ESTIMATING INDUSTRIAL ENERGY DEMAND WITH FIRM-LEVEL DATA: THE CASE OF INDONESIA

by

Mark M. Pitt*

Discussion Paper No. 182, August, 1983

Center for Economic Research
Department of Economics
University of Minnesota
Minneapolis, Minnesota 55455

* The author is grateful to Lung-Fei Lee, Christopher Sims, Robert Porter and Craig Swan for helpful comments and suggestions and to Joan Rodgers for research assistance. The assistance of the Biro Pusat Statistik and the members of its staff is gratefully acknowledged.

Estimating Industrial Energy Demand with Firm-Level Data: The Case of Indonesia

Mark M. Pitt
University of Minnesota

I. Introduction

In recent years, there have been a number of studies analyzing the role of energy in the structure of production. Most of these studies have used either a single time series for a country's manufacturing sector or time series data pooled by country or manufacturing sub-sector. The absence of similar data sets for developing countries has precluded the same type of analysis of their production structures. This is unfortunate since the impact of higher energy prices on these countries has been at least as severe as on the industrial countries. Furthermore, since it is likely that their structure of production is significantly different, the results of the existing econometric literature may not be applicable in understanding the role of energy prices in their economies.

Indonesia is an oil exporter and as a result its' readjustment to higher energy prices differed from the experiences of most of the developing world. Nevertheless, Indonesia is still a poor country, with a 1980 per capita GDP of only $430. Continued growth of energy consumption at a rate in excess of ten percent per annum (1974-79) threatens to turn Indonesia into a net energy importer by the end of this century (Gillis 1980). Underlying this rapid rate is the huge economic subsidy provided energy in Indonesia. As of December 1981, the weighted average price of energy in Indonesia was only 35 percent of the international price - as low as 18 percent for kerosene and as high as 79 percent for gasoline. The energy subsidy amounted to 5.4 percent of GDP in 1981-82. One often stated justification for retaining the subsidy is the supposedly adverse effect raising energy prices would have on its rapidly growing manufacturing sector and its products competitiveness in international export markets.

A better understanding of the effect of raising energy prices on the Indonesian manufacturing sector could be achieved if estimates of own and cross-price elasticities for individual fuels were available. Given the widely different levels of energy consumption across industries, and their heterogeneous nature, these elasticities would best be estimated on an industry-by-industry basis. The difficulty is that Indonesia, like most developing countries, does not have a sufficiently long time-series for this kind of analysis.

This paper avoids the time series data constraint by making use of firm-level sample survey cross-section data. These data, containing information on the operation of thousands of manufacturing firms, permit us to estimate production structures with five energy inputs for 27 manufacturing sub-sectors. The approach is similar to the two-stage procedure of Fuss (1977) and Pindyck (1979). It differs in that we estimate a variable cost function, which requires cost-minimization only among a subset of inputs, and because the estimation procedure takes into consideration the prevalence of corner solutions (non-consumed inputs) in firm-level data. The wide spatial variation in prices characteristic of island Indonesia, as well as the large number of observations, permit the estimation of variable cost functions with these kind of data.

II. The Model

It is assumed that the production function is weakly separable in the major kinds of energy inputs. Thus, the cost-minimizing mix of energy inputs is independent of the mix of aggregate factors - capital, labor and materials. Furthermore, if the energy aggregate is homothetic in its components (electricity, gasoline, fuel oil, diesel and kerosene), cost-minimization becomes a two stage procedure (Denny and Fuss, 1977): optimize the mix of fuels which make up the energy aggregate and then optimize the mix of the energy aggregate, labor, capital and materials. Finally, it assumed that materials are weakly separable from the labor, capital and energy inputs. This assumption is necessary because the data required to construct a materials price index are not available. These assumptions on the structure of production can be summarized by the following production function:

$$Q = F\left[(K, L, E\,(E_1, E_2, E_3, E_4, E_5));\ M\right] \qquad (1)$$

where K, L, and M are capital labor and materials respectively and E is the energy aggregate which is a homothetic function of the five fuels.

The most common approach to derive cost functions assumes that firms minimize the total cost of production with respect to all inputs. Such an approach assumes full static equilibrium. Alternatively, one can model the firm as optimizing with respect to a subset of inputs conditional on the quantities of "quasi-fixed" inputs. If factor prices and output levels are exogenously determined and if capital is treated as a quasi-fixed factor, duality implies that cost-minimization given the production function (1) can be uniquely represented by a variable cost-function of the form

$$CV = G\left[g\,(P_L, P_E\,(P_{E_1}, P_{E_2}, P_{E_3}, P_{E_4}, P_{E_5}), K, Q);\ M\right] \qquad (2)$$

where P_E is an aggregate price index for energy.

In Fuss (1977) and Pindyck (1979), the price of energy P_E, which is also unit energy cost to the optimizing firm, is represented by an arbitrary unit cost function. Estimation of this cost function provides estimates of the elasticities of substitution among alternative fuels as well as their own and cross-price demand elasticities. In addition, estimates of the parameters of the energy cost function can be used to calculate $\hat{P}_E$, an estimate of the energy price index, up to an arbitrary scaling factor. In the second-stage, variable cost of industrial output is represented by a nonhomothetic cost function, and $\hat{P}_E$ is used as an instrumental variable for the price of energy. Estimation of this aggregate cost function provides estimates of variable cost elasticities of substitution and demand elasticities for capital, labor and energy aggregates.

