



THE DEMAND FOR ENERGY IN THE KENYAN MANUFACTURING SECTOR

Author(s): Susan Moraa Onuonga, Martin Etyang and Germano Mwabu

Source: *The Journal of Energy and Development*, Vol. 34, No. 1/2 (Autumn, 2008 and Spring, 2009), pp. 265-276

Published by: International Research Center for Energy and Economic Development (ICEED)

Stable URL: <https://www.jstor.org/stable/24812704>

Accessed: 17-10-2022 08:14 UTC

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at <https://about.jstor.org/terms>



JSTOR

International Research Center for Energy and Economic Development (ICEED) is collaborating with JSTOR to digitize, preserve and extend access to *The Journal of Energy and Development*

THE DEMAND FOR ENERGY IN THE KENYAN MANUFACTURING SECTOR

*Susan Moraa Onuonga, Martin Etyang, and Germano Mwabu**

Introduction

The manufacturing sector accounts for approximately 10 percent of Kenya's gross domestic product (GDP). The sector's output grew at an average rate of 8 percent per annum between 1970 and 2005. The growth of manufacturing was associated with the greater use of inputs, including all forms of energy. In the government's planning document, *Kenya Vision 2030*, the manufacturing sector is expected to continue contributing 10 percent annually to Kenya's GDP.¹ The manufacturing sector mainly uses electricity and oil as sources of energy in its production processes, distribution, and transport services. The utilization of these

*Susan Moraa Onuonga, Chair of and Lecturer at the Department of Econometrics and Statistics, School of Economics, Kenyatta University (Kenya), holds a B.Edu. and Ph.D. in economics from Kenyatta University and an M.A. in the same discipline from the University of Nairobi. Her specializations include energy economics and environmental issues; her articles have appeared in such publications as the *International Journal of Afro-Asian Studies* and *The Journal of Developing Areas*.

Martin Etyang, Associate Professor at the School of Economics, Kenyatta University, earned his bachelor and master degrees in economics from the University of Nairobi and an M.S. and Ph.D. in agricultural economics from Purdue University. The author teaches graduate and undergraduate courses in economic theory and international economics; his research areas include agricultural production and resource economics. The author previously taught at the University of Nairobi and the Catholic University of Eastern Africa.

Germano Mwabu is a Professor of Economics at the University of Nairobi. His areas of academic research focus on the fields of the economics of health and development. The author holds a Ph.D. in economics from Boston University.

The authors wish to express their appreciation for the suggestions from colleagues within the School of Economics at Kenyatta University, Kenya.

The Journal of Energy and Development, Vol. 34, Nos. 1 and 2

Copyright © 2011 by the International Research Center for Energy and Economic Development (ICEED). All rights reserved.

two forms of energy, on average, has been rising, resulting in increased costs in terms of energy and total production.

The manufacturing sector is the third largest energy end user in the Kenyan economy.² It is the second largest user of petroleum products, after the transport sector, and the largest consumer of electricity.³ However, few studies have been undertaken that focus on energy demand in the manufacturing sector. S. Gor studied demand for commercial energy in the residential sector in Kenya over the period 1970 to 1990.⁴ The research found wage employment, income, past energy consumption, and population size to be the major determinants of energy consumed. P. K. Kimuyu studied demand for energy in Kenya using secondary data for the period 1963 to 1985.⁵ The results showed that income is the major determinant of demand for energy and that energy demand is price inelastic. J. O. Sasia carried out a study on demand for gasoline and light diesel in Kenya's transport sector over the period 1964 to 1985.⁶ The study's findings suggested that the demand for these two forms of energy is determined by level of income and past levels of energy consumed. The price of energy was statistically insignificant.

Production Processes and Energy Use

Most manufacturing activity is concentrated around the three major urban centers in Kenya: Nairobi, Mombasa, and Kisumu. The major sub-sectors within the manufacturing sector include food-processing (such as grain milling, beer production, and sugarcane crushing), paper production, textile and apparels, pharmaceutical and medical equipment, building construction and mining, and chemical and chemical-related industries. Kenya has an oil refinery that processes imported crude petroleum into petroleum products, mainly for the domestic market. In addition, a substantial and expanding informal sector engages in small-scale manufacturing of household goods, motor vehicle parts, and farm implements.

