes to determine whether there is systematic evidence of asymmetry in the sample path of a time series. Chapter 3 will be devoted entirely to an explanation of Neftci's methodology, since it is his procedure which will be used in the following chapters to test for asymmetry. Consequently, this section provides only a brief outline of the test procedure.

The Neftci test is as follows:

Let  $\{X_t\}$  be a countercyclical stationary stochastic process. Then  $\{I_t\}$  can be defined as follows:

$$I_t = \begin{cases} +1 & \text{if } X_t > 0 \\ -1 & \text{if } X_t \leq 0 \end{cases}$$

During an economic expansion,  $I_t$  will be a sequence of -1's, and during a contraction it will be a string of +1's. Given the series  $I_t$ , it is possible to calculate the maximum likelihood estimate of the probability of a transition from one state to another. Statistically significant differences in relevant transition probabilities are an indication of asymmetry. For instance, Neftci tested for the difference between the following transition probabilities:

$$l_{00} = P(I_t = -1 \mid I_{t-1} = -1, I_{t-2} = -1)$$

$$l_{11} = P(I_t = +1 \mid I_{t-1} = +1, I_{t-2} = +1)$$

where asymmetry is said to exist if  $l_{00} \neq l_{11}$ : A confidence ellipsoid was calculated as follows:

$$[\hat{l} - l]^T (-H_T) [\hat{l} - l] = X(\alpha)^2$$

where  $\hat{l}$  = vector of transition probabilities

$l$  = vector of estimated transition probabilities

$\alpha$  = confidence interval

Neftci's results are presented in Table 3.

Table 3

Results of Neftci's Test for Asymmetry

<u>Series</u>	$\hat{l}_{00}$	$\hat{l}_{10}$
Total Unemployment Rate	.77(.09)	.66(.07)
Unemployment for Insured Workers	.79(.07)	.66(.05)
Unemployment, 15 weeks and over	.81(.08)	.74(.05)

(standard errors are in parenthesis)

Source: S. Neftci, Business Cycles and Asymmetry

Note that the results concentrate on employment related series. The reason for this is that presence of a trend biases the test procedure for a procyclical series, a positive trend will bias the test toward asymmetry. However, when the test is applied to a countercyclical series, a positive trend will bias the test toward symmetry. Thus, since the series tested contain a slight positive trend, any evidence of asymmetry is actually an understatement. There are two important points concerning Neftci's results. First, for all 3 series, the null hypothesis of symmetry can be rejected at the 80% confidence level. Second, the estimated transition probabilities have the expected relationship in the sense that  $\hat{l}_{00} > \hat{l}_{11}$ . This latter point follows from the fact that unemployment has long gradual downturns and abrupt upswings.

Given the evidence of asymmetry produced by the confidence interval approach, Neftci then "sharpened" his

results by calculating posterior odds ratios.<sup>4</sup> The posterior odds ratio is the ratio of the mass of the posterior probability assuming asymmetry, to the mass of the posterior probability assuming symmetry. The ratio is as follows:

$$r(H_a, H_o, S_T) = \frac{P(l_{ij} | H_a, S_T)}{P(l_{ij} | H_o, S_T)}$$

where  $l_{ij}$  = transition of probabilities

$H_o$  = hypothesis of symmetry,  $l_{oo} = l_{11}$

$H_a$  = hypothesis of asymmetry,  $l_{oo} \neq l_{11}$

Table 4

Results of Neftci's Posterior Odds Ratio Tests

<u>Variable</u>	<u>Prior Odds Ratio = 2</u>	<u>Prior Odds Ratio = 2</u>	<u>Prior Odds Ratio = 2</u>	<u>Prior Odds Ratio = 3</u>	<u>Prior Odds Ratio = 3</u>
	(A)	(B)	(C)	(D)	(E)
Total Unemployment	0.93	2.25	2.76	5.03	6.20
Unemployment for Insured Workers	1.40	3.25	3.92	7.30	8.78
Unemployment 15 weeks and over	0.64	1.48	1.79	3.34	4.02

Source: S. Neftci, Business Cycle and Asymmetry

These results require some explanation. Column (A) contains the posterior odds ratio, when the prior distribution is assumed to be uniform, and the prior odds ratio is equal to two. Thus, strong prior beliefs about asymmetry are not being imposed. Columns (B) through (E)

all have a prior mean for the transition probabilities derived from pre-World War II data of the respective series. In columns (C) and (E) twice as many pre-World War II observations were used to estimate the transition probabilities which were used as priors, then in columns (B) and (D). In addition, columns (B) and (C) have a prior odds ratio of two, while the prior odds ratio of columns (D) and (E) is equal to three. To summarize the results, for the cases of moderately strong prior beliefs, such as columns (D) and (E), we see that asymmetry can be as much as eight times more likely than symmetry.

The recent work of DeLong and Summers (1984) takes yet another approach to measuring the degree of asymmetry present in economic time series. To a large extent, their paper is a response to the Neftci paper. That is, they argued that Neftci's approach to the problem is not optimal because useful information is lost by transforming the series into a string of plus and minus ones. They derived their own test which involves calculating the coefficient of skewness for the distribution of growth rates of the two series under investigation. If asymmetry is present, then the distribution should have a significant degree of skewness. The reason for this is that a series which has gradual expansions and sharp contractions will have fewer negative growth rates than positive growth rates. Consequently, it will be skewed leftward, with the median exceeding the mean. A Monte Carlo procedure was used to calculate the standard deviation of the coefficient of skewness.

In light of the results we have seen from previous works, the results of Delong and Summers are quite surprising. First, consider the results in Table 5.

Table 5

**Skewness of Quarterly and Annual Changes in  
GNP and Industrial Production, U.S.**

<u>Period</u>	<u>Annual Data</u>		<u>Quarterly Data</u>	
	<u>Skewness</u>	<u>Std. Error</u>	<u>Skewness</u>	<u>Std. Error</u>
GNP 1891-1915	-.47	.73	.55	.29
GNP 1923-1940	-.70	1.12	.04	.42
GNP 1949-1983	-1.37	.74	-.33	.29
IP 1949-1983	-.55	.68	-.58	.40

Source: B. Delong and L. Summers, Are Business Cycles Symmetric?

The quarterly GNP series does not show any significant degree of skewness for any of the time periods examined. The annual post World War II GNP series has a slightly significant skew. The industrial production series for quarterly and annual data show no skewness.

Delong and Summers also examined Industrial Production and GNP for several European countries and Japan. The results of these tests are presented in Table 6.

Table 6

**Skewness of Quarterly Changes in GNP and  
Industrial Production, 1950-1979**

<u>Country</u>	<u>Ind. Prod.</u>		<u>GNP</u>	
	<u>Skewness</u>	<u>Std. Error</u>	<u>Skewness</u>	<u>Std. Error</u>
U.S.	-.61	.42	-.33	.29
West Germany	-.01	.34	-.11	.26
Japan	-.66	.40	-.43	.29
United Kingdom	.13	.35	.61	.27
Canada	-.52	.39	-.42	.30
France	.27	.33	-.03	.24

Source: Delong and Summers, Are Business  
Cycles Symmetric?

We see that generally there is no indication of skewness in either the GNP or Industrial Production data for any of the countries examined, except for a slight positive skew in the GNP of the United Kingdom.

Delong and Summers also examined unemployment data for asymmetry. These results are presented in Table 7.

**Table 7**  
**Skewness of Quarterly Changes in Unemployment Rate**  
**1950-1979**

<u>Country</u>	<u>Skewness</u>	<u>Standard Error</u>
U.S.	1.02	.30
Japan	.40	.28
Canada	.55	.29
West Germany	-.13	.27
United Kingdom	.27	.30
France	.14	.33

Source: B. DeLong and L. Summers, Are Business  
Cycles Asymmetric?

As indicated by Table 7, the U.S. employment rate shows a significant positive skew. However, none of the other countries show any sign of symmetry in unemployment.

In light of their findings, DeLong and Summers conclude that the apparent asymmetry in production series, pointed out by Mitchell and other, is a "statistical artifact"<sup>5</sup> caused by the presence of a trend. That is, they argue that the expansion and contraction lengths of the growth cycle for the production related series which they examined are essentially the same, while the average expansion length of the reference cycle for these series is considerably larger than the average length of contraction. This point is important, because as previously mentioned, if asymmetry exists, it will be present in the detrended data series.

One disturbing aspect of the DeLong and Summers paper is that they never examined the U.S. GNP series in its

entirety. Skewness would be more accurately estimated with a larger sample size. A second point concerning their results is that they used highly aggregate time series. In general, one would expect aggregation to hide asymmetry which may be present at the industry level. The reason for this is that since disaggregate series do not precisely coincide, the aggregation process smooths out the expansions and contractions.

Thus, to summarize the findings outlined above, we have seen that both Mitchell (1927) and Blatt (1981) present data which tends to support the contention that asymmetry exists in U.S. economic time series. However, their analytical techniques lack statistical rigor. Neftci (1984) presents evidence of asymmetry in employment series. Delong and Summers (1984) confirm Neftci's findings, but are unable to find any evidence of asymmetry in U.S. production series, thereby failing to confirm the observations of Mitchell (1927), and Blatt (1981).

## Notes to Chapter 2

1. Mitchell and Burns (1947) also present evidence of asymmetry, but the work by Mitchell (1927) is representative of this work.
2. See Blatt (1981) for the details of this test.
3. Blatt (1981) p. 478.
4. See Neftci (1984) for details.
5. See Delong and Summers (1984) for additional details.

### Chapter 3 - Methodology

This chapter consists of three sections. The first section is an outline of the test for asymmetry developed by Neftci (1984), which will be used throughout the paper. The second section contains a discussion on the effects of nonstationarity on the Neftci test. The third section discusses the series to be tested.

#### A. Statistical Framework

The Neftci (1984) test for asymmetry in the sample path of a time series is as follows:

Let  $\{X_t\}$  denote an economic time series.

Define the series  $\{I_t\}$  as follows:

$$I_t = \begin{cases} +1 & \text{if } X_t > 0 \\ -1 & \text{if } X_t \leq 0 \end{cases}$$

Thus, if  $\{X_t\}$  is a procyclical production series, cyclical downswings will be characterized by a sequence of -1's and upswings by a sequence of +1's. Alternatively, if  $\{X_t\}$  is countercyclical,  $I_t = +1$  during periods of economic contraction and  $I_t = -1$  during periods of expansion.

If  $\{I_t\}$  is a stationary secondary Markov process, the following transition probabilities can be defined.

$$\begin{aligned} l_{00} &= P(I_t = -1 \mid I_{t-1} = -1, I_{t-2} = -1) \\ l_{11} &= P(I_t = +1 \mid I_{t-1} = +1, I_{t-2} = +1) \\ l_{01} &= P(I_t = -1 \mid I_{t-1} = -1, I_{t-2} = +1) \\ l_{10} &= P(I_t = +1 \mid I_{t-1} = +1, I_{t-2} = -1) \end{aligned}$$

The complements of each of these transition probabilities is as follows:

$$1 - l_{00} = P(I_t = +1 \mid I_{t-1} = -1, I_{t-2} = -1)$$

$$1 - l_{11} = P(I_t = -1 \mid I_{t-1} = +1, I_{t-2} = +1)$$

$$1 - l_{01} = P(I_t = +1 \mid I_{t-1} = -1, I_{t-2} = +1)$$

$$1 - l_{10} = P(I_t = -1 \mid I_{t-1} = +1, I_{t-2} = -1)$$

The likelihood function for  $\{I_t\}$  is,

$$\begin{aligned} L(I_1, I_2, I_3, \dots, I_T) &= P(I_T = i_T \mid I_{T-1} = i_{T-1}, I_{T-2} = i_{T-2}) \times \\ &P(I_{T-1} = i_{T-1} \mid I_{T-2} = i_{T-2}, I_{T-3} = i_{T-3}) \dots \times P(I_3 = i_3 \mid I_2 = i_2, I_1 = i_1) \\ &\times P(I_2 = i_2, I_1 = i_1). \end{aligned}$$

Denoting the initial state probability as

$\pi_0 = P(I_2 = i_2, I_1 = i_1)$ , the likelihood function can be written as:

$$\begin{aligned} L(I_1, I_2, \dots, I_T) &= \pi_0 l_{00}^{N_{00}} (1 - l_{00})^{T_{00}} l_{11}^{N_{11}} (1 - l_{11})^{T_{11}} l_{01}^{N_{01}} (1 - l_{01})^{T_{10}} \\ &l_{10}^{N_{10}} (1 - l_{10})^{T_{10}} \end{aligned}$$

where the  $N$ 's and  $T$ 's represent the number of transition in the sample series. For instance,  $T_{00}$  is the number of times  $I_t = +1$ ,  $I_t = -1$  and  $I_{t-2} = -1$ .

Given the likelihood function, the maximum likelihood estimates of  $l_{00}$ ,  $l_{11}$ ,  $l_{01}$  and  $l_{10}$  can be calculated by setting the four partial derivatives of the log-likelihood equal to zero and solving them simultaneously. These four equations can be summarized as follows:

$$\frac{\partial \ln L(.)}{\partial l_{ij}} = \frac{\ln \pi_0}{l_{ij}} + \frac{N_{ij}}{l_{ij}} - \frac{T_{ij}}{(1 - l_{ij})} \quad i, j = 0, 1$$

Since  $\pi_0$  is a function of all  $l_{ij}$ , calculating the maximum likelihood estimates requires the use of a nonlinear optimization technique. The Newton-Raphson<sup>2</sup> procedure was used to find the maximum likelihood estimates for each of the series tested. There is, however, a much easier method which can be employed to calculate the approximate likelihood estimates of the transition possibilities. This approximate method also makes the calculation of the test statistics considerably easier. The key assumption underlying the approximate method is that it omits the initial state probability from the likelihood function. The justification for this assumption is that for a large sample size, the effect of the initial state (probability) on the transition probabilities can be assumed to be unimportant.

If the  $\pi_0$  is disregarded, then the partial derivatives of the log-likelihood function simplify to:

$$\frac{\partial \ln L(.)}{\partial l_{ij}} = \frac{N_{ij}}{l_{ij}} - \frac{T_{ij}}{1-l_{ij}} \quad i, j = 0, 1$$

The maximum likelihood estimates for the transition probabilities are as follows:

$$\begin{aligned} \hat{l}_{00} &= \frac{N_{00}}{N_{00}+T_{00}} & \hat{l}_{11} &= \frac{N_{11}}{N_{11}+T_{11}} \\ \hat{l}_{01} &= \frac{N_{01}}{N_{01}+T_{01}} & \hat{l}_{10} &= \frac{N_{10}}{N_{10}+T_{10}} \end{aligned}$$

Table 8 contains a comparison of the estimates of the transition probabilities using the Newton-Raphson procedure and the approximate method, for a sample of the series tested. The cost of using the approximate method in terms of the loss of accuracy in the estimates is undoubtedly smaller than the savings which result from not having to use the Newton-Raphson method on all of the restricted and unrestricted likelihood functions. The approximate technique was, therefore, used to calculate all likelihood ratio statistics. However, as a double check of the approximate technique, the unrestricted transition probabilities were also calculated using the Newton-Raphson procedure. This did not involve too much additional computational time, and it seemed worthwhile, even if it may appear as an overly cautious measure.

Table 8

<u>Unemployment Series</u>	<u>Newton-Raphson Estimates</u>	<u>Approximate Method Estimates</u>
<b>Durable Goods Industries</b>	l <sub>00</sub> = 0.7810 l <sub>11</sub> = 0.6345 l <sub>01</sub> = 0.6894 l <sub>10</sub> = 0.6145	l <sub>00</sub> = 0.7742 l <sub>11</sub> = 0.6389 l <sub>01</sub> = 0.6818 l <sub>10</sub> = 0.6190
<b>Non-Durable Goods Industries</b>	l <sub>00</sub> = 0.6279 l <sub>11</sub> = 0.6897 l <sub>01</sub> = 0.7205 l <sub>10</sub> = 0.4019	l <sub>00</sub> = 0.6200 l <sub>11</sub> = 0.6944 l <sub>01</sub> = 0.7143 l <sub>10</sub> = 0.4073
<b>Mining</b>	l <sub>00</sub> = 0.4481 l <sub>11</sub> = 0.5675 l <sub>01</sub> = 0.5232 l <sub>10</sub> = 0.4015	l <sub>00</sub> = 0.4375 l <sub>11</sub> = 0.5714 l <sub>01</sub> = 0.5135 l <sub>10</sub> = 0.4054
<b>Construction</b>	l <sub>00</sub> = 0.6174 l <sub>11</sub> = 0.6468 l <sub>01</sub> = 0.7374 l <sub>10</sub> = 0.5721	l <sub>00</sub> = 0.6087 l <sub>11</sub> = 0.6512 l <sub>01</sub> = 0.7308 l <sub>10</sub> = 0.5769
<b>Finance and Services</b>	l <sub>00</sub> = 0.5223 l <sub>11</sub> = 0.5517 l <sub>01</sub> = 0.5350 l <sub>10</sub> = 0.3209	l <sub>00</sub> = 0.5128 l <sub>11</sub> = 0.5556 l <sub>01</sub> = 0.5263 l <sub>10</sub> = 0.3243
<b>All Manufacturing Industries</b>	l <sub>00</sub> = 0.7358 l <sub>11</sub> = 0.6243 l <sub>01</sub> = 0.7150 l <sub>10</sub> = 0.5606	l <sub>00</sub> = 0.7288 l <sub>11</sub> = 0.6286 l <sub>01</sub> = 0.7083 l <sub>10</sub> = 0.5652
<b><u>Production Series</u></b>		
<b>Pig Iron</b>	l <sub>00</sub> = 0.2469 l <sub>11</sub> = 0.3804 l <sub>01</sub> = 0.3964 l <sub>10</sub> = 0.6358	l <sub>00</sub> = 0.2308 l <sub>11</sub> = 0.3846 l <sub>01</sub> = 0.3750 l <sub>10</sub> = 0.6400

The tests for asymmetry are based on the following procedures. A second order Markov process yields two basic definitions of symmetry.

$$\begin{aligned} \text{Simple (1}^{\text{st}} \text{ Order) Symmetry: } & l_{00} = l_{11} \\ \text{Compound (2}^{\text{nd}} \text{ Order) Symmetry: } & l_{00} = l_{11} \\ & l_{01} = l_{10} \end{aligned}$$

In the case of simple symmetry, the null hypothesis is;

$$H_0': l_{00} = l_{11}$$

This hypothesis may be tested by calculating the likelihood ratio statistic:

$$2(\ln L - \ln L^*) \xrightarrow{d} \chi^2_{(1)}$$

Where  $L$  refers to the unconstrained approximate likelihood function and  $L^*$  refers to the constrained approximate likelihood function.

The unconstrained likelihood value,  $L$ , is derived by calculating the approximate maximum likelihood estimates of the transition probabilities and substituting them back into the likelihood function.

The constrained likelihood value,  $L^*$ , is calculated by assuming that the null hypothesis is in effect, and then calculating the estimated transition probabilities and substituting them into the constrained likelihood equation.

