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Industrial structural change and the demand for electricity in Pennsylvania

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City University of New York, 1988

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INDUSTRIAL STRUCTURAL CHANGE

AND

THE DEMAND FOR ELECTRICITY IN PENNSYLVANIA

BY

NICK S. POULIOS

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.

1988

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.

April 18, 1988
Date

Chair of Examining Committee

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Date

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Supervisory Committee

The City University of New York

Abstract

INDUSTRIAL STRUCTURAL CHANGE AND THE DEMAND FOR ELECTRICITY IN PENNSYLVANIA

by

Nick S. Poulios

Advisor: Professor Michael Grossman

The purpose of this study is to examine the changes in the demand for electricity, specifically in the industrial sector in Pennsylvania,identify the mechanisms of change and characterize their respective roles in reducing electric growth.

A flexible functional form model (translog) is developed and estimated for five major industries, namely, paper, refining, glass and clay, primary and fabricated metals, and from this, own and substitution elasticities are estimated. The model also provides estimates of technological change which give an indication of the undergoing structural changes that have taken place in the above industries through the years.

Acknowledgements

My greatful appreciation to professors Michael Grossman and Salih Neftci, whose suggestions, criticisms and editorial assistance have done so much to improve the organization, content and readibility of this paper.

Also, many thanks to all friends and associates who contributed to the improvement of this paper.

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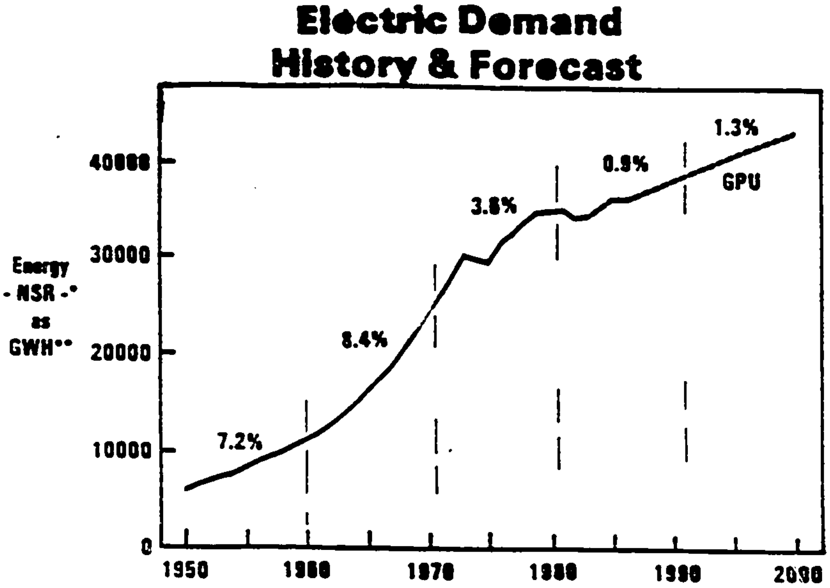
CHAPTER ONE

1.1 INTRODUCTION

During the last few years following the 1973 Arab oil embargo, significant changes took place in U.S. electricity consumption. After years of steady growth, consumption of about 7-8% per annum (50's and 60's) began to slow down and during the decade ended in 1984 electricity consumption was growing at 2.6% per year.[1]

Higher prices after the oil embargo and other factors (gas regulation) induced individuals, business and institutions to conserve electricity by purchasing more efficient appliances, turning down thermostats and insulating homes. Some industries modernized while others shut down. Economic growth slowed and the economy shifted away from energy intensive activities to minimize energy costs. A typical electric utility's historic pattern of growth would look like the one presented on Graph(1). In the 50s, General Public Utilities (GPU) was growing at 7.2% annually, in the 60s 8.4% annually, in the 70s, this growth slowed down to 3.6% while during the 1980-1986 period it dropped even more; down to 1.3% annually.

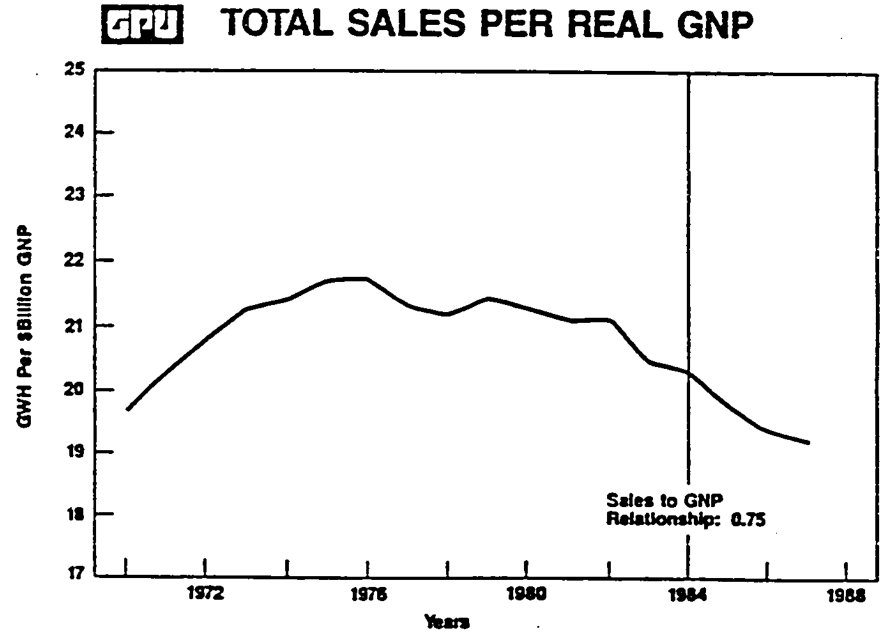
Graph-1



The relationship between electricity and real GNP is important because "conventional wisdom" suggests that electricity growth is a requirement for growth in economic activity, such that the two are nearly proportional.

However, the data and Graph(2) show a different picture.

Graph-2



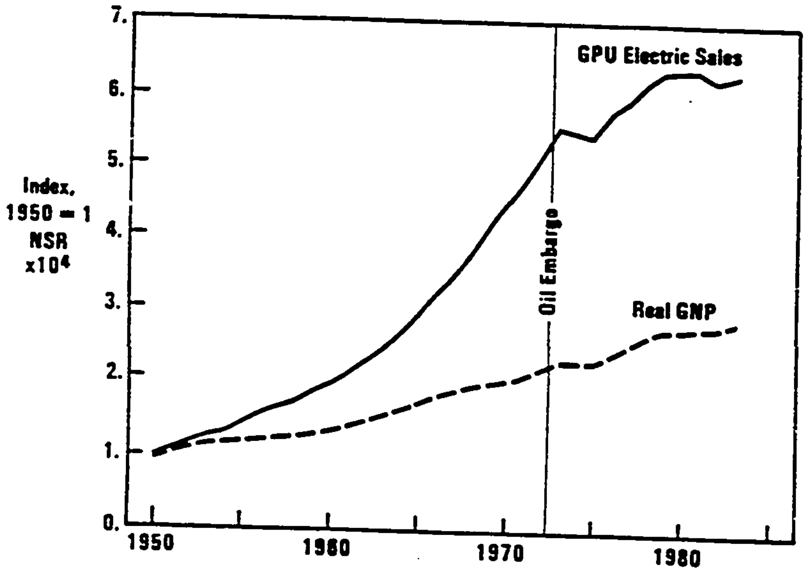
During the 50s and early 60s, electricity per GNP declined steadily by about 1.0% per year. During the late 60s, electric use increased more rapidly than did GNP. Thereafter, the ratio resumed its downward trend, however, at about double the 1950s rate.

