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ABSTRACT

ENERGY-SUBSTITUTION IN THE PAPER INDUSTRY IN BRAZIL: A TRANSLOG FUNCTION APPROACH

By

Josmar Verillo

This study attempts to estimate energy substitution possibilities in the manufacturing sector of the economy. Unlike the majority of studies it focuses at the micro level instead of the aggregate. The method employed involves the use of econometric techniques to estimate translog cost and production functions, and the estimation of the Allen Elasticities of Substitution (AES) from the coefficients. The data used in the study come from firms in the paper industry of Brazil during the period of January, 1982 to December, 1987.

When using aggregated data, findings concerning energy-capital substitution are often controversial. Some authors find substitutability while others find complementarity between energy and capital. This study found that this ambiguity also appears at the micro level. Even when the firms belong to the same industry, two inputs can be complements in one firm and substitutes in another.

The basic findings are: 1) Energy demand is found to be responsive to price changes, 2) Fossil fuels and biomass are

substitutes, 3) Biomass and capital are substitutes, 4) Fossil fuels and hydroelectricity are complements, 5) Hydroelectricity and capital are complements, 6) Labor and materials are substitutes, and 7) Capital and labor are substitutes. The other elasticities are ambiguous, varying from firm to firm, or not significant at the 5 per cent level.

The method used did not capture the dynamics of the data. Further research is needed in the improvement of the method. The time span and the size of the sample should be increased in future studies. For some industries five years is too short a period to capture important structural changes.

The ambiguity found in the elasticity estimates is enough to render assumptions behind some government policies unwarranted. For the effect of macroeconomic policy it is not correct to assume either energy-capital complementarity or substitutability. Furthermore, some fuel groups are shown to be complements rather than substitutes. In such cases, government policies designed to encourage reduction in the consumption of one type of fuel may increase consumption of both fuels. Knowledge about those elasticities of substitution may help planners to argue against energy policies which have little chance of succeeding.

To Fernanda.

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All mistakes are my responsibility.

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LIST OF SYMBOLS AND ABBREVIATIONS

AES	Allen Elasticity of Substitution
A_{ij}	Elasticity of substitution from production function
C	Cost
CL	Coal
Cruzado	Brazilian currency since February, 1986
Cruzeiro	Brazilian currency until January, 1986.
E	Energy
E_1	Biomass
E_2	Fossil Fuels
E_3	Hydroelectricity
E_{ij}	Elasticity of demand
Fiscal OTN	OTN used for taxation purposes, daily readjusted
G_{ij}	Elasticity of substitution in general
I3SLS	Iteractive Three Stage Least Squares
ICs	Industrialized Countries
IKPC	Indústrias Klabin de Papel e Celulose S/A
K	Capital
KLME	Refers to the 4 input model of estimating cost and production functions.
L	Labor

LICs	Less Industrialized Countries
ln	Natural logarithm
M	Materials
NG	Natural gas
N_{ij}	Hicks Elasticity of Complementarity
OECD	Organization for Energy Conservation and Development
OECs	Oil Exporting Countries
OEICs	Oil Exporting Industrialized Countries
OELICS	Oil Exporting Less Industrialized Countries
OICs	Oil Importing Countries
OIICs	Oil Importing Industrialized Countries
OILICS	Oil Importing Less Industrialized Countries
OLS	Ordinary Least Squares
ORTN	Indexed National Treasury Bonds
OTN	Indexed National Bonds, monthly readjusted.
PCC	Papel e Celulose Catarinense S/A
Pi	Price of input i
RIOCELL	Riocell S/A
SHARE	Share of energy in the total cost
SHARE1	Share of biomass in the total cost
SHARE2	Share of fossil fuels in the total cost
SHARE3	Share of hydroelectricity in the total cost
SHARK	Share of capital in the total cost
SHARL	Share of labor in the total cost
SHARM	Share of materials in the total cost
Si	Share of output i in the total cost

