IMPACT OF ENERGY PRICES ON
SMALL BUSINESS
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1.0 Introduction

Five major criteria are used by the EEE Research in critically reviewing the studies on impact of energy prices on firms and industries. First, do these studies directly relate to small or large firms? Second, is the time period adopted for the study relevant for the recent increases in energy prices? Third, are the industries covered by the studies disaggregated by SIC codes or too aggregated to be meaningful for policy decision-making aimed at specific industries. Fourth, do the studies use the state of the arts methodologies for theoretical and empirical estimation of the impact of energy prices on firms within an industry. Fifth, what are the policy implications of the results of the estimated equations.

Based on the abovereferred criteria, we have reviewed over a dozen studies on the impact of energy prices on firms and/or industries. The information collected from these studies will be used to specify the equation(s) for the analysis of small firms. These equations will be estimated in Task 3 through 4 and reported in the final report required for Task 5.

This study used the U.S. Census of Manufacturing, 1947-1971, data so that it includes only those small firms that employ 20 or more workers in the establishments. In short, small manufacturing establishments with less than 20 employees are excluded since the definition used by the Bureau of the Census exclude them from the data. Second, the period covered, 1947-1971, excludes the time period after the multi-fold increase in oil prices by the O.P.E.C. in 1974. Third, the data on manufacturing industries are not disaggregated by SIC codes so that impact on specific industries within the manufacturing sector cannot be analysed. Fourth, both the theoretical and the empirical methodologies are very robust so that the results are useful for policy decision-makers.

The theoretical methodology is that of estimating the transcendental logarithmic production function (translog) which is an improvement over the Cobb-Douglas, the Constant Elasticity of Substitution (CES) or the homothetic production function. For instance, unlike the Cobb-Douglas elasticity of substitution between capital and labor being restricted to one, the translog permits this elasticity to be greater or less than one. Similarly, unlike the constancy of the elasticity of substitution in the CES, the translog permits a variable elasticity of substitution. Secondly, the translog specification permits estimation of economies or diseconomies of scale. This is unlike the Cobb Douglas where there are only constant returns to scale. Third, the translog function is not unduly restrictive of factor shares. In the Cobb Douglas, the sum of the factor shares, that is, the sum of the shares of capital and labor, is restricted to unity. Fourth, the translog function is not unduly restrictive about the assumption of strict separability of one factor of production from another, as say, in the Cobb Douglas. In the translog function, one need not assume that energy as a factor of production is separable from capital and labor but can verify it. The verification on separability can be further divided into weak or strong separability in terms of Hicks, Harrod or Leontief
neutrality. The separability test also permits combination of factors of production, such as, separability of capital and labor from a mix of energy and material. Fifth, the translog permits simultaneous estimation of technological change parameter, the economies of scale parameter, coefficients of factor shares, elasticity of substitution parameter and the own- and cross-price elasticity of demand. Sixth, the translog is also relatively less demanding for data since its dual is a cost function so that if one cannot obtain data on production and factor inputs, one can get the factor shares data and estimate the cost function.

Berndt and Wood's empirical methodology consists of iterative three stage least squares (3SLS) for estimating three simultaneous equations. It is rendered free of simultaneous equations bias by using instrument variables. It may be recalled that the simultaneous equations bias is a common problem in the identification of the demand or supply of energy when price is an explanatory variable and energy is a dependent variable. This methodology also enables them to simultaneously estimate the technological change; economies of scale; elasticity of substitution between and among combinations of energy and capital, labor or materials over time as well as across space; and own- and cross-price elasticity of demand.

The results obtained by Berndt and Wood and their implications are as follows:

- The own-price elasticity of energy demand is (-0.47), that is, a 1% increase in price will, on an average, reduce the demand for energy in the manufacturing sector by 0.47%.