If one was to estimate the corresponding elasticity with a simple model, one would get a reduction of this elasticity from over 1.0 in the pre-1975 period to about 0.75 of the 80s.

This can also be seen by looking at Graph(3) where GPU electric sales and real GNP have been indexed for comparison. Electric sales were taking off faster prior to the oil embargo whereas they slowed down considerably after it.

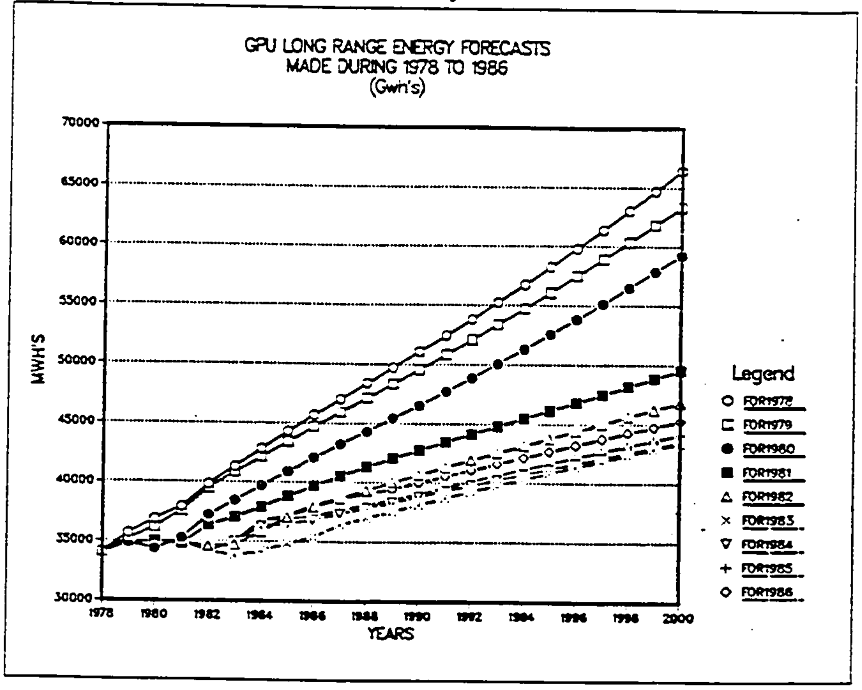
Graph-3

Past Relationship of GNP to GPU Electric Sales



As a result of all these, plans for energy supply projects, especially the ones with long lead times for implementation, such as nuclear plants, were disrupted. Year after year, long-range energy forecasts were revised downwards and the business of forecasting energy and electricity in particular became a very difficult one indeed. (Graph(4))

Graph-4



As a result of the above, a question was raised: if the economy was to expand again and if prices were stabilized, like they are today, might it not be the case that electricity demand will begin to rise and return to past patterns of growth? Also, since the lead time for implementation of generating facilities is long, might not these facilities needed to meet demand be years out of phase?

Therefore, a better understanding of the forces which contributed to these changes is needed to lower the risk and uncertainty involved as well as restore investor confidence in the need for energy supply facilities.

With this work, I examine the changes in the demand for electricity, specifically in the industrial sector which took place over the years, identify the mechanisms of change and characterize their respective roles in reducing growth in industrial demand for electricity. I examine shifts in input-output mix and changes in efficiencies induced by technological change. This study concetrates in the territory serviced by Pennsylvania Electric, a subsidiary of the General Public Utilities (GPU) system, since this territory has an industry structure which is of tremendous interest due to the mixture of the traditional old smock-stock industries and other industries which have incorporated technological innovation in their production process.

1.2 THE INDUSTRIAL SECTOR IN GENERAL

The U.S. economy is comprised of five major components which are presented below along with their 1986 energy consumption:[2]

Residential: 6.0 quadrillion BTU
Commercial: 3.6 quadrillion BTU
Industrial: 17.4 quadrillion BTU
Transportation: 20.9 quadrillion BTU
Elec. Utilities: 27.0 quadrillion BTU

In terms of electricity consumption, the first three major sectors have shown the following distribution:

Residential: 2.8 quadrillion BTU
Commercial : 2.4 quadrillion BTU
Industrial : 2.8 quadrillion BTU

In 1986, the fuel type consumption in the industrial sector was distributed as follows:

Petroleum : 7.9 quadrillion BTU
Natural Gas: 6.8 quadrillion BTU
Electricity: 2.8 quadrillion BTU
Coal : 2.6 quadrillion BTU

In terms of prices -- current dollars per million BTU-electricity in the industrial sector is 3.1 times higher than residual fuel, 3.5 times higher than natural gas and 8.5 times higher than coal. The fact that electricity is 8.5 times more expensive than coal and at the same time is used as much as coal, has to do with electricity's physical and other properties which will be discussed later on.

The industrial sector is comprised of agriculture, mining, construction and manufacturing. In 1982, the breakdown of the above sectors in terms of gross national product was as follows:[3]

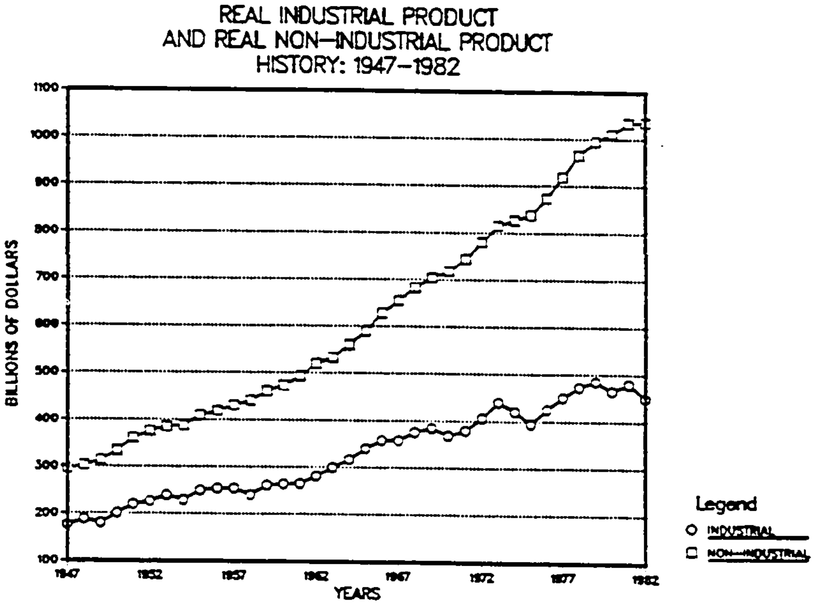
Agriculture : 9.8%
Mining : 4.6%
Construction : 10.6%
Manufacturing: 74.9%

In terms of energy consumption, manufacturing and mining account for more than 90% of industrial energy use and over 80% of electricity use, and the industrial sector in general accounts for about 35% of total electricity use.[4]

1.3 SIZE AND GROWTH OF THE INDUSTRIAL SECTOR

The industrial sector accounts for nearly one third of the gross national product. Since 1947, real industrial product, discounted for inflation, has grown by 157 percent or an average of 2.8 percent per year. However, as Graph(5) shows, one can distinguish among three periods in which the industrial sector experienced different rates of growth: between 1947 and 1961 when the sector's output advanced by 3.0 percent per year, the period between 1962 and 1970 in which output increased at the rate of 3.4

Graph-5



percent per year and the period between 1970 and 1982 when industrial output slowed down to 1.7 percent per year. The industrial output, as a percent of total output, fell to 30.3 percent in 1982 from 37.2 percent in 1947.