In the stage in which the demand for aggregate inputs is modeled the variable cost function (2) is represented by a nonhomothetic translog second-order approximation of the form

$$\log CV = \alpha_0 + \Sigma\alpha_i \log P_i + \Sigma\alpha_k \log F_k + \tfrac{1}{2}\sum_i \sum_j \gamma_{ij} \log P_i \log P_j + \tfrac{1}{2}\sum_k \sum_m \gamma_{km} \log F_k \log F_m + \tfrac{1}{2}\sum_k \sum_i \gamma_{ki} \log F_k \log P_i + \tfrac{1}{2}\sum_i \sum_k \gamma_{ik} \log P_i \log F_k \qquad (3)$$

where i, j = E, L; k, m = Q, K, and F_k is the quantity of the kth quasi-fixed factor or output. From Shepards lemma (Diewert 1971), the variable cost minimizing level of use of the ith variable factor $V_i = \partial CV/\partial P_i$. Therefore, input demand functions in terms of cost shares are given by

$$\partial \log CV/\partial \log P_i = \frac{P_i V_i}{CV} = S_i \text{ or}$$

$$S_i = \alpha_i + \sum_j \gamma_{ij} \log P_j + \sum_k \gamma_{ki} \log F_k, \qquad i = E, L. \tag{4}$$

The linear share equations (4) can be estimated by the usual Zellner efficient techniques. Since the two variable input shares must sum to 1, only one of them needs to be estimated. In order to identify the parameters α_0, α_i, α_k and γ_{km}, the variable cost function itself (3) must be estimated along with any one of the share equations (4).

In order that the variable cost function and the share equations satisfy the properties of a neoclassical production structure, the following parameter restrictions are required: $\sum_i \alpha_i = 1$, $\sum_j \gamma_{ij} = \sum_i \gamma_{ij} = 0$, $\sum_i \gamma_{ik} = 0$, $\gamma_{ij} = \gamma_{ji}$, $i \neq j$, $\gamma_{ik} = \gamma_{ki}$, $\gamma_{km} = \gamma_{mk}$, $m \neq k$.

Price elasticities of demand for the aggregate variable factors can be calculated from the estimated parameters.

$$\eta_{ii} = \frac{\gamma_{ii}}{S_i} + S_i - 1, \qquad i = E, L \tag{5}$$

$$\eta_{ij} = \frac{\gamma_{ij}}{S_i} + S_j, \qquad i, j = E, L \tag{6}$$

The elasticity of demand for variable factors with respect to a change in the quantity of the quasi-fixed factor can be calculated as:

$$\phi_{i,K} = \alpha_K + \sum_m \gamma_{Km} \ln F_m + \sum_i \gamma_{Ki} \ln P_i + \gamma_{Ki}/S_i \tag{7}$$

$$i = E, L; \; m = Q, K$$

The elasticities of total cost with respect to the price of aggregate energy and each of the five fuels are calculated as

$$\eta_{TC,E} = (\alpha_E + \sum_j \gamma_{Ej} \log P_j + \sum_k \gamma_{kE} \log F_k) \frac{CV}{CT} \tag{8}$$

and

$$\eta_{TC,\ i} = S_i\ \eta_{TC,\ E},\ i = 1,\ 5 \tag{9}$$

where CV/CT is the share of variable costs in total costs.

Calculating standard errors for these elasticities is complicated because the elasticities are nonlinear functions of the estimated parameters. Following Pindyck (1979), approximate estimates of the standard errors are obtained by assuming that the shares are constant and equal to the means of their estimated values.

In the stage in which the demand for alternative fuels is modeled, the price of energy (the cost per unit to the optimizing firm) is represented by Fuss (1977) and Pindyck (1979) as a homothetic translog cost function with constant returns to scale:

$$P_E = \beta_0 + \sum_i \beta_i \log P_i + \sum_i \sum_j \beta_{ij} \log P_i \log P_j. \tag{10}$$

Cost-minimization implies demand equations in terms of each fuel's share in aggregate energy cost.

$$S_i = \beta_i + \sum_j \beta_{ij} \ln P_j,\ i = 1,\ \ldots 5 \tag{11}$$

with, the following parametric restrictions: $\sum_i \beta_i = 1,\ \sum_j \beta_{ij} = \sum_i \beta_{ij} = 0,$ $\beta_{ij} = \beta_{ji},\ i \neq j$. Error terms are appended to (11) to reflect errors in optimization, errors in measuring the observed shares and other random disturbances.

Estimation of input demand equations such as these presents special problems when the data are at the level of the firm. As would be expected, most firms do not use all five fuels. Standard approaches to estimating this model result in inconsistent parameter estimates because the random disturbances have non-zero means and are correlated with the exogenous variables. Moreover, dropping those firms which do not use all of the inputs would reduce the sample size severely and still result in biased estimates.

What is required is an estimator which allows for a pile-up of density whenever the use of one or more inputs is zero. A multivariate extension of the limited dependent model of Tobin (1958) (tobit) provides a likely candidate for estimating equations such as (11) since it provides for a positive probability of observing zero input levels. Occasionally, only one fuel is used by a firm and thus allowance must also be made for a pile-up of density for unit shares. Rosett and Nelson (1975) have extended Tobin's model to the case of double truncation and theirs seems the appropriate estimator in this situation.

It is important to note that the parameter estimates obtained by the application of a tobit-type estimator to the share equations (11) are not those of a cost function. It is evident that when corner solutions occur marginal rates of transformation may not equal the input price ratios. The relationship between optimal input levels and prices thus depends on whether the relevant Kuhn-Tucker first-order conditions are met with equality, that is, whether the <u>unconstrained</u> cost minimum occurs at some point where an input's use is negative.

In general, optimal shares are given by (11) only if none of the input non-negativity restrictions are binding. If any of them are, then optimal shares have a form different from (11). The formulation and estimation of production and demand structures in the presence of corner solutions is a problem which is not easily solved. Our approach is to estimate the share equations (11), treating them as reduced form input demand equations. As the estimated coefficients are not those of an underlying cost function, the usual symmetry restrictions of cost functions are not applicable. In any case, the lack of a computationally tractable multivariate estimator requires us to estimate the equations singly. Homogeneity of degree zero in prices is imposed. There is no guarantee that predicted shares will add-up.