SIC	Standard Industrial Classification
SURE	Seemingly Unrelated Regression Equations
TOE	Tons of oil equivalent
Translog	Transcendental logarithmic function
UPC	Standard Unity of Capital
URP	Standard readjustment unity - used to readjust wage rates.
VAR	Variance
Xi	Quantity of input i
Y	Output
σ_{ij}	Elasticity of substitution from cost function
δ	Partial derivative

CHAPTER 1

INTRODUCTION

This dissertation investigates the general area of energy substitution, with special focus on the paper industry in Brazil. The study of input substitution using translog functions at the macro level was argued against recently by John Solow on the basis that the methodology is not appropriate for macro-level studies. This work will focus at the micro level, the firm. The objective is to learn something not only about the process of energy-capital substitution but also about the appropriateness of the methodology, which consists basically of a technique for estimating demand functions derived from translog cost and production functions, and subsequent calculation of the elasticities based on the estimated parameters.[1]

Fist, however, the study must be put in the context of a broader picture, including the dilemma facing Less Industrialized Countries (LICs), and the importance of government policy concerning energy use, conservation and substitution.

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1. Blitzer, C. R. "Energy-Economy Interactions in Developing Countries" The Energy Journal Vol. 7, No. 1, 1986.

Defining Energy

Energy may be looked at from several perspectives. In areas where more elaborate energy sources are not present, the main source of energy is human energy. In order to avoid any misinterpretation of what is meant by energy in the context of this thesis, a definition should be in place. Depending on the discipline analyzing energy, the distinction between human and other sources of energy becomes blurred, so a cuttoff point will be provided in order that this study be confined to those limits. Energy in this study is constrained to include certain types of fuel including oil, coal, biomass, and hydroelectricity.[2]

It must also be clarified that in thermodynamics energy does not disappear, it is simply converted to a different form. From an economists' perspective, when energy is used in the production process, for all intents and purposes, it disappears. This study will not be concerned with the energy contained in the paper produced by the firms; it will be concerned only with the energy used to manufacture the product.

The Role of Energy in Economic Development

Energy plays a major role in the achievement of a higher standard of living among industrialized nations. It

2. Hydroelectricity is electricity generated by dams, water falls, etc... Water at a certain height contains an energy potential. When this potential is released and converted into electricity, it is referred to as hydroelectricity.

is an important and pervasive input. It has been associated with increased use of capital and labor productivity enhancement. Labor productivity in ICs has increased considerably due to the use of energy. Evidence indicates that as a country goes through the stages of industrialization, output becomes more energy intensive.[3] This fact raises questions about the capability of Less Industrialized Countries (LICs) to increase their standards of living in a world of steadily dwindling energy resources.

Energy Price Differentials Among Countries

Energy prices differ among countries. An appropriate way of establishing the true cost of energy is to measure, at the local level, the basket of goods traded for the equivalent of a barrel of oil, or any other energy equivalent. Such an analysis shows that imported energy is often considerably more expensive in countries which depend on primary goods or low specialization manufacturing exports to earn foreign exchange needed to purchase oil.[4] To illustrate the point, terms of trade for Brazil deteriorated from an index of 100 in 1977 to 55 in 1985. That translates

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3. Energy in Transition:1985-2010, Final Report of the Committee on Nuclear and Alternative Energy Systems, National Research Council, National Academy of Sciences, Washington, D.C., 1979. page 109; Cleveland at al. (1984).

4. "The Effects of National and International Policies on Renewable Resource Use," in Transforming Natural Resources for Human Development: A Resource Systems Framework for Development Policy, Keneth Ruddle, and Dennis A. Rondinelli, The United Nations University, 1983.

to a loss of roughly 45 per cent in purchasing power.[5] Exports are valued significantly less than imports. In order to better understand the effects of the energy crisis in different groups of countries, they may be classified in two major categories: industrialized countries (ICs) and less industrialized countries (LICs). The ICs can be oil importing industrialized countries (OIICs) or oil exporting industrialized countries (OEICs). The LICs can also be subdivided into oil importing less industrialized countries (OILICs) and oil exporting less industrialized countries (OELICs). This classification is shown in Figure 1.