Output of the non-industrial sector increased by 251 percent from 1947 to 1982 but this growth was smoother with no major interruptions. Between 1947 and 1961, non-industrial output increased 3.7 percent per year; it accelerated to 4.1 percent from 1962 to 1970 and it slowed down to 3.1 percent per year from 1970 to 1982.[5]

It is therefore apparent, that the industrial sector is more sensitive to economic cycles than the rest of the economy and as such, it has shown significant fluctuations through the years.

Part of the variation in industrial output has occurred as a result of structural changes, i.e., shifts towards more technologically advanced products. For example, electronics and instruments have grown to take a 6 percent share of total GNP in 1981 compared to 3.5 percent in 1947. At the same time, the shifts in the heavy industry have been in the opposite direction: primary and fabricated metals fell to 3.0 percent from 4.5 percent in 1947. As expected, the electricity levels utilized by these industries have been affected by the changes in production and demand. Factors such as efficiency improvements and conservation efforts have increasingly played an important role in the overall energy utilization of the above industries. Energy intensity (energy use per unit of production) has fallen considerably over the years as a result of the above mentioned factors.

1.4 INDUSTRIAL PRODUCTIVITY

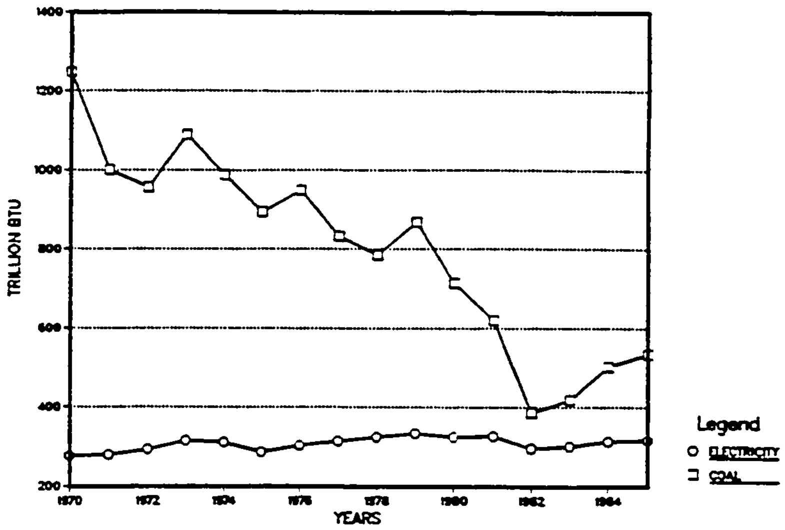
Production per man-hour in manufacturing increased by 2.6 percent annually from 1947 to 1981. Part of this industrial growth was achieved through use of energy, yet technology combined with better skills and education have kept down the energy used per unit of output.

The various forms of energy associated with production and their corresponding prices are unavoidably connected and correlated with cost of production. This is equivalent to saying that the factor price of a form of energy directly influences the use of that form of energy in the production process. If a decision was to be made for choosing between two different fuels, the one with the lower factor price would, most likely, contribute to a certain level of production at a lower total cost, ceteris paribus.

Economic theory suggests that the usage of cheaper fuels would most likely correspond to increasing productivity. Fuels that are abundant, and therefore cheap, often lead to greater economies than fuels that are less abundant and more expensive.

As stated before, electricity is 8.5 times more expensive than coal. Graph(6) shows the demand for electricity and coal for the industrial sector in the middle Atlantic region, a relatively heavy industrial region of the country. The demand for electricity increased an average of 0.9 percent per year from 1970 to 1985 whereas, the demand for coal decreased by 5.5 percent per year for the same time period. Given that productivity in the industrial sector has been increasing during the last few years, the following question is asked: how is it that by adapting the most costly energy form, such as electricity, the industry shows increases in productivity?

Graph-6



US ELECTRICITY AND COAL DEMAND
FOR THE INDUSTRIAL SECTOR

To answer this question, one has to go beyond the standard calorimetric distinction of the various forms of energy during which each form is evaluated according to the amount of energy they release under similar conditions. The high correlation between electric usage and productivity growth stems from the fact that electricity has an advantage over all other fuels in terms of adaptable production techniques and innovation. Its coherent

]

nature allows for the employment of distinct effects in material systems in a controllable environment. Hence, the opportunity for technological innovation is great. It is here that production becomes more direct, eliminating most of the unnecessary costs.

Increase in the prices of the inputs motivated improvements in process efficiency, influenced the shifts of the output mix, etc. Real prices to manufacturers increased more than fourfold for oil and natural gas and doubled for electricity and coal. Economists proved the influence of prices to energy and economic growth with econometric models but the question still remains of whether prices only are to be faulted for all these, or, are there any other underlying causes beyond the price effect.

Other factors, such as prices of labor and capital, combined with outdated inefficient technologies and internationalization of domestic markets also contributed to the changes of electricity demand and economic growth.

Some of these forces of change can be quantified easier than others, if at all. For example, labor costs in steel making have generally declined over the last 2-3 years, although in different proportions for different technologies; an integrated steel producer saw labor costs going down by 18.8% since 1979 whereas a mini-mill with an electric furnace had labor costs reduced by 25.4% for the same time period.

However, in an internationally competitive environment, it is not the absolute costs that matter, but rather the costs relative to those of other markets. For example, in 1985, there was a 40% premium in base wages paid to steel workers versus the all manufacturing average. When benefits and other employment costs are included, that number jumps to around 50%. In a different, but equally important industry, such as the automobile industry, these labor premiums are even more dramatic: the U.S. labor compensation premium over Japan's is 140%, 150% for Italy and so on.[5]

No matter how dramatic these changes are, they can be measured relatively easy and at low cost. However, measuring technological change has always been a difficult task; we know it is there but it is just about always indirectly measured as a catch all type of thing. Therefore, a model which describes the changes in electricity demand in the industrial sector must incorporate a mechanism for measuring technological change in a direct way.

CHAPTER ONE FOOTNOTES

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CHAPTER TWO

2.1 REVIEW OF EXISTING MODELS

Electricity is one of the many inputs used in the production of goods in the manufacturing sector. Thus, one may start the modeling process with a production function which summarizes the technical relationship between inputs and output. A firm chooses the production process and inputs which minimize the cost of production of a certain level of output.