Most of the manufacturing processes use industrial diesel oil and fuel oil for their thermal energy requirements. Many processes also utilize electricity for drying, grading, and packing. A significant fraction—mostly in food processing—relies on wood fuel. The recent rise in the cost of industrial diesel oil and fuel oil, coupled with an unsustainable supply of wood fuel, particularly in the smallholder tea sector, now directly threatens the operations of many companies and the livelihood of thousands of employees. The supply of electricity to the sector is commonly rationed, especially during the dry season since most of the country's electricity is hydro-based. The result is that the Kenyan manufacturers incur losses in production, sales, damaged equipment from power surges, and overall efficiency losses caused by power interruption and uncertainty.

Given the challenges of this situation to the manufacturing industry in Kenya, we have sought to further the research on this subject by estimating energy price

elasticities and to determine substitution possibilities between energy forms and among total energy and other non-energy inputs by studying the Kenyan manufacturing sector over the 1970 to 2005 period.

*The Model and Data*⁷

Following S. Mahmud, the model was estimated in two stages. In the first stage, the input demand functions for various types of energy were estimated and an aggregate Price Divisia Index was developed. In the second stage, the index was used as an instrumental variable to estimate the input demand functions for labor, capital, and total energy.⁸

The study derived the energy input demand function from a translog total cost function. The translog form is one that was preferred in this study because it is flexible; it does not hold the inputs at fixed proportions at different output levels; it does not restrict the substitution possibilities between inputs; it allows for interactive effects of the independent variables; and it is, therefore, more realistic. Following W. Greene, the cost function (C) was approximated by a translog second-order approximation expressed as:⁹

$$\begin{aligned} \ln TC = & \beta_0 + \sum_i \beta_i \ln P_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \frac{1}{2} (\theta_1 (\ln Y)^2 + \theta_2 T^2) \\ & + \delta_1 \ln Y + \delta_2 T + \sum_i a_i \ln Y \ln P_i + \sum_i \alpha_i \ln P_i T + \vartheta \ln Y T \end{aligned} \quad (1)$$

where, $i, j = E(\text{energy}), L (\text{labor}), K (\text{capital}),$ and $TC = \text{total cost}.$

Equation (1) was used to derive input demand. Under the conditions of perfect competition, partially differentiating equation (1) and using Shephard's Lemma yields the input demand functions in terms of cost shares:¹⁰

$$S_i = \frac{\partial \ln TC}{\partial \ln P_i} = \frac{P_i X_i}{TC} = \beta_i + \sum_j \gamma_{ij} \ln P_j + \sum_i a_i \ln Y + \alpha_i T. \quad (2)$$

where S_i is the cost share of the input i demanded and $\sum_i S_i = 1, i = K, L, E.$

Homogeneity, additivity, and symmetry conditions for prices are necessary properties of a well-behaved cost function and were imposed on the model through the following parameter restrictions:

Additivity condition expressed as : $\sum_i \beta_i = 1,$

Symmetry condition expressed as : $\gamma_{ij} = \gamma_{ji},$

Homogeneity condition expressed as : $\sum \gamma_{ij} = \sum \alpha_i = \sum \alpha_i = 0,$ (3)

where, $i = K, L, E$.

The restrictions in equation (3) are necessary and sufficient conditions ensuring TC is linearly homogeneous in input prices.

After obtaining the estimates of the parameters β_i and β_{ij} , the Allen-Uzawa elasticities of substitution (A_{ij}), cross-price elasticities (E_{ij}), and own-price elasticities (E_{ii}) were calculated by using the following formulas:

$$E_{ii} = A_{ii} \cdot S_i \quad (4)$$

where

$$A_{ii} = (\beta_{ii} + S_i^2 - S_i) / S_i^2$$

$$A_{ij} = (\beta_{ij} + S_i S_j) / S_i S_j \quad (5)$$

$$E_{ij} = A_{ij} S_j. \quad (6)$$

Before estimating the above model, a similar translog sub-model in energy components was estimated. The translog cost function corresponding only to the two energy components included in this study was presented as:

$$\ln P_E = \beta_0 + \sum_i \beta_i \ln P_{Ei} + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln P_{Ei} \ln P_{Ej} \quad (7)$$

where P_E is the aggregate price index of energy that also was taken to be the cost per unit of energy to the optimizing firm. Using Shephard's Lemma, the following energy cost shares were obtained and estimated using the maximum likelihood method:

$$S_i^E = \beta_i + \sum_j \beta_{ij} \ln P_j + U_i \quad (8)$$

where $i, j =$ electricity (EL), oil (O), P_j represent prices of electricity and oil and for the other inputs consumed by the sector (labor and capital), $S_i^E =$ the share of energy type i in total energy cost, and β are the parameters that were estimated for the energy model.