The lower prices of commodities, and higher prices of industrialized goods make the energy crisis a thing of the past for the ICs, at least for the time being. This explains the decrease of research activity in alternative energy sources, conservation, and energy substitution among these countries. The wealth transferred in the 1970s from the OICs to the OECs has been reclaimed, in part, by the OIICs. The OILICs, however, lost purchasing power when oil prices were increased and they had to pay more for it; they lost again when ICs increased the prices of their goods to compensate for the higher oil prices. This may be one explanation for the relatively increasing impoverishment of OILICs. Their share of the global pie declined considerably

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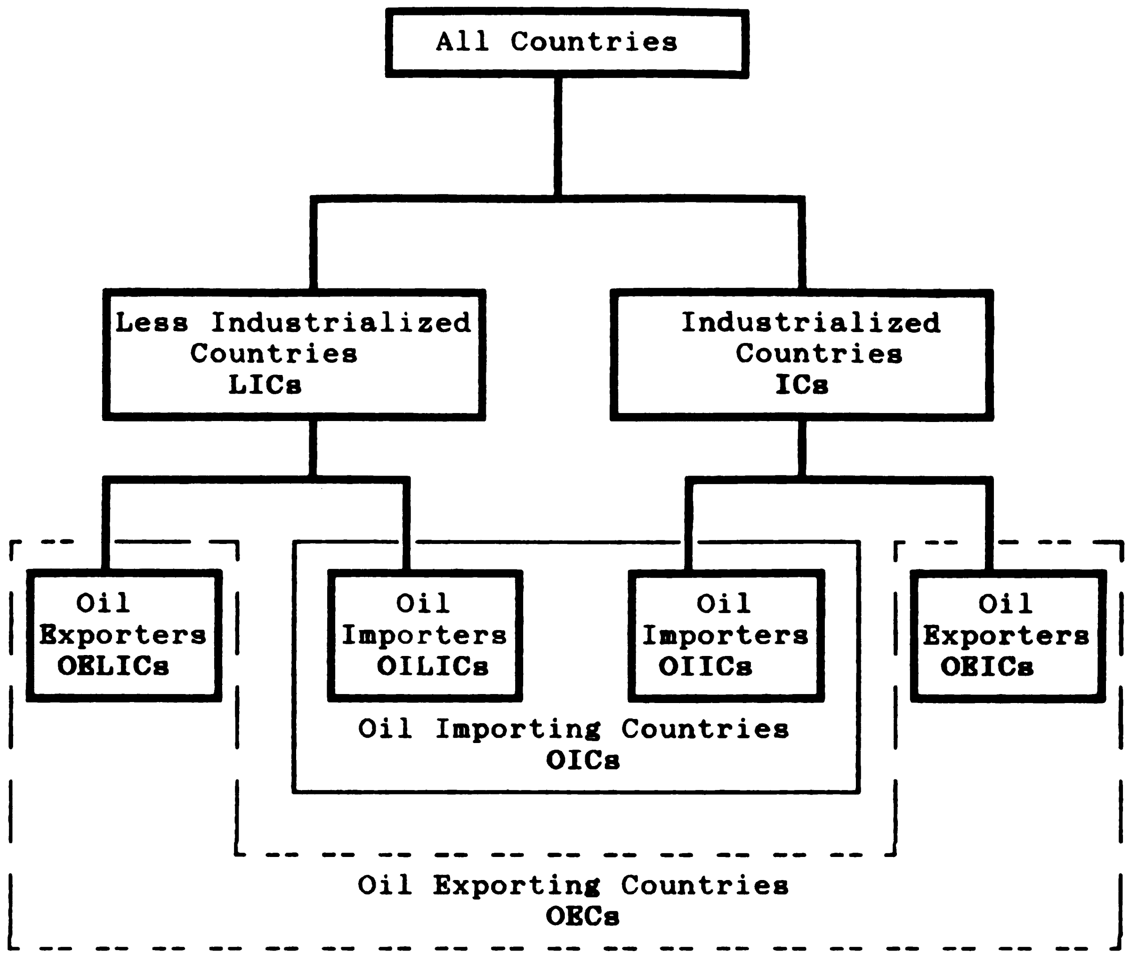
5. Baer, Werner; "The Resurgence of Inflation in Brazil, 1974-86, Word Development, Vol. 15, N.8, 1987, p. 1013.