The constrained approximate likelihood function for simple asymmetry is as follows:

$$L^* = l_R^{\frac{N_{00}+N_{11}}{l_R}} (1-l_R)^{\frac{T_{00}+T_{11}}{(1-l_R)}} l_{01}^{\frac{N_{01}}{l_{01}}} (1-l_{01})^{\frac{T_{01}}{(1-l_{01})}} l_{10}^{\frac{N_{10}}{l_{10}}} (1-l_{10})^{\frac{T_{10}}{(1-l_{10})}}$$

where  $l_R = l_{11} = l_{00}$

The maximum likelihood estimates are:

$$\hat{l}_R = \frac{N_{00}+N_{11}}{N_{00}+N_{11}+T_{00}+T_{11}}$$

$$\hat{l}_{01} = \frac{N_{01}}{N_{01}+T_{01}}$$

$$\hat{l}_{10} = \frac{N_{10}}{N_{10}+T_{10}}$$

In the case of the compound asymmetry test, the null hypothesis is:

$$H_0 = l_{00} = l_{11} \\ l_{10} = l_{01}$$

The likelihood statistic is:

$$2(\ln L - \ln L^*) \xrightarrow{d} \chi^2(2)$$

The constrained approximate likelihood function for compound asymmetry is:

$$L^* = l_{R1}^{\frac{N_{00}+N_{11}}{l_{R1}}} (1-l_{R1})^{\frac{T_{00}+T_{11}}{(1-l_{R1})}} l_{R2}^{\frac{N_{01}+N_{10}}{l_{R2}}} (1-l_{R2})^{\frac{T_{01}+T_{10}}{(1-l_{R2})}}$$

The maximum likelihood estimates are:

$$\hat{l}_{R1} = \frac{N_{00} + N_{11}}{N_{00} + N_{11} + T_{00} + T_{11}}$$

$$\hat{l}_{R2} = \frac{N_{01} + N_{10}}{N_{01} + N_{10} + T_{01} + T_{10}}$$

$$\text{where } l_{R1} = l_{00} = l_{11}$$

$$l_{R2} = l_{01} = l_{10}$$

While the simple asymmetry test is not as restrictive a test as the compound asymmetry test, an even less restrictive test which will be used later on involves the assumption that the series  $\{I_t\}$  is a first order of Markov process. If  $\{I_t\}$  is assumed to be a first order Markov process, then the likelihood function is as follows:

$$L(I_1, I_2, I_3, \dots, I_T) = \pi_0 l_0^{N_0} (1 - l_0)^{T_0} l_1^{N_1} (1 - l_1)^{T_1}$$

$$\text{where } l_0 = P(I_t = -1 \mid I_{t-1} = -1)$$

$$l_1 = P(I_t = +1 \mid I_{t-1} = +1)$$

$$1 - l_0 = P(I_t = +1 \mid I_{t-1} = -1)$$

$$1 - l_1 = P(I_t = -1 \mid I_{t-1} = +1)$$

As in the case of the second order Markov process,  $\pi_0$  will be ignored under the assumption that the initial state becomes unimportant as the sample size increases.

The maximum likelihood estimates of the transition probabilities are:

$$\hat{l}_1 = \frac{N_1}{N_1 + T_1}$$

$$\hat{l}_0 = \frac{N_0}{N_0 + T_0}$$

The null hypothesis to test for asymmetry is:

$$H_0: l_0 = l_1$$

$$\text{where } 2(\ln L - \ln L^*) \xrightarrow{d} \chi^2(1)$$

The constrained likelihood function is:

$$L^*(.) = l_R^{N_0 + N_1} (1 - l_R)^{T_0 + T_1}$$

The maximum likelihood estimate of  $l_R$  is:

$$\hat{l}_R = \frac{N_0 + N_1}{N_0 + N_1 + T_0 + T_1}$$

Based on the work by Mitchell (1927), and others, discussed in the previous two chapters, the sequence of +1's for a procyclical series during the course of the business cycle, should be longer than the sequence of -1's. In this instance, asymmetry implies that  $l_{11} > l_{00}$  and  $l_{10} > l_{01}$  for the second order Markov process. For a countercyclical

series such as unemployment, asymmetry implies that  $l_{00} > l_{11}$  and  $l_{01} > l_{10}$  for the second order Markov test, and  $l_0 > l_1$  for the first order Markov test.

#### B. Test for Bias and Trends

As noted in the previous chapter, the presence of a trend in an economic time series may create an illusion of asymmetry. The reason for this is that when a positive trend is imposed on a series which is symmetric with regard to the ascending and descending phases, the result is an elongation of the ascending phase and a shortening of the descending phase. Similarly, for an asymmetric series which has a long ascending phase and an abrupt descending phase, a positive trend will exaggerate the degree of asymmetry. However, in the case of an asymmetric series which has an ascending phase and a long, gradual descending phase, a positive trend will understate the degree of asymmetry, since it will lengthen the ascending phase and shorten the descending phase. Thus, given the nature of the Neftci (1984) test, the presence of a trend will bias the test results, since it will change the transition mix, thereby altering the estimated transition probabilities.

In the case of the employment sector test for asymmetry done by Neftci (1984), there are two basic reasons why this bias is unimportant. First, the unemployment series he tested have only a slight trend. Second, since unemployment is a countercyclical series, the positive trend biases the test toward symmetry. Thus, given that there is a slight

bias in his findings due to the presence of a small positive trend, the true degree of asymmetry in the employment sector is actually understated. This is not, however, the situation for most of the series to be tested here.

All of the test results presented in the next chapter pertain to procyclical series, most of which possess a strong positive trend. Therefore, it is important to remove the trend since it will bias the results of the Neftci test toward asymmetry. In addition, it is important to have some idea of the effects of the detrending methodology on the Neftci test. That is, while a positive trend in a production sector series can be expected to bias the test toward asymmetry, the detrending procedure itself can also be expected to bias the test. However, the direction of the bias resulting from the detrending procedure is considerably more difficult to determine.

The effects of the various detrending procedures on the Neftci test for asymmetry have been analyzed by Neftci.<sup>3</sup> A summary of this analysis is presented in the next few paragraphs. The results play a very important role in interpreting the asymmetry test results presented in the next chapter.

First, consider the effect of eliminating a linear trend from a logged economic time series by the use of ordinary least squares. The effect of the ordinary least squares procedure on the shape of the detrended series, and consequently the Neftci asymmetry test, depends upon the shape of the original series. That is, suppose the original

series has hump-shaped peaks, V-shaped troughs and a positive trend. Then, detrending the series using OLS will cause the maxima to shift left while the minima will not shift at all. This results from the fact that OLS minimizes the vertical distance between the positive trend line and the original series. The presence of the positive trend results in the greatest vertical distance lying to the left of the maxima of the original series. This is not the case for the troughs, however, since they are V-shaped. Next, consider a series which is V-shaped in both the peaks and troughs. In this instance, OLS detrending procedures will not shift the maxima or the minima.

Thus, the bias in the Neftci test resulting from the elimination of a linear trend by the use of OLS depends upon the shape of the original series. Given series of the two basic shapes discussed in the previous paragraph, suppose both appear to be asymmetric in the sense that the upturns are long and gradual but the downturns are steep and abrupt. The use of OLS to eliminate a positive linear trend from the series with hump-shaped peaks and V-shaped troughs will bias the test results toward symmetry. The reason for this is that the detrending process will shorten the upturns and lengthen the downturns by shifting the maxima to the left, thereby tending to understate the degree of asymmetry. On the other hand, if the original series has V-shaped peaks and troughs the OLS detrending procedure will not introduce any test bias, since it will not shift the positions of the extreme.

As we have seen, the presence of a trend poses some serious problems for the Neftci test. On the one hand, detrending must be carried out, because a positive trend will bias the test results toward asymmetry even if the detrended series symmetric. On the other hand, the use of OLS to remove a linear trend may or may not bias the test results in the direction of symmetry, depending upon the shape of the original series. Fortunately, major U.S. economic time series are frequently observed to have hump-shaped peaks and V-shaped troughs, so that the bias of the test results for any series detrended using OLS will most likely tend to understate the true degree of asymmetry, thereby allowing for a conservative assessment of asymmetry in the U.S. production sector. Appendix A contains graphs of the economic time series which were examined. A casual examination of these series tends to support the contention that the peaks are hump-shaped and the troughs are V-shaped, although it is not overly apparent for yearly data.

The uncertainty which the OLS procedure introduces into the interpretation of the estimated transition probabilities suggest the need for an alternative detrending technique. Neftci has determined that the use of a one sided moving average filter may provide a preferable alternative.<sup>4</sup> This procedure is as follows:

Let  $\{X_t\}$  be a stochastic process which contain a log linear trend,  $X_t = T_t + X^*_t$

where  $X^*_t$  = trend free component

$T_t$  = trend

Using an n-period moving average filter, the detrended series can be calculated as:

$$X_t^* = X_t - \sum_{i=0}^{n-1} X_{t-i}$$

This type of detrending procedure will not introduce any nonlinearity into the data, although it may remove some of it. The preliminary advantage of this technique seems to be that it allows one to emphasize different frequencies by changing the period length of the moving average filter. For instance, detrending with a two period moving average is equivalent to first differencing the data. The two period moving average removes low frequency components of the variation in the series, thereby emphasizing the high frequency components of the series. When the period length of the moving average filter is increased to three, a lower frequency is emphasized than in the case of the two period moving average. Using a four period moving average to detrend annual data emphasizes the business cycle frequency. Thus, in general, using different length filters to detrend is a way of testing for different types of nonlinear behavior.

In light of the effects of the various detrending techniques on the test for asymmetry, it seems as though it would be best not to rely entirely on any one particular technique. Therefore, in the next chapter, in addition to using OLS to remove a log linear trend from the original series, the data is also detrended using two, three, and

four period moving average filters. Hopefully, this will allow for a more definitive determination as to whether or not a particular series is asymmetric.

### C. The Data

The goal of the next chapter will be to determine whether or not asymmetry exists in the production sector of the U.S. economy. Recall that Neftci (1984), and Delong and Summers (1984) both found asymmetry in the employment sector. While Neftci did not apply his test to production series, Delong and Summers did test aggregate Industrial Production and Gross National Product. They did not find asymmetry in either case. If asymmetry does, in fact, exist in production series, it may be the case that it is hidden by aggregation. That is, adding up asymmetric series that do not coincide over time may result in a symmetric aggregate series. To account for this, most of the series tested represent industries, or industry groups. In addition, since most cyclical activity in the economy is found in the durable goods sector, and since theories of the business cycle generally stress business investment as the primary force behind cyclical movement, the sample of series to be tested is heavily represented by factors used in the production of capital goods.

The series which were tested are shown in Table 9 along with the time period of each series. In many instances, the actual length of the series tested depended upon the detrending technique which was being applied.

Consequently, it was not always possible to use the entire series. In these instances, the length of the series tested is specified in the analysis of the results presented in Chapter 4. An examination of Table 9 indicates that Automobile Sales from the Factory is the only consumer durable tested at the industry level. In light of the importance of this series, it was felt it should be tested. At the industry group level the Durable Goods component of the Industrial Production Index, as well as eight of its components, were tested. Most of the tests were performed on annual data. However, quarterly data was available for the IPI components, so these were also tested using quarterly data. Sources for the series listed in Table 9 are in Appendix B. Finally, note that Real GNP was also tested, although a priori expectations are that it will not exhibit asymmetry because of its high level of aggregation.

Table 9

## Series to be Tested for Asymmetry

<u>Series</u>	<u>Time Period</u>
Bituminous Coal	1800-1981
Primary Lead	1821-1981
Copper	1845-1981
Raw Steel	1863-1981
Pig Iron	1892-1981
Steel and Iron Structures	1892-1970
Lumber	1905-1981
Automobile Sales from the Factory	1910-1981
Real GNP	1929-1981
IPI, Durable Goods	1948-1981
IPI, Lumber and Products	1948-1981
IPI, Furniture and Fixtures	1948-1981
IPI, Primary Metals	1948-1981
IPI, Fabricated Metal Products	1948-1981
IPI, Non Electrical Machinery	1948-1981
IPI, Electrical Machinery	1948-1981
IPI, Transportation and Equipment	1948-1981
IPI, Instruments	1948-1981

## Notes to Chapter 3

1. See Neftci (1984) appendix for details of the derivation of the initial state possibility.
2. The Newton-Raphson procedure is an iterative procedure of the following form:  
where  $l_k = l_{k-1} + \theta H^{-1} \Delta$   
 $l_k$  = a column vector for the  $k^{\text{th}}$  iteration  
 $\theta$  = step size  
 $H$  = Hessian matrix for the likelihood function  
 $\Delta$  = gradient matrix of the likelihood
3. See McNevin and Neftci (1986) for details on the effects of an OLS detrending procedure on the Neftci asymmetry test.
4. See McNevin and Neftci (1986) for details.

#### Chapter 4 - Results of Tests for Asymmetry in Production Series

Tables 10 through 37 contain the results of the asymmetry tests for various production series. Tables 10 through 16 are tests of annual data assuming a second order Markov process, detrended using 2, 3, and 4 year moving averages as well as a log linear trend. Tables 17 through 23 are tests of annual data assuming a first order Markov process. All series were tested in log and non-log form. Tables 24 through 37 are tests of quarterly,<sup>1</sup> logged and non-logged series, detrended with 2, 3, and 4 period moving averages.

To make the interpretation of the results less cumbersome, the analysis is done according to groups. The long series group consists of those annual series which date back prior to WW II. The short series group consists of those annual series which cover the period 1948-1983.<sup>2</sup> In general, the results indicate a moderate level of asymmetry which is most apparent in the long series group. For instance, 16% of all the tests on annual series indicate that the null hypothesis can be rejected with an 85% level of confidence.<sup>3</sup> For the long series group, 25% of the tests indicate that the null hypothesis can be rejected with an 85% level of confidence, while only 2% of the tests in the short series group reject the null hypothesis with an 85% level of confidence. The difference between the short and long series groups is probably due to the fact that the short series group only covers about 7 business cycles.

With regard to the long series group, there doesn't appear to be a major difference between the logged and non-logged data in that in both cases approximately 25% of the tests indicate that the null hypothesis can be rejected with an 85% level of confidence. Within the long series group, for logged and non-logged data, the tests made under the second order Markov assumption show a slightly greater degree of asymmetry than the tests made under the first order Markov assumption, with the null hypothesis being rejected at the 85% level of confidence for 27% and 21% of the tests, respectively.

Examining the long series group according to detrending procedure we see that the series detrended with the 2 period moving average show the highest frequency of asymmetry, accounting for 41% of the instances in which the null hypothesis was rejected with an 85% level of confidence. The series detrended with the log linear procedure show the lowest frequency of asymmetry, accounting for 10% of the instances in which the null hypothesis was rejected with an 85% level of confidence. The 3 and 4 period moving averages each accounted for 25% of the observed asymmetry.

Regarding the quarterly data, 23% of all the tests rejected the null hypothesis with an 85% level of confidence. The distribution among the null hypothesis was evenly split. There was little difference in the test results for logged and non-logged data. Differentiating according to the detrending procedure, 15% of the tests rejecting the null hypothesis at the 85% confidence level

were for the two period moving average technique. The 3 and 4 period moving average technique, and the log linear trend, accounted for 10%, 2%, and 1%, respectively, of the total number of tests for which the null hypothesis was rejected at the 85% confidence level.

Table 10

**Log Linear Trend, Annual Data**  
 **$\chi^2$  Statistics, Second Order Markov Process**

<u>Series</u>	$\chi^2$ <u><math>\chi(2)</math></u>	$\chi^2$ * <u><math>\chi(2)</math></u>
Bituminous Coal	0.83	8.22
Primary Lead	0.66	4.31
Copper	0.02	2.81
Raw Steel	0.23	1.89
Pig Iron	0.96	4.44
Steel and Iron Structures	0.35	1.35
Lumber	0.76	1.76
Automobile Sales from the Factory	1.09	1.34
Real GNP	0.61	0.61
IPI, Lumber and Products	0.76	1.76
IPI, Furniture and Fixtures	2.47	2.47
IPI, Primary Metals	1.08	1.28
IPI, Fabricated Metals	0.56	0.81
IPI, Non Electrical Machinery	$N_{00}=0$	$T_{00}=5$
	$N_{11}=7$	$T_{11}=5$
IPI, Electrical Machinery	0.71	1.00
IPI, Transportation and Equipment	-0-	2.04
IPI, Instruments	0.27	0.27

$$* \chi_1^2(10\%) = 2.5 \quad \chi_1^2(5\%) = 3.8$$

$$\chi_2^2(10\%) = 4.6 \quad \chi_2^2(5\%) = 6.0$$

Table 11

2<sup>nd</sup> Order Moving Average, Annual Data (Raw)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>		$\chi_1^2$	$\chi_2^2$		
Bituminous Coal		0.01	0.73		
Primary Lead		2.86	7.46		
Copper		0.02	0.14		
Raw Steel		0.003	11.19		
Pig Iron		2.33	4.69		
Steel and Iron Structures		1.13	1.35		
Lumber		0.50	0.52		
Automobile Sales from the Factory		0.14	3.14		
Real GNP		0.42	1.49		
IPI, Lumber and Products	$N_{00}=3$	$T_{00}=5$	$N_{01}=5$	$T_{01}=5$	
	$N_{11}=0$	$T_{11}=3$	$N_{10}=3$	$T_{10}=6$	
IPI, Furniture and Fixtures		0.03	0.09		
IPI, Primary Metals		0.32	10.09		
IPI, Fabricated Metals	$N_{00}=0$	$T_{00}=6$	$N_{01}=6$	$T_{01}=4$	
	$N_{11}=1$	$T_{11}=2$	$N_{10}=2$	$T_{10}=7$	
IPI, Non Electrical Machinery		0.04	0.60		
IPI, Electrical Machinery		0.02	1.30		
IPI, Transportation and Equipment	$N_{00}=3$	$T_{00}=6$	$N_{01}=6$	$T_{01}=4$	
	$N_{11}=0$	$T_{11}=2$	$N_{10}=2$	$T_{10}=7$	
IPI, Instruments		0.75	2.36		

Table 12

3<sup>rd</sup> Order Moving Average, Annual Data (Raw)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>		$\chi_1^2$	$\chi_2^2$		
Bituminous Coal		2.20	7.16		
Primary Lead		3.06	3.06		
Copper		0.001	0.51		
Raw Steel		0.84	6.13		
Pig Iron		1.61	4.28		
Steel and Iron Structures		2.94	4.28		
Lumber		0.04	2.66		
Automobile Sales from Factory		1.07	1.83		
Real GNP		2.75	3.02		
IPI, Lumber and Products	$N_{00}=5$	$T_{00}=6$	$N_{01}=5$	$T_{01}=3$	
	$N_{11}=0$	$T_{11}=4$	$N_{10}=4$	$T_{10}=4$	
IPI, Furniture and Fixtures		0.80	1.25		
IPI, Primary Metals		0.76	0.89		
IPI, Fabricated Metals	$N_{00}=0$	$T_{00}=5$	$N_{01}=5$	$T_{01}=3$	
	$N_{11}=3$	$T_{11}=5$	$N_{10}=5$	$T_{10}=2$	
IPI, Non Electrical Machinery		1.90	2.16		
IPI, Electrical Machinery		0.0	0.0		
IPI, Transportation and Equipment		0.12	0.17		
IPI, Instruments		0.12	0.25		

Table 13

4<sup>th</sup> Order Moving Average, Annual Data (Raw)  
 $X^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\bar{X}_1^2$	$\bar{X}_2^2$		
Bituminous Coal	1.11	5.61		
Primary Lead	3.07	3.08		
Copper	0.15	1.57		
Raw Steel	0.48	3.88		
Pig Iron	0.45	0.80		
Steel and Iron Structures	2.64	3.10		
Lumber	0.07	0.59		
Automobile Sales from the Factory	0.01	0.14		
Real GNP	4.88	4.40		
IPI, Lumber and Products	1.75	2.06		
IPI, Furniture and Fixtures	1.32	2.42		
IPI, Primary Metals	3.06	3.51		
IPI, Fabricated Metals	1.18	1.47		
IPI, Non Electrical Machinery	$N_{00}=0$	$T_{00}=5$	$N_{01}=5$	$T_{01}=2$
	$N_{11}=5$	$T_{11}=5$	$N_{10}=5$	$T_{10}=1$
IPI, Electrical Machinery	$N_{00}=3$	$T_{00}=4$	$N_{01}=5$	$T_{01}=1$
	$N_{11}=4$	$T_{11}=6$	$N_{10}=5$	$T_{10}=0$
IPI, Transportation and Equipment	$N_{00}=0$	$T_{00}=4$	$N_{01}=4$	$T_{01}=5$
	$N_{11}=2$	$T_{11}=5$	$N_{10}=4$	$T_{10}=4$
IPI, Instruments	1.32	1.34		