- Energy and labor are substitutes because the elasticity of substitution between labor and energy is 0.65, that is, a 1% increase in the energy price to wage ratio will increase demand for energy by 0.65%. In short, the impact of an increase in energy price can be moderated by using more labor instead of energy.
Energy and capital are complementary goods with the elasticity of substitution between capital and energy at (-3.2), that is, a 1% increase in the price of energy will result in a decrease in capital by 3.2%.

Capital and labor are substitutes with the elasticity of substitution of capital for labor at 1.01, that is, an increase in rental rate of capital by 1% will tend to increase demand for labor by 1.01%.

Capital is price elastic with an own-price elasticity of (-0.48), that is, a 1% increase in rental rate will tend to reduce demand for capital by 0.48%.

Labor is also price elastic with its elasticity of (-0.45) so that an increase in wage by 1% will tend to reduce demand for labor by 0.45%.

The policy implication recommended by Berndt-Wood is the elimination of the existing fiscal incentives in the form of investment tax credits and accelerated depreciation allowances. This is because their study showed that capital and energy are complementary goods. The impact of the fiscal incentives is to increase the demand for capital which will also tend to increase the demand for energy, thereby exacerbating the energy shortage.

Some of the limitations of this study include their assumption that the ratio of energy demand to GNP was fixed or time-trended. This assumption ignored the price-induced compositional changes in GNP such as the reduction in utilization rate of existing capital stock in energy-intensive industries and the corresponding unemployment in these industries and an increase in utilization rated in non-energy intensive industries to produce substitute outputs and hence the changes in GNP. It also ignored (i) the substitution of existing capital stock for energy inputs, improvement in energy efficiencies by retrofitting, etc., (ii) the substitution
of such other inputs as labor or non-energy materials for energy and/or capital, and (iii) the employment of new technologies embodied in energy efficient capital stocks. The second assumption of B-W was that the ratio between energy demand and output level was flexible, albeit within a given range instead of being fixed, so that energy demand can change with a given GNP. This assumption is the other extreme of the substitution possibilities noted above, namely, that the technical substitution possibilities may be very limited – within the range.

In this paper, B-W introduced the concept of "utilized capital"—an aggregation of energy and capital—to analyze relationships between this and other inputs in production. They, however, continued to use the same database as in their 1975 study so that the effect of the increase in energy prices since 1974 has been excluded.

The concept of "utilized capital" is used in this study to estimate the substitution possibilities between energy and capital within their composite factor of production called "utilized capital". They, however, continue to use the earlier database.
This study used a different methodology from that of Berndt-Wood but arrived at similar conclusion, namely, that energy and capital are complementary goods so that their policy implications are similar to that of Berndt-Wood. Hudson-Jorgenson (H-J) methodology consists of a production model for nine industrial sectors: (agriculture; non-fuel mining and construction; manufacturing, excluding petroleum refining; transportation; communications, trade and services; coal mining; crude petroleum and natural gas; petroleum refining; electric utilities and gas utilities). They use an econometric and an integrated input-output model of the U.S. economy to analyse both demand and supply of energy. The model first projects economic activity of the year 2000 and then simulates the energy utilization to the year 2000. The production data are from the U.S. Census of Manufacturing Industries so that small establishments with less than 20 employees are excluded. The methodology for estimating production function is the translog function.

H-J conclude that there is widespread ability to substitute between fuels, for example, between coal and oil in electricity generation, between oil and gas in industrial heating, between gas and electricity in home cooking and so on. They add that this "substitution is not merely a matter of switching fuels, for the associated capital stock must also be changed to permit the use of a different fuel. Our production models, by treating all inputs simultaneously, take account of the possibilities for both interfuel substitutions and substitutions of fuel for nonfuel inputs, but do this in such a way that the constraints implied by complementarities between inputs are recognised, so that a consistent analysis of the entire input picture is obtained". (p.512).

As a result of complementarity of energy and capital, the H-J model concludes that energy consumption can be reduced considerably by increasing
energy prices, say, by means of a Btu tax on energy consumption. Since capital requirements will also be reduced along with energy consumption, there is only an insignificant decrease in growth rate. For example, an increase in energy prices in 1980 simulation would result in an 8% decrease in energy input and only a 0.4% decrease in real income. In short, H-J conclude that a substantial reduction in energy use can be achieved without major economic cost because energy and capital are complements.