as their products faced lower demand and increased competition.

Figure 1



The OILICs face the paradoxical situation that to increase exports, they may have to become more energy intensive. ICs demand energy-intensive products. The products are more elaborate, which causes them to have a larger energy content than the products demanded in less industrialized societies. LICs trying to increase exports to that market must necessarily turn their production process into a more energy-intensive one, unless they are able to produce technological innovations capable of generating elaborated products with low energy content, or if they are able to tap other sources of energy (like sun light, for example) at lower cost. This is not likely to happen in the near future because LICs are known to import technology from the ICs.[6] Energy intensity can only increase if significant technological advances are not made in the LICs.

Price Differentials, Terms of Trade, and Elasticities

Industrialized products do not suffer supply and demand shocks which cause export earnings and the entire economy to be essentially unstable.[7] Production of video cassette players, cameras, autos, or capital goods takes some time to increase since plants need to be built. Production is affected only years ahead. In the case of crops, there are sharp fluctuations from one year to another. It is common to see large number of farmers planting corn because in the previous year prices of corn were good. When a farmer loses money on a crop, he normally tries something else. If everybody follows the same logic, following a year of low

6. Sosin, Kim; and Fairchild, Loretta; "Capital Intensity and Export Propensity in Some Latin American Countries," Oxford Bulletin of Economics and Statistics, N. 49, 1987 (2).

7. Murray, David; "Export Earnings Instability: Price, Quantity, Supply, Demand?" Economic Development and Cultural Change, October, 1978.

prices, a great number farmers would raise an alternative crop. If the majority chooses to grow the same crop, the same thing would happen again. The difficulty in planning what to grow is that nobody knows with certainty what the demand for the commodity is going to be at the time of harvest. Besides the uncertainty in the demand side there is the uncertainty in the supply side because there is no way to know how much of each crop is being cultivated.[8]

Even within the same country, it is very difficult to plan how much of each crop to sow. In many countries the government intervenes to try to avoid the problem of over cultivation. Yet, significant mismatches between supply and demand happen. When it comes to the international market, the farmers in South America do not know what the North Americans are planting. It might be the case that most farmers will go to the same crop which means that an excess supply of that commodity will emerge in the international market. A familiar situation arises. Sellers lower prices as an incentive to buyers causing revenues to fall sharply. Countries depending for revenues to import oil on crops subject to overcultivation will be in a position where they have to borrow for energy imports, or to cut consumption.

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8. New techniques like remote-sensing techniques may help USDA and FAO to know how much of each crop is planted. But this is known only after the fields are sown, and this information may never get to the farmers. The knowledge about the amount of each crop planted all over the world may in fact harm the farmers instead of helping them.

The competitive market for crops exists, in part, because entry is easier than in other very specialized activities. Knowledge to practice agriculture is public information at the reach of any interested customer. It is a popular belief that hunger is associated with lack of production. Commonly advocated solutions to the problem of hunger call for increases in agricultural production. Some programs succeed in increasing agricultural production only to find out that there are no buyers. Hunger exists because the entitlements to buy the products are not available, not because there is lack of production or knowledge to go into the business of agriculture.[9] Knowledge to grow crops is not lacking; it is made available anywhere in the globe. Knowledge is not a constraint in the same way as it would be in building a microchip. The latter kind of knowledge is kept in private hands as much as possible so that rent for the exploitation of that knowledge can be maximized.