The stochastic model underlying doubly truncated tobit regression is given by the following relationship:

$$
\begin{aligned}
Y_t &= X_t\beta + u_t \text{ if } L_1 \leq X_t\beta + u_t \leq L_2 \\
&= L_2 \text{ if } X_t\beta + u_t > L_2 \qquad\qquad (12) \\
&= L_1 \text{ if } X_t\beta + u_t < L_1 \qquad t = 1, 2, \ldots, N
\end{aligned}
$$

Where N is the number of observations, Y_t is the dependent variable, X_t is a vector of independent variables, β is a vector of unknown coefficients, L_1 and L_2 are known upper and lower truncation values and u_t is an independently distributed error term assumed to be normally distributed with zero mean and variance σ^2. The expected value of the dependent variable is nonlinear in X_t and with $L_1 = 0$ and $L_2 = 1$ is given by

$$E(Y|X) = \sigma zF(z) + \sigma w\,(1-F(w)) + \sigma z + \sigma\,(f(z)-f(w)) \qquad (13)$$

where $z = -X\beta/\sigma$, $w = (1-X\beta)/\sigma$ and F( ) and f( ) represent the normal cumulative distribution and unit normal density functions respectively (subscripts have been omitted for simplicity).

The energy price index, $\hat{P}_E$, is approximated by a geometric index

$$\ln \hat{P}_E = \Sigma_i \hat{S}_i^* \ln P_i \tag{14}$$

where

$$\hat{S}_i^* = \hat{S}_i/\Sigma_i \hat{S}_i \tag{15}$$

where $\hat{S}_i$ is the expected value of S_i, as given by (13). The normalization of these expected values (15) is required to guarantee the linear homogeneity of the price index $\hat{P}_E$ in the individual fuel prices. Note that by substituting the share equations (11) into the translog cost function (10), a translog price index can also be written as a geometrically weighted price index, with shares as weights. Thus, the estimated input demand equations and aggregate energy price index estimated are similar to the translog forms used by Fuss (1977) and Pindyck (1979).

The choice of predicted shares as weights means that the prices of all fuels have positive weights in the price indices of every firm. It could be argued that the price of a fuel which is not used by a firm should have zero weight in its energy price index. However, close to the corner, the point at which the non-negativity constraint is "just" binding, this price may be relevant. In the tobit formulation, the expected share approaches zero for small values of the latent variable. Thus, the further away a fuel is from tangency at a corner, the smaller is its weight. Observed shares, an alternative to predicted shares as weights in the price index, give unused fuels zero weights. The problem is that disturbances associated with the choice of individual fuels will now enter into the aggregate cost function raising the possibility of biased estimation.

From the estimated energy share equation parameters we can compute estimates of the price elasticity of demand, which taking into account the doubly truncated tobit estimator, are calculated as[1]

$$\eta_{ii} = \frac{\gamma_{ii}(F(w_i)-F(z_i))}{S_i} + S_i - 1, \qquad i = 1, 5 \tag{16}$$

and

$$\eta_{ij} = \frac{\gamma_{ij}(F(w_i)-F(z_i))}{S_i} + S_j, \qquad i, j = 1, 5 \tag{17}$$

In summary, estimation of the complete model is accomplished with the following two-stage procedure:

1. Estimate the set of share equations (11) with a doubly-truncated tobit estimator. An estimate of an aggregate price index $\hat{P}_E$ is obtained by using the normalized expected shares as weights in (14).

2. Estimate the cost function (3) along with one share equation (4) by Zellner efficient techniques, replacing P_E by its instrumental variable $\hat{P}_E$.

III. Data

The data used in the estimation are taken from the Industrial Surveys (Survai Industri) of 1976, 1977 and 1978, conducted by the Central Bureau of Statistics (Biro Pusat Statistik) of the Republic of Indonesia. These surveys contain information on the activities of a large sample of Indonesia manufacturing establishments with 20 or more employees.[2]

Prices for energy inputs were available from the questionnaires of firms which reported the use of those inputs. The prices facing firms which did not use an input were imputed to be the average price faced by consuming firms in the same year in the same district (kabupaten/kotamadya), in the case of Java and Madura, or in the same province, in the case of the Outer Islands. There were 106 kabupaten/kotamadya in Java and Madura in 1976/78, and 20 provinces in the Outer Islands.

The five energy inputs studied - electricity, gasoline, fuel oil, diesel fuel and kerosene - accounted for about 86 percent of total energy use by value of large and medium manufacturing firms in 1977. The energy input "fuel oil" includes some diesels. The input "diesel" refers to high speed diesel. Although the government nominally set the wholesale price of petroleum derivative fuels during the period 1976/78, their prices did vary over space (and time) at the point of final sale. For example, official published statistics for 1976 demonstrate <u>average</u> provincial retail prices for kerosene ranging from Rp 29.11 to 60.62 per liter. The range of prices in 1977 and 1978 was of the same magnitude. It is the substantial spatial variation of prices characteristic of Indonesia, as well as the large sample size, that make it possible to estimate price response from cross-section data with reasonable precision.

Direct measures of capital stock are not available from the manufacturing surveys. Instead, capital was measured as the horsepower of installed machines. Although horsepower is probably a poor measure of the intersectoral variance of capital input, it may capture well intrasectoral inter-firm variations in capital. This is all that is required with the relatively fine sectoral disaggregation with which we are working.

IV. Empirical Results

The model described in the preceding sections was estimated separately for seven two-digit ISIC sectors - 31, 32, 33, 34, 35, 36, and 38. Even at the two-digit level, it seems likely that product mix is not homogeneous across firms. That is, the cost functions for the three-digit sectors which comprise a two-digit sector may vary and therefore it would be inappropriate to estimate only a single cost function for each two-digit sector. In order to avoid the cost of estimating separate models for all three-digit sectors, but still get at inter-sectoral differences in elasticities, dummy variables representing three-digit ISIC codes were introduced. These dummy variables allow the intercepts of the share equations and the intercepts and linear term parameters of the cost equations to vary. In addition, as it is likely that product mix and production efficiency are also not homogenous across regions, dummy variables representing firm location - Java - Madura/Outer Islands and urban location/rural location - were introduced in the same manner.[3] Thus, there are four different cost functions for each of 27 three-digit sectors, one for each geographic location for a total of 108. A description of the three-digit sectors identified in the analysis is found in the appendix.