There are various models that are utilized for this purpose, namely engineering, econometric and engineering- econometric.

Engineering models tend to be very detail descriptions of the processes involved and together with engineering assumptions and data model the firm's behavior.

Econometric models describe the firm's behavior with information contained in a production function and explicit cost minimized functions. These functions reflect decisions made regarding equipment and production processes as input prices and output quantities change. Due to the fact that econometric models use information derived from historic data, these models can be estimated from these data which describe the firm's behavior in response to changes in relative prices of inputs, etc. Log-linear forms have been utilized as an attempt to simplify the formulation of these models and the interpretation of the results.

There are three types of econometric models which have been utilized to model electricity demand:

- Fuel Share models
- Factor Demand models
- Flexible Functional Form models

Fuel share models (Chern 1983, Pindyck 1980)[1] incorporate energy demand and individual fuels and the sum of individual fuels demanded equals total energy demand. These models have been critisized as being only statistical descriptors of the process they represent and as such are not derived from economic theory.

Factor demand models (Fisher and Kaysen 1962, Halvorsen 1978)[2] describe the demand for a specific production factor, such as electricity, as a function of electric price and other inputs as well as the quantity of output. There are some drawbacks in estimating factor demand models, namely the inability to impose behavioral restrictions such as symmetry. Separability is preserved though and together with the small data requirements and the ease of estimation, these models present an attractive alternative.

Fisher and Kaysen studied the demand for electricity in ten manufacturing industries by employing factor demand models whereas Mount Chapman and Tyrrell[3] specified a Koyck type distributed lag dynamic model.

Baxter and Rees[4] in an earlier study of industrial demand for electricity in the United Kingdom, showed that demand was responsive to changes in output but was relatively unresponsive to changes in prices. Chern[5] estimated demand functions in 16 major electric consuming industries utilizing a demand model with a geometric lag and his findings showed industrial demand to be price elastic in the long-run whereas the evidence was inconclusive for short-run responses. Others, such as Halvorsen[6], have attempted different model specifications, such as a simultaneous demand and price equation model; Chern et al[7] developed models using pooled time-series and cross section data and derived elasticities by applying two and three-stage least squares techniques. These studies also gave mixed results concerning price elasticities: elasticity coefficients varied from -0.04 to -1.40.

All of the above-mentioned studies are an indication of the heterogeneity which characterizes the industrial sector. The demand for electricity is a derived demand and in the industrial sector electricity is used as a direct and/or indirect input in the production process. Direct uses may be operation of machinery and application of chemical processes whereas indirect uses may be lighting, cooling, heating, etc. Electricity is utilized along with the capital stock, instead of consumed directly, and as such its consumption depends on the changes-replacements of this stock. However, the ability of the industrial sector to change electricity consumption patterns is limited. It takes a considerable amount of time and resources to alter existing stocks of machinery. Business decisions to change machinery and/or products are influenced from shifts in demand for certain or all products. New machinery, new products and new methods of production may mean shifts in the income flow to certain industries and consequently to individuals. Also, labor and wage policies play an important role on productivity. All of the above influence business decisions in terms of present behavior as well as future behavior.

The ability to predict requires knowledge of why expansion occurred in the past and which of the forces that stimulated it are still at work. By getting these answers one could explain why energy productivity in general, and electricity consumption in particular, have changed from one period to another, and an attempt can be made to analyze this growth pattern.

Analyzing a growth pattern though, may be so complex and may fall into the fields of a sociologist, psychologist as well as that of the economist. Traditionally, economists have tried to limit themselves to a set of exogenous (independent) variables that can be easily obtained and applied to a particular problem. Obtaining and utilizing a set of such variables to build a model is only a part of the whole model generating process; one has to estimate future values for these variables and use these values to project the endogenous (dependent) variable. Oftentimes, these exogenous variables are very complex and difficult to predict. Their variation may be the result of various simultaneous phenomena.[8] Therefore, one attempts to utilize those variables which are simple to explain, fairly easy to predict and produce satisfactory results.

Based on the above observations, one may formulate a demand for electricity model by assuming that given a change in the demand for electricity, a firm or an individual, adjusts to a desired level of consumption, partially and not immediately.

Therefore, if $K_t^* - K_{t-1}$ is the desired change in consumption between time t and t-1 and $K_t - K_{t-1}$ is the change that actually occurred, then the expression

$$(1) \quad k_t - k_{t-1} = d(k^*_t - k_{t-1}) \qquad \text{with } 0<d<1$$

shows that only a proportion d of the gap between actual and desired consumption levels is closed in one time period.

The desired level K^* of course is not measurable since it is not observable, but we can mathematically manipulate the above equation (1) and eliminate K^*, as follows: suppose K^* is a function of say income and price, i.e., it can be written as:

$$(2) \quad k^*_t = a + bV_t$$

where Vt is a matrix made of economic variables such as income and price and a and b are regression coefficients.

Then, by combining (1) and (2) we get

$$(3) \quad k_t - k_{t-1} = d(a + bV_t - k_{t-1})$$

or by rearranging

$$(4) \quad k_t = ad + bdV_t + (1-d)k_{t-1}$$

Equation (4) can be estimated via regression since all variables are observable. Therefore, we derive coefficients for ad, bd and 1-d algebraically. Under the above specification, bd gives us short-run elasticities and d gives us long-run elasticities. This comes by applying the formula:

$$\text{Long-run elasticity} = \frac{\text{short-run coefficient}}{1 - \text{lag coefficient}}$$

Another way of looking at the partial adjustment model is by considering it in terms of ratios, i.e.,

$$\frac{K_t^*}{K_{t-1}} = \left(\frac{K_t}{K_{t-1}}\right)^d$$

Then, by taking logarithms we get,

$$(5) \quad \log K^*_t - \log K_{t-1} = d\log K_t - d\log K_{t-1}$$

By going through the same algebra as before, we derive an equation such as (4) with logs. This is precisely the present GPU industrial model specification.

The conversion from short-run to long-run is heavily dependent upon the adjustment or replacement of the capital stock. It turns out that the higher the replacement rate, the lower the lag coefficient. Current research shows that it took 15 years for the price elasticity to achieve 88 percent of its long-run value.

In the above model the price of electricity in the industrial sector and the prices of oil and natural gas, although statistically significant, form lower elasticities than those anticipated in the industry and those one would find in the literature. Although economic theory suggests that, with some allowance for time lag, industries adjust to price trends as perfectly as possible -price elasticities around - 1.0, one may be surprised with the plethora of price elasticities found in the literature. The industry mix is a determining factor for the elasticity variance observed in various studies. Aggregate models, which mix large users of electricity with less intensive users, tend to produce "averaged" elasticity coefficients since they reflect price responses attributed to the behavior of large users and small users or the market in general. Also, one must consider the fact that large users of electric energy have located traditionally in areas of low electric rates, therefore no conclusions can be drawn from elasticities as to the behavior of industries when rates in all regions change. This is equivalent to saying that when locational effects are removed, industrial demand for electric energy is price inelastic. This conclusion is in line with the conclusion of other major studies which have dealt with the demand for electricity in the industrial sector.[9]

Finally, the inclusion of an alternate fuel, such as oil or natural gas has proven to be statistically significant but with low substitution effects. The price elasticity for oil is 0.03 whereas for gas ranges from 0.04 to 0.15. These values are lower than the 0.16 to 0.18 range reported in the Electric Energy Institute (EEI) survey where cross elasticities are said to be relatively stable over time.