The point to be made is that the market for primary products is inherently unstable because entry is easy, making competition intense. Demand fluctuates severely from year to year; it is difficult to plan in advance what to sow. Once the crops are sown, there is no reversal. Many products are perishable, while others have close substitutes which creates pressure to sell fast. These characteristics

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9. Sen, Amartya; Poverty and Famines: An Essay on Entitlement and Deprivation, Clarendon Press, Oxford, 1981.

in agricultural products are not shared by many of the IC's products.

One can argue that technological knowledge is a matter of degree. Some technologies are public knowledge, others are not. The LICs are active in the areas where the technology of production is public knowledge; ICs are active in the areas where technology is private knowledge. To be successful in the markets where technology is public knowledge, the producer must have lower cost or higher quality. There are near public knowledge technologies which are still not within the reach of LICs because of lack of capital and organizational constraints.[10] The LICs are active in markets where the ICs can enter and compete freely. The LICs, however, do not have the option of choosing to compete in the high technology markets.[11] The U.S., for example, is active in markets for both agricultural and high technology products.

In the case of high tech products like audio recorder/players, trucks, computers, optical devices, advanced medicines, machine tools, robots, and chemicals; knowledge is a constraint, if not at the level of physical production, at the level of organization and marketing, or

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10. An example is the automobile. Production is capital intensive, and competitive prices may be achieved only with the type of organization the Japanese and the Americans have. The specialized knowledge in this case is in the organizational aspect of production, not in the assembly line itself.

11. There are exceptions, but they cannot be explained solely on the grounds of economic policy.

capital availability. It is difficult for the LICs to compete in this market. Production of such goods is restricted to firms in the ICs, while demand for the products exists all over the world, including the LICs.

It is very difficult for LIC governments to convince their urban middle classes that priorities need to be assigned in the use of foreign currency. Once people know about an innovation that makes life easier, or more pleasant, they want to acquire it if resources are available. Most of these innovations occur in the ICs, but once known in the LICs, demand for them grows there also. Priorities are justified by the criterion of social returns. Accordingly, foreign currency should be used in purchases which maximize accrual to the society. A government normally assigns priority to medicines, oil, and capital goods, among others. In its view, returns on these goods are greater than if each individual is allowed to buy according to means. Non adherence to this criterion would have serious consequences in countries with a very unbalanced distribution of income such as Brazil. In this case the most well off portion of the population would have access to a disproportionate amount of foreign currency in detriment to the majority of the population.

In non-socialist countries the simple need of adoption of those priorities is tantamount to the recognition of failure in the efforts to democratize economic opportunities. Be that as it may, the widespread existence of black markets in LICs is an indication that the government cannot effectively control or suppress the demand for industrialized products, unless they push wage rates further down. But this is only feasible up to a point due to the risk of social unrest. The government is left with two alternative paths: 1) Try to initiate its own production (public or private), or 2) Allow the producing firms to install plants within the country, and try to make the most of it.

The first alternative could be very costly because it involves duplication of effort.[12] Many things must be rediscovered. Instead of using knowledge readily available, the country must travel a road already travelled by others and run the risk of staying far behind in that road. If the country does not have a considerable market this alternative is not realistic. The second alternative may not be available to all countries as well. If the country is small, and the majority of the people are poor, the market is small; large firms are not impressed by small markets. They are attracted to potentially sizeable markets such as China, India, Mexico, Brazil, and the USSR. A small country may find itself in the position of having to offer unusual benefits to a multinational for the installation of a plant. The Andean Pact in South America (Venezuela, Colombia,

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12. Dahlman, Carl J., Ross-Larson, Bruce, and Westphal, Larry E.; "Managing Technological Development: Lessons from the Newly Industrializing Countries," World Development, Vol. 15, N. 6, June 1987, pp. 759-775.