Given that, in the past studies, output (Y), technology (T), and energy efficiency (F) have been found to influence energy use, they were added in the set of explanatory variables. Therefore, the model that was estimated for the demand for the energy forms is expressed as:

$$S_i^E = \beta_i + \sum_j \beta_{ij} \ln P_j + \beta_{iY} \ln Y + \beta_{iT} T + \beta_{iF} \ln F + D_i. \quad (9)$$

However, the energy efficiency was dropped from the equation after it was found to be highly correlated with the output variable.

Two steps were followed in the estimation of the empirical equations. First, the sub-energy models equations (7) and (9) were estimated and then the interfuel substitution and price elasticities were estimated.

This study used published data for the period 1970-2005 focusing on the Kenyan manufacturing sector. The data used was extracted from official Kenyan government publications including the *Statistical Abstracts*, *Economic Surveys*, Kenya Power and Lighting Company Limited *Annual Reports* and *Tariff Booklets*, the *International Financial Statistics (IFS)*, and the Ministry of Energy's summaries of the petroleum-sector data.

Results

Interfuel Results: Estimation of the models was done by use of the maximum likelihood method. Overall, the diagnostic results were satisfactory for the inter-fuel model since it passed most of the diagnostic tests. Table 1 presents the results of the interfuel translog cost model, and own-price elasticities are shown in table 2. Table 3 shows the own-price elasticities for inputs in the sector over the sample period.

The interfuel results were good, as shown by the value of the adjusted R-squared (0.89) and the number of significant coefficients. About 89 percent of the changes in the shares of electricity and oil in the total fuel expenditure, respectively, were explained by the changes in the explanatory variables included in the interfuel translog model. Significant cross-price relationships existed between oil and electricity.

Each fuel share significantly responded to own-price changes. Table 2 presents estimates of own elasticities, Allen (A_{ij}) elasticities, and cross-elasticities (E_{ij}) of the share equations (interfuel) computed at the mean values for the time frame 1970-2005.

The study expected own-price elasticities to be negative and inelastic. The results presented in table 2 show that own-price elasticities have the expected signs. However, the absolute values of own-price elasticities are small but statistically significant at a 5-percent level. Holding other things constant, with a 1-percent increase in the prices of electricity and oil, their utilization decreases by 0.082 and 0.013 percent, respectively. These values suggest that utilization for electricity and oil are price inelastic. In other words, the demand for both of the energy components has a very low response to their respective price changes. With an increase in the price of electricity or oil, the manufacturers reduce their use of these two forms of energy by a smaller percentage than their respective price increase. Such inelastic estimates for energy are intuitively plausible for a

Table 1
PARAMETER ESTIMATES OF THE SHARE MODELS (INTERFUEL)^a

Parameter	Parameter Estimate	T-statistic
<i>Electricity model</i>		
Constant β	-0.204	-0.29
Price of electricity (β_{EL})	0.179	6.67 ^b
Price of oil (β_O)	-0.193	-6.56 ^b
Price of labor (β_L)	0.053	1.83
Price of capital (β_K)	-0.001	-1.81
Output (β_Y)	0.066	3.15 ^c
Technology (β_T)	0.007	4.31 ^c
Droughts of years 1980 and 2000, and the 2003 U.S. military attack on Iraq	-0.034	-2.04 ^c
Adjusted R-squared	0.89	
Durbin-Watson statistic	1.144	
<i>Oil model</i>		
Constant β	1.204	1.70
Price of electricity (β_{EL})	-0.179	-6.67 ^b
Price of oil (β_O)	0.193	6.56 ^b
Price of labor (β_L)	-0.053	-1.83
Price of capital (β_K)	0.001	1.81
Output (β_Y)	-0.066	-3.15 ^c
Technology (β_T)	-0.008	-4.31 ^c
Droughts of years 1980 and 2000, and the 2003 U.S. military attack on Iraq	0.034	2.04 ^c
Adjusted R-squared	0.89	
Durbin-Watson statistic	1.144	

Source: Authors' calculations.

^aAll variables are expressed in natural logs except price of capital. EL = electricity, O = oil, K = capital, T = technology, Y = output, and L = labor.

^bDenotes significance at a 5-percent level.