Table 14

2<sup>nd</sup> Order Moving Average, Annual Data (Logs)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi_1^2$	$\chi_2^2$		
Bituminous Coal	1.27	1.72		
Primary Lead	6.43	13.18		
Copper	2.57	4.84		
Raw Steel	2.53	19.74		
Pig Iron	2.65	8.56		
Steel and Iron Structures	0.034	0.24		
Lumber	0.026	1.21		
Automobile Sales from Factory	$N_{00}=6$	$T_{00}=14$	$N_{01}=14$	$T_{01}=8$
	$N_{11}=0$	$T_{11}=5$	$N_{10}=5$	$T_{10}=16$
Real GNP	0.061	1.36		
IPI, Lumber and Products	$N_{00}=4$	$T_{00}=6$	$N_{01}=6$	$T_{01}=3$
	$N_{11}=0$	$T_{11}=3$	$N_{10}=3$	$T_{10}=5$
IPI, Furniture and Fixtures	0.03	0.09		
IPI, Primary Metals	0.32	1.79		
IPI, Fabricated Metals	$N_{00}=0$	$T_{00}=6$	$N_{01}=6$	$T_{01}=5$
	$N_{11}=1$	$T_{11}=2$	$N_{10}=2$	$T_{10}=8$
IPI, Non Electrical Machinery	$N_{00}=2$	$T_{00}=5$	$N_{01}=4$	$T_{01}=5$
	$N_{11}=0$	$T_{11}=4$	$N_{10}=3$	$T_{10}=6$
IPI, Electrical Machinery	0.02	1.30		
IPI, Transportation and Equipment	$N_{00}=3$	$T_{00}=6$	$N_{01}=6$	$T_{01}=4$
	$N_{11}=0$	$T_{11}=2$	$N_{10}=2$	$T_{10}=7$
IPI, Instruments	0.31	1.88		

Table 15

3<sup>rd</sup> Order Moving Average, Annual Data (Logs)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi^2$ <u>X<sub>1</sub></u>	$\chi^2$ <u>X<sub>2</sub></u>		
Bituminous Coal	1.36	2.27		
Primary Lead	6.55	6.55		
Copper	0.32	2.60		
Raw Steel	4.57	4.84		
Pig Iron	No <sub>0</sub> =10	To <sub>0</sub> =16	No <sub>1</sub> =16	To <sub>1</sub> =8
	N <sub>11</sub> =0	T <sub>11</sub> =12	N <sub>10</sub> =12	T <sub>10</sub> =11
Steel and Iron Structures	0.69	0.93		
Lumber	0.43	3.10		
Automobile Sales from the Factory	0.93	0.93		
Real GNP	0.16	0.37		
IPI, Lumber and Products	No <sub>0</sub> =3	To <sub>0</sub> =6	No <sub>1</sub> =5	To <sub>1</sub> =3
	N <sub>11</sub> =0	T <sub>11</sub> =4	N <sub>10</sub> =4	T <sub>10</sub> =4
IPI, Furniture and Fixtures	0.71	0.71		
IPI, Primary Metals	-0-	0.13		
IPI, Fabricated Metals	1.45	1.99		
IPI, Non Electrical Machinery	0.29	0.31		
IPI, Electrical Machinery	-0-	-0-		
IPI, Transportation and Equipment	0.45	0.50		
IPI, Instruments	2.27	No <sub>1</sub> =5	To <sub>1</sub> =1	
		N <sub>10</sub> =5	T <sub>10</sub> =0	

Table 16

3<sup>rd</sup> Order Moving Average, Annual Data (Raw)  
 $X^2$  Statistics, Second Order Markov Process

<u>Series</u>		$\chi^2$ <u>X<sub>1</sub></u>	$\chi^2$ <u>X<sub>2</sub></u>		
Bituminous Coal		0.007	1.29		
Primary Lead		6.19	6.20		
Copper		1.22	1.22		
Raw Steel		1.40	1.47		
Pig Iron		1.34	1.43		
Steel and Iron Structures		0.81	1.31		
Lumber		0.02	6.02		
Automobile Sales from Factory		1.69	1.55		
Real GNP		2.49	3.10		
IPI, Lumber and Products		0.15	0.60		
IPI, Furniture and Fixtures		1.22	2.40		
IPI, Primary Metals		3.06	3.51		
IPI, Fabricated Metals		1.18	1.47		
IPI, Non Electrical Machinery	$N_{00}=0$	$T_{00}=6$	$N_{01}=6$	$T_{01}=1$	
	$N_{11}=4$	$T_{11}=5$	$N_{10}=5$	$T_{10}=1$	
IPI, Electrical Machinery		1.32	1.34		
IPI, Transportation and Equipment	$N_{00}=0$	$T_{00}=4$	$N_{01}=4$	$T_{01}=5$	
	$N_{11}=2$	$T_{11}=5$	$N_{10}=5$	$T_{10}=4$	
IPI, Instruments		0.80	$N_{01}=64$	$T_{01}=05$	
			$N_{10}=5$	$T_{10}=0$	

Table 17

**Log Linear Trend, Annual Data  
X<sup>2</sup> Statistics, First Order Markov Process**

<u>Series</u>	<u>X<sub>1</sub><sup>2</sup></u>
Bituminous Coal	6.42
Primary Lead	1.01
Copper	1.36
Raw Steel	1.10
Pig Iron	2.51
Steel and Iron Structures	1.29
Lumber	-0-
Automobile Sales from Factory	1.42
Real GNP	0.25
IPI, Lumber and Products	0.12
IPI, Furniture and Fixtures	1.08
IPI, Primary Metals	0.12
IPI, Fabricated Metals	0.12
IPI, Non Electrical Machinery	0.97
IPI, Electrical Machinery	-0-
IPI, Transportation and Equipment	1.28
IPI, Instruments	0.26

Table 18

2<sup>nd</sup> Order Moving Average, Annual Data (Raw)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	<u><math>\chi^2</math></u>
Bituminous Coal	0.27
Primary Lead	5.70
Copper	0.04
Raw Steel	5.45
Pig Iron	4.79
Steel and Iron Structures	0.66
Automobile Sales from Factory	1.12
Real GNP	0.79
IPI, Lumber and Products	1.60
IPI, Furniture and Fixtures	0.05
IPI, Primary Metals	0.43
IPI, Fabricated Metals	0.75
IPI, Non Electrical Machinery	0.43
IPI, Electrical Machinery	0.56
IPI, Transportation and Equipment	3.32
IPI, Instruments	0.06

Table 19

3<sup>rd</sup> Order Moving Average, Annual Data (Raw)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$ <u><math>\chi_1</math></u>
Bituminous Coal	4.86
Primary Lead	1.38
Copper	0.17
Raw Steel	0.38
Pig Iron	0.21
Steel and Iron Structures	1.40
Automobile Sales from Factory	0.68
Real GNP	1.37
IPI, Lumber and Products	0.16
IPI, Furniture and Fixtures	0.47
IPI, Primary Metals	0.16
IPI, Fabricated Metals	0.16
IPI, Non Electrical Machinery	0.51
IPI, Electrical Machinery	0.005
IPI, Transportation and Equipment	0.21
IPI, Instruments	-0-

Table 20

4<sup>th</sup> Order Moving Average, Annual Data (Raw)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	<u><math>\chi^2</math></u>
Bituminous Coal	3.35
Primary Lead	0.81
Copper	0.72
Raw Steel	0.49
Pig Iron	0.10
Steel and Iron Structures	1.50
Automobile Sales from Factory	0.06
Real GNP	1.30
IPI, Lumber and Products	0.31
IPI, Furniture and Fixtures	0.89
IPI, Primary Metals	0.79
IPI, Fabricated Metals	0.31
IPI, Non Electrical Machinery	0.89
IPI, Electrical Machinery	0.02
IPI, Transportation and Equipment	0.54
IPI, Instruments	0.03

Table 21

2<sup>nd</sup> Order Moving Average, Annual Data (Logs)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$ <u><math>\chi_1</math></u>
Bituminous Coal	1.03
Primary Lead	10.49
Copper	4.59
Raw Steel	14.84
Pig Iron	16.3
Steel and Iron Structures	0.08
Automobile Sales from Factory	6.35
Real GNP	0.94
IPI, Lumber and Products	2.48
IPI, Furniture and Fixtures	0.05
IPI, Primary Metals	0.43
IPI, Fabricated Metals	0.75
IPI, Non Electrical Machinery	0.50
IPI, Electrical Machinery	0.56
IPI, Transportation and Equipment	3.32
IPI, Instruments	0.75

Table 22

3<sup>rd</sup> Order Moving Average, Annual Data (Logs)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	<u><math>\chi^2</math></u> <u><math>X_1</math></u>
Bituminous Coal	-0-
Primary Lead	1.39
Copper	0.99
Raw Steel	0.67
Pig Iron	2.99
Steel and Iron Structures	0.02
Automobile Sales from Factory	0.26
Real GNP	0.20
IPI, Lumber and Products	0.16
IPI, Furniture and Fixtures	0.13
IPI, Primary Metals	-0-
IPI, Fabricated Metals	-0-
IPI, Non Electrical Machinery	-0-
IPI, Electrical Machinery	0.25
IPI, Transportation and Equipment	-0-
IPI, Instruments	0.30

Table 23

4<sup>th</sup> Order Moving Average, Annual Data (Logs)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$ <u><math>\chi_1</math></u>
Bituminous Coal	0.25
Primary Lead	2.04
Copper	0.54
Raw Steel	0.23
Pig Iron	0.13
Steel and Iron Structures	0.87
Automobile Sales from Factory	0.23
Real GNP	0.68
IPI, Lumber and Products	0.03
IPI, Furniture and Fixtures	0.89
IPI, Primary Metals	0.79
IPI, Fabricated Metals	0.31
IPI, Non Electrical Machinery	0.31
IPI, Electrical Machinery	0.68
IPI, Transportation and Equipment	0.54
IPI, Instruments	0.52

Table 24

**Log Linear Trend, Quarterly Data  
X<sup>2</sup> Statistics, First Order Markov Process**

<u>Series</u>	<u>X<sub>i</sub><sup>2</sup></u>
IPI, All Durables	2.54
IPI, Lumber and Products	0.70
IPI, Furniture and Fixtures	1.46
IPI, Primary Metals	0.54
IPI, Fabricated Metals	0.24
IPI, Non Electrical Machinery	1.59
IPI, Electrical Machinery	0.09
IPI, Transportation and Equipment	0.48
IPI, Instruments	-0-

Table 25

**Log Linear Trend, Quarterly Data**  
 **$\chi^2$  Statistics, Second Order Markov Process**

<u>Series</u>	$\chi_1^2$	$\chi_2^2$
IPI, All Durables	0.33	3.88
IPI, Lumber and Products	0.80	0.81
IPI, Furniture and Fixtures	0.83	1.34
IPI, Primary Metals	0.09	0.50
IPI, Fabricated Metals	0.13	0.36
IPI, Non Electrical Machinery	0.95	1.68
IPI, Electrical Machinery	0.12	0.19
IPI, Transportation and Equipment	0.78	0.82
IPI, Instruments	-0-	0.05

Table 26

2<sup>nd</sup> Order Moving Average, Quarterly Data (Raw)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$
IPI, All Durables	2.81
IPI, Lumber and Products	3.72
IPI, Furniture and Fixtures	0.006
IPI, Primary Metals	0.14
IPI, Fabricated Metals	1.44
IPI, Non Electrical Machinery	2.64
IPI, Electrical Machinery	1.14
IPI, Transportation and Equipment	2.95
IPI, Instruments	0.01

Table 27

2<sup>nd</sup> Order Moving Average, Quarterly Data (Raw)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi^2$ <u><math>\chi_1</math></u>	$\chi^2$ <u><math>\chi_2</math></u>
IPI, All Durables	2.45	3.65
IPI, Lumber and Products	4.35	4.55
IPI, Furniture and Fixtures	0.13	0.26
IPI, Primary Metals	0.05	0.59
IPI, Fabricated Metals	3.42	3.47
IPI, Non Electrical Machinery	1.37	2.22
IPI, Electrical Machinery	0.59	0.79
IPI, Transportation and Equipment	1.23	3.64
IPI, Instruments	7.99	12.19

Table 28

3<sup>rd</sup> Order Moving Average, Quarterly Data (Raw)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$ <u>X<sub>1</sub></u>
IPI, All Durables	0.19
IPI, Lumber and Products	2.09
IPI, Furniture and Fixtures	0.97
IPI, Primary Metals	0.03
IPI, Fabricated Metals	1.76
IPI, Non Electrical Machinery	0.02
IPI, Electrical Machinery	0.07
IPI, Transportation and Equipment	1.42
IPI, Instruments	0.02

Table 29

3<sup>rd</sup> Order Moving Average, Quarterly Data (Raw)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi^2$ <u>X<sub>1</sub></u>	$\chi^2$ <u>X<sub>2</sub></u>
IPI, All Durables	2.98	5.32
IPI, Lumber and Products	2.46	3.12
IPI, Furniture and Fixtures	2.17	2.24
IPI, Primary Metals	1.14	1.20
IPI, Fabricated Metals	1.81	2.30
IPI, Non Electrical Machinery	0.03	0.09
IPI, Electrical Machinery	0.27	0.27
IPI, Transportation and Equipment	0.09	5.27
IPI, Instruments	0.50	1.47

Table 30

4<sup>th</sup> Order Moving Average, Quarterly Data (Raw)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$ <u>X<sub>1</sub></u>
IPI, All Durables	0.04
IPI, Lumber and Products	0.30
IPI, Furniture and Fixtures	0.005
IPI, Primary Metals	0.28
IPI, Fabricated Metals	1.07
IPI, Non Electrical Machinery	0.04
IPI, Electrical Machinery	0.1
IPI, Transportation and Equipment	1.04
IPI, Instruments	0.1

Table 31

4<sup>th</sup> Order Moving Average, Quarterly Data (Raw)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi^2$ <u><math>\chi_1</math></u>	$\chi^2$ <u><math>\chi_2</math></u>
IPI, All Durables	0.75	1.82
IPI, Lumber and Products	0.06	0.73
IPI, Furniture and Fixtures	0.42	1.17
IPI, Primary Metals	0.08	0.03
IPI, Fabricated Metals	0.96	1.36
IPI, Non Electrical Machinery	0.96	1.36
IPI, Electrical Machinery	0.05	0.16
IPI, Transportation and Equipment	0.23	1.41
IPI, Instruments	0.03	0.08

Table 32

4<sup>th</sup> Order Moving Average, Quarterly Data (Logs)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$
IPI, All Durables	3.26
IPI, Lumber and Products	4.59
IPI, Furniture and Fixtures	0.21
IPI, Primary Metals	0.26
IPI, Fabricated Metals	1.93
IPI, Non Electrical Machinery	2.64
IPI, Electrical Machinery	2.79
IPI, Transportation and Equipment	5.56
IPI, Instruments	0.47

Table 33

2<sup>nd</sup> Order Moving Average, Quarterly Data (Logs)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi_1^2$	$\chi_2^2$
IPI, All Durables	3.11	4.35
IPI, Lumber and Products	5.21	5.66
IPI, Furniture and Fixtures	0.33	0.34
IPI, Primary Metals	1.48	1.49
IPI, Fabricated Metals	6.61	6.66
IPI, Non Electrical Machinery	1.37	2.22
IPI, Electrical Machinery	1.07	2.36
IPI, Transportation and Equipment	2.32	6.34
IPI, Instruments	2.73	7.78

Table 34

3<sup>rd</sup> Order Moving Average, Quarterly Data (Logs)  
 $\chi^2$  Statistics, First Order Markov Process

<u>Series</u>	$\chi^2$
IPI, All Durables	1.04
IPI, Lumber and Products	2.09
IPI, Furniture and Fixtures	1.33
IPI, Primary Metals	0.29
IPI, Fabricated Metals	1.76
IPI, Non Electrical Machinery	0.08
IPI, Electrical Machinery	0.18
IPI, Transportation and Equipment	1.85
IPI, Instruments	0.02

Table 35

3<sup>rd</sup> Order Moving Average, Quarterly Data (Logs)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi_1^2$	$\chi_2^2$
IPI, All Durables	3.82	4.18
IPI, Lumber and Products	2.46	3.11
IPI, Furniture and Fixtures	1.44	1.51
IPI, Primary Metals	6.04	0.25
IPI, Fabricated Metals	2.30	1.81
IPI, Non Electrical Machinery	0.02	0.11
IPI, Electrical Machinery	0.09	0.09
IPI, Transportation and Equipment	0.03	3.11
IPI, Instruments	1.34	2.31

Table 36

**4<sup>th</sup> Order Moving Average, Quarterly Data (Logs)  
X<sup>2</sup> Statistics, First Order Markov Process**

<u>Series</u>	<u>X<sub>i</sub><sup>2</sup></u>
IPI, All Durables	11.27
IPI, Lumber and Products	0.46
IPI, Furniture and Fixtures	0.22
IPI, Primary Metals	0.74
IPI, Fabricated Metals	1.73
IPI, Non Electrical Machinery	0.03
IPI, Electrical Machinery	0.03
IPI, Transportation and Equipment	2.10
IPI, Instruments	0.29

Table 37

4<sup>th</sup> Order Moving Average, Quarterly Data (Logs)  
 $\chi^2$  Statistics, Second Order Markov Process

<u>Series</u>	$\chi_1^2$	$\chi_2^2$
IPI, All Durables	1.60	2.00
IPI, Lumber and Products	0.06	1.37
IPI, Furniture and Fixtures	0.006	0.88
IPI, Primary Metals	0.42	0.71
IPI, Fabricated Metals	1.98	2.38
IPI, Non Electrical Machinery	0.02	0.02
IPI, Electrical Machinery	0.04	0.11
IPI, Transportation and Equipment	0.71	2.63
IPI, Instruments	0.23	0.29

## Notes to Chapter 4

1. Since the average business cycle lasts approximately 5 years, for annual data, a 2<sup>nd</sup> order Markov process should be able to capture asymmetry over the business cycle. The 1<sup>st</sup> order Markov process using annual data constitutes a weaker test. The 1<sup>st</sup> and 2<sup>nd</sup> order Markov tests for quarterly data test for asymmetry at a higher frequency than the business cycle, and in some respects are of secondary interest to this study.
2. See Table 8 for the time periods covered by each series.
3. Specifically, 28% of all tests on annual data had a chi-square statistic that exceeded two in the case of the first order Markov process and the single hypothesis for the second order Markov process, or, exceeded four for the compound hypothesis of the second order Markov process.

$$X_1^2(15\%) = 2.0$$

$$X_2^2(15\%) = 4.0$$

## Chapter 5 - Asymmetry in the Employment Sector of the U.S. Economy

The overall goal of this chapter is to examine a hypothesis proposed by Delong and Summers (1984) relating to the etiology of the asymmetric movement of U.S. unemployment data found by Neftci (1984) and themselves. First, unemployment series for various industrial sectors (mining, manufacturing, etc.) of the economy are tested for asymmetry. The purpose of these tests is to determine the location of asymmetry within the employment sector of the U.S. economy. Next, there is a discussion of the Delong and Summers (1984) hypothesis regarding the cause of asymmetry in U.S. unemployment data. A statistical test based on the theory of Markov processes is then derived to test their hypothesis. This test is largely a variation of the asymmetry test developed by Neftci and outlined in Chapter 3. Next, there is an analysis of the test results. The test is applied at a fairly disaggregate level to that sector of the economy found to have the most significant level of asymmetry in unemployment. The final section of the chapter contains a conclusion and discussion of possible alternative explanations for the asymmetry in unemployment data.