Ecuador, Peru, and Bolivia) is an attempt to create an ample market to attract foreign direct investment, besides expanding the market for their own industries.

Beside the fact that LICs operate in competitive activities[13] while ICs operate in areas of specialized knowledge and relatively less (international) competition[14], the ICs can often easily substitute an input when its price goes up. An example is sugar. The price of sugar went up to $1500.00 a ton in 1976. Consequently, many industries in the ICs started to use corn syrup and dozens of other substitutes. In a two-year span, the price of sugar dropped to $140.00 a ton, less than one tenth that of its peak.[15]

The example above illustrates the nature of demand and the substitutability of LICs products. The nature of demand explains in part why terms of trade deteriorate against the latter. Except for some fossil fuels and minerals which might have low price elasticity of demand in the short-run, demand for agricultural products and low level manufacturing is very responsive to price increases. High competition, absence of privileged knowledge, and/or comparative

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13. Even when the domestic markets have monopolistic characteristics, in the international context, they operate in areas of high competition.

14. The ICs operate in an environment more like monopolistic competition. Firms are able to segment markets and differentiate products in such a way as to lessen the effects of the competition.

15. Barzelay, Michael; The Politicized Market Economy: Alcohol in Brazil's Energy Strategy, University of California Press, Berkeley, 1986, p. 135.

advantages make OILICs' products highly substitutable. In a contest to maintain a share of the global product, they come out the losers.

Addressing Priorities

If terms of trade deteriorate for the OILICs even when nominal oil prices remain stable, real prices go up because the basket of goods necessary to pay for each caloric unit of oil must increase. If energy remains a very expensive and important input for those economies, the research effort in the field should not diminish. If developing products for which high demand exists is difficult, the alternative might be to develop internal markets for alternative energy sources. Research is needed in those countries where governments keep adopting contradictory policies which deepen the negative effects of an energy crisis instead of alleviating them.[16] One example of such a policy is the Brazilian government's subsidy to hydroelectricity. Hydroelectric power is not as cheap as it was initially thought because the capital costs are enormous. The construction of huge hydroelectric facilities to produce power which is supplied at subsidized prices is partially

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16. DeLucia, R. J. & Lesser, M. C. Energy Policies in Developing Countries. Energy Policy 13(4), 1985, pp. 345-349; Lin, Ching-Yuan, "Global Pattern of Energy Consumption Before and After the 1974 Oil Crisis," Economic Development and Cultural Change, 1984.; MacKillop, Andrew; "Energy Sector Investment in LDCs: The Credibility Gap Widens," Energy Policy, August 1986, pp 318-328.

responsible for the country's external debt crisis, and the decapitalization of the energy sector in the country.

The example above illustrates why continuing research in the energy substitution field is needed in LICs. Research in the field would hopefully demonstrate that the assumptions behind such policies are not warranted; carrying out the policy at its term could bring serious consequences for the country's entire economy. This need is also voiced by the World Bank:

> *The developing countries are in a period of adjustment to higher world energy prices and increasingly widespread shortages of fuelwood and other traditional fuels. The recent decline in international energy prices and their short-term unpredictability do not reduce the need to continue planning on the premise of increased energy prices in the longer term.*[17]

Some authors articulate the need to make energy planning an integral part of any development plan.[18]

Energy Substitution

One topic highly debated in the U.S. in recent years is the question of substitutability[19] between energy and capital in the production process. The substitutability between inputs is thought to be important among economists

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17. The Energy Transition in Developing Countries, The World Bank, Washington D.C., 1983.