^cDenotes significance at a 10-percent level.

relatively energy-scarce country like Kenya, which does not have enough of its own locally available sources of energy. The locally generated electricity does not satisfy the demand and the country does not have local sources of oil but depends wholly on oil imports, with the price being determined by the international oil market. There are no major energy substitutes, hence the insensitivity of the sector to energy price changes. Moreover, energy is a key input the manufacturers cannot do without even when energy prices increase.

The value obtained of own-price elasticities falls in the range of those previously found by other researchers such as B. Lin and S. Chishti and F. Mahmud, who estimated electricity price elasticity to be -0.032 and -0.1144 , respectively.¹¹ The policy implication of these results is that energy prices alone cannot achieve

Table 2
OWN-PRICE ELASTICITIES

Elasticity	Estimate
Electricity own-price (E_{EEL})	-0.082
Oil own-price (E_{OO})	-0.013
Allen cross-price ($A_{EL O}$)	0.045
Electricity cross-price ($E_{EL O}$)	0.032
Oil cross-price ($E_{OL O}$)	0.032

Source: Authors' calculations.

much in controlling the future use of electricity and oil in the Kenyan manufacturing sector.

The results in table 2 for cross-price elasticities suggest that there are significant substitution possibilities between the types of energy utilized by the manufacturing sector. Electricity and oil were found to be substitutes. This also is confirmed by the estimated Allen-Uzawa cross-price elasticity that was found to be 0.045. However, the substitution possibility was very low: 0.032. This means that a 1-percent increase in the price of oil, given the price of other factors, will lead to a 0.032-percent increase in the relative share of electricity in the total fuel expenditure. Similarly, a 1-percent increase in the price of electricity, given the price of other factors, will lead to a 0.032-percent increase in the relative share of oil. Generally, it seems that there has been little interfuel substitution in the manufacturing sector in Kenya. Substitution between oil and electricity is practically impossible without major modifications to the stock of capital, especially where lighting and appliances are concerned. Moreover, some manufacturing processes require electric energy while others require oil. Other previous studies have found similar low substitution possibilities between various forms of energy in absolute terms. S. Chishti and F. Mahmud found cross-price elasticities ranging between 0.13 and 0.4 in absolute terms, and that electricity and oil were substitutes.¹² S. Mahmud found also that electricity and oil are substitutes, with the cross-price elasticities ranging from positive 0.00787 to 0.144.¹³ In contrast to these findings, other studies suggested that oil and electricity were complementary.¹⁴

Table 3 shows the estimated results for the total energy model. All the own-price elasticities take the expected negative signs. The demands for total energy and labor were own-price inelastic. The price elasticity of total energy was the smallest (-0.20) in absolute terms compared to all factors own-price elasticities. This suggested that energy utilization within the manufacturing sector was least sensitive to own-price changes as compared to price sensitivities of other inputs of production utilized in this sector. With a 1-percent increase in the price of energy,

Table 3
PARAMETER ESTIMATES OF TRANSLOG TOTAL COST MODEL FOR THE KENYAN
MANUFACTURING SECTOR WITH ENERGY PRICE AS AN INSTRUMENT^a

Parameter	Parameter Estimate	T-statistic
<i>Energy model</i>		
Constant for the total energy model β	1.8293	1.25
Price of capital in the energy model (β_K)	-0.007341	-5.46 ^b
Price of labor in the energy model (β_L)	-0.05081	-0.79
Price of energy in the energy model (β_E)	0.08914	3.24 ^b
Output in the energy model (β_Y)	-0.09256	-1.96 ^c
Technology in the energy model (β_T)	-0.0086	-2.53 ^b
Adjusted R-squared (Energy)	0.93	
Durbin-Watson(Energy)	1.2	
<i>Labor model</i>		
Constant for the labor model β	-1.6793	-0.83
Price of capital in the labor model (β_K)	0.004104	2.22 ^b
Price of labor in the labor model (β_L)	0.0974	1.10
Price of energy in the labor model (β_E)	-0.09627	-2.5 ^b
Output in the labor model (β_Y)	0.1144	1.76
Technology in the labor model (β_T)	0.005290	1.13
Adjusted R-squared (Labor)	0.84	
Durbin-Watson (Labor)	1.45	
<i>Capital model</i>		
Constant for the capital model β	0.8499	0.48
Price of capital in the capital model (β_K)	0.00324	1.98 ^c
Price of labor in the capital model (β_L)	-0.04657	-0.59
Price of energy in the capital model (β_E)	0.007134	0.21
Output in the capital model (β_Y)	-0.02189	-0.38
Technology in the capital model (β_T)	0.003313	0.80
Dummy D=1 for the years 1985, 2002, and = 0 if otherwise	-0.2037	-4.72 ^b

Source: Authors' calculations.