### A. Asymmetry in Disaggregate U.S. Unemployment Series

In an attempt to determine what sector of the economy has the most significant level of asymmetry in unemployment, tests were performed on quarterly unemployment rates for 6

major industry groups for the period 1948-1983. Tables 38 and 39 contain the test results under the assumptions of a first order and second order Markov process, respectively.

Given the assumption of a first order Markov process (Table 38), unemployment for Durable Goods Manufacturing and All Manufacturing both indicate fairly strong evidence of asymmetry. In addition, the Non-Durable Goods Manufacturing and Services and Finance sectors both show weak to moderate levels, while Construction and Mining show virtually no asymmetry. Note that  $\hat{l}_0 > \hat{l}_1$  for all sectors of the economy except mining. This relationship reflects the fact that the asymmetry found in unemployment is characterized by abrupt increases and gradual declines.

Under the assumption of the second order Markov process (Table 39), for the simple hypothesis, Durable Goods Manufacturing is the only series to show even a moderate level of asymmetry. For the compound hypothesis, which is the strongest of the three tests of asymmetry, Non-Durable Goods Manufacturing has a surprisingly high test statistic, while the other sector show little evidence of asymmetry. Note also, that for Durable Goods Manufacturing and All Manufacturing,  $\hat{l}_{00} > \hat{l}_{11}$  and that  $\hat{l}_{01} > \hat{l}_{10}$  for all series.

Table 38

**Estimated Transition Probabilities  
First Order Markov Process**

<u>Unemployment Series</u>	<u>Estimates</u>	<u>2 X<sub>1</sub></u>	<u>Significance Level</u>
All Manufacturing Industries	l <sub>0</sub> =0.7229 l <sub>1</sub> =0.5072	2.60	11%
Durable Goods Manufacturing	l <sub>0</sub> =0.7500 l <sub>1</sub> =0.6207	2.69	10%
Non-Durable Goods Manufacturing	l <sub>0</sub> =0.6538 l <sub>1</sub> =0.5625	1.23	27%
Services and Finance	l <sub>0</sub> =0.5195 l <sub>1</sub> =0.4154	1.54	21%
Construction	l <sub>0</sub> =0.6438 l <sub>1</sub> =0.6232	0.065	80%
Mining	l <sub>0</sub> =0.4712 l <sub>1</sub> =0.4861	0.031	87%

\* All series are quarterly, for the period 1948-1983. Data is from the Business Conditions Digest, U.S. Dept. of Commerce.

Table 39

**Estimated Transition Probabilities  
Second Order Markov Process**

Unemployment Series	Estimates*	<sup>1</sup> <u>H<sub>0</sub></u>		<sup>2</sup> <u>H<sub>0</sub></u>	
		<u>X<sub>1</sub></u>	<u>Signif. Level</u>	<u>X<sub>2</sub></u>	<u>Signif. Level</u>
All Manuf. Industries	l <sub>00</sub> =0.7288 l <sub>11</sub> =0.6286	1.02	32%	2.07	37%
Durable Goods Manufacturing	l <sub>00</sub> =0.7742 l <sub>11</sub> =0.6389	2.05	16%	2.24	33%
Non-Durable Gds. Manufacturing	l <sub>00</sub> =0.6200 l <sub>11</sub> =0.6944	0.51	83%	5.87	6%
Services and Finance	l <sub>00</sub> =0.5128 l <sub>11</sub> =0.5556	0.12	93%	3.23	19%
Construction	l <sub>00</sub> =0.6087 l <sub>11</sub> =0.6512	0.17	90%	1.54	47%
Mining	l <sub>00</sub> =0.4375 l <sub>11</sub> =0.5714	1.20	27%	2.08	37%

\* All series are quarterly, for the period 1948-1983. Data is from the Business Conditions Digest, U.S. Dept. of Commerce.

These results suggest that the most significant level of asymmetry is to be found in Durable Goods Manufacturing. This is quite interesting in view of the fact that most cyclical movement occurs in the durable goods sector of the economy. In light of these results, the tests of the Delong and Summers hypothesis will concentrate on durable goods producing industries.

#### B. The Delong and Summers Hypothesis

As discussed in Chapter 2, Delong and Summers (1984) examined GNP, Aggregate Industrial Production and Unemployment in the U.S., Japan, and several European countries for evidence of asymmetry.<sup>1</sup> They found that asymmetry only exists in the U.S. unemployment series. Their findings led them to conclude that "asymmetry is not a phenomenon of first order importance in understanding business cycles."<sup>2</sup> Given their findings, they sought an explanation as to why asymmetry appears to be peculiar to the employment sector of the U.S. economy. Using a graph, they examined the relationship between deviations of industrial production in the U.S. from trend, and the detrended unemployment rate. They found that at business cycle peaks, the unemployment rate lags behind output, and that output begins to fall relative to trend before unemployment begins to rise. Thus, for a period of time, output is falling relative to trend and employment is rising relative to trend. They noted that this "discrepancy in timing" only occurs at business cycle peaks. At cyclical

troughs they found that the U. S. unemployment rate peaks within one quarter of the trough of output.

As a result of their observations, they concluded that the asymmetry in U.S. unemployment appears to be a manifestation of an "end of expansion productivity effect."<sup>3</sup> That is, during the initial stage of an economic contraction, the fact that unemployment is still rising when output is falling causes worker productivity to take a sharp downturn. Once productivity falls below its reservation level, firms layoff workers and the level of unemployment takes a sharp drop. As output expands from its trough, employment increases along with it, so that unemployment decreases gradually. Thus, output leads employment at the business cycle peak, and the two coincide at the trough. It is this aspect of their hypothesis that will be tested later on in this chapter.

As a possible explanation as to why firms expand employment coming out of the trough so that it coincides with the upturn in output, but do not contract employment so that it coincides with the decrease in output at the end of the cyclical expansion, Delong and Summers suggest the theory of labor hoarding.<sup>4</sup> Basically, labor hoarding can be said to result from labor being a quasi-fixed factor of production. Some specific reasons why an employer might hold onto workers when output is falling include: contractual commitments, transactions costs of adjustment, sacrificing rather than optimizing behavior, fear of adverse effects on labor morale, and the desire to possess an

inventory of certain skills that may be needed quickly during an upturn.

A recent study by Medoff and Fay (1985) used micro data to test for the presence of labor hoarding at the firm level. They found that for the trough quarter of a typical plant, 4% of the workers should be classified as hoarded. This result tends to lend credence to the Delong and Summers hypothesis, although a knowledge of the amount of hoarded labor a firm possesses at the trough quarter is not overwhelming proof that hoarding is a cause of asymmetry. In particular, it doesn't provide any information about the "hoarding habits" of the firm from the point in time when output peaks until the trough quarter. In addition, the degree of hoarding found by Fay and Medoff (1985) leaves unanswered questions regarding the importance of its role in causing asymmetry. That is, even if hoarding exists and causes asymmetry in the manner hypothesized by Delong and Summers (1984), a question arises as to whether the degree of hoarding is great enough to create the level of asymmetry reported in Tables 38 and 39. All of this suggests that an examination of the relationship between the sample paths of output and employment might provide some insight into the variety of the Delong and Summers hypothesis.

### C. A Test for Asymmetry Between Two Series

The procedure which will be used to test the Delong and Summers hypothesis is designed to be a more systematic means



Table 40

## One Step Transitions for Concurrent States

	<sup>t</sup> I <sub>11</sub>	<sup>t</sup> I <sub>10</sub>	<sup>t</sup> I <sub>01</sub>	<sup>t</sup> I <sub>00</sub>
<sup>t-1</sup> I <sub>11</sub>	N <sub>1</sub>	N <sub>2</sub>	N <sub>3</sub>	N <sub>4</sub>
<sup>t-1</sup> I <sub>10</sub>	N <sub>5</sub>	N <sub>6</sub>	N <sub>7</sub>	N <sub>8</sub>
<sup>t-1</sup> I <sub>01</sub>	N <sub>9</sub>	N <sub>10</sub>	N <sub>11</sub>	N <sub>12</sub>
<sup>t-1</sup> I <sub>00</sub>	N <sub>13</sub>	N <sub>14</sub>	N <sub>15</sub>	N <sub>16</sub>

where  $N_i$  = transition occurrences,  $i = 1, \dots, 16$

The matrix of transition probabilities is as follows:

$$L = \begin{bmatrix} l_1 & l_2 & l_3 & l_4 \\ l_5 & l_6 & l_7 & l_8 \\ l_9 & l_{10} & l_{11} & l_{10} \\ l_{13} & l_{14} & l_{15} & l_{16} \end{bmatrix}$$

$$\text{where, } \begin{aligned} l_1 &= P(I_{11}^t | I_{11}^{t-1}) \\ l_2 &= P(I_{10}^t | I_{11}^{t-1}) \\ l_3 &= P(I_{01}^t | I_{11}^{t-1}) \\ l_4 &= P(I_{00}^t | I_{11}^{t-1}), \text{ etc.} \end{aligned}$$

Note that since  $l_1 + l_2 + l_3 + l_4 = 1$  and the same relationship holds for each row of conditional probabilities, the following useful relationships hold:

$$l_4 = 1 - l_1 - l_2 - l_3$$

$$l_8 = 1 - l_5 - l_6 - l_7$$

$$l_{12} = 1 - l_9 - l_{10} - l_{11}$$

$$l_{16} = 1 - l_{13} - l_{14} - l_{15}$$

These complementary relationships help simplify the calculation of the estimated transition probabilities.

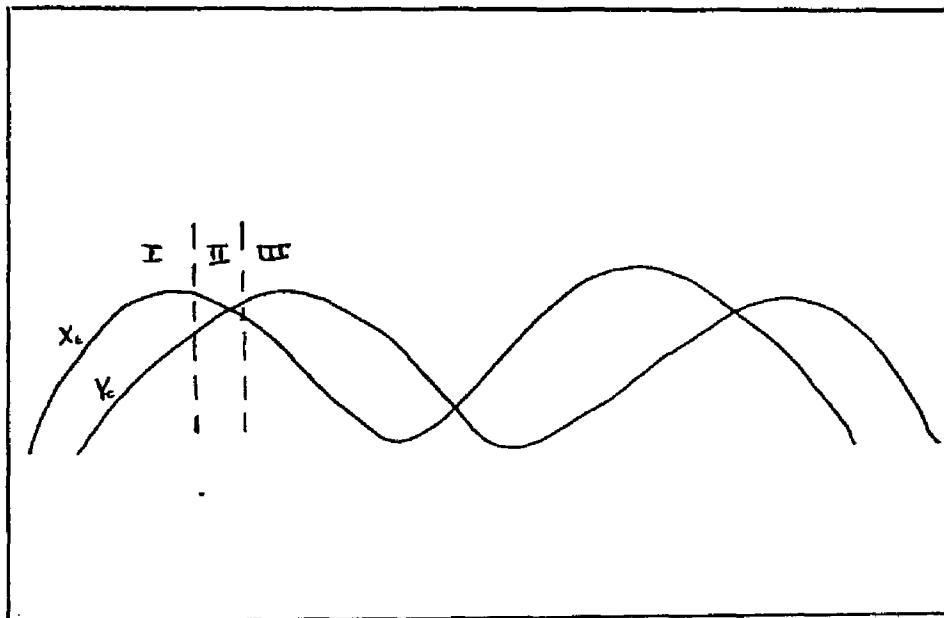
With the aid of Figure 3, we can now define the null hypothesis. We want to determine whether the relationship between  $\{X_t\}$  and  $\{Y_t\}$  at the cyclical peak is systematically different from the relationship between these two series at the trough. In figure , Region I is characterized by  $\{X_t\}$  turning down while  $\{Y_t\}$  continues to increase. In Region II,  $\{X_t\}$  is falling while  $\{Y_t\}$  is rising. In Region III,  $\{X_t\}$  is falling while  $\{Y_t\}$  is turning down.

In turns of the concurrent states defined above, the peak regions are denoted as:

<u>Region</u>	<u>State</u>
I	$I_{01}^t \mid I_{11}^{t-1}$
II	$I_{01}^t \mid I_{01}^{t-1}$
III	$I_{00}^t \mid I_{01}^{t-1}$

Figure 3

## An Illustration of Two Series Asymmetry



Thus, the null hypothesis which will be tested is:

$$H_0: P(I_{01}^t \mid I_{11}^{t-1}) = P(I_{10}^t \mid I_{00}^{t-1})$$

$$P(I_{01}^t \mid I_{01}^{t-1}) = P(I_{10}^t \mid I_{10}^{t-1})$$

$$P(I_{00}^t \mid I_{01}^{t-1}) = P(I_{11}^t \mid I_{10}^{t-1})$$

In terms of the transition probability notation, the null hypothesis can be expressed as:

$$H_0: l_3 = l_{14}$$

$$l_{11} = l_6$$

$$l_{12} = l_5$$

Estimates of the transitions probabilities are calculated using the maximum likelihood technique. The likelihood function is:

$$L(.) = l_1^{N_1} l_2^{N_2} l_3^{N_3} (1 - l_1 - l_2 - l_3)^{N_4} l_5^{N_5} l_6^{N_6} l_7^{N_7} \\ \times (1 - l_5 - l_6 - l_7)^{N_8} l_9^{N_9} l_{11}^{N_{11}} l_{12}^{N_{12}} (1 - l_9 - l_{11} - l_{12})^{N_{10}} \\ l_{13}^{N_{13}} l_{14}^{N_{14}} l_{15}^{N_{15}} (1 - l_{13} - l_{14} - l_{15})^{N_{16}}$$

Note that the initial state probability is omitted. This makes the calculation of the estimates of the transition probabilities considerably easier. Also, note the role of the complements defined above. In particular, in order to accommodate the null hypothesis, and simplify the calculations,  $l_{10}$  is expressed in terms of  $l_9$ ,  $l_{11}$ , and  $l_{12}$ .

The estimated  $l$ 's are found by taking the derivatives of the log-likelihood function, setting them equal to zero and solving. The first order conditions are as follows:

$$\begin{aligned} \frac{\partial \ln L(.)}{\partial l_1} &= \frac{N_1}{l_1} - \frac{N_4}{(1 - l_1 - l_2 - l_3)} = 0 \\ \frac{\partial \ln L(.)}{\partial l_2} &= \frac{N_2}{l_2} - \frac{N_4}{(1 - l_1 - l_2 - l_3)} = 0 \\ \frac{\partial \ln L(.)}{\partial l_3} &= \frac{N_3}{l_3} - \frac{N_4}{(1 - l_1 - l_2 - l_3)} = 0 \\ \frac{\partial \ln L(.)}{\partial l_5} &= \frac{N_5}{l_5} - \frac{N_8}{(1 - l_5 - l_6 - l_7)} = 0 \\ \frac{\partial \ln L(.)}{\partial l_6} &= \frac{N_6}{l_6} - \frac{N_8}{(1 - l_5 - l_6 - l_7)} = 0 \\ \frac{\partial \ln L(.)}{\partial l_7} &= \frac{N_7}{l_7} - \frac{N_8}{(1 - l_5 - l_6 - l_7)} = 0 \\ \frac{\partial \ln L(.)}{\partial l_9} &= \frac{N_9}{l_9} - \frac{N_{10}}{(1 - l_9 - l_{11} - l_{12})} = 0 \\ \frac{\partial \ln L(.)}{\partial l_{11}} &= \frac{N_{11}}{l_{11}} - \frac{N_{10}}{(1 - l_9 - l_{11} - l_{12})} = 0 \\ \frac{\partial \ln L(.)}{\partial l_{12}} &= \frac{N_{12}}{l_{12}} - \frac{N_{10}}{(1 - l_9 - l_{11} - l_{12})} = 0 \\ \frac{\partial \ln L(.)}{\partial l_{13}} &= \frac{N_{13}}{l_{13}} - \frac{N_{16}}{(1 - l_{13} - l_{14} - l_{15})} = 0 \\ \frac{\partial \ln L(.)}{\partial l_{14}} &= \frac{N_{14}}{l_{14}} - \frac{N_{16}}{(1 - l_{13} - l_{14} - l_{15})} = 0 \\ \frac{\partial \ln L(.)}{\partial l_{15}} &= \frac{N_{15}}{l_{15}} - \frac{N_{16}}{(1 - l_{13} - l_{14} - l_{15})} = 0 \end{aligned}$$

These 12 equations can be broken up into 4 independent subsystems each consisting of 3 equations. Each subsystem can be solved for  $l_i$  using Cramers rule. The solutions are of the following form:

$$\hat{l}_1 = \frac{BC}{ABC + AC + BC + AB}$$

$$\hat{l}_2 = \frac{AC}{ABC + AC + BC + AB}$$

$$\hat{l}_3 = \frac{AB}{ABC + AC + BC + AB}$$

$$\text{where, } A = \frac{N_4}{N_1} \quad B = \frac{N_4}{N_2} \quad C = \frac{N_4}{N_3}$$

The remaining  $l$ 's are calculated in a similar manner.

The calculation of the restricted likelihood is more difficult because of the effects of the restrictions. The restricted likelihood function is as follows:

$$L^*(.) = l_1^{N_1} l_2^{N_2} l_{R1}^{N_3+N_{14}} (1 - l_1 - l_2 - l_{R1})^{N_4} l_{R2}^{N_5+N_{12}} l_{R3}^{N_6+N_{11}}$$

$$\times (1 - l_{R2} - l_{R3} - l_7)^{N_8} l_9^{N_9} (1 - l_9 - l_{R2} - l_{R3})^{N_{10}} l_{13}^{N_{13}} l_{15}^{N_{15}}$$

$$(1 - l_{13} - l_{R1} - l_{15})^{N_{16}}$$

$$\text{where, } l_{R1} = l_3 = l_{14}$$

$$l_{R2} = l_5 = l_{12}$$

$$l_{R3} = l_6 = l_{11}$$

Solving the restricted likelihood function for the maximum likelihood estimates requires the use of a nonlinear optimization technique. Consequently, it becomes quite difficult to calculate the likelihood ratio statistic. Fortunately, a method by Wald can be used as an alternative means of calculating the test statistic. As pointed out by Silvey,<sup>5</sup> the Wald technique is designed for instances where calculation of the restricted likelihood function is difficult.

According to Wald, the following test statistic is distributed approximately as  $\chi^2_{(R)}$ .

$$\hat{h}(\theta)' [H'B^{-1}B^{-1}H] \hat{h}(\theta)$$

where,  $\theta$  = vector of parameters

$h$  = matrix of restrictions

$$H = \frac{\partial h_i}{\partial \theta_i}$$

$B$  = Hessian matrix of the unrestricted likelihood function

The Wald test is a large sample equivalent of the likelihood ratio test.

#### D. Test Results

The results of the tests are presented in Tables 41-43. The selection of industries reflects the observation made in Section A of this chapter that the durable goods sector of the economy possesses the most significant level of asymmetry in unemployment. Since the test is attempting to

pick up the effects of firm behavior with regard to employment and output over time, industry level (or less aggregate) data is probably most suitable for testing. However, tests were also applied at the industry group level.