Recent research has focused on flexible functional form models which are second order approximations to the cost function, and thus, are less restrictive than the traditional Cobb-Douglas and CES specifications. These forms include the translog, generalized Leontief, and generalized Cobb-Douglas specifications. These models are the so called KLEM models (Capital, Labor, Energy, Materials), and their major advantage is their ability to model the entire production process. Therefore, they capture the functional relationship of electricity demanded and the demand of other factors of production. Their disadvantage is the computation and data requirements which are large.

2.2 THEORETICAL FOUNDATION FOR FLEXIBLE FUNCTIONAL FORM MODELS

In theory, flexible functional form models can approximate an arbitrary cost function. However, because very often we are faced with typical problems such as limited number of observations, multicollinearity, insufficient degrees of freedom, etc., we can not model the underlying structural relationships correctly. As a result, we often attempt to approximate the cost function with a Taylor series expansion (translog) of sufficiently high order. Even in this case we have to arbitrary truncate the expansion when a limited number of observations exist, and thereby ignore the consequences of the bias and precision of the estimated parameters. As a result, we have to introduce some structure into our models because otherwise we may be asking too much of our data and run the risk of loosing much of the valuable information[10] (klein(1977)).

The cost function mentioned above which will be used in this study will be the KLEM model of the transcendental logarithmic form (translog) which provides a second order approximation to an arbitrary twice differentiable unit cost function (i.e., the cost of producing a unit of output.)

The equations that form a KLEM model are derived from a two-step process; first, a production function or a cost function describes the technology involved. Second, demand equations and therefore changes in industrial demand for electricity are measured with input share equations derived from cost functions using Shephard's lemma. This is a flexible functional form model which describes the relationship between the total cost and demand equations.

In the simplest case the translog cost function will be of the form:

$$(6)\quad LnC = a_0 + \sum_i a_i LnP_i + a_Y LnY + \frac{1}{2}\sum_i\sum_j \gamma_{ij} LnP_i LnP_j + \frac{1}{2}\gamma_{YY} LnY^2 + \sum_i \gamma_{iY} LnP_i LnY$$

where: Pij are prices of inputs i and j Y is level of output

If the above cost function meets certain regularity conditions to be stated below,we can derive input demand functions simply by differenciating the cost function with respect to P, the vector of input prices. This procedure eliminates the usage of production functions and it is a very convenient way to estimate demand functions, especially in cases where estimates of some parameters of the production function are highly non linear and difficult to estimate.

From duality theory we know that the cost function is derived from a given production function that is quasiconcave and twice continuously differentiable.

Shephard's Lemma: If there exists a cost function C(P,Y) which is differentiable with respect to P at some (P^*,Y^*) and meets the conditions outlined below, then $X(P^*,Y^*) = \partial C(P^*,Y^*)/\partial P$ where $X(P^*,Y^*)$ is the vector of cost minimizing input quantities necessary to produce Y^* units of output and P^* is the given vector of input prices.

Using Shephard's lemma, the cost minimizing input demand equation is given by:

$$(7)\quad \frac{\partial C}{\partial P_i} = X_i$$

In case where the factor demand equations are highly non-linear and difficult to estimate, a variation of Shephard's lemma is used to estimate fuel share equations as the partial derivative of the logarithm of total cost with respect to the logarithm of factor price:

$$(8)\quad \frac{\partial LnC}{\partial LnP_i} = S_i$$

Assuming that cost for fuel i is quantity times its price, the fuel share is related to the factor demand equations according to:

$$(9)\quad S_i = \frac{P_i X_i}{C}$$

In the case of equation (6) Si will be given by:

$$(10)\quad S_i = a_i + \sum_j \gamma_{ij} LnP_j + \gamma_{iY} LnY$$

which is linear in the parameters.

From the above equation one can proceed to estimate various parameters which are useful for characterizing the estimated model such as the substitution and price elasticities. The substitution elasticities measure factor substitution in production and are given by the Allen-Uzawa form:

$$(11)\quad \sigma_{ij} = \frac{C(\partial^2 C/\partial P_i \partial P_j)}{(\partial C/\partial P_i)(\partial C/\partial P_j)}$$

The own and cross-price elasticities of demand would be expressed by:

$$(12)\quad \sigma_{ii} = \frac{\partial LnX_i}{\partial LnP_i} \text{ and } \sigma_{ij} = \frac{\partial LnX_i}{\partial LnP_j}$$

Aside from estimating the model one has to be concerned about the behavior of the cost function. In a well behaved cost function, costs should be monotonically increasing and concave in input prices.

The translog function does not satisfy these restrictions globally; therefore, we have to check monotonicity and concavity.

Monotonicity implies:

$$(13)\quad \frac{\partial C}{\partial P_i} \geq 0 \qquad \text{OR} \quad S_i \geq 0$$

In short, increasing one or more input prices cannot lower the minimum cost of producing the same level of output.

Concavity requires:

$$(14)\quad \frac{\partial^2 C}{\partial {P_i}^2} \leq 0$$

This implies that the cost function is concave in input prices, but this check is only a necessary, not a sufficient condition.

We also want to assume and test homogeneity, since in general, output in the translog is not homogeneous in the inputs.

Homogeneity imposes some testable parametric restrictions on the system, including those for symmetry.

$$\gamma_{ij} = \gamma_{ji} \qquad \sum_i a_i = 1 \qquad \sum_i \gamma_{ij} = 0 \qquad \sum_i \gamma_{iY} = 0$$

Symmetry also implies:

$$(15) \quad \frac{\partial^2 C}{\partial P_i \partial P_j} = \frac{\partial^2 C}{\partial P_j \partial P_i}$$

or by applying Shephard's lemma

$$(16) \quad \frac{\partial X_i}{\partial P_j} = \frac{\partial X_j}{\partial P_i}$$

Another necessary structural assumption on the cost function is the concept of separability which concerns the decomposition of a function into groups of subfunctions.

The impact of separability is to impose additional structure on the function which one can study by an examination of the function's derivatives. Separability allows the aggregation of inputs in such a fashion that the value of each aggregate is invariant with respect to the levels of inputs outside the aggregate.

It is therefore obvious that separability can constrain the association on economic variables and one needs to be constantly aware of the ramifications of the selected structure.