^aAll variables are expressed in natural logs except the price of capital. EL = electricity, O = oil, K = capital, T = technology, Y = output, E = energy, and L = labor.

^bDenotes significance at a 5-percent level.

^cDenotes significance at a 10-percent level.

given the price of other factors, its demand declines by 0.20 percent. Given that energy is an essential input in the manufacturing process and that not enough energy substitutes exist in Kenya, the low price elasticity was expected. Other reasons for the low energy response to own-price changes are that the country has a scarcity of energy resources and that there is no locally available source of oil.

Labor demand was also price inelastic, suggesting that the manufacturing sector was less sensitive to labor price changes. With a 1-percent increase in the price of labor, the labor cost share in total production cost within the

manufacturing sector is reduced by 0.36 percent. However, this effect was found to be insignificant.

Demand for capital was found to be almost price elastic (-0.88). With a 1-percent increase in the price of capital, its demand declines by 0.88 percent. This sector was moderately sensitive to the changes in the cost of obtaining commercial bank loans, which was used as a proxy for the price of capital. The finding of this study on capital's price elasticity of demand exceeded that found by previous research. For example, the works by D. Christopoulos and by S. Chishti and F. Mahmud offer price elasticities of -0.15 and -0.24, respectively.¹⁵ Table 5 gives the estimated Allen-Uzawa and cross-price elasticities calculated at the mean values of the cost shares given in table 4.

From the results in table 5, energy and capital and energy and labor were found to be substitutes. Labor and capital and energy and technology were found to be complementary inputs in the production processes within the manufacturing sector. The substitution relationships between energy and technology, labor and energy, and energy and capital were found to be significant. The positive cross-price elasticity was as expected, given that the period under evaluation was long (36 years), which allowed the manufacturing firms to substitute capital with other factors of production. However, the substitution possibilities between the factors were very limited as shown by the cross-price elasticities. For example, the cross-price elasticity between energy and capital was 0.07. S. Chishti and F. Mahmud found capital and energy to be complements, which was in contrast to the findings of this study.¹⁶ In spite of this, the S. Chishti and F. Mahmud study suggested low substitution possibilities between the two factors. With these limited substitution possibilities between factors of production, the costs of production may rise significantly as a result of increases in the prices of the inputs, especially energy price shocks, which were common in Kenya. The Kenyan manufacturing firms seem to be faced with difficulties in obtaining the best-input combinations that minimize total cost.

The Allen-Uzawa elasticities provide a different picture that suggests that substitution possibilities are higher. For example, the Allen cross-price elasticity

Table 4
OWN-PRICE ELASTICITIES OF DEMAND FOR INPUTS IN THE KENYAN
MANUFACTURING SECTOR

	Own-Price Demand Elasticity
Labor (E_{LL})	-0.36
Capital (E_{KK})	-0.88
Total energy (E_{EE})	-0.20

Source: Authors' calculations.

Table 5
ALLEN AND CROSS-PRICE ELASTICITIES OF THE FACTORS USING THE
PRICE OF ENERGY AS AN INSTRUMENT

Elasticities	Estimate
Allen cross-price between capital and labor (A_{KL})	-1.25
Allen cross-price between capital and energy (A_{KE})	1.13
Allen cross-price between labor and capital (A_{LK})	1.20
Allen cross-price between labor and energy (A_{LE})	0.43
Allen cross-price between energy and labor (A_{EL})	0.70
Allen cross-price between energy and capital (A_{EK})	0.86
Cross price-between capital and labor (E_{KL})	-0.32
Cross price-between labor and capital (E_{LK})	0.09
Cross price-between capital and energy (E_{KE})	0.75
Cross price-between energy and capital (E_{EK})	0.07
Cross price-between labor and energy (E_{LE})	0.29
Cross price-between energy and labor (E_{EL})	0.18

Source: Authors' calculations.

between labor and capital was 1.20, but the cross-price elasticity was 0.09, suggesting that the changes in the price of capital will not induce substantial changes in the use of labor.

The conclusion of this part of the estimation is that the price of energy, technology, value added, the price of capital, and unusual events significantly influence the use of energy in the Kenyan manufacturing sector. Furthermore, this study found that energy, labor, and capital were substitutes in the total production in this sector.