Unlike Berndt-Wood and Hudson-Jorgensen, Griffin-Gregory concludes that energy and capital are substitute instead of complementary goods. Griffin-Gregory (G-G) use the translog methodology used by Berndt-Wood but adopted pooled international data for manufacturing because G-G argue that Berndt-Wood as well as Hudson-Jorgensen had limited range of variation in their annual time series price data and hence their results cannot be generalised. G-G also cite cross sectional data used by David Humphrey and John Moroney (Section 2.7) in using four digit U.S. manufacturing branches to deal with input substitutions among capital, labor and natural resource inputs. G-G point out that the range of input price variation in H-M sample is likely to be limited. Also, the price variation can be due to differences in transportation costs instead of the "real" input quality differences.

G-G used pooled international data for manufacturing sector in nine countries for the period 1955-1969. These data are similar to the data on the U.S. Census of manufactures so that establishments with less than 20 employees are excluded. They, however, rightly suggest that their sample has wide variation in prices and reflect long term equilibrium (unlike the short term equilibrium of time series data) as price differences tend to be the result of long-standing national tariff, indirect taxes and subsidy policies.

G-G conclude that energy and capital are substitutes with the elasticity of substitution in the range of 1.02 to 1.07. Their estimate of elasticity of substitution between capital and labor ranged between 0.39 (U.K. and Belgium) and 0.52 (Denmark) which are much lower than B-W (1.01) and H-J (1.09). G-G rationalize these results by stating that an "increase in the relative capital price in the short run tends to cause substitutions away from E which must be compensated for by increases in L or M to keep output constant. In the long run, such a price change would cause substitutions in favor of both E and L and would suggest ceteris paribus a relatively smaller long-run elasticity of substitution of capital for labor" (p.853).
Some of the problems with G-C's methodology include the potential measurement error, simultaneous equation bias, and specification error. These are readily admitted by the authors since they do not use a model of simultaneous equations. They also point out the problem of aggregation bias in lumping together all manufacturing branches and suggest that future research should be at industry level in an international cross section of pooled data.

As suggested in the title, B-W attempt to reconcile the conflicting findings of energy-capital complementarity and energy-labor substitutability found in B-W (1975) for U.S. data on manufacturing for 1947-71; Berndt-Jorgenson (1973) for slightly different industrial data but for the same time period; by M.G.S. Denny and C. Pinto (1976) based on 1949-70 time series for Canadian manufacturing and by M. Fuss (1977) using pooled cross-section time-series data of Canadian manufacturing by region, 1966-71; and that of energy-capital substitutibility found by Griffin and Gregory (1976) and Robert S. Pindyok (1977) using international pooled cross-section and time series data for industry.

B-W use their concept of "utilized capital" to reconcile the engineering notion of substitutability and the econometric derivation of complementarity between energy and capital. They hypothesize a two-input weakly separable function which combines the inputs of aggregate capital and aggregate energy and produces an output called "utilized capital". In the context of an engineering example, they refer to refrigerators where utilized capital services could be the number of hours in which a specified amount of space is cooled to a certain temperature; the utilized capital services would be the output of a production process with two inputs—a refrigerator and KWH of electricity. The weakly separable utilized capital in the context of a linearly homogeneous production function implies that the optimal E/K ratio within the utilized capital sub-function depend solely on $P_K$, $P_E$, and not on the other input prices $P_L$, $P_M$ or the level of gross output $Y$.