The Energy Submodel

Table 1 presents estimates of the energy submodel for sectors 31 (agricultural processing) and 38 (fabricated metal products, machinery and transport equipment). The parameter estimates of the other five energy submodels are not presented for reasons of space. The complete set of parameter and elasticity estimates are available from the author. Five share equations were estimated by doubly-truncated tobit maximum likelihood methods for each of the seven two-digit sectors analyzed. The dependent variables were the shares of electricity, gasoline, fuel oil, diesel and kerosene. The set of independent variables are the same in each share equation: the logarithms of the prices of the five fuels and dummy variables for island location (Java or Outer Islands), urban/ rural location and for all but one three-digit sector. Prices for fuels were expressed in rupiah per ton of oil equivalent.

Estimated own- and cross-price elasticities for two of the 27 three-digit sectors (311 and 381) are presented in Table 2. These are partial elasticities, reflecting the substitution possibilities among energy inputs which are consistent with a constant level of aggregate energy input. All the own-price elasticities in Table 2 are significantly different from zero and seven of the 10 are different from -1 at the .01 level. Eleven of 20 cross-price elasticities are significantly different from zero in both of the three-digits sectors of Table 2. All of these 11 are greater than zero in sector 311 and 10 of 11 are greater than zero in sector 381.

Of the 134 own-price elasticities estimated for all 27 sectors, 117 are significantly different from zero at the .05 level of significance.[4] Of these, 90 are less than -1, indicating elastic demand. Most of the inelastic own-price response is for fuel oil and electricity. Indeed, 16 out of 27 and 13 out of 27 own-price elasticities for fuel oil and electricity respectively are greater than -1. Price responsiveness would appear to be significant and pervasive but also to vary substantially in magnitude across fuels and sectors.

Out of 546 total cross-price elasticities, 266 are significantly different from zero. The large number of statistically significant cross-price elasticities is indicative of the precision of the estimates with cross-section data. As expected, most fuels in most sectors are substitutes - 233 out of the 266 statistically significant cross-price elasticities are positive. Of some interest, the statistically significant cross-price elasticities of all fuels for all sectors with respect to the price of electricity are positive. Among pair-wise patterns of substitutability, fuel oil and electricity seems to be one of the strongest. Twenty-four of the 27 fuel oil elasticities with respect to the price of electricity are statistically significant and positive as are 18 of 27 electricity with respect to fuel oil price elasticities. In addition, the elasticity of kerosene demand with respect to the price of fuel oil is large and significant in 18 of 27 cases, and exceeds 1.0 in 17 of the sectors studied. Thus, increases in the price of fuel oil may induce substantial substitution of kerosene for fuel oil in many manufacturing sectors. This is of interest because Indonesia has heavily subsidized kerosene, the primary fuel of the household sector, since the early 1970s. Recently, the rate of subsidization has fallen resulting in a significantly lower fuel oil/kerosene price ratio.

The Aggregate Model

The aggregate model estimates the parameters of the underlying variable cost function containing capital, output, labor and aggregate energy as factors. Capital and output are treated as fixed, and the price of energy is measured as a price index whose weights are derived from the estimated energy submodel. In addition, the same set of location and three-digit ISIC dummy variables that appeared in the energy submodel are included in the estimation of the aggregate cost function. Note that these dummy variables allow both the intercept and first-order slope terms for all factors in the cost function to vary. Table 3 presents the results of estimating the variable cost function jointly with the energy share equation for sectors 31 and 38.[5]

Own- and cross-price elasticities for variable factors are presented in Table 4. In a model with only two variable factors, cross-price elasticities are equal to minus the own-price elasticities, that is, $\eta_{EL} = -\eta_{EE}$ and $\eta_{LE} = -\eta_{LL}$. All of the own-price elasticities for energy and labor are negative and significantly different from zero at the .05 level with the sole exception of the own-price elasticities of sector 332. For energy, own-price elasticities range from -.074 in the wood furniture sector (332) to -.830 in cement and cement products (363). Other sectors which are more responsive to changes in energy prices are structural clay products (ISIC 364, $\eta_{EE} = -.786$), other nonmetallic mineral products (ISIC 369, $\eta_{EE} = -.753$) and beverages (ISIC 313, $\eta_{EE} = -.705$). Only one own-price energy elasticity has an absolute value less than .34, while 21 out of 27 of them are above .50. These results are comparable to the range of estimates found by other investigators and surveyed in Pindyck (1979).

Own-price elasticities for labor ($=\eta_{LE}$) are generally much smaller in magnitude than they are for energy. They range from -.006 in the wood furniture sector (332) to -.449 in ceramics and porcelain (361). Moreover, 25 out of 27 of them are less than .25 in absolute value, and 12 of these are less than .10. In every sector, the own-price responsiveness of labor was less than that of energy. Pindyck (1979) obtained a similar result in the ten developed countries he studied. Remember, however, that our elasticities are conditional on capital being quasi-fixed. The Le Chatelier principle requires that the own-price response of variable factors decrease in absolute value with the number of quasi-fixed factors.

Table 4 also provides estimates of the ϕ_{KE}'s, the elasticities of energy demand with respect to levels of capital. Note that this elasticity is positive and statistically significant in every instance. The positive ϕ_{KE}'s are a reflection of the positive and large cost function parameters γ_{KE}, which imply that energy shares are increasing in capital use. The sign of these elasticities suggests that energy and capital are complements; this is likely to be the case. If firms are fully optimizing with respect to all inputs, that is, capital is optimally employed, then the relationship between the ϕ_{KE} and the long-run Allen elasticity of substitution can be written as (Schankerman and Nadiri 1980): $\sigma_{EK} = \frac{1+\pi}{-\pi} \phi_{EK}$, where π is the ratio of capital costs to variable costs. Since π is positive, σ_{EK} always has the opposite sign of ϕ_{EK}. Using value-added minus the wage bill as an estimate of π, rough estimates of σ_{EK} have been constructed and are presented in Table 4.[6]

There is mixed evidence on the issue of energy-capital substitutability from other studies. Fuss (1977) found slight complementarity while Pindyck (1979) found substitutability, although both studies used pooled cross-section time series data. Berndt and Wood (1979) have provided an interpretation of energy-capital complementarity consistent with engineering evidence of energy-capital substitutability. Our findings are not directly comparable with other published studies for a number of reasons. First, to the best of our knowledge, no published study has used individual firms as units of observation.