18. Foell, Wesley K., "Energy Planning in Developing Countries," Energy Policy, August 1985.

19. "Substitutability" is used to refer to the degree of easiness which one input is alternatively used in the production process. A is said to be substitute for B if A can be easily used in the place of B.

because it might determine the effectiveness of government policies and hopefully influence policy changes. Suppose, for example, that it is determined that capital and energy are complements. A government policy of reducing taxes to make capital less expensive in an energy crisis would lead to an increase rather than a decrease in the expenditure on energy. In such a case, a policy of subsidizing energy would increase capital expenditures, and vice-versa. On the other hand, if capital and energy are substitutes, a policy of subsidizing energy prices would only delay technological change. Lower energy prices would encourage the use of energy instead of capital. The policy would be ineffective, if not harmful. If capital and energy are substitutes, the government should let market forces interact and firms make their own decisions on input substitution.

It is not an easy task to test these ideas and demonstrate complementarity or substitutability between capital and energy. Several studies have been done and the debate has sometimes been heated. Capital and energy can be technological and/or economic substitutes/complements, depending on the period being analyzed (short-run/long-run). Furthermore, substitution is a micro phenomenon which cannot be analyzed in the aggregate using methods designed to analyze firm behavior. The hypothesis of this dissertation is that the spectrum of input substitution varies significantly from firm to firm, even when the same core technology is used. The range of input substitution varies with the degree of integration of the firm. The implication is that elasticities, even when analyzed at the micro level, cannot be used as a guide for macroeconomic policies. Elasticities could be used in some cases for sector-specific economic policies. Even though the elasticities should be interpreted with care, because the methods being used up to now do not produce unambiguous estimates.

Firms change the output mix in response to price changes. This may not be the case in situations where market prices do not reflect the real cost of inputs due to market imperfections, existence of externalities, or government intervention. The failure to identify the real prices of inputs may distort the computation of elasticities. In some cases the firm is forced to make input changes independent of input prices, due to regulation, strategic behavior, or the correction of a past mistake. In such cases there will be no connection between prices and quantities of inputs being used. Still, in the long run, as the prices of energy increase, firms tend to use more energy efficient machines at a higher capital cost. Substitution is more difficult in those capital and energy intensive activities when the time horizon for the investment is long run. In such cases, short-run price changes may cause the firm not to react, and the computed elasticities may not indicate immediately the decisions made by management. Fuel substitution is considerably easier to accomplish than energy substitution.[20] This, while helpful in defusing short run energy crisis, may not help in fostering technological changes.

Organization of the Thesis

An account is presented in Chapter 2 of the work done in the field of energy substitution since 1973 when the first studies of capital-energy substitution appeared. The method is outlined in Chapter 3 and the data estimation results presented in Chapter 4. In Chapter 5, the results are discussed and the conclusions presented.

20. Fuel substitution, for example, is when coal is used instead of oil, or electricity is used instead of coal, but the caloric content remains roughly the same. Energy substitution is when the caloric content of the product is reduced while the quantity of other inputs is increased. For example, if instead of 1 barrel of oil and 2 tons of wood being used to produce 1 ton of paper, 1/2 barrel of oil and 2.5 tons of were used, energy would be displaced by materials. Energy could also be substituted for capital, in the form of a new machinery.

CHAPTER 2

THE CAPITAL-ENERGY COMPLEMENTARY DEBATE

Early studies about energy consumption in different sectors of the economy in the wake of the energy crisis in the 1970s ignored the fact that energy use represents essentially a derived demand. Firms demand energy as a function of their output level. Nevertheless, they tend to choose the mix of inputs which minimizes their total cost. Accordingly, estimates of energy demand based only on the levels of output could not be very accurate.[1] The main weakness in input-output models is that they are not grounded in a theory explaining the behavior of decision makers--in this case the firms; and in the way prices are ignored altogether:

> *The most glaring defect of the Forrester-Meadows models is the absence of any sort of functioning price system. I am no believer that the market is always right, and I am certainly no advocate of laissez-faire, where the environment is concerned. But the price system is, after all, the main*

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1. Casler, Stephen and Wilbur, Suzanne; "Energy Input-Output Analysis," Resources and Energy. June 1984, pp. 187-201; Constanza, Robert and Herendeen, Robert A., "Embodied Energy and Economic Value in the United States Economy: 1963, 1967 and 1972," Resources and Energy, June 1984, pp. 129-163, Hannon, Bruce M.; "An Energy Standard of Value," The Annuals of the American Academy of Political and Social Science, Vol. 410, November 1973, pp. 139-153; and MADDISON (1987).