Summary and Conclusions

The purpose of this study was to estimate energy demand elasticities and the substitution possibilities between energy and non-energy inputs in the Kenyan manufacturing sector. Interfuel estimation results provided evidence that oil and electricity were significant substitutes in the Kenyan manufacturing sector. However, the substitution possibilities were low. There was little evidence that electricity and oil substitute each other in order to minimize the cost of energy in the Kenyan manufacturing sector. The study found electricity and oil to be price inelastic.

As regards the substitution between energy and non-energy factors, the study found that all factors were substitutes in the Kenyan manufacturing sector. However, the substitution coefficients were low but statistically significant.

Therefore, there was some evidence that energy, labor, and capital substitute for each other in the production process in the Kenyan manufacturing sector. Given that energy price shocks are common in the developing world, this result suggests that price increases in energy may lead to substantial increases in the costs of production for manufacturing firms. Demand for energy and labor was found to be price inelastic. The price elasticity of capital was approximately unity.

NOTES

¹Republic of Kenya, *Kenya Vision 2030: A Globally Competitive and Prosperous Kenya* (Nairobi: Government Printer, 2007).

²Republic of Kenya, *Economic Survey* (Nairobi: Government Printer, 2002).

³Republic of Kenya, *Economic Survey* (Nairobi: Government Printer, 2000).

⁴S. Gor, "Consumption of Commercial Energy in the Residential Sector of Kenya: 1970-1990," (Master's thesis, Kenyatta University, Nairobi, Kenya, 1994).

⁵P. K. Kimuyu, "Demand for Commercial Energy in Kenya: A Structural Investigation," (Ph.D. dissertation thesis, University of Nairobi, Kenya, 1988).

⁶J. O. Sasia, "Demand for Gasoline and Light Diesel in Kenya," (Master's thesis, University of Nairobi, Kenya, 1987).

⁷The following are the definitions we use in our model. *Input demand functions* are a mathematical expression that shows the explanatory variables (such as the price of energy, income, etc.) that determine the dependent variable (such as energy consumption). *Allen elasticity* is a share-weighted cross-price elasticity that measures the proportionate change in relative factor shares induced by proportionate changes in relative price of factors. *Manufacturing sector* consists of all manufacturing firms that were in operation within Kenya between 1970 and 2005. *Total energy* refers to firms' consumption of major types of energy: oil and oil products, electricity, coal, and natural gas. *Commercial energy* refers to that energy which is sold in a measurable quantity and standardized value in a market. This study considered only petroleum and electricity. *Energy*: source of power, such as electricity. *A manufacturing firm* refers to a firm that is engaged in mechanical, physical, or chemical transformation of materials, substances, or components into new products. *Elasticity*: this provides a measure of a proportionate change in one variable brought about by a unit proportionate change in another variable. *Own-price elasticity*: this is a measure of the proportionate change in quantity demanded of a particular commodity brought about by the corresponding proportionate change in price of the same commodity or a measure of how responsive quantity demanded is to corresponding changes in price. *Cross-elasticity of demand* is a measure of the responsiveness of demand for one commodity to changes in the price of another commodity.

⁸Syed F. Mahmud, "The Energy Demand in the Manufacturing Sector of Pakistan: Some Further Results," *Energy Economics*, December 2000, pp. 641-48.

⁹W. H. Greene, *Econometric Analysis* (New York: Macmillan Publishing Company, 1990).

¹⁰R. Shephard, *The Theory of Cost and Production* (Princeton, New Jersey: Princeton University Press, 1970).

¹¹B. Q. Lin, "Electricity Demand in the People's Republic of China: Investment Requirements and Environmental Impact," *Asian Development Bank*, ERD Working Paper no. 37 (Manila, Philippines: The Asian Development Bank, 2003), and Salim Chishti and Fakhre Mahmud, "The Demand for Energy in the Large-scale Manufacturing Sector of Pakistan," *Energy Economics*, October 1990, pp. 251-54.

¹²S. Chishti and F. Mahmud, *op. cit.*

¹³S. Mahmud, *op. cit.*

¹⁴Dimitris K. Christopoulos, "The Demand for Energy in Greek Manufacturing," *Energy Economics*, October 2000, pp. 569-86.

¹⁵D. Christopoulos, *op. cit.*, and S. Chishti and F. Mahmud, *op. cit.*

¹⁶S. Chishti and F. Mahmud, *op. cit.*