B-W showed that the G-G \([(K, L, E), M]\) separability assumption and their (GG's) use of only KLE data implied that the GG elasticity estimates were not directly comparable with B-W, since different outputs were being held constant.
B-W derive and empirically estimate the gross and net A.E.S. based on gross and weak separability respectively by using the method of Maximum Likelihood Estimates for the U.S. and Canadian manufacturing data for 1971. Based on their estimation, they conclude as follows:

"We conclude that the seemingly inconsistent Berndt-Wood energy-capital complementarity and Griffin-Gregory energy-capital substitutability econometric results may simply be due to the fact that different elasticities are being compared; when the distribution between net and gross elasticities is acknowledged and the same output is held constant, the various net elasticity estimates are reasonably consistent with one another. Any remaining discrepancies are likely to be statistically insignificant, especially since standard errors for the G-G energy-capital elasticity estimates are large", (p.45).

B-W also added that the only other (apart from B-W's) four input KLEM study of which they were aware was that by Paul Swain and Gerhard Friede (1976) for manufacturing in West Germany. Swain and Friede also found E-K complementary.

In their concluding remarks, B-W are candid in admitting that the controversy of the empirical issue of E-K complementarity is far from settled because of four major reasons. First, there is a dire need to use the post-1973 data to include the impact of dramatic increase in energy prices. Second, the true long-run relationships of E-K substitutability cannot be resolved by pooled cross section and time series data, as done by G-G, because Fuss's pooled cross section and time series data revealed complementarity. The resolution would require econometric model of the disequilibrium or adjustment process in which explicit dynamic optimization instead of ad hoc constant coefficient adjustment specifications are used. Third, there are a number of data problems. For instance, both G-G and Pindyek were unable to take into account variations in effective corporate and property tax rates among OECD countries and over time. Also, both studies computed the value of capital services as value added minus the wage bill. This procedure was criticized by Berndt (1976) because the
resulting residual captures not only the return to capital equipment and structures but also the returns to land, inventories, economic rent, working capital and any errors in the measurement of value added or wage bill. Berndt (1976) found that elasticity estimates were very sensitive to such data errors and to the choice of rate of return. Also, in an unpublished KLE study, Barry Fields and Charles Grebenstein (1977) used total U.S. manufacturing cross-section data for states in 1971 and obtained E-K substitutability when the return to capital was computed as value added minus wage bill, but found E-K complementarity when the capital rental price measure referred only to plant and equipment. Lastly, they acknowledge that the study need be extended to other industries, and other time periods.
An objective of this paper is to determine if natural resource as a factor of production is a complement or substitute for capital or labor. Such a determination is important because such depletable natural resources as petroleum, natural gas, coal, iron, copper, and other non-ferrous metal ores can act as "limits to growth" of the U.S. Gross National Product if labor and/or capital cannot be substituted for these resources. The finding can also put an end to the "Leontief Paradox" (that the U.S., with relatively capital-rich country, was exporting labor-intensive products) controversy ranging in the economics literature for over two decades. For instance, Leontief (1953, 1956) and Baldwin (1971) concluded that natural resources and capital were complements so that manufactured commodities that are intensive in the use of natural resources also required intensive use of capital. In contrast, Barnett and Morse (1963) describe several processes in which capital and labor can substitute natural resources within a given state of technical knowledge. In technically progressive sectors, Hogen (1953), Adler (1961), Barnett and Morse (1963) and others emphasize that capital and natural resources are often substituted in the improvement in technical knowledge.

The data used by Humphrey-Moroney (H-M) consist of 19 two-digit product groups encompassing 235 SIC 4-digit industries. Twelve of these product groups consisted of renewable resource products (dairy farm products; poultry and eggs; meat, animals and misc. products; cotton; food, feed grains and grass seeds; tobacco; fruits and tree nuts; vegetables, sugar, and misc. crops; oil-bearing crops; forest, greenhouse, and nursery products; forestry and fishery products; logging, camps and logging contractors) and seven comprised nonrenewable natural resource products (iron and ferroalloy ores mining; copper ore mining; nonferrous metal ores mining, except copper; coal mining; crude petroleum and natural gas; stone and clay mining and quarrying; chemical and fertilizer mineral
mining). The source of the data was the Census of Manufactures, 1963.