For the industry level data, tests were performed on quarterly and monthly series. There are both costs and benefits to using either of these two types of series. On the one hand, the likelihood of any of the 16 states not occurring is lower with monthly data than with quarterly data. This is important, because if one of the states does not occur, a meaningful test statistic cannot be calculated. On the other hand, monthly data may have so much movement that the cyclical relationship between the two series will be obscured. That is, the state occurrences that are recorded will be less representative of the business cycle movement in the monthly series than the quarterly data series because of "noise". It would seem that this problem would be more important for a shorter time series since it would include fewer complete business cycles. Since we have only 30 years of data at the industry level, it would seem that the quarterly data would give rise to the most reliable results.

First, consider Table 41 which contains quarterly data at the industry level for the period, 1954-1983. For two of the six industries tested, Hardware and Tools, and Fabricated Structural Metal Products, the test statistics are high enough to suggest that the relationship between

output and employment at the peak differs, with a moderate degree of significance, from the relationship between output and employment at the trough. For three of the remaining four industries, the Wald statistic indicates virtually no systematic difference between peak and trough movement. The test statistic for the Raw Steel industry could not be calculated because one of the states did not occur. Appendix C contains the number of occurrences of each state for all of the tests performed.

Table 42 contains test results for monthly data for the same industries as in Table 41. Raw Steel and Basic Iron and Steel both show fairly strong evidence of "two series asymmetry". The Metal Working Machinery industry shows a suspiciously high level of two series asymmetry, while the Hardware and Tools industry shows a moderate level. The two remaining industries, Fabricated Structural Metal Products and Construction and Related Machinery, indicate no evidence of two series asymmetry.

A comparison of the results in Table 41 to those in Table 42 reveals dramatic differences without any apparent systematic pattern.

Table 41

## Two Series Asymmetry, Quarterly Data, 1954-1983

<u>Industry</u>	$\hat{l}_3$	$\hat{l}_{14}$	$\chi^2_{(3)}$	<u>Sig. Level</u>
Basic Iron and Steel	$\hat{l}_3 = .24$	$\hat{l}_{14} = .27$	1.58	.71
	$\hat{l}_5 = .41$	$\hat{l}_{12} = .27$		
	$\hat{l}_6 = .24$	$\hat{l}_{11} = .16$		
Hardware and Tools	$\hat{l}_3 = .21$	$\hat{l}_{14} = .12$	4.25	.24
	$\hat{l}_5 = .25$	$\hat{l}_{12} = .26$		
	$\hat{l}_6 = .13$	$\hat{l}_{11} = .16$		
Fabricated Structural	$\hat{l}_3 = .22$	$\hat{l}_{14} = .07$	4.54	.21
	$\hat{l}_5 = .23$	$\hat{l}_{12} = .26$		
	$\hat{l}_6 = .23$	$\hat{l}_{11} = .30$		
Construction and Related Machinery	$\hat{l}_3 = .14$	$\hat{l}_{14} = .14$	2.50	.48
	$\hat{l}_5 = .70$	$\hat{l}_{12} = .27$		
	$\hat{l}_6 = .10$	$\hat{l}_{11} = .33$		
Metal Working Machinery	$\hat{l}_3 = .15$	$\hat{l}_{14} = .16$	.085	---
	$\hat{l}_5 = .20$	$\hat{l}_{12} = .20$		
	$\hat{l}_6 = .10$	$\hat{l}_{11} = .13$		
Raw Steel	*			

\* Estimates of the transition probabilities could not be calculated due to transition counts of zero.

Source: Production Data is from the Federal Reserve Industrial Production Series. Employment data is from the Bureau of Labor Statistics, Employment and Earnings.

Table 42

## Two Series Asymmetry, Monthly Data, 1954-1983

<u>Industry</u>	$\hat{\lambda}_3$	$\hat{\lambda}_{14}$	$\chi^2_{(3)}$	<u>Sig. Level</u>
Basic Iron and Steel	$\hat{\lambda}_3 = .13$	$\hat{\lambda}_{14} = .16$	4.26	.24
	$\hat{\lambda}_5 = .45$	$\hat{\lambda}_{12} = .29$		
	$\hat{\lambda}_6 = .27$	$\hat{\lambda}_{11} = .35$		
Hardware and Tools	$\hat{\lambda}_3 = .16$	$\hat{\lambda}_{14} = .27$	3.79	.29
	$\hat{\lambda}_5 = .31$	$\hat{\lambda}_{12} = .16$		
	$\hat{\lambda}_6 = .09$	$\hat{\lambda}_{11} = .18$		
Fabricated Structural	$\hat{\lambda}_3 = .22$	$\hat{\lambda}_{14} = .22$	0.58	---
	$\hat{\lambda}_5 = .22$	$\hat{\lambda}_{12} = .26$		
	$\hat{\lambda}_6 = .16$	$\hat{\lambda}_{11} = .20$		
Construction and Related Machinery	$\hat{\lambda}_3 = .27$	$\hat{\lambda}_{14} = .27$	0.81	---
	$\hat{\lambda}_5 = .23$	$\hat{\lambda}_{12} = .21$		
	$\hat{\lambda}_6 = .15$	$\hat{\lambda}_{11} = .15$		
Metal Working Machinery	$\hat{\lambda}_3 = .25$	$\hat{\lambda}_{14} = .03$	26.80	.001
	$\hat{\lambda}_5 = .21$	$\hat{\lambda}_{12} = .19$		
	$\hat{\lambda}_6 = .26$	$\hat{\lambda}_{11} = .71$		
Raw Steel	$\hat{\lambda}_3 = .13$	$\hat{\lambda}_{14} = .17$	5.22	.16
	$\hat{\lambda}_5 = .50$	$\hat{\lambda}_{12} = .31$		
	$\hat{\lambda}_6 = .16$	$\hat{\lambda}_{11} = .35$		

Source: Production Data is from the Federal Reserve Industrial Production Series. Employment data is from the Bureau of Labor Statistics, Employment and Earnings.

Table 43

## Two Series Asymmetry, Quarterly Data, 1948-1983

<u>Industry Group</u>	$\hat{\lambda}_3$	$\hat{\lambda}_{14}$	$\chi^2_{(3)}$	<u>Sig. Level</u>
Lumber + Related Products	$\hat{\lambda}_3 = .20$	$\hat{\lambda}_{14} = .30$	2.84	.42
	$\hat{\lambda}_5 = .36$	$\hat{\lambda}_{12} = .27$		
	$\hat{\lambda}_6 = .14$	$\hat{\lambda}_{11} = .27$		
Furniture and Fixtures	*		---	---
Primary Metals	*		---	---
Fabricated Metals	*		---	---
Non Electrical Machinery	*		---	---
Electrical Machinery	*		---	---
Instrument	*		---	---
Lumber + Related Products	$\hat{\lambda}_3 = .06$	$\hat{\lambda}_{14} = .13$	2.27	.52
	$\hat{\lambda}_5 = .50$	$\hat{\lambda}_{12} = .33$		
	$\hat{\lambda}_6 = .17$	$\hat{\lambda}_{11} = .27$		

\* Estimates of the transition probabilities could not be calculated due to transition counts of zero.

Source: Production data is from the Federal Reserve Series. Employment data is from the Bureau of Labor Statistics, Employment and Earnings.

While there is an overall tendency for the monthly data to give rise to higher test statistics than the quarterly data, this is not necessarily true of the individual series. In addition, a comparison of the estimated transition probabilities does not reveal any pattern of change. The original intent behind testing both monthly and quarterly data was to see if the monthly data would strengthen the results derived from the quarterly data. The quarterly data at the industry level was the data of first choice for this test. The results of Table 42 do not support the results in Table 41, possibly because of the "noise" effect present in monthly data.

Table 43 contains the results of tests on quarterly data at the industry group level. Only two of the eight series tested had a complete set of state occurrences. This is the major drawback of using quarterly data for this test. Of the two series for which the Wald Statistic could be calculated, there is little evidence of any systematic difference between output and employment at the peak and trough of the business cycle.

#### E. Alternative Reasons for Asymmetry in Unemployment

The results of the previous section suggest that the Delong and Summers hypothesis is not of primary importance in explaining the asymmetry found in the employment sector of the U.S. economy. While the degree of two series asymmetry evidenced by the Wald statistics might be strong enough to reveal itself in plots of output and unemployment

such as those examined by Delong and Summers, it seems unlikely that labor hoarding or some other phenomenon causing the end of productivity effect is anything other than a secondary effect compounding some other cause of asymmetry. To a large extent, the results of Chapter 4 support this conclusion. Delong and Summers (1984) based their hypothesis on the fact that they found asymmetry in the U.S. employment sector but not in either the employment sector of any of the other countries they examined or in the production sector of the U.S. or any other countries. The results of Chapter 4 dispute the Delong and Summers findings, in that asymmetry through moderate in degree, clearly exists in the production sector of the U.S. economy. Thus, the question of what causes asymmetry in the employment sector of the U.S. should probably be rephrased as the following two questions: one; what causes asymmetry in the U.S. economy as a whole, and two; why is asymmetry in the employment sector of the U.S. economy greater than asymmetry in the production sector? The first question will have to remain unanswered. The answer to the second question might be that the primary (unknown) cause of asymmetry is compounded by labor hoarding which results in employment turning down after output, thereby causing productivity to drop sharply and unemployment to rise abruptly. Of course, this is not the only explanation for asymmetric behavior in the employment sector. In light of the weak statistical results of the Delong and Summers hypothesis, it might be best to at least mention an alternative hypothesis.

A recent paper by Pissarides (1985) offers an alternative explanation for the asymmetry found in unemployment. According to Pissarides, job vacancies play a key role in the asymmetric behavior of unemployment. For instance, suppose there is a negative shock to the economy. The shock will decrease the number of acceptable job matches (via an increase in the reservation productivity), resulting in a simultaneous jump in unemployment and decrease in the number of job vacancies. On the other hand, if there is a positive shock to the economy, job vacancies will jump on impact, indicating a desire on the part of firms to increase employment. However, the matching of employees and employers takes time, so that unemployment falls gradually. Thus, the Pissarides model predicts that unemployment will rise abruptly during economic contractions and fall gradually during expansions. As an explanation of unemployment asymmetry this is an interesting alternative to the Delong and Summers hypothesis which I intend to make the subject of future research.

The goal of this chapter was to test a hypothesis made by Delong and Summers (1984) concerning the cause of asymmetry in the employment sector of the U.S. economy. As a preliminary step toward accomplishing this goal and attempt was made to determine the industry group with the greatest level of asymmetry. The durable goods manufacturing sector of the economy was found to have the strongest level of asymmetry in unemployment. Next, a statistical test was developed to test the Delong and Summers

hypothesis. The text was applied at the industry and industry group level for the durable goods manufacturing sector of the economy. The results did not lend strong support to the Delong and Summers hypothesis. An explanation was offered which suggested that the Delong and Summers hypothesis might be of secondary importance and that the primary cause of asymmetry is some factor which is pervasive throughout the U.S. economy. Finally, a possible alternative cause of asymmetry in unemployment was discussed.

## Notes to Chapter 5

1. See Table 2.6 for a summary of their results.
2. Delong and Summers (1984) p. 2.
3. Delong and Summers (1984) p. 16.
4. See Medoff and Fay (1985) for details of this theory.
5. See Silvey pp. 119-125 for details of the Wald test.

## Chapter 6 - Secular Change in the Degree of Asymmetry

The purpose of this chapter is to determine whether the degree of asymmetry in economic time series has changed over time. To a certain extent this analysis stands at odds with an underlying premise of the work in Chapter 4. The reason for this is that if a series tests positive for asymmetry, as do some of the series tested in Chapter 4, then one might expect it to be consistently asymmetric throughout time. On the other hand, it is not entirely unreasonable to argue that the basic characteristics of business cycles are subject to change over time, perhaps as a result of institutional changes. Given the various viewpoints, an empirical investigation into the issue seems warranted.

The first part of the chapter contains a discussion of analyses by Burns and Mitchell (1947) and Zarnowitz (1985) relating to secular change in the business cycle. Next, there is a brief discussion of a model by Farmer (1985) relating to secular change in the business cycle. Next, there is a brief discussion of a model by Farmer (1985) which serves to highlight the importance of the topic. Finally, test results are presented and discussed.

The question of whether the degree of asymmetry found in economic time series has changed over time is really one aspect of the more general question of whether the business cycle has experienced secular change. The idea of secular change in the business cycle is an important one, particularly if one intends to use "average" cycles for

analytical purposes. For this reason, the possibility of secular change was important to Burns and Mitchell (1947). Although they did not directly address the issue of a change in the degree of asymmetry, Burns and Mitchell's analysis of secular change in the duration of the cycle does provide some information about the asymmetry issue. Consider the following table:

Table 44

**Average Duration and Amplitude of Expansions and Contractions of Three Successive Groups of Specific Cycles**

Series and Period Covered	No. of Specific Cycles	Average Expansion	Average Contraction	Average Rise PerMonth	Average Fall PerMonth
<b>Pig Iron</b>					
1879-1896	5	29	14	2.6	3.8
1896-1914	5	32	11	2.1	5.6
1914-1933	5	25 (0.46)	18 (0.62)	2.6 (0.35)	4.6 (0.49)
<b>Deflated Clearings</b>					
1879-1896	5	28	9	1.0	1.7
1896-1914	5	33	8	0.8	3.0
1914-1933	5	37 (.43)	17 (1.38)	0.7 (.90)	1.1 (.49)
<b>Freight Car Orders</b>					
1879-1896	6	22	26	13.9	8.3
1896-1914	6	22	18	9.4	10.4
1914-1933	7	12 (1.65)	19 (1.16)	41.3 (1.11)	15.9 (1.61)

Source: Burns and Mitchell (1947)

In an attempt to determine whether secular change had taken place, Burns and Mitchell divided each series into 3 segments and looked at the average length of expansion and

contraction as well as the average rise and fall per month. They used analysis of variance to test the null hypothesis that there was no secular change. The F-tests relating to these tests are in parenthesis. In all of the instances shown above and most of the other series they tested, they were unable to reject the hypothesis that the observed segment variation was random. Test statistics aside, this is not that surprising a result, since none of the series show any substantial tendency toward change in any particular direction. Note that given the categories they examined, if there was any change in the degree of asymmetry it would probably have shown up in their tests.<sup>1</sup>

As an additional test, Burns and Mitchell examined the average duration of business cycles for the U.S. and several European countries under the assumption that any secular change in the specific cycles may show up in the business cycles. The results for the U.S. are presented in the following table.

Table 45

Average Duration of Three Successive Groups  
of Business Cycles, U.S. 1854-1933

<u>Period</u>	<u>No. of Business Cycles</u>	<u>Avg. Expansion</u>	<u>Avg. Contraction</u>
1854-1885	6	31	30
1885-1908	7	24	16
1908-1933	7	21 (1.89)	21 (1.75)

Source: Burns and Mitchel (1947)

As in the case of the specific cycles, they were unable to reject the null hypothesis of no secular change

A recent survey of the business cycle literature by Zarnowitz (1985) presented an updated version of the Burns and Mitchell table of the average duration of the business cycle.<sup>2</sup> This table is reproduced below.

Table 46

Average Duration of Three Successive Groups of  
Business Cycles, U.S., 1854-1982

<u>Period</u>	<u>No. of Business Cycles</u>	<u>Avg. Expansion</u>	<u>Avg. Contraction</u>
1854-1885	10	27( 9)	27(17)
1885-1933	10	23(10)	20(10)
1933-1982	10	49(27)	11( 3)

Source: Zarnowitz (1985)  
(Standard errors in parentheses)

As in the case of the Burns and Mitchell analysis, there is no evidence of secular change up to 1933. However, for the period 1933-1982 there appears to be a substantial increase in the mean expansion and decrease in the mean contraction. To a certain extent this change in the character of the cycle is tempered by an increase in the coefficient of variation of the average expansion. Nevertheless, there still appears to be some indication of a secular change in the cycle. If this is true, then given the nature of the change, it may show up as an increase in the degree of asymmetry for specific cycles.

Before turning to the test results, it might be interesting to briefly consider a theoretical situation where the presence of asymmetry would play an important

role. Farmer (1985) has constructed a nonlinear, endogenous model of the economy in which he analyzes the effects of two types of government spending policies. These policies include a constant stock policy in which the real value of government debt outstanding is fixed and a constant flow policy in which government expenditure is fixed but debt varies. Farmer shows that if flows are fixed and stocks allowed to fluctuate, endogenous cycles may result. Since the fixed flow policy is roughly equivalent to the type of policy followed when there is no active stabilization policy, this result suggests that in a non linear world, an active stabilization policy may be necessary to prevent recurrent fluctuations. Thus, given the Farmer model, the possibility that economic time series have become increasingly asymmetric appears to have very important implications for stabilization policy.

The procedure used to test for secular change in asymmetry was to divide each series under consideration into segments compatible with the Zarnowitz (1985) analysis and test each segment for asymmetry using the Neftci test. Tables 47-53 contain the test results.<sup>3</sup>

The results do not support the hypothesis that there has been a tendency toward increased asymmetry among economic time series. Some series, such as pig iron and coal, show a slight increase in asymmetry for one or two of the tests, but in general the chi-square statistics do not show any tendency to increase over time. An examination of the direction of change of the estimated transition

probabilities from the second period to the third period does, however, show weak support for the hypothesis of a secular increase in asymmetry. That is,  $\hat{l}_{11}$  increased for 4 of the 7 series tested and  $\hat{l}_{00}$  decreased for 5 of the 7 series. However, this pattern of change does not exist for  $\hat{l}_{10}$ ,  $\hat{l}_{01}$ ,  $\hat{l}_0$ , and  $\hat{l}_1$ .