2.3 INCORPORATING TECHNOLOGICAL CHANGE

The rate of technological change is an important parameter in electricity forecasting models because it changes a firm's cost of production over time. One may think that technological change is endogenous to the firm, responding to market prices and investment in research and development. However, in most empirical studies technology is taken as exogenous and measured by a proxy variable. We shall call this disembodied technical change to distinguish it from technology "embodied" in new capital which we shall call embodied. It is therefore natural to assume that embodied technology is a function of the average age, or vintage of an industry's or firm's equipment and the translog cost function (6) is modified as follows:

$$
\begin{aligned}
(19)\ \mathrm{LnC} = {} & a_o + \sum_i a_i \mathrm{LnP}_i + a_Y \mathrm{LnY} + \frac{1}{2}\sum_i\sum_j a_{ij}\mathrm{LnP}_i\mathrm{LnP}_j + \frac{1}{2}a_{YY}\mathrm{LnY}^2 \\
& \sum_i a_{iY}\mathrm{LnP}_i\mathrm{LnY} + \beta_T T + \frac{1}{2}\beta_{TT}T^2 + \beta_{TY}\mathrm{TLnY} + \\
& \sum_i \beta_{Ti}\mathrm{TLnP}_i + \gamma_V \mathrm{LnV} + \frac{1}{2}\gamma_{VV}\mathrm{LnV}^2 + \gamma_{VT}\mathrm{TLnV} + \\
& \gamma_{VY}\mathrm{LnVLnY} + \sum_i \gamma_{Vi}\mathrm{LnVLnP}_i
\end{aligned}
$$

Where: Pij are prices of inputs i and j, Y is the level of output,

T is technology, V is vintage of equipment

2.4 INCORPORATING DYNAMIC ADJUSTMENT

Koyck partial adjustment type of models have been widely used as a simple-quick way to transform a function into its dynamic counterpart.

For example the investment model:

$$(20)\ I = f(K^{*} - K_{-1}) + bK_{-1}$$

shows the adjustment of capital stock K towards its desired or equilibrium level K^{*} with b being the speed of adjustment coefficient.

However, the Koyck model has been critizied because the specification is not derived from any explicit model of consumer behavior optimization, but is merely an ad hoc adjustment. Also, the derived ratio of short-to-long run elasticities for all factors depends only on b, i.e.,

$$(21)\ \text{Long-term coefficient} = \frac{\text{Short-term coefficient}}{1\text{-lag coefficient}}$$

This adjustment parameter b is taken as a constant over all time periods and assumed to be exogenous to the firm. If other factor inputs are specified in the model, their adjustment parameters are taken to be constant as well. Thus, there is no distinction between variable and fixed factors in the model.

Brown and Christensen (1981)[11] have come up with an alternative model specification derived from a more realistic representation of the firm's economic behavior. It is assumed that a firm can only minimize the cost of the variable factors used in production while the fixed factors are constrained to their current levels. If capital is the fixed factor, the transformation of (19) entails the replacement of capital's factor price with its quantity, in which case the translog function becomes:

$$\begin{aligned}(22)\ LnC= {} & a_0 + \sum_i a_i LnP_i + a_y LnY + \frac{1}{2}\sum_i\sum_j a_{ij} LnP_i LnP_j + \delta_k LnK + \\ & \frac{1}{2}a_{YY}LnY^2 + \sum_i a_{iY} LnP_i LnY + \beta_T T + \frac{1}{2}\beta_{TT}T^2 + \beta_{TY}TLnY + \\ & \sum_i \beta_{Ti} TLnP_i + \gamma_V LnV + \frac{1}{2}\gamma_{VV}LnV^2 + \gamma_{VT}TLnV + \\ & \gamma_{VY}LnVLnY + \sum_i \gamma_{Vi} LnVLnP_i + \sum_i \delta_{iK} LnP_i LnK + \frac{1}{2}\delta_{KK}LnK^2 + \\ & \delta_{KY}LnKLnY + \delta_{KT}LnKT\end{aligned}$$

From equation (22) the rate of technological change may be expressed by a representation of the embodied and disembodied technology as follows:

$$(23)\ T_c = \frac{\partial LnC}{\partial T} + \frac{\partial LnC}{\partial LnV} * \frac{1}{V} * \frac{dV}{dT}$$

where: $\frac{\partial LnC}{\partial T}$ is disembodied change and the second right hand term represents the effects on total cost of embodied technical change.

The combination of (22) and (23) gives an estimate of the change in technology as follows:

$$(24)\ T_c = \beta_T + \beta_{TT}T + \beta_{TY}LnY + \sum_i \beta_{Ti}LnP_i + \gamma_{VT}LnV + \delta_{KT}LnK$$

$$(\gamma_V + \gamma_{VV}LnV + \gamma_{VT}T + \gamma_{VY}LnY + \sum_i \gamma_{Vi}LnP_i) * \frac{1}{V} * \frac{dV}{dT}$$

Here, we need to estimate $\frac{dV}{dT}$ i.e. the change in vintage over time. The vintage is an index which is computed as the weighted average of the age of the industry's equipment. The weights will be the contribution of each equipment sub-group into the production process.

Following the development of $\frac{dV}{dT}$, we regress this ratio as lagged values of Pi and output Y (as an Almon lag model) to get an estimate of the change in vintage over time.

Short run price and substitution elasticities are estimated from equations (11) and (12) using the parameter estimates and observed share values. The long run or optimal values of the fixed factors have to be solved for before calculating the long run values of the elasticities.

CHAPTER TWO FOOTNOTES

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CHAPTER THREE

3.1 DATA BASE DEVELOPMENT

Data requirements and development is a crucial step in model estimation and one has to identify the type of information needed as well as the sources from which this information will be drawn from.

The data requirements for this model discussed previously include prices of and expenditures on inputs and industrial output on the state level for the state of Pennsylvania.

The variables needed to estimate the model are real output, expenditures and prices of capital, labor, materials, electricity, natural gas, oil and coal and the capital stock in manufacturing.

For real output, defined as the real dollar value of shipments by firms in an industry plus the change in inventories during the year, the data requirements are:

-value of shipments -beggining and end of year inventories -output deflator One major problem with this variable is the fact that there is double

counting since there are many industries which sell both to final demands and to other industries at various stages of manufacturing. There is no known way to avoid this problem with existing data.

Capital is by far the most difficult variable to measure. The difficulty arises because the price os assets which are observed are the aquisition cost and do not represent the real value of these assets which will presumably last several periods.

Here, the rental price of capital concept comes into play which represents the cost minimizing implicit price paid to use the capital for one period. Thus, the total cost of capital is the rental price of it times the quantity of capital that is still in service.

Under the above assumption, the cost of using capital for one period is given by the equation:

$$(25)\quad PC(t) = p(t-1)*r + p(t)*d - [p(t) - p(t-1)]$$

where: PC(t) is the rental price of capital at time t p(t) is the acquisition price of capital at time t, r is the interest rate and d is the depreciation rate

The above equation incorporates no tax terms, i.e. no tax distortions. Fraumeni and Jorgenson (1982)[1] have estmated a similar equation for the rental price of capital, one which includes tax distortions:

$$(26)\quad PC(t) = \frac{1-U(t)*Z(t)-K(t)}{1 - U(t)}*p(t-1) * r(t) + p(t) * d - [p(t)-p(t-1)] + p(t)T(t)$$

where: U(t) is the marginal corporate profit tax rate at time t

K(t) is the investment tax credit rate at time t T(t) is the property tax rate at time t Z(t) is the present discounted value of depreciation deduction of $1.0 of investment

Over the years, there have been various methods which attempted to estimate the capital stock at the national level but no estimates have been made for state capital stocks. For this study, the estimates of national stock made by the Office of Business Analysis (OBA), Department of Commerce and a perpetual inventory model developed by the Department of Labor were studied.