Thus, our estimates avoid the aggregation bias that may plague other econometric evidence. Second, our level of sectoral disaggregation is much greater than most. Berndt and Wood (1979) have noted that some empirical research at a more disaggregated level has tended to support energy-capital complementarity. Thirdly, other studies have estimated long-run rather than variable cost functions. Our variable cost energy-capital elasticities were estimated without requiring that firms be in full static equilibrium.[7] Finally, Indonesia is a developing country with very different relative factor prices than the industrialized countries. Even if Indonesian technologies are the same as in the industrialized countries, the relevant elasticities are being evaluated at different points on the production frontier.

Table 5 provides estimates of the elasticities of average total cost with respect to the price of aggregate energy and each of the five fuels. These elasticities tell us the effect of energy price increases on the total cost of output, assuming constant levels of output and capital. If total cost is exhaustive of output, that is unit total cost equals the ex-factory unit price of output, these elasticities represent proportional increases in the prices of manufactured output in response to a rise in the price of energy.

Four subsectors in the two-digit sector 36, nonmetallic mineral products, are the most cost-sensitive. The largest cost-energy price elasticities are .157 and .080 in ceramics and porcelain (361) and glass and glass products (362) respectively. After four nonmetallic minerals sectors, the most energy-cost sensitive sectors are basic chemicals (351), spinning and weaving (3211), other food products (312) and cement products (363).

The elasticity of total cost of basic chemicals, ranked fifth out of 27, is only one-fourth that of the first-ranked sector. For 18 out of 27 sectors analyzed, a 1 percent increase in energy prices results in a .025 percent increase in total costs or less. These total cost elasticities would appear to be about the same as Fuss (1977) found for Canadian manufacturing (.03) but somewhat lower than most estimates of Pindyck (1979) for the manufacturing sectors of 10 industrialized countries. His estimates for 1972 ranged from .032 in the United States to .067 in Italy. The simple average of the Indonesian total cost elasticities is about .029 which is the same as Pindyck's estimate for the United States manufacturing sector in 1963.

Table 5 also provides estimates of total cost elasticities with respect to the prices of individual fuels. Nonmetallic mineral sectors dominate the top ranks in all cases. Fuel oil's price would appear to be the most important of the five in influencing costs of production with kerosene being least important. All five textile sectors (32), as well as beverages (313), tobacco (314), printing and publishing (342), machinery (382) and measuring and optical equipment (385), are more cost sensitive to the price of electricity than any other fuel price. The ceramic and porcelain (361) and glass and glass products (362) sectors are most sensitive to the price of diesel. All other sectors are more cost sensitive to the fuel oil price than any other fuel price.

To study the effects of large increases in energy prices, the estimated cost equations have been used to predict energy demand and variable cost for a doubling of energy prices in Table 6. As was noted, such an increase in price would not have been sufficient to bring a weighted average energy price up to its international level as of December 1981. A doubling of energy prices induces a reduction in energy consumption in the range of 30 to 40 percent for most sectors. Only in wood furniture manufacturing (332) is the reduction less than 20 percent. In 17 of 27 sectors, the doubling of energy prices results in less than a 2 percent rise in total cost. Besides the nonmetallic mineral sectors (36), the sectors most effected are basic chemicals (351), spinning and weaving (3211), other food products (312), plastic wares (356) and printing and publishing (342).

Are these cost elasticities large? That is, would increasing energy prices in Indonesia result in a significant loss of competitiveness for manufacturing sectors and serious inflationary pressure? On its face, a 3 percent increase in total costs resulting from a doubling of energy prices does not seem large. Indeed, for 23 out of 27 sectors, the cost increase would be less than this. This cost increase seems particularly small when compared to the effect on total costs of such government interventions as tariffs, sales taxes, export incentives, subsidized borrowing and investment regulation. Relatively minor alterations in these programs will have a much greater impact on the competitiveness and prices of most manufacturing subsectors than the largest energy price adjustments considered (Pitt 1981a, 1981b).

Footnotes

1. Approximate estimates of the standard errors are calculated on the assumption that the shares and the probability of non-limit consumption $(F(w_i) - F(z_i))$ are constant and equal to the means of their estimated values.

2. As these are multiple cross-sections, many firms appear more than once in the data leading to the possibility that disturbances may not be independent. Allowing for a firm specific time invariant random variable is troublesome in the tobit context. If the firm specific component is independent of the other exogenous variables, we have the tobit version of the variance components model. Estimation is burdensome computationally since evaluation of a three-dimensional normal integral is required. An alternative approach, the fixed effect model, requires direct estimation of the firm specific effects and a long time series for consistency. Robinson (1982) has demonstrated that under mild weak-dependence conditions of the disturbance, the tobit estimator is strongly consistent and asymptotically normal although not in general asymptotically efficient. Reported standard errors may be biased.

3. Time dummy variables are not included to capture technical change or other time specific phenomena. The time series are short and technical change may be captured by the quasi-fixed factor and its interaction terms in any case. Adding time dummies was not statistically significant when it was tried and had very little effect on other coefficients.

4. Five own-price elasticities have positive signs, thus violating the postulate of cost-minimizing factor demand theory. None of these elasticities are statistically different from zero even at very weak levels

of significance. Fuel shares in these cases are very small and thus the elasticities are not very meaningful.

5. The parametric restrictions necessary for homotheticity and homogeneity were tested for all seven cost functions. Since these are nested hypothesis, homotheticity was tested first and then, conditional on the validity of that hypothesis, homogeneity was tested. The overall level of significance is set at .05, divided equally between the two tests. Homotheticity is rejected in all cases except sectors 31, 33 and 34. Proceeding conditionally on the hypothesis of homotheticity for these sectors, homogeneity is not rejected only for sector 34.

6. Although Pindyck (1979) and Griffin and Gregory (1976), among others, have computed the value of capital services in this manner, Berndt (1976) argues that estimates may be quite poor. They are used here only to suggest the magnitudes of energy-capital complementarity in the familiar context of Allen elasticities of substitution.