Table 47

## Tests for Secular Change in Asymmetry

## Pig Iron

## First Order Markov Process

<u>Time Period</u>	$\bar{X}(1)$ <sup>2</sup>	$\underline{l}_0$	$\underline{l}_1$
1892-1933	1.08	.35	.5
1933-1982	0.48	.37	.48

## Second Order Markov Process

<u>Time Period</u>	$\bar{X}(1)$ <sup>2</sup>	$\bar{X}(2)$ <sup>2</sup>	$\underline{l}_{00}$	$\underline{l}_{11}$	$\underline{l}_{01}$	$\underline{l}_{10}$
1892-1933	0.97	5.88	0.29	.10	.36	.82
1933-1982	2.76	.14	.14	.50	.46	.46

Table 48

## Tests for Secular Change in Asymmetry

## Coal

## First Order Markov Process

<u>Time Period</u>	$\bar{X}(1)$ <sup>2</sup>	$\underline{l}_0$	$\underline{l}_1$
1854-1890	0.16	.40	.53
1890-1933	2.83	.31	.58
1933-1984	2.28	.44	.67

## Second Order Markov Process

<u>Time Period</u>	$\bar{X}(1)$ <sup>2</sup>	$\bar{X}(2)$ <sup>2</sup>	$\underline{l}_{00}$	$\underline{l}_{11}$	$\underline{l}_{01}$	$\underline{l}_{10}$
1854-1890	2.23	3.68	.58	.25	.57	.86
1890-1933	1.79	2.98	.20	.53	.36	.60
1933-1984	0.23	3.10	.50	.60	.40	.78

Table 49

**Tests for Secular Change in Asymmetry**  
**Primary Lead**

**First Order Markov Process**

<u>Time Period</u>	$\chi^2_{(1)}$	$l_0$	$l_1$
1854-1890	1.97	.74	.50
1890-1933	.06	.47	.57
1933-1984	0	.38	.38

**Second Order Markov Process**

<u>Time Period</u>	$\chi^2_{(1)}$	$\chi^2_{(2)}$	$l_{00}$	$l_{11}$	$l_{01}$	$l_{10}$
1854-1890	1.40	1.51	.76	.50	.60	.50
1890-1933	.10	.06	.67	.62	.40	.44
1933-1984	2.16	3.00	.56	.22	.27	.43

Table 50

## Tests for Secular Change in Asymmetry

## Raw Steel

## First Order Markov Process

<u>Time Period</u>	$\bar{X}^{(1)}$	$\underline{l}_0$	$\underline{l}_1$
1863-1890	1.26	.40	.63
1890-1933	1.15	.32	.48
1933-1982	0.38	.43	.52

## Second Order Markov Process

<u>Time Period</u>	$\bar{X}^{(1)}$	$\bar{X}^{(2)}$	$\underline{l}_{00}$	$\underline{l}_{11}$	$\underline{l}_{01}$	$\underline{l}_{10}$
1863-1890	.03	1.39	.5	.56	.33	.67
1890-1933	1.06	1.06	.22	.43	.58	.58
1933-1982	.006	2.81	.17	.18	.42	.75

Table 51

**Tests for Secular Change in Asymmetry**  
**Steel and Iron Structures**

**First Order Markov Process**

<u>Time Period</u>	$\overset{2}{\underline{X}}(1)$	$\underline{l}_0$	$\underline{l}_1$
1892-1933	.10	.40	.45
1933-1970	.11	.61	.56

**Second Order Markov Process**

<u>Time Period</u>	$\overset{2}{\underline{X}}(1)$	$\overset{2}{\underline{X}}(2)$	$\underline{l}_{00}$	$\underline{l}_{11}$	$\underline{l}_{01}$	$\underline{l}_{10}$
1892-1933	.57	2.29	.25	.11	.45	.73
1933-1970	.20	.25	.60	.50	.63	.57

Table 52

**Tests for Secular Change in Asymmetry**  
**Automobile Sales from the Factory**

**First Order Markov Process**

<u>Time Period</u>	$\overset{2}{X}(1)$	$\underline{l}_0$	$\underline{l}_1$
1900-1933	.10	.53	.59
1933-1982	.12	.50	.52

**Second Order Markov Process**

<u>Time Period</u>	$\overset{2}{X}(1)$	$\overset{2}{X}(2)$	$\underline{l}_{00}$	$\underline{l}_{11}$	$\underline{l}_{01}$	$\underline{l}_{10}$
1900-1933	0	.12	.50	.50	.57	.67
1933-1970	.37	.75	.42	.54	.58	.45

Table 53

**Tests for Secular Change in Asymmetry**  
**Copper**

**First Order Markov Process**

<u>Time Period</u>	$\overset{2}{X}(1)$	<u>l<sub>0</sub></u>	<u>l<sub>1</sub></u>
1854-1890	.49	.53	.65
1890-1933	.14	.61	.67
1933-1982	.07	.50	.54

**Second Order Markov Process**

<u>Time Period</u>	$\overset{2}{X}(1)$	$\overset{2}{X}(2)$	<u>l<sub>00</sub></u>	<u>l<sub>11</sub></u>	<u>l<sub>01</sub></u>	<u>l<sub>10</sub></u>
1854-1890	.27	.39	.5	.62	.57	.67
1890-1933	.10	.37	.5	.56	.75	.86
1933-1982	.05	.05	.45	.50	.54	.54

## Notes to Chapter 6

1. See Chapter 10 of Burns and Mitchel (1947) for an interesting discussion on secular change in the business cycle.
2. See Zarnowitz (1985) for details.
3. Each segment of each series was detrended, assuming a log linear trend.

## Chapter 7 - Conclusion

While the stated purpose of this study was to examine several sample path properties of U.S. economic time series, its primary emphasis was on determining the extent to which asymmetry exists in production data for the U.S. The notion of asymmetry in economic time series derives its importance from the fact that it is one of several economically interesting types of nonlinearity. As such, an indication of its presence suggests the need for it to be explicitly taken into account both theoretically and empirically. One instance where a knowledge of the presence of asymmetry might play an important role is forecasting. If asymmetry exists in a series, one would expect a nonlinear forecasting procedure to provide a better forecast than a linear procedure.

The results in Chapter 4 present a fairly strong case in favor of an asymmetry hypothesis. Tests on production series at the industry and industry group level, representing a broad spectrum of the capital goods producing sector of the U.S. economy, show evidence of asymmetry. In general, for the 8 longest series we were able to reject the null hypothesis of symmetry, with an 85% level of confidence, approximately 25% of the time. If the results are broken down according to detrending procedure, the null hypothesis of symmetry can be rejected with an 85% level of confidence for the long series group for 41% of the instances when the series are detrended using a 2 period

moving average. This evidence of asymmetry in the production sector of the U.S. economy, taken in conjunction with the previously established results of Neftci (1984) relating to asymmetry in the employment sector of the U.S. economy, strongly suggests that this type of nonlinearity should not be overlooked in economic modeling and forecasting.

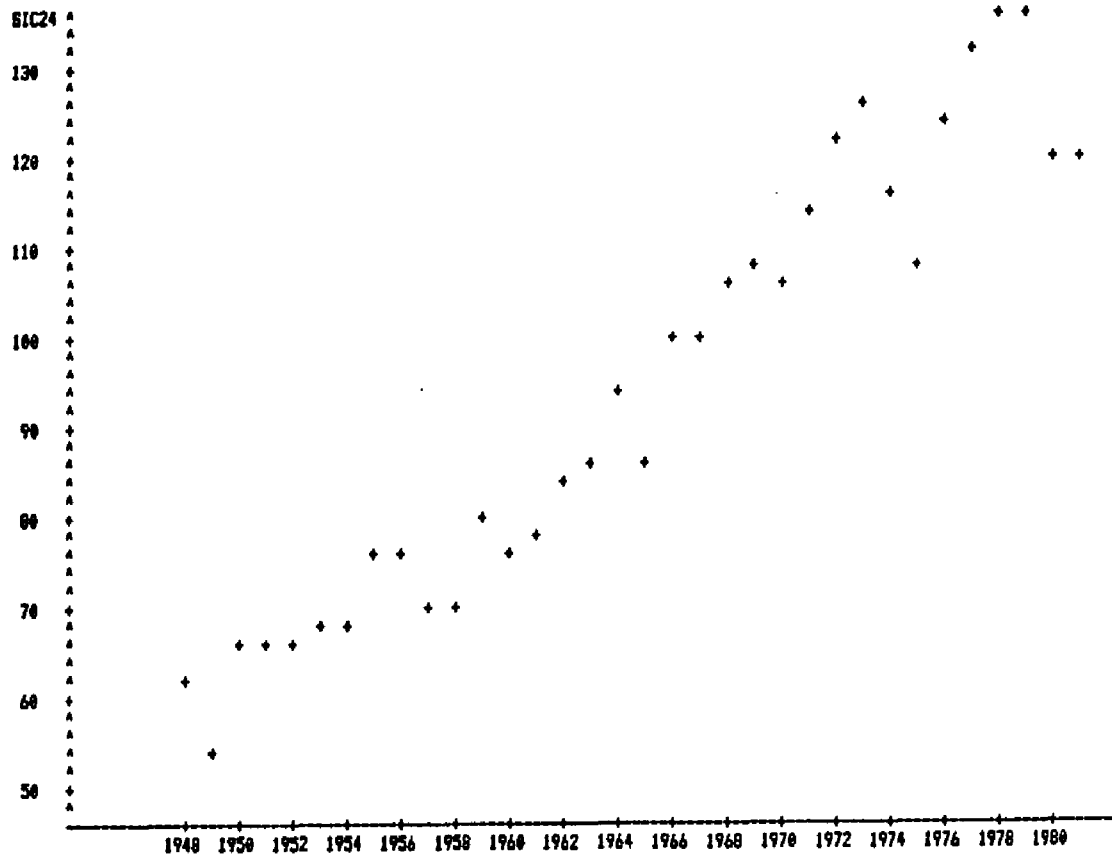
Chapter 5 considered the feasibility of a hypothesis put forth by Delong and Summers (1984) to explain the asymmetry found in employment data. The results of the tests showed some support for their hypothesis that the asymmetry in employment relates to labor hoarding. However, as was pointed out in Chapter 5, their hypothesis probably isn't the only reason for asymmetry in the employment sector, since asymmetry was also found to exist in the production sector of the economy.

Chapter 6 tested the hypothesis that there has been a tendency toward increased asymmetry among economic time series. Tests were performed on the six longest production series tested in Chapter 4. In general, the test results did not support the hypothesis that there has been secular change in the degree of asymmetry.