The theoretical methodology consisted of estimating both the translog production function and a translog cost function because H-M emphasize that the results of the two approaches need not be comparable. They use four factors of production -- capital, labor, natural resources (N) and nonresource intermediate inputs (I). The empirical methodology is that of Zellner's iterative two stage least squares so that it is free of simultaneous equations bias as it is similar to Maximum Likelihood Estimators (MLEs).

The results reveal that natural resources are not complementary with capital or labor so that there need be no limits to the growth of U.S. GNP. While natural resources are substitutes for both capital and labor, they are better substitutes for capital than for labor. (The elasticity of substitution of N for K was greater than the elasticity of substitution of N for L in most of the product groups. Only in pulp and paper products group was the N more substitutable for L than K while the converse held for chemical products).

The results of estimating the translog cost function by using the Zellner iterative two stage method concluded that the hypothesis of fixed coefficients in the Leontief's production function would be rejected. The Cobb-Douglas hypothesis of unitary elasticity of substitution was also rejected in all the product groups.
Hagan rightly notes that engineering examples of capital and energy substitutability come to mind readily, such as the use of insulation as capital which reduces the demand for energy or the introduction of a waste heat recovery equipment capital which also reduces energy requirements but complementarity of capital and energy cannot be illustrated in terms of such engineering examples. He notes that the confusion on complementarity is due to the notion of more than two inputs used in analysis of production function in economic studies in general and in terms of Allen's partial elasticity of substitution in particular. Hogan resolves the conflict of capital-energy complementarity/substitutes in theoretical terms. He demonstrates that the empirical findings of Allen elasticity of substitution (AES) complementarity are not in conflict with the engineering examples of capital-energy substitution.

Hagen disputes the Berndt-Wood analysis of microeconomic analysis of manufacturing industries to determine the capital-energy complementarity/substitutability by estimating A.E.S. as positive or negative. He believes that a general equilibrium framework is necessary. We agree with Hagen because, as noted earlier in our criticism of B-W, the partial equilibrium approach of manufacturing industries tends to ignore the price-induced compositional changes in GNP such as the reduction in utilization rate of existing capital stock in energy-intensive industries and the corresponding unemployment in these industries and an increase in utilization rates in non-energy industries to produce substitute outputs and hence the changes in GNP in the context of general equilibrium framework of an economy. In a general equilibrium framework, Hagen showed that capital and energy would be complementary if we assumed (i) constant real returns on capital, and (ii) exogeneity of labor supply in a general equilibrium growth path. His policy implication is that restrictions on aggregate energy use (by increasing
its price or by mandatory allocations) should induce reductions in demand for capital and, therefore, exacerbate the economic impacts of the energy policy.

Our criticism of Høgen is that he has not empirically verified the theoretical derivation of complementarity between energy and capital.
The translog cost function will not give expected results if any of the factor shares become negative over a forecast period. Lutton-LeBlanc of the U.S. Department of Agriculture (Energy Research Section of the Economics and Statistics Service) illustrate by estimating both a translog cost function and a multivariate logit function. They obtained better results with the latter relative to the former. The multivariate logit function constrains cost shares between zero and one so that its forecasting results are robust.

The data used by L-L include the 3-digit SIC Food Manufacturing (SIC 20 - Food and Kindred Products) industries for the period 1955-1976 from the Census and the Annual Surveys of Industries. The input cost shares include oil, coal, gas, electricity, capital structures, capital equipment, labor and intermediate materials. The results revealed that oil and coal, electricity and oil, gas and coal, equipment and structures, equipment and labor, and structures and labor were all complements in the logit formulation but substitutes in the translog specification. As the elasticities of the two specifications cannot be compared, since their mathematical formulations are different, the authors conclude that the logit formulation is more "flexible" than the translog since the predicted shares need not be linear functions of factor prices. Also, "the logit form does represent an advance in estimating and simulating share equation systems where symmetry and homogeneity conditions are desired". (p. 23).
Selected References (excluding those discussed in the report).