7. Two studies have found that estimated Allen elasticities were not robust to the choice (or absence) of a quasi-fixed factor. Brown and Christensen (1981) found that Allen elasticities for U.S. agriculture were quite different when family labor was treated as a variable as opposed to a quasi-fixed factor. In many instances, elasticities switched sign. Schankerman and Nadiri (1980) found large differences in elasticities derived from models of R & D in the Bell system in which R & D or capital were treated as quasi-fixed factors or all factors were assumed in full static equilibrium. The dependence of the estimates on choice of a quasi-fixed factor would imply that the assumption of long run equilibrium (and hence the estimation of a long run cost function) is

inappropriate. However, Schankerman and Nadiri could not statistically reject the null hypothesis that quasi-fixed factors were used in cost-minimizing amounts.

References

Berndt, Ernst R. "Reconciling Alternative Estimates of the Elasticity of Substitution," Review of Economics and Statistics, 58 (1976), 59-68.

Berndt, Ernst R. and David O. Wood. "Engineering and Econometric Interpretations of Energy-Capital Complementarity," American Economic Review, 69 (1979), 342-354.

Brown, Randall S. and Laurits R. Christensen. "Estimating Elasticities of Substitution in a Model of Partial Static Equilibrium: An Application to U.S. Agriculture, 1947-1974" in E. R. Berndt and B. C. Field, editors, Measuring and Modelling Natural Resource Substitution, MIT Press, 1981.

Denny, Michael and Melvyn Fuss. "The Use of Approximation Analysis to Test for Separability and the Existence of Consistent Aggregates," American Economic Review, 67 (June 1977), 404-418.

Diewert, W. E. "An Application of the Sheperd Duality Theorem: A Generalized Leontief Production Function," Journal of Political Economy, 79 (May 1971), 481-507.

Fuss, Melvyn A. "The Demand for Energy in Canadian Manufacturing," Journal of Econometrics, 5 (1977), 89-116.

Gillis, Malcolm. Energy Demand in Indonesia: Projections and Policies, Harvard Institute of International Development, Development Discussion Paper No. 92, April 1980.

Griffin, James M. and Paul R. Gregory. "An Intercountry Translog Model of Energy Substitution Responses," American Economic Review, 66 (1976), 845-857.

Pindyck, Robert S. "Interfuel Substitution and the Industrial Demand for Energy: An Intenational Comparison," Review of Economics and Statistics, 62 (May 1979), 169-179.

Pitt, Mark M. "Alternative Trade Strategies and Employment in Indonesia," in Anne O. Krueger, Hal B. Lary, Terry Monson and Narongchai Akrasanee, editors, Trade and Employment in Developing Countries, I: Individual Studies, University of Chicago Press, 1981a.

Pitt, Mark M. "Indonesia: Selected Issues of Industrial Development and Trade Strategy - The Foreign Trade Regime," manuscript, 1981b.

Robinson, Peter M. "On the Asymptotic Properties of Estimators of Models Containing Limited Dependent Variables," Econometrica, 50 (1982), 27-41.

Rosett, Richard N. and F. D. Nelson. "Estimation of the Two-Limit Probit Regression Model," Econometrica, 43 (1975), 141-146.

Schankerman, M. A. and M. Ishaq Nadiri. Variable Cost Functions and the Rate of Return to Quasi-Fixed Factors: An Application to R & D in the Bell System, C. V. Starr Center for Applied Economics, New York University Discussion Paper No. 80-17, September, 1980.

Tobin, James. "Estimation of Relationships for Limited Dependent Variables," Econometrica 26 (1958), 24-36.

Table 1: Parameter Estimates of the Energy Share Equations

	Exogeneous Variables											
Shares	Elect.	Gasoline	Fuel Oil	Diesel	Kerosene	Java	Urban	SSect1	SSect2	SSect3	SSect4	Intercept
Sector 31: (N = 3125)												
Electricity	-.2354	-.0940	.0806	.1826	.0663	-.2728	.4692	-.3764	-.6339	-.1360		.9044
	.0504	.1510	.0891	.0866	.1046	.0316	.0231	.0360	.0398	.0670		.1829
Gasoline	.0031	-.4496	-.0832	.2566	.2731	-.0508	-.1147	-.4654	-.3549	-.1214		.7791
	.0500	.1338	.0832	.0784	.0951	.0284	.0213	.0335	.0354	.0628		.1666
Fuel Oil	.1667	-.0729	-.2040	-.0987	.2089	.3360	-.1977	.3827	.5584	.1636		.2616
	.0495	.1357	.0808	.0778	.0947	.0281	.0212	.0368	.0391	.0684		.1680
Diesel	-.1123	1.4570	-.1985	-1.3401	.1939	-.1105	-.0451	.3578	.0910	-.2745		-2.3434
	.1057	.2886	.1769	.1543	.2032	.0608	.0430	.0847	.0909	.1956		.3655
Kerosene	.0255	.3352	.4009	.2738	-1.0353	-.2338	-.0140	.2209	.2038	.2364		-.8575
	.0601	.1646	.0990	.0950	.1062	.0358	.0255	.0452	.0479	.0811		.2026
Sector 38: (N = 1329)												
Electricity	-1.1387	.3465	.0982	.3771	.3169	-.3328	.4508	-.3410	-.0151	-.4004	-.2573	2.6393
	.0850	.1769	.1104	.1450	.1553	.0556	.0455	.1141	.1173	.1206	.1175	.2670
Gasoline	.0224	-.1276	-.0889	-.1147	.3089	.0045	.0318	.0405	.0252	.1112	.1255	.0307
	.0477	.0970	.0631	.0840	.0875	.0306	.0244	.0644	.0669	.0678	.0664	.1493
Fuel Oil	.7406	-.2069	-.0985	-.2905	-.1447	.2185	-.3112	.4188	.2578	.4766	.4148	-1.4660
	.0701	.1458	.0864	.1195	.1268	.0428	.0346	.1038	.1068	.1086	.1063	.2237
Diesel	.3561	.2286	-.0238	-.1493	-.4115	-.1557	-.1221	1.2000	.9998	1.2232	.9379	-2.6703
	.0517	.1104	.0665	.1564	.1013	.0370	.0247	.3133	.3142	.3141	.3143	.3487
Kerosene	.0459	.1115	.1971	.1854	-.5398	.0519	-.0025	-.2616	-.2684	.2226	-.2859	-.1198
	.0464	.0961	.0587	.0794	.0796	.0299	.0239	.0570	.0595	.0605	.0595	.1400

Note: SSect1 to SSect3 in Sector 31 refer to sub-sectors 311, 312 and 313. SSect1 to SSect4 in Sector 38 refer to sub-sectors 381, 382, 383 and 384. Asymptotic standard errors below coefficients. Column headings with fuel names refer to prices.