## Appendix A

Figure 4

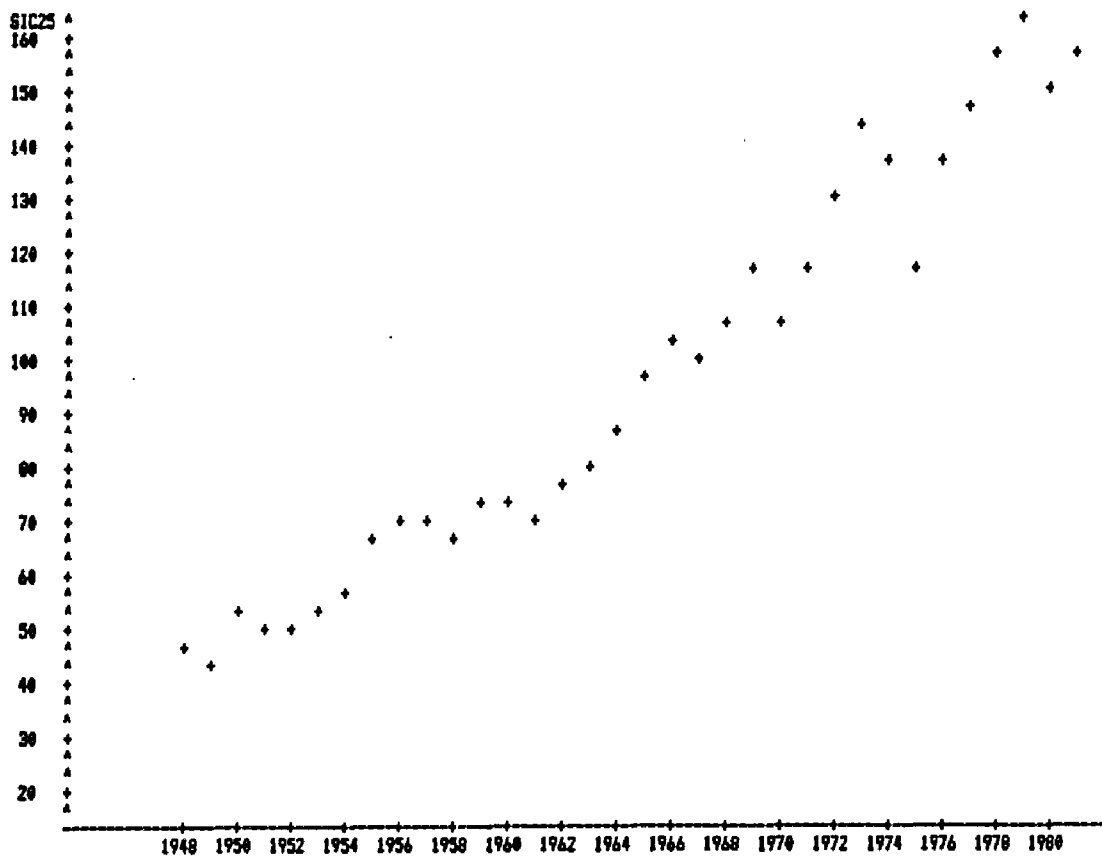
IPI, Lumber, 1948-1981



## Appendix A

Figure 5

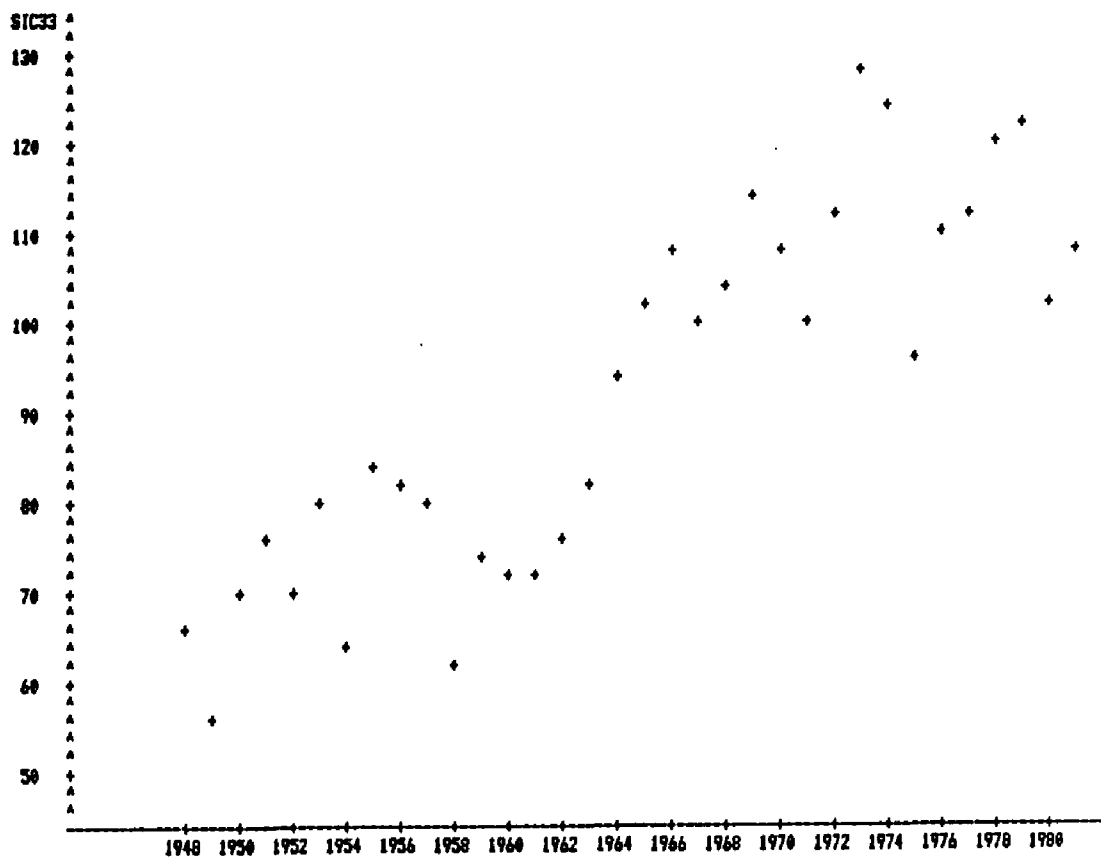
IPI, Furniture and Fixtures, 1948-1981



## Appendix A

Figure 6

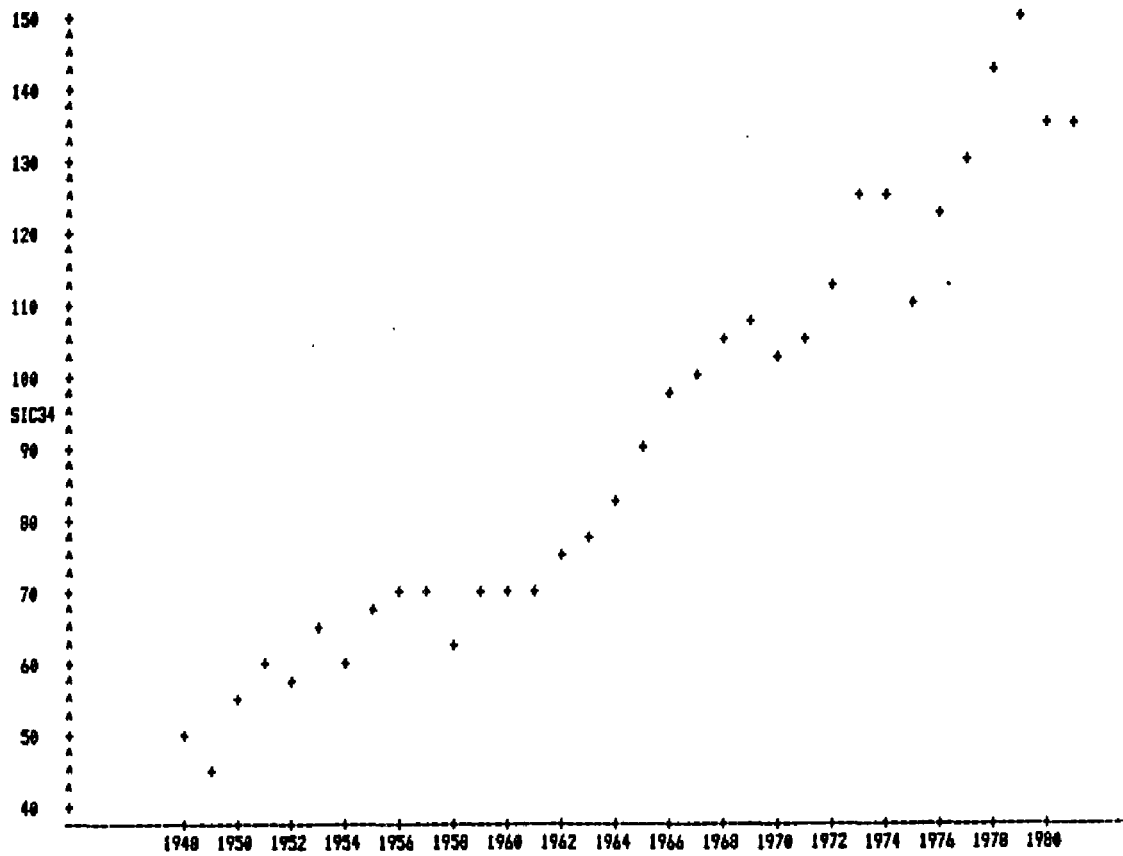
IPI, Primary Metals, 1948-1981



## Appendix A

Figure 7

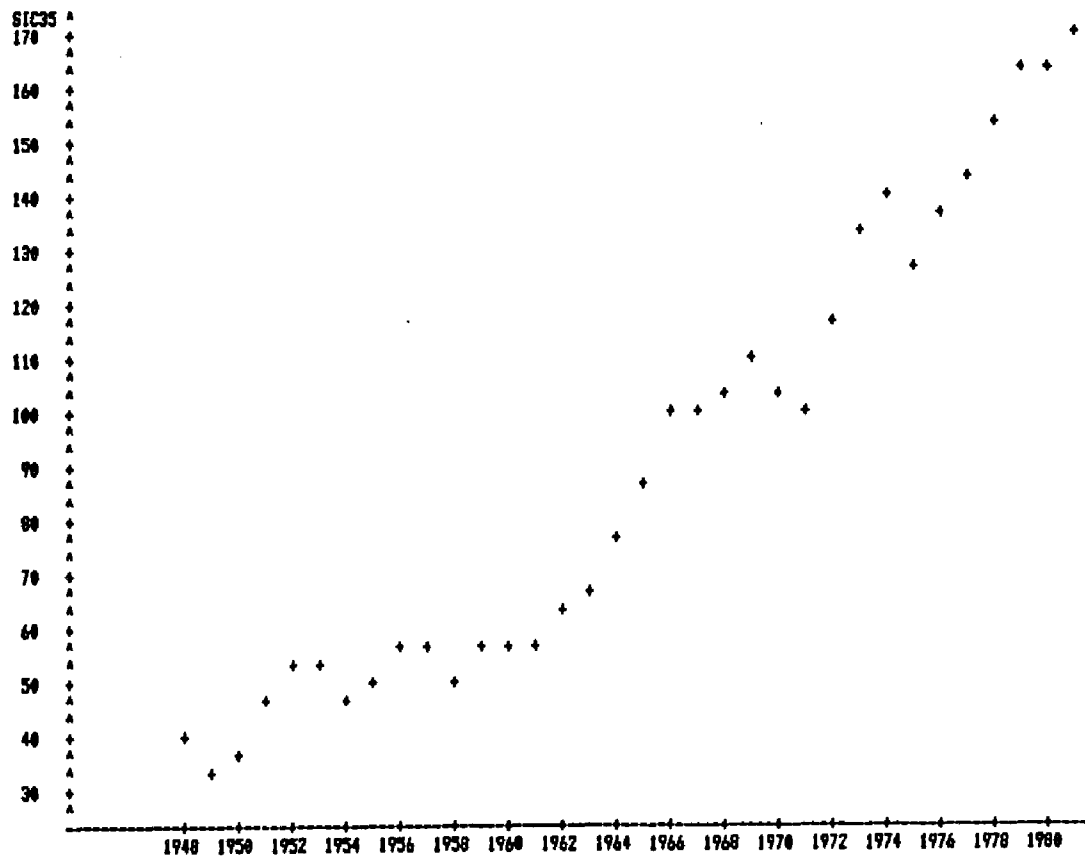
IPI, Fabricated Metals, 1948-1981



## Appendix A

Figure 8

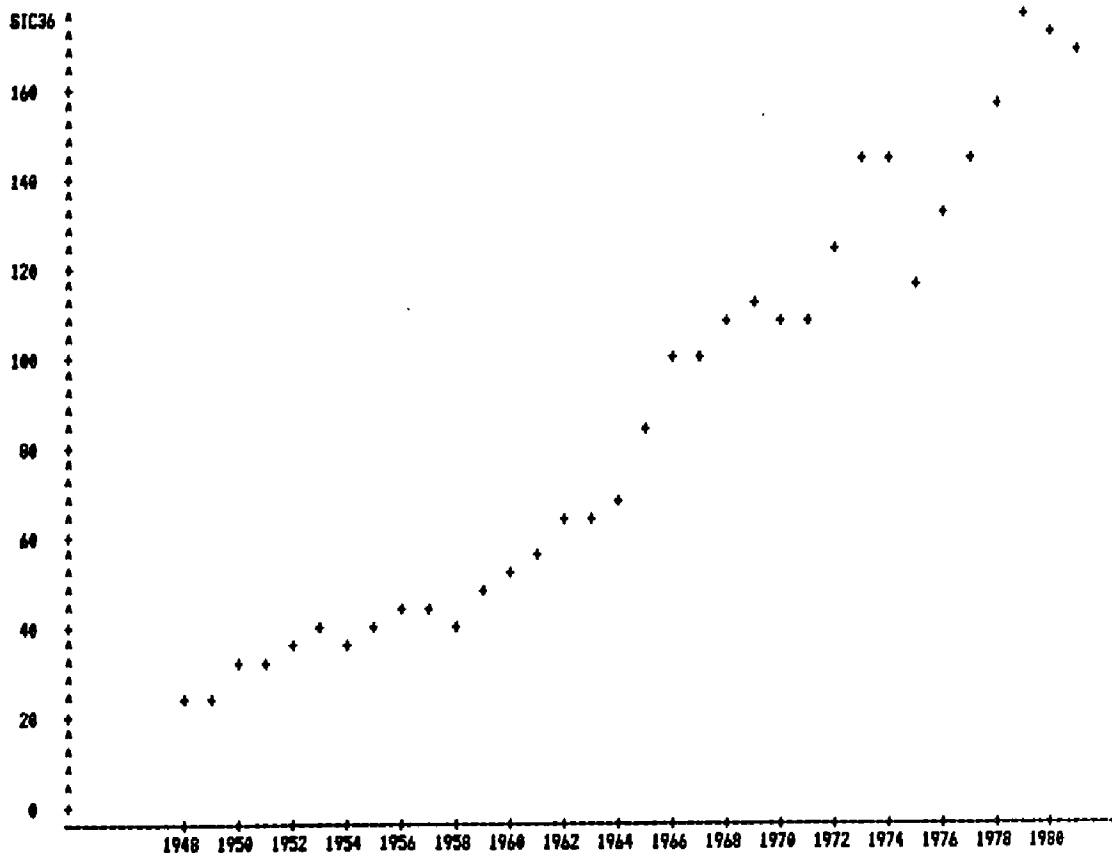
IPI, Non Electrical Machinery, 1948-1981