The general form of the OBA model is given by the following equation:

$$(27)\ K(t) = K(t-1) + I(t) - \sum_{y=1}^{t-1} E(t-y+1) - E(t-y) * I(t-y)$$

where: K(t) is the capital stock in year t I(t) is gross investment in year t E(t-y) is the relative efficiency of assets remaining in year t and purchased y years prior to year t

The relative efficiency of an asset which remains in service after y years is given by the equation:

$$(28)\ [1 - E(y)] = 1 - \frac{L - a}{L - Da}$$

where: L is the useful lifetime of an asset D is a depreciation parameter a is the age of the asset

Estimation of equation (28) requires knowledge of the age distribution of the asset as well as the useful lifetime of that asset.

The general form of the perpetual inventory model is given by the equation:

$$(29)\quad k(t) = k(t-1) + I(t) - \sum_{y=0}^{t} [DE(y) * I(t-y)]$$

where DE(y) is the decline in relative efficiency of an asset in its yth year of service. Assets are assumed to have relative efficiency of 1 when purchased and this efficiency declines to zero as these assets age, based on an assumed depreciation rate.

The difference between the two models is the form of depreciation assumed, which in the case of the perpetual inventory model, is assumed to decline geometrically over time. This implies that assets depreciate most rapidly in the early years of their lives. On the other hand, the OBA model takes a more realistic view, by implying that most of the depreciation occurs at the end of the asset's life. As mentioned before, this method requires estimates of the age distribution of assets, information not available at the state level.

Surprisingly enough, the two methods produce estimates of capital stocks which are very close and one can infer that the OBA model behaves as though it was generated by a geometric process.

To measure capital cost one finds himself bound by two approaches; the book value, which measures capital at the prices which assets were originally purchased mixing dollars of different values from different time periods, and a perpetual inventory approach whose general form is:

(30) $K_t = I_t + K_{t-1} - D_t$

where: K_t is capital stock in year t I_t is real gross investment in year t D_t is depreciation cumulative to year t

If it is assumed that an asset's efficiency declines geometrically, the depreciation of the entire stock reduces to a constant proportion of the capital stock. In this case, the model known as the partial adjustment model of capital accumulation derived from geometric depreciation is given by:

(31) $K_t = I_t + (1-d)K_{t-1}$

In this model, age distribution is elimated and the current capital stock is estimated from gross investment, last period's stock and the rate of depreciation, d.

The rate of depreciation can be estimated either by subtracting I_t from both sides of (31) and then calculating 1-d or by an optimization procedure: various values of d are tried out on (31) and the resulting values of K are introduced into a typical production function relating value added to capital and labor and testing for the minimization of the sum of the squared residuals.

The rental price of capital mentioned above does not exist on the state level, therefore, its national countepart will be used recognizing that there might be regional differences. Data was obtained from Data Resources, Inc.

For labor, the hourly wage is needed and is calculated as expenditures on labor divided by the total hours worked. The data required for this calculation was obtained from Chase Econometric's regional data base.

Energy data was obtained from DRI's regional data base. Expenditures on electricity, natural gas, oil and coal as well as quantities and the corresponding price deflators were used to calculate the average price for these fuels on the state basis.

Expenditures on and prices of materials also needed for the model estimation were also obtained from Chase's regional model. Energy expenditures were subtracted from materials since the former were modeled explicitly. Price for materials is the all manufacturing price converted to real by a materials deflator.

3.2 ECONOMETRIC ISSUES AND ESTIMATION RESULTS

The estimation interval is 1965 through 1983 which incorporates the oil price shocks and recessions which are phenomena that one would expect trigger mechanisms for structural and technological changes. This interval was chosen because patterns of electricity growth have changed dramatically prior to that and previous research has shown that elasticities derived from intervals prior to mid-sixties are not the true representation of the values one would derive with more recent data. Chow-tests have shown that coefficients have changed rapidly in many cases from one interval to another.

There were a number of practical and theoretical problems regarding the data. One of the most important ones was the fact that some of the state series had discontinuities present which made it necessary to use their national counterparts in order to fill in the gaps. Also, because the variation in prices is small when using state data, we are faced with the problem of obtaining inefficient parameter estimates which yield the approximate shape of the cost function within the range of observed prices. One is faced with an uncertainty when we extrapolate outside the range of the observed prices.

In this study, the dynamic model incorporating technological change is estimated assuming capital is fixed in the short-run. Under this assumption, the cost of variable inputs is a function of the quantity of capital, as well as that of output and the prices of variable inputs. When all the restrictions are imposed, the final set of estimated equations is:

$$(32)\ S_E = a_E + \gamma_{EK}Ln(K/Y) + \gamma_{EL}Ln(P_L/P_M) + \gamma_{EE}Ln(P_E/P_M) + \gamma_{EF}Ln(P_F/P_M) + \gamma_{Et}t$$

$$(33)\ S_L = a_L + \gamma_{LK}Ln(K/Y) + \gamma_{LL}Ln(P_L/P_M) + \gamma_{LE}Ln(P_E/P_M) + \gamma_{LF}Ln(P_F/P_M) + \gamma_{Lt}t$$

$$(34)\ S_F = a_F + \gamma_{FK}Ln(K/Y) + \gamma_{LF}Ln(P_L/P_M) + \gamma_{EF}Ln(P_E/P_M) + \gamma_{EF}Ln(P_F/P_M) + \gamma_{Ft}t$$

Since the share equations are constrained by $\sum_i S_i = 1$, only three of the four share equations are estimated. The choise of the equation omitted is inconsequential. Barten (1969) has shown that the maximum likelihood parameter estimates are independent of the equation omitted. Thus, the materials equation is omitted.

The above system of equations plus the cost function are estimated simultaneously using the iterative Zellner's Seemingly Unrelated Regression technique. The own and cross-price elasticities of demand are given by the equations:

$$(35)\quad n_{ii} = \frac{\gamma_{ii} + S_i(S_i-1)}{S_i}$$

$$(36)\quad n_{ij} = \frac{\gamma_{ij} + S_iS_j}{S_i}$$

where S_i and S_j are shares of inputs i and j.

Monotonicity is checked by estimating equation (13) and concavity is checked by examining equation (14) or equivalently by satisfying the inequality: $\gamma_{ii} \leq S_i - S_i^2$

The analysis has shown that there were concavity violations which were corrected by applying the Jorgensen and Fraumeni approach of setting the higher order terms of the translog to zero, i.e., imposing a partial Cobb-Douglas structure on the system.

The model's performance was evaluated by assesing various statistics such as t-statistics, R-squared and goodness of fit, as well as whether the regularity conditions were satisfied. In addition, the estimated parameters were compared against those from other studies to see whether substantial differences were present. The concentration was on five major industrial groups since these groups make up the bulk of the electric sales in the Pennsylvania Electric case. They are: paper, refining, Stone-Clay-Glass, and Primary and Fabricated metals.

The tabulation below shows the mean own factor price elasticities of demand for electricity for the above mentioned industries.