Table 2: Partial Fuel Price Elasticities

	Electricity	Gasoline	Fuel Oil	Diesel	Kerosene
Sector 311					
Electricity	-1.3388	-.0166	.3813	.6138	.3487
	.1149	.3440	.2030	.1974	.2383
Gasoline	.1088	-2.3020	-.1602	.8987	.9502
	.1558	.4168	.2592	.2442	.2962
Fuel Oil	.6944	.3694	-.8084	.3345	.7517
	.0671	.1840	.1096	.1056	.1284
Diesel	-.1922	3.4725	-.3936	-4.0597	.5228
	.2468	.6739	.4130	.3604	.4746
Kerosene	.1896	.9904	1.1603	.8318	-3.5536
	.1554	.4256	.2561	.2457	.2747
Sector 381					
Electricity	-2.8214	.9196	.4613	.9761	.8649
	.1569	.3265	.2038	.2675	.2866
Gasoline	.2181	-1.3492	-.2028	-.3002	1.3016
	.1806	.3670	.2387	.3176	.3307
Fuel Oil	1.6326	.0739	-.7477	-.0637	.1763
	.1152	.2399	.1420	.1965	.2085
Diesel	1.2988	.8543	-.0260	-1.4636	-1.3779
	.1802	.3849	.2318	.5452	.3533
Kerosene	.3023	.6443	1.0906	1.0295	-3.7509
	.2420	.5011	.3061	.4139	.4150

Note: Row headings are quantities and column headings are prices.

Standard errors below elasticities.

Table 3: Parameter Estimates of the Aggregate Model[a]

	Sector 31		Sector 38	
Intercept	8.976	(.508)	8.575	(.996)
P_L	1.138	(.0492)	1.326	(.054)
K	-.5773	(.0635)	.130	(.115)
Y	.0825	(.0751)	.148	(.124)
P_E	-.138	(.0492)	-.326	(.0538)
Java	1.439	(.173)	-.0595	(.2675)
Urban	.223	(.130)	-.300	(.215)
SSect1	.152	(.241)	-1.049	(.867)
SSect2	-.132	(.278)	-1.094	(.890)
SSect3	.654	(.525)	-1.913	(.894)
SSect4	- - -	- - -	-1.183	(.885)
P_E*P_L	-.0195	(.0047)	-.0405	(.0052)
P_E*P_E	.0195	(.0047)	.0405	(.0052)
P_L*P_L	.0195	(.0047)	.0405	(.0052)
$K*P_E$	.0190	(.0019)	.0142	(.0022)
$K*P_L$	-.0190	(.0019)	-.0142	(.0022)
$Y*P_E$	.0013	(.0020)	.0105	(.0024)
$Y*P_L$	-.0013	(.0020)	-.0105	(.0024)
K*K	.0955	(.0078)	.0048	(.0089)
Y*Y	.0346	(.0065)	.0047	(.0093)
K*Y	.0141	(.0056)	-.0002	(.0067)
Java*K	.0076	(.0183)	-.0836	(.0350)
Urban*K	-.0321	(.0137)	-.0138	(.0243)
SSect1*K	.0323	(.0286)	-.0545	(.0944)
SSect2*K	.104	(.0308)	.0190	(.0974)
SSect3*K	.176	(.0553)	-.1122	(.0954)
SSect4*K	- - -	- - -	-.0637	(.0943)
Java*Y	-.160	(.0164)	.0075	(.0305)
Urban*Y	-.0304	(.0127)	.0323	(.0227)
SSect1*Y	-.116	(.0230)	.111	(.0836)
SSect2*Y	-.135	(.0265)	.1008	(.0873)
SSect3*Y	-.187	(.0568)	.2168	(.0850)
SSect4*Y	- - -	- - -	.1491	(.0852)
Java*PE	.0139	(.0068)	.0102	(.0088)
Urban*PE	.0328	(.0052)	-.0029	(.0072)
SSect1*PE	.105	(.0104)	.0599	(.0193)
SSect2*PE	.160	(.0122)	.0134	(.0198)
SSect3*PE	.0664	(.0176)	.0345	(.0204)
SSect4*PE	- - -	- - -	.0173	(.0199)
Java*PL	-.0139	(.0068)	-.0102	(.0088)
Urban*PL	-.0328	(.0052)	.0029	(.0072)
SSect1*PL	-.105	(.0104)	-.0599	(.0193)
SSect2*PL	-.160	(.0122)	-.0134	(.0198)
SSect3*PL	-.0664	(.0176)	-.0345	(.0204)
SSect4*PL	- - -	- - -	-.0173	(.0199)

a. Numbers in parentheses are asymptotic standard errors.