## Appendix A

Figure 9

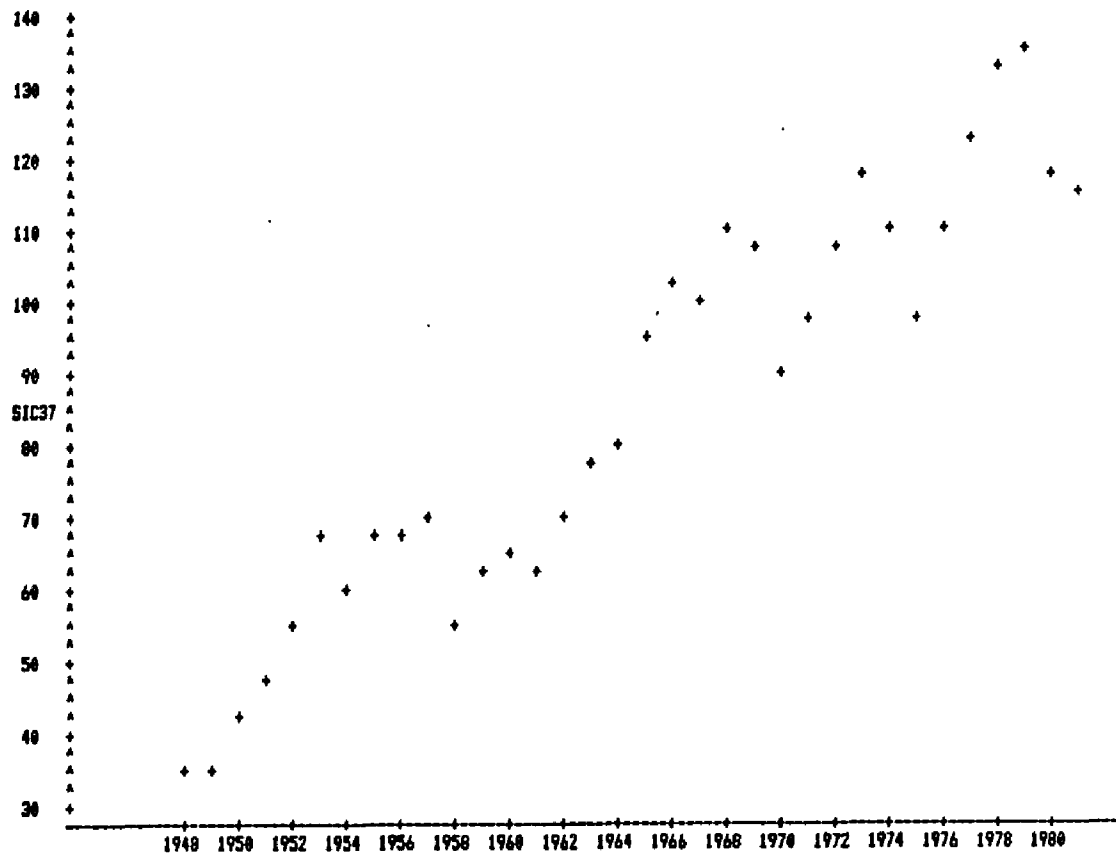
IPI, Electrical Machinery, 1948-1981



## Appendix A

Figure 10

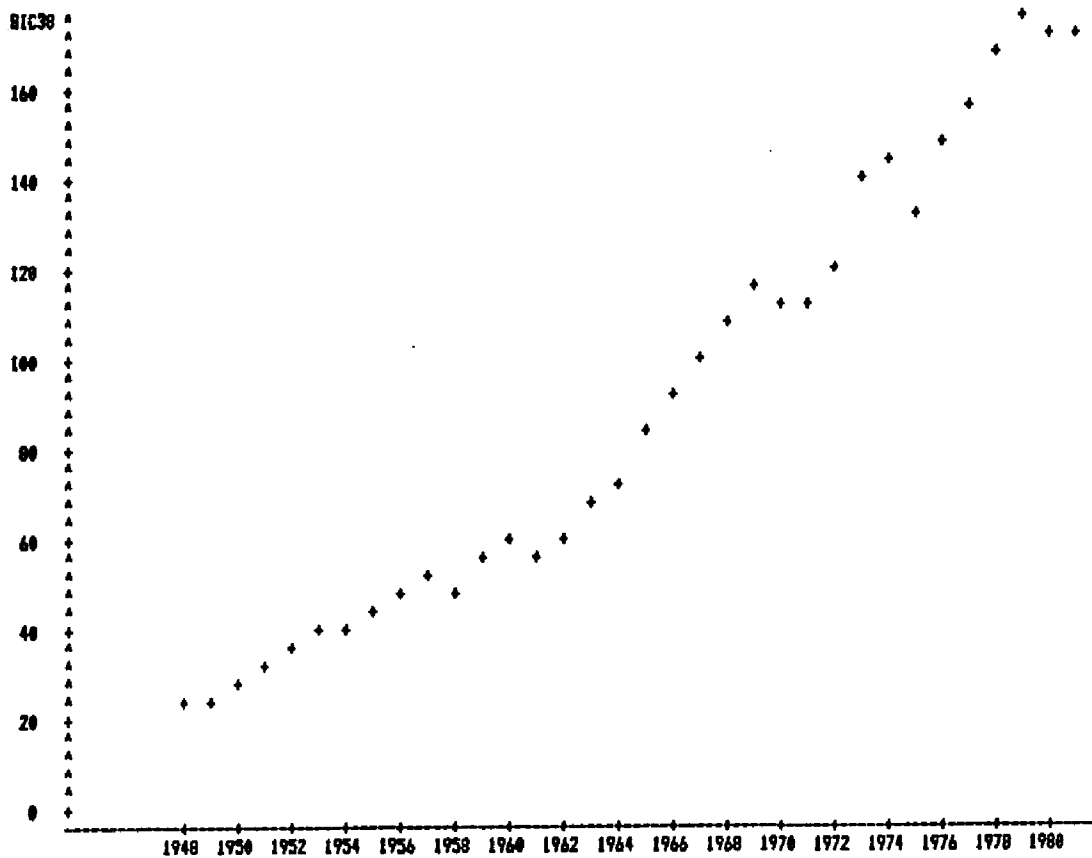
IPI, Transportation, 1948-1981



## Appendix A

Figure 11

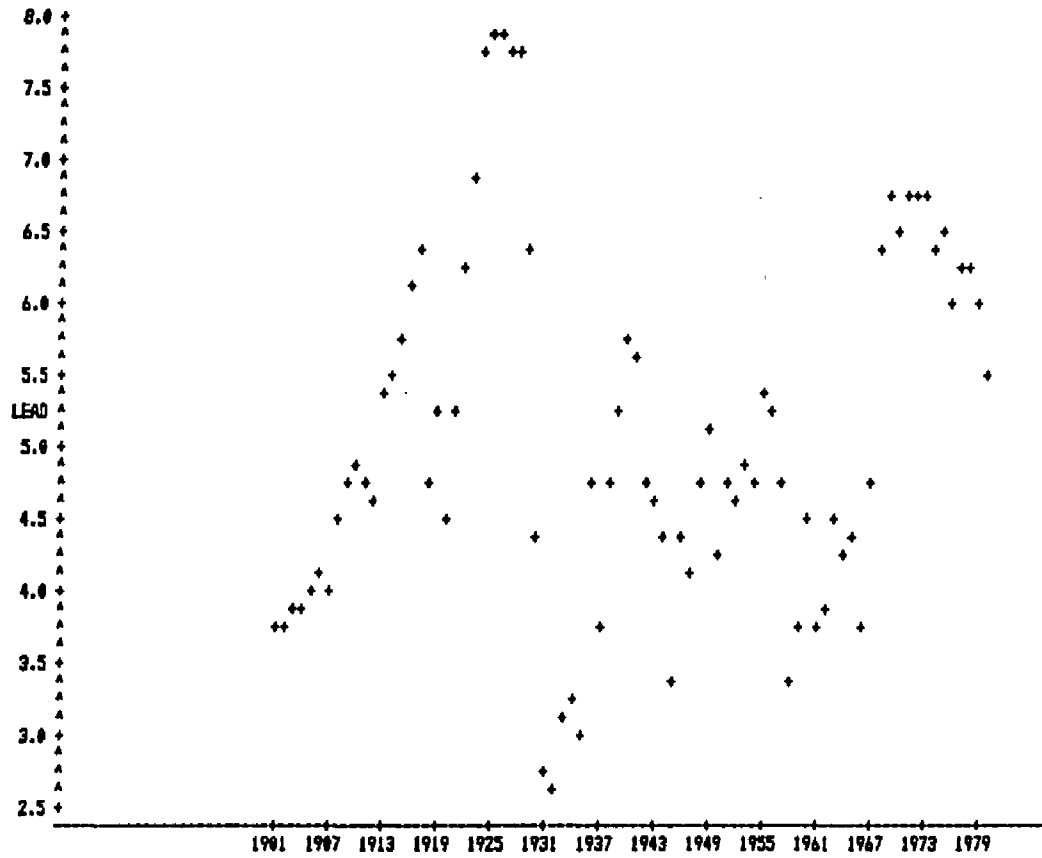
IPI, Instruments, 1948-1981



## Appendix A

Figure 12

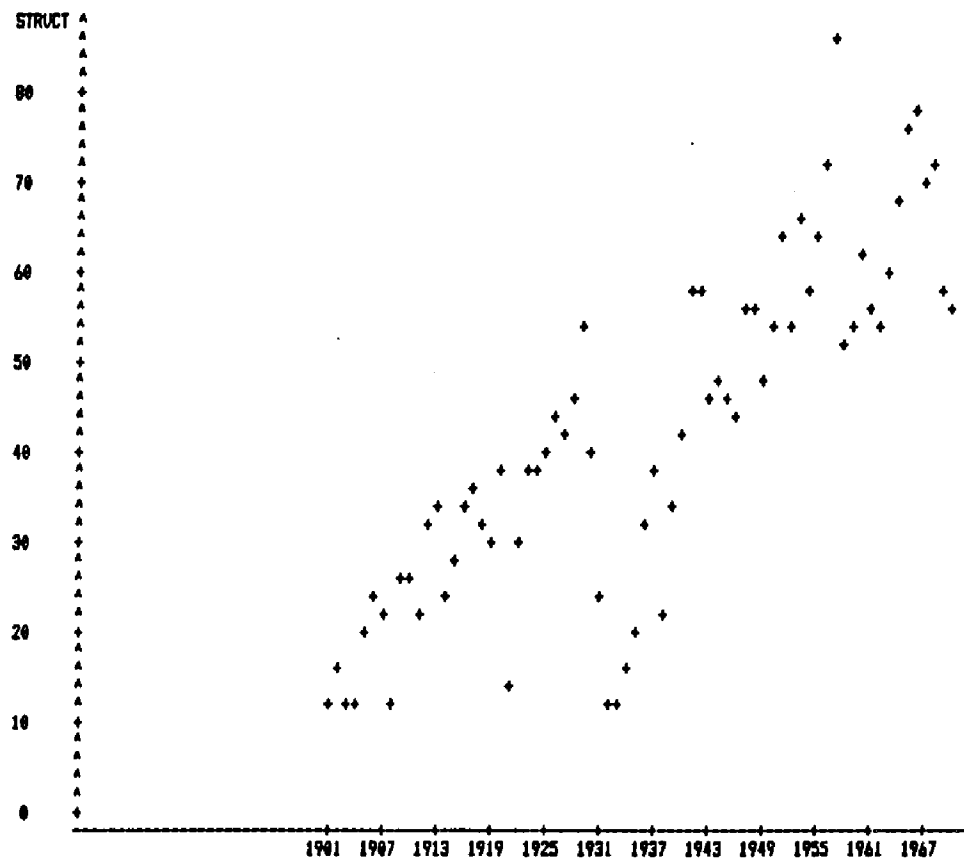
Primary Lead Production, 1901-1980



## Appendix A

Figure 13

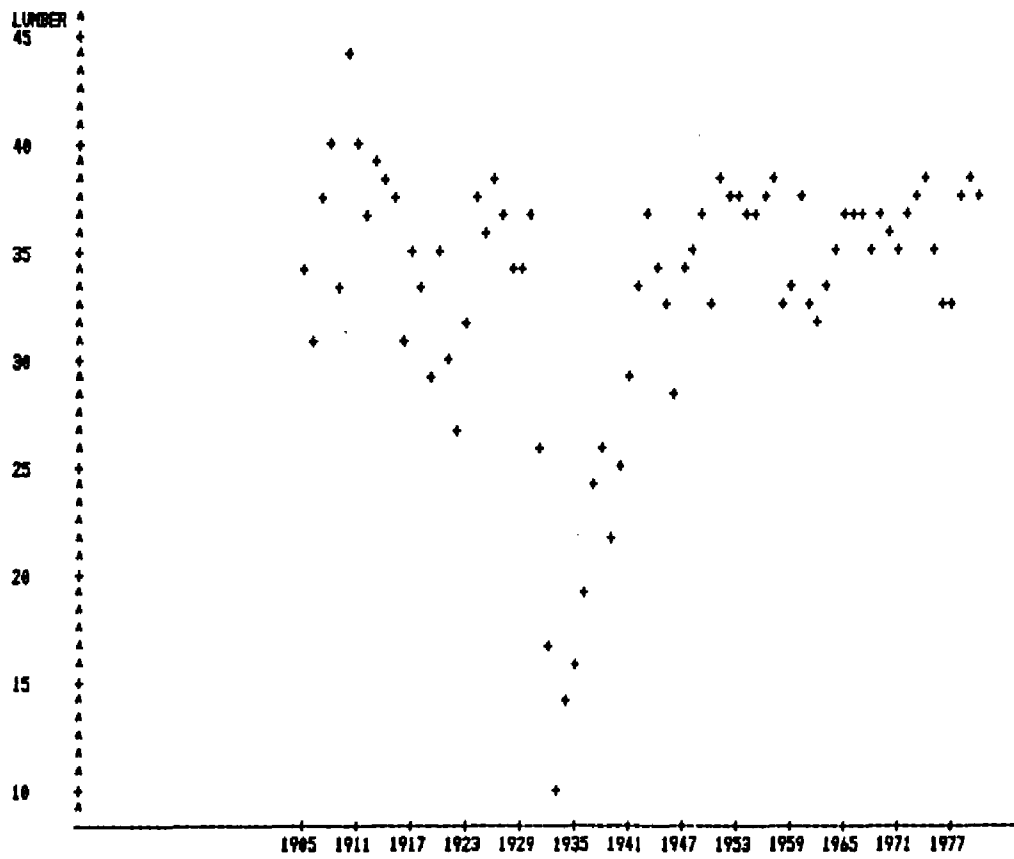
Steel and Iron Structures, 1901-1970



## Appendix A

Figure 14

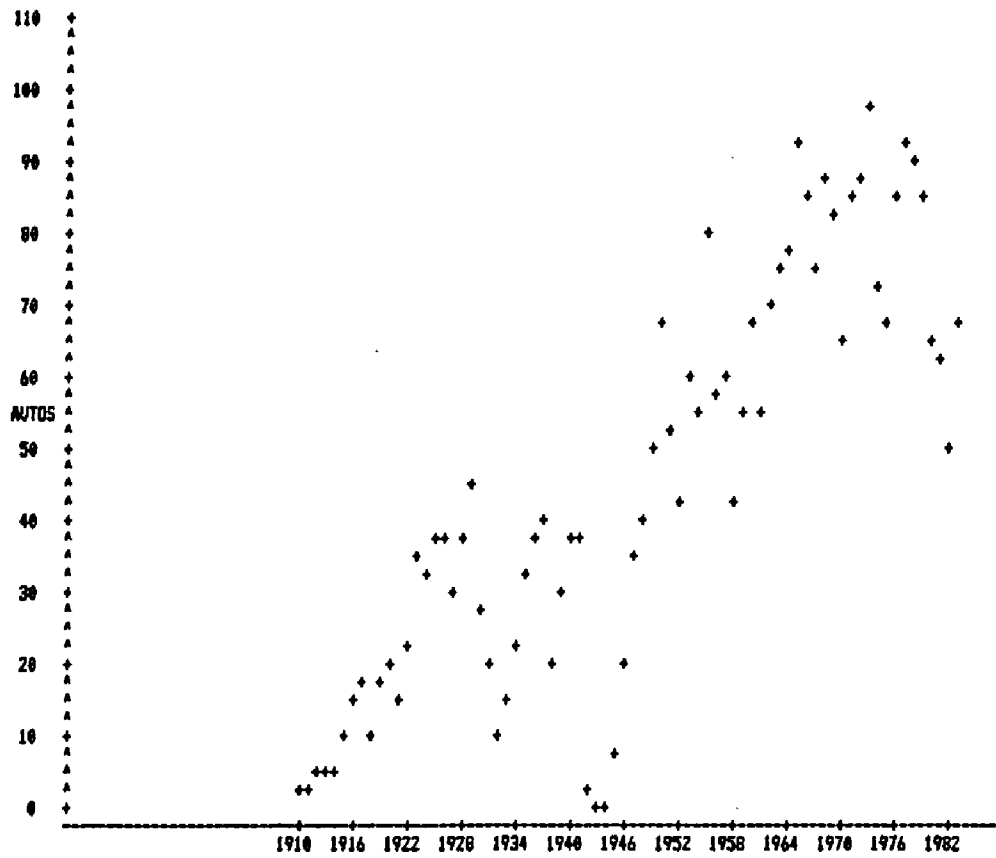
Lumber Production, 1905-1980



## Appendix A

Figure 15

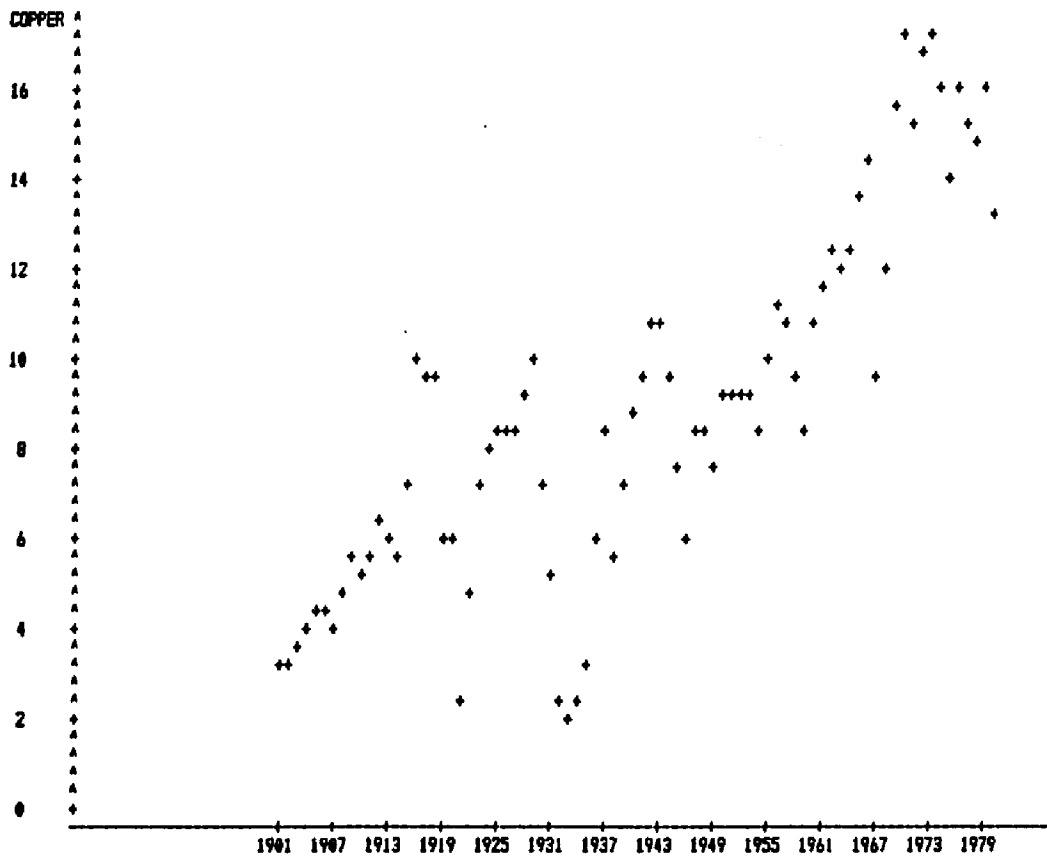
Automobile Sales from the Factory, 1910-1980



## Appendix A

Figure 16

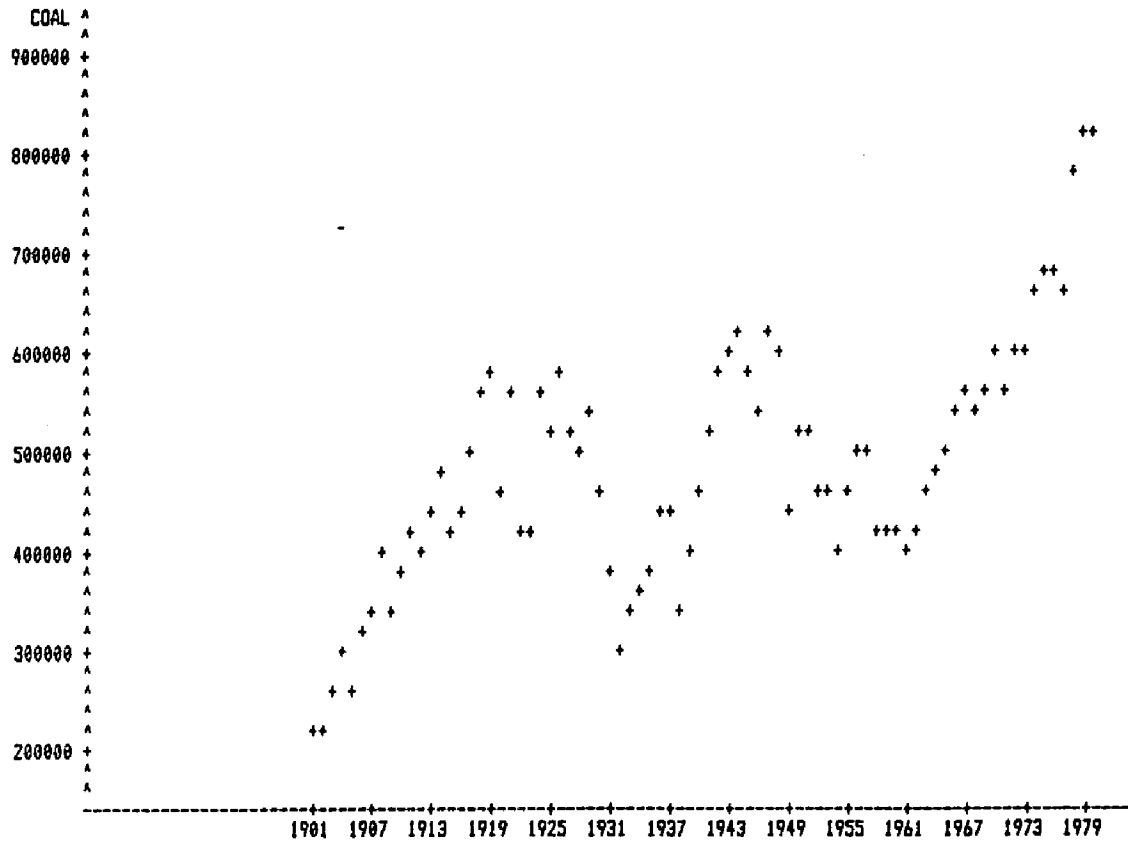
Copper Production, 1901-1980



Appendix A

Figure 17

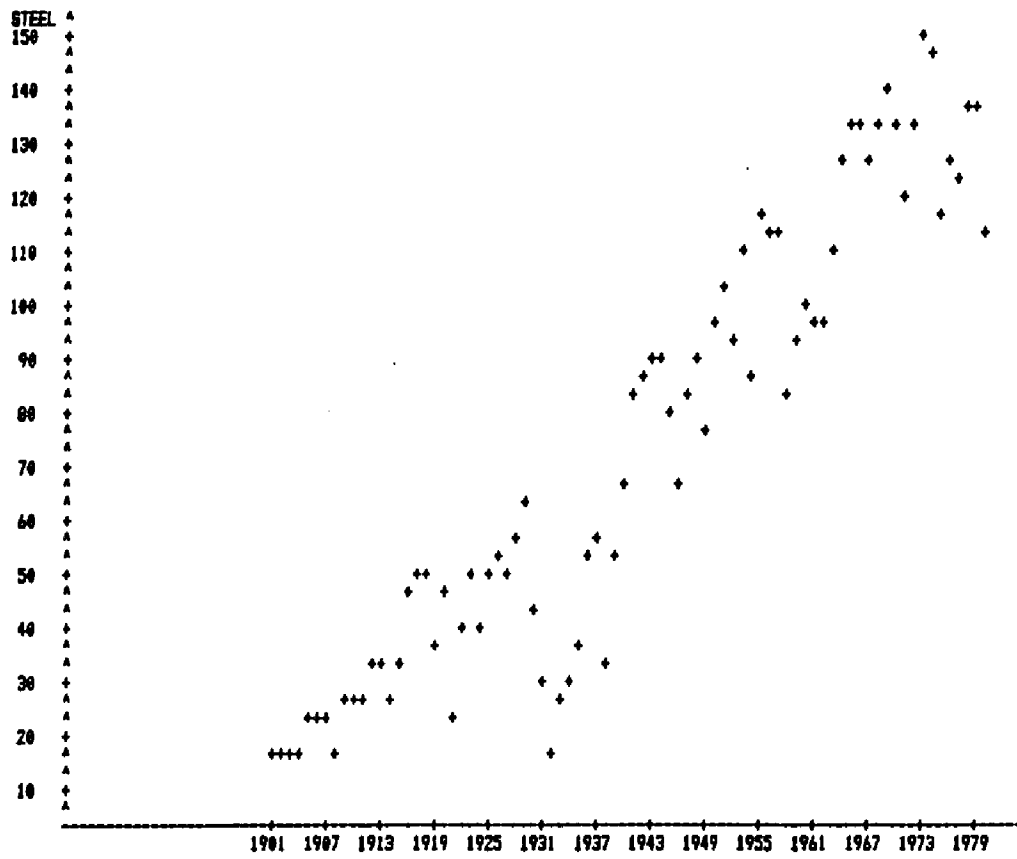
Bituminous Coal Production, 1901-1980



## Appendix A

Figure 18

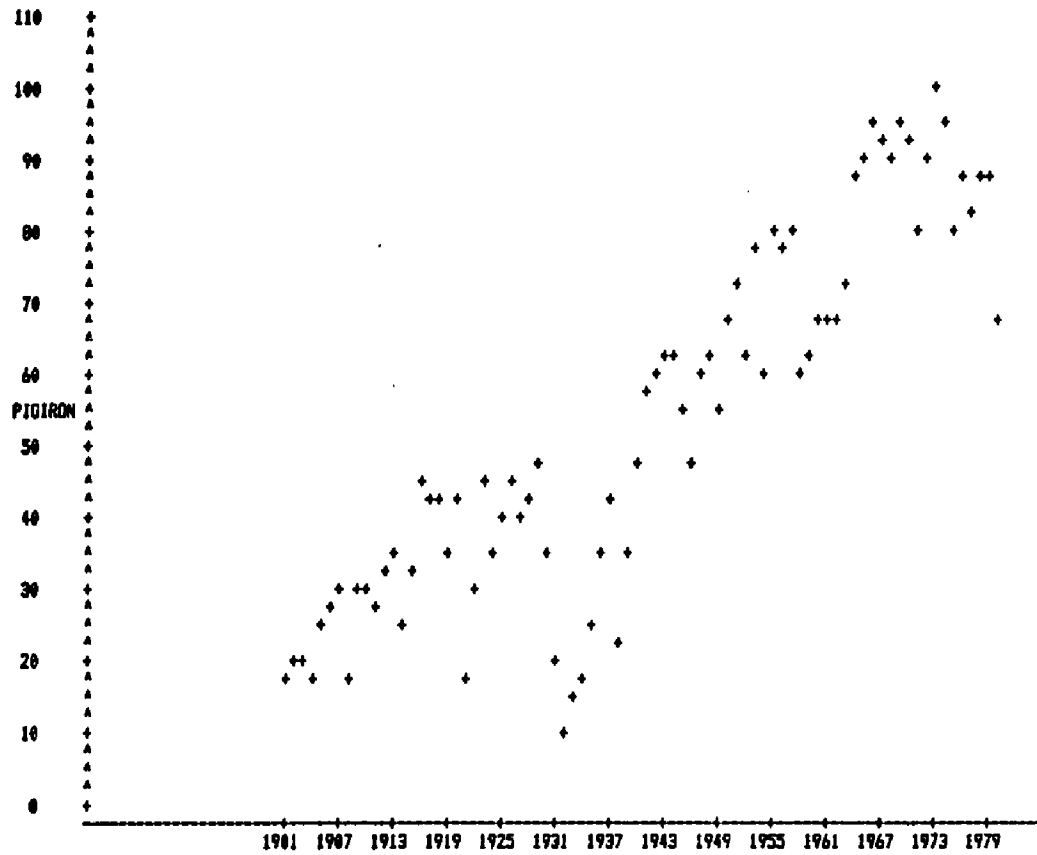
Raw Steel Production, 1901-1980



## Appendix A

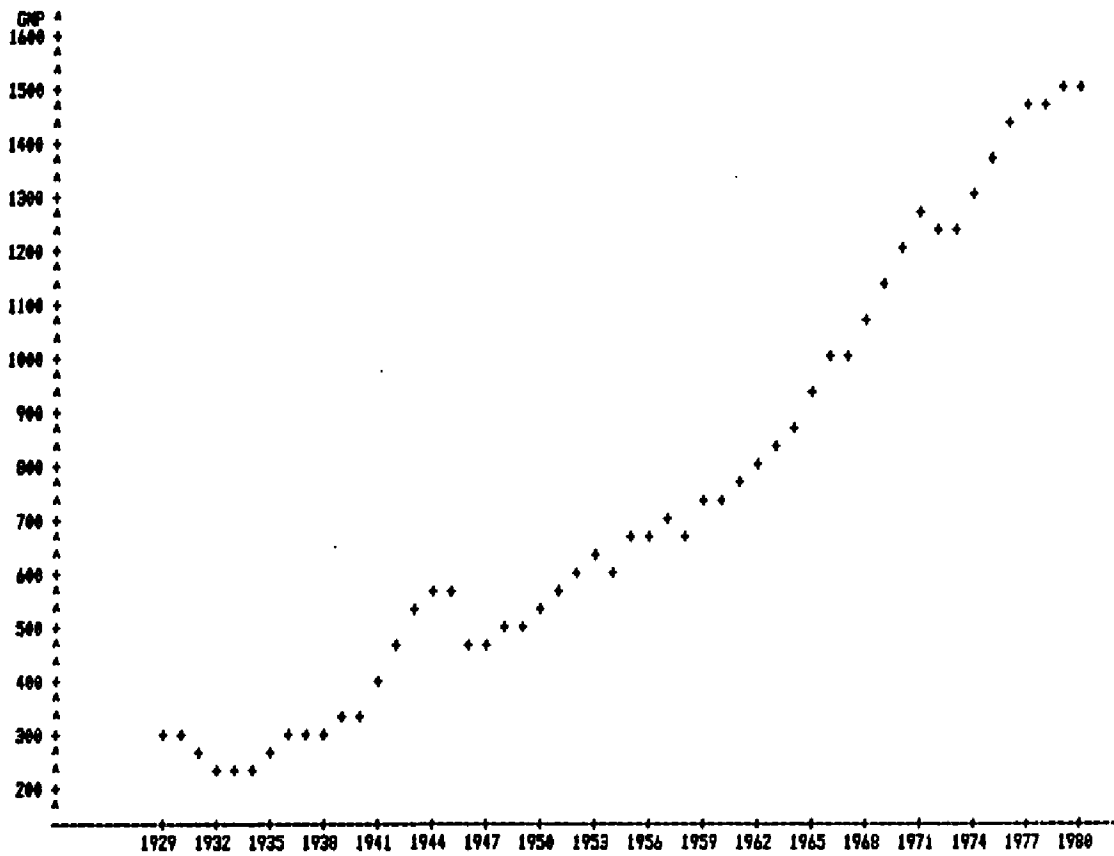
Figure 19

Pig Iron Production, 1901-1980



## Appendix A

Figure 20  
Real GNP, 1929-1980



## Appendix B

IPI Components - Transition Counts for Two Series  
Asymmetry (Quarterly, 1948-1983)Lumber

		t			
		+ +	+ -	- +	- -
t - 1	+ +	34	3	11	6
	+ -	8	3	4	7
	- +	7	3	6	6
	- -	6	13	1	23

Furniture and Fixtures

		t			
		+ +	+ -	- +	- -
t - 1	+ +	47	2	6	10
	+ -	4	4	3	4
	- +	5	1	1	3
	- -	10	8	0	33

Primary Metals

		t			
		+ +	+ -	- +	- -
t - 1	+ +	47	2	6	10
	+ -	4	4	3	4
	- +	5	1	1	3
	- -	10	8	0	33

## Appendix B

Fabricated Metals

		t			
		+ +	+ -	- +	- -
t - 1	+ +	40	3	6	10
	+ -	8	4	0	2
	- +	5	0	3	6
	- -	7	7	4	36

Non Electrical Machinery

		t			
		+ +	+ -	- +	- -
t - 1	+ +	55	3	6	9
	+ -	4	2	1	1
	- +	3	0	2	6
	- -	12	3	2	32

Electrical Machinery

		t			
		+ +	+ -	- +	- -
t - 1	+ +	43	1	9	8
	+ -	6	1	0	3
	- +	4	0	4	7
	- -	9	8	2	36

## Appendix B

Instruments

		t			
		+ +	+ -	- +	- -
t - 1	+ +	35	1	10	4
	+ -	7	8	0	5
	- +	6	0	13	5
	- -	2	12	1	32

Transportation

		t			
		+ +	+ -	- +	- -
t - 1	+ +	38	2	4	18
	+ -	6	2	2	2
	- +	5	1	4	5
	- -	14	7	5	26

## Appendix C

## Sources of Data

Coal, copper, primary and recoverable lead, steel, steel and iron structures and lumber were obtained from Historical Statistics of the U.S., Colonial Times to 1970, and Statistical Abstract of the U.S. (various years). Bureau of Census, U.S. Dept. of Commerce.

Pig Iron data was obtained from Metal Statistics 1983, American Metal Market, Fairchild Publications.

Data for the constant dollar (1972) series was obtained from the Business Conditions Digest, U.S. Dept. of Commerce.

Automobile sales data was obtained from the Motor Vehicles Manufacturers of the U.S., Annual Report.

Historical data for the Industrial Production Index components came from Industrial Production, 1976 Revision, Board of Governors of the Federal Reserve System. Data for the subsequent years came from the Board of Governors IPI releases.

All employment series came from Employment Earnings, U.S. Department of Labor, 1984.

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