Table-1: Penelec Industry Test
Mean Own Price Elasticities

INDUSTRIES	Electricity	Fossil Fuel	Capital	Labor	Materials
Paper	−0.5	−0.6	−0.28	−0.17	−0.62
Refining	−0.34	−0.4	−0.2	−0.3	−0.3
Stone,Glass	−0.61	−0.76	−0.44	−0.53	−0.82
Primary Metals	−0.57	−0.6	−0.22	−0.28	−0.46
Fabr. Metals	−0.87	−0.82	−0.46	−0.29	−0.42

On average, electricity demand is less elastic than fossil fuels but more elastic than all the other factors. Furthermore, all factors are relatively inelastic, even for industries not reported here.

Comparing these results with those of other studies we see that there are not incosistent, although some differences exist.

Table-2: Comparison Of Electricity Own-Price Elasticities

INDUSTRY	IndMOd	Denny,Fuss,Waverman	Halvorsen	Poulios
Paper	−0.5	−0.55	−0.2	−0.38
Refining	−0.34			
Stone,Glass	−0.61			
Primary Metals	−0.57	−1.42	−0.83	−0.34
Fab. Metals	−0.87	−0.43	−1.1	−0.38

Here, Indmod is the model estimated in this study and Poulios is a model estimated for Pennsylvania Electric according to equation (5).

The Denny, Fuss and Waverman's (1981)[2] estimates are derived from a dynamic model of eighteen Canadian manufacturing industries whereas the Halvorsen (1977)[3] estimates are from a static translog model of the United States manufacturing using cross sectional data. Table-2 shows that with the exeption of primary and fabricated metals, all industries are price inelastic.

Another way of estimating the own price elasticities was to pool the data and run this regression as a cross check against the previous approach. Table-3 shows that differences exist but they are not significant in a statistical sense.

Table-3: Own Elasticities, Pooled Data

INDUSTRIES	Electricity	Fossil Fuel	Capital	Labor	Materials
Paper	−0.4	−0.72	−0.33	−0.23	−0.66
Refining	−0.45	−0.45	−0.31	−0.25	−0.54
Stone,Glass	−0.53	−0.66	−0.55	−0.47	−0.66
Primary Metals	−0.63	−0.58	−0.2	−0.33	−0.59
Fabr. Metals	−0.75	−0.8	−0.41	−0.32	−0.48

The tabulation below shows the electricity cross price elasticities of demand for the factor inputs.

Table-4: Cross Price Elasticities

INDUSTRIES	Fossil Fuel	Capital	Labor	Material
Paper	−0.33	−0.7	2	0.93
Refining	0.46	−1.25	0.33	2.5
Stone,Glass	−0.18	−0.2	−1.04	0.98
Primary Metals	0.23	0.25	0.23	−0.35
Fab. Metals	0.3	−0.15	−0.72	0.55

Electricity and fossil fuels are found to be substitutes in refining and metals and compliments in the rest. Electricity and capital are only substitutes in primary metals. This is intuitively acceptable except in the case where a metal producer installs an electric arc furnace in which case, capital will increase electric usage. Electricity and labor are substitutes in paper, refining and primary metals; also, electricity and materials are substitutes in all but one of the industries studied, that of primary metals.

The rate of technological change depends, to a great extend, on input prices. It is also understood that, in a world of a changing regulatory environment in which utilities are becoming more competitive, input prices may indeed impeed technological change. If the price of electricity becomes high enough an electric customer may seek power elsewhere or seek more favorable treatment from the provider. In this type of scenario, and assuming a product such as steel is produced more efficiently with electricity versus any other fuel, higher electric prices may not induce changes in technology. In this model, technological change is captured by estimating equation (23). If $T_c > 0$ we say that technological change is factor-using in input i, and if $T_c < 0$ then technological change is factor saving in input i.

Table-5 shows that total technological change, measured by the sum of disembodied and embodied technological change, is found to be electricity saving in paper and refining but using in metals and stone, clay and glass. With regard to the production of paper, the following new technologies are found to be electricity saving: hydropyrolisis and vapor recompression which are alternatives to the conventional recovery boilers used in the pudping process; mach nozzles which decrease the electricity consumption by assisting in the drying of the paper and sludge drying, a chemical rather than heating method for drying sludge.

Table-5
Embodied And Disembodied Technological Change

INDUSTRIES	Electricity	Labor	Fuels	Capital
Paper	↑	↑	↓	↓
Refining	↑	↑	↑	↓
Stone,Clay,Glass	↓	↓	↓	↓
Primary Metals	↓	↑	↑	↓
Fab. Metals	↓	↓	↓	↓

↑ Saving
↓ Using

In the case of primary metals, the installation of newer equipment, newer from a technological point of view, may be more electricity intensive than older ones. For example, an electric arc furnace, although facilitates the production of high quality products, requires huge amounts of electricity. Furthermore, only the initial face of the melting process is efficient because the whole process requires an inefficient delay during the final stages of melting which reduces productivity and uses more energy.

With regard to labor, paper, refining and primary metals are found to be labor saving. Here one has to be carefull in interpreting these results since the changes in labor may be the result of other factors rather than technological change. For example, in the steel industry, major changes in the labor force have occured as a result of reduced demand for steel (downsizing of automobiles, material substitution), import competition (price effects), etc.

Refining and primary metals are found to be fuels saving because these two industries utilize other sources of energy in their production process, such as steam heat and electricity, respectively.

With respect to capital, technological change is factor using for all industries studied here.

The results from table-5 are not trivial to interpret; for example, a big steel company may go into a large expense of installing electric arc furnaces which consume huge amounts of electricity, but at the same time control the costs associated with electricity by installing electronic equipment to keep the electric load below a maximum and avoid extra large charges.

Therefore, it is not apparent if factor saving is an isolated or combined event in altering costs of production and the results here are not conclusive but rather indicative only. Ther results vary dramatically from industry to industry which is another indication of the heterogeneity of the industrial sector. One also has to keep in mind that the period covered here allows for tremendous differences in spending patterns among firms due to recent modernization efforts that have been taking place during the last few years.

3.3 CONCLUDING REMARKS

This study has concentrated on the structural and other changes that have taken place in the demand for electricity in the Pennsylvania Electric territory, an area which may be seen as an example of industrial deterioration of a once healthy economic base. The reasons for this deterioration may be attributed to the unaccessibility of markets and forcefull competition as well as the typical economic forces of product substitution, overun costs and the inability to adopt to new technologies timely.

The industries studied, although small in number, make up almost 60 percent of the industrial electric sales for Pennsylvania Electric and are the type of industries which have been affected by price competition, technological as well as structural changes.

The results show that the price elasticity of electricity demanded is inelastic for all industries studied here. Nevertheless, overall cost competitiveness is a requirement for survival for these industries, especially in a depressed area, and therefore, one can not ignore the fact that utility rate design may be the balancing wheel in terms of overall consideration for relocation and even existense. Under these circumstances, aggressive marketing programs are required by the utility in order to prevent existing electric base from being substituted by other fuels or cogeneration which may be more cost effective. Economic incentives must be in place to facilitate technological progress since the latter may be seen as a required ingredient for quality and efficiency. These programs are changing the way utilities plan their market strategies and one may admitt that the once advocated strategy of conservation of electric power may be a thing of the past.

CHAPTER THREE FOOTNOTES

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