Table 4: Elasticities for Aggregate Inputs

Sector	$\eta_{EE} = -\eta_{EL}$	$\eta_{LL} = -\eta_{LE}$	ϕ_{EK}	σ_{EK}
311	-.7053 (.0244)	-.1704 (.0059)	.1927 (.0154)	-.2806
312	-.6777 (.0196)	-.2160 (.0063)	.2329 (.0158)	-.4228
313	-.7207 (.0349)	-.1132 (.0055)	.2111 (.0511)	-.2710
314	-.6899 (.0542)	-.0662 (.0052)	.2041 (.0320)	-.2342
3211	-.6214 (.0239)	-.1619 (.0062)	.2954 (.0126)	-.5770
321	-.6045 (.0358)	-.0968 (.0057)	.2159 (.0217)	-.4150
322	-.4641 (.0637)	-.0390 (.0054)	.2784 (.0328)	-.4459
323	-.6184 (.0306)	-.1191 (.0059)	.2350 (.0471)	-.2925
324	-.4749 (.0619)	-.0412 (.0054)	.4928 (.0420)	-.7404
331	-.4168 (.0440)	-.0775 (.0082)	.2660 (.0291)	-.4546
332	-.0742 (.0873)	-.0064 (.0075)	.3217 (.0544)	-.9542
341	-.4923 (.0416)	-.1107 (.0093)	.3543 (.0356)	-.5231
342	-.3724 (.0656)	-.0491 (.0086)	.4313 (.0396)	-.7981
351	-.5747 (.0331)	-.1637 (.0094)	.2296 (.0316)	-.3148
352	-.5013 (.0618)	-.0676 (.0083)	.3228 (.0316)	-.4576
355	-.5679 (.0288)	-.1947 (.0099)	.3350 (.0251)	-.3831
356	-.5749 (.0357)	-.1487 (.0092)	.2337 (.0238)	-.4008
361	-.5252 (.0228)	-.4489 (.0195)	.2316 (.0528)	-.6444
362	-.6400 (.0308)	-.3314 (.0159)	.2378 (.0344)	-.4032
363	-.8295 (.0918)	-.1071 (.0118)	.2155 (.0495)	-.3341
364	-.7856 (.0588)	-.1706 (.0128)	.2725 (.0397)	-.8309
369	-.7528 (.0482)	-.2095 (.0134)	.1388 (.0613)	-.2530
381	-.5795 (.0349)	-.1016 (.0061)	.2506 (.0224)	-.4111
382	-.5173 (.0483)	-.0626 (.0058)	.3675 (.0367)	-.7956
383	-.5567 (.0405)	-.0821 (.0060)	.2131 (.0288)	-.3029
384	-.5030 (.0508)	-.0575 (.0058)	.2750 (.0307)	-.3834
385	-.4114 (.0656)	-.0355 (.0057)	.3938 (.0954)	-.5650

Table 5: Elasticity of Average Total Cost of Output with Respect to Energy and Fuels

	$\eta_{TC, E}$	$\eta_{TC, 1}$	$\eta_{TC, 2}$	$\eta_{TC, 3}$	$\eta_{TC, 4}$	$\eta_{TC, 5}$
311	.0184	.0038	.0019	.0090	.0013	.0024
312	.0296	.0032	.0044	.0173	.0010	.0036
313	.0136	.0050	.0030	.0037	.0002	.0017
314	.0028	.0011	.0008	.0006	.0001	.0002
3211	.0300	.0185	.0015	.0064	.0015	.0021
321	.0213	.0113	.0016	.0063	.0006	.0015
322	.0099	.0076	.0012	.0009	.0001	.0001
323	.0078	.0036	.0007	.0029	.0003	.0002
324	.0141	.0071	.0023	.0039	.0004	.0005
331	.0222	.0015	.0041	.0159	.0004	.0002
332	.0220	.0079	.0039	.0101	.0000	.0001
341	.0235	.0041	.0027	.0125	.0025	.0016
342	.0240	.0142	.0040	.0038	.0004	.0016
351	.0377	.0047	.0030	.0246	.0038	.0016
352	.0134	.0039	.0030	.0049	.0003	.0013
355	.0141	.0032	.0014	.0069	.0016	.0009
356	.0289	.0069	.0022	.0165	.0023	.0009
361	.1567	.0274	.0109	.0482	.0565	.0136
362	.0799	.0154	.0045	.0196	.0351	.0053
363	.0293	.0099	.0037	.0142	.0008	.0007
364	.0752	.0032	.0054	.0480	.0123	.0062
369	.0486	.0004	.0044	.0402	.0023	.0013
381	.0166	.0049	.0023	.0072	.0010	.0011
382	.0210	.0107	.0026	.0058	.0005	.0013
383	.0117	.0035	.0020	.0047	.0007	.0008
384	.0093	.0030	.0017	.0038	.0002	.0005
385	.0097	.0053	.0011	.0015	.0000	.0018

Note: E = energy, 1 = electricity, 2 = gasoline, 3 = fuel oil, 4 = diesel, 5 = kerosene.

Table 6: Arc Elasticity of Average Total Cost and Energy Demand Response to a 100% Energy Price Increase

Sector	Percent change in Energy Consumption	Percent change in Total Cost
311	-38.57	1.40
312	-37.26	2.31
313	-39.31	1.05
314	-38.03	.20
3211	-34.87	2.38
321	-34.61	1.70
322	-29.87	.82
323	-34.99	.61
324	-30.25	1.17
331	-26.58	1.87
332	-13.00	1.94
341	-29.40	1.92
342	-25.12	2.00
351	-32.77	2.99
352	-29.99	1.03
355	-32.30	1.14
356	-32.86	2.23
361	-30.41	12.86
362	-35.74	6.30
363	-43.68	2.16
364	-41.92	5.62
369	-40.57	3.68
381	-33.48	1.33
382	-31.46	1.71
383	-32.76	.94
384	-30.97	.76
385	-27.83	.82

Appendix

Three-Digit ISIC Codes

31	
311	Food Processing
312	Other Food Products
313	Beverages
314	Tobacco
32	
3211	Spinnning and Weaving
Other 321	Textiles Except 3211
322	Wearing Apparel
323	Leather and Leather Substitutes
324	Leather Footwear
33	
331	Wood and Wood Products
332	Wood Furniture
34	
341	Paper and Paper Products
342	Printing and Publishing
35	
351	Basic Chemicals
352	Other Chemical Products
355	Rubber
356	Plastic Wares
36	
361	Ceramic and Porcelain
362	Glass and Glass Products
363	Cement
364	Structural Clay Products
369	Other Nonmetallic Metal Products
38	
381	Fabricated Metal Products
382	Machinery
383	Electrical Machinery
384	Transport Equipment
385	Measuring and Optical Equipment