> *social institution evolved by capitalist economies (and, to an increasing extent, socialist economies too) for registering and reacting to relative scarcity. There are several ways that the working of the price system will push our society into faster and more systematic increases in the productivity of natural resources.*[2]

It is argued that the profit maximizing behavior assumed in economic theory, in spite of being a very simplifying assumption, is better than no theory at all. The use of econometric techniques makes sense only if there is a theory behind the model.

Econometric studies attempt to explain input substitution in the context of profit maximization or cost minimization behavior by economic agents. These models include prices of the inputs since prices affect the demand for the inputs. Engineering studies demonstrate the technological viability of physical substitution,[3] but they fail to make the connection with prices and the behavior of the decision maker.[4]

This dissertation accepts the view that substitution of inputs is determined at any time by production technology

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2. Solow, Robert; "Is the End of the World at Hand?" Challenge, March-April 1973.

3. Ross, Marc; "Industrial Energy Conservation," Natural Resources Journal, Vol. 24, April 1984, pp. 369-404; Marlay, Robert C. "Trends in Industrial Use of Energy," Science, vol. 226, December 14, 1984.

4. Hammond, Allen, L. (1977b), "Energy: Brazil Seeks a Strategy Among Many Options," Science, Vol 195, no. 4278 (February): 566-567; Hannon, Bruce M.; An Energy Standard of Value," The Annals of the American Academy of Political and Social Science, Vol. 410, November 1973, pp. 139-153.

and prices of inputs. When the energy crisis hit the world in the 1970s, the absence of studies in the substitutability of inputs, particularly energy, did not allow quick formulation of impact analysis on higher energy prices in the economy.

In response to the developments of the 1970s, a significant number of studies with the objective of estimating the parameters of energy substitution for other inputs appeared. Many of them were written by economists. They were basically trying to determine if energy was easily substitutable for other inputs. If so, firms could shift easily to a different input mix, the transition to a world of higher energy prices would not be painful, and government intervention would be unnecessary. The publication of these studies was also an indication that economists had started to pay more attention to theoretical and empirical research on the issues of natural resource exhaustion.

The methodology employed involved jointly estimating the demand functions for inputs derived from a production function. Based on the resulting parameters, calculations on the cross elasticity of substitution, input own-price elasticity of substitution, and the price elasticity of demand could be determined. Conceptually, cross elasticity of substitution is a measure of how the amount of product X changes when the price of product Y changes. The input own-price elasticity is measured against the input own price. The price elasticity of demand measures, in general, how the demand for product X changes if the price of Y changes. The elasticity of substitution is the price elasticity of demand weighted by the product cost share. Theoretically we should expect the own elasticities of substitution to be always negative because the law of demand tells us that if the price of a product goes up, the quantity demanded of it falls. For those inputs expected to be substitutes, the cross elasticities of substitution should be positive (If the price of X goes up, more Y is used). For the complementary inputs, the cross elasticities should be negative (If the price of X goes up, less Y is used).

In order to develop good theoretical ground, economists normally estimate demand functions derived from production or cost functions. These functions are believed to encompass all the relevant economic information about the firm. They summarize the economic behavior of the firm. The estimation of demand functions, derived from cost and production functions, allows for testing their existence. The major problem faced by researchers is finding out the shape of those functions. In recent years several new functions have appeared in the literature, but they have not proved fruitful. One exception is the translog function. In the absence of more appropriate forms the, Leontieff, Cobb-Douglas, CES, and translog functional forms have been widely used in the past. In recent years the translog, which is a relatively flexible form, is the most widely used in studies of input substitution.

Many of the studies, up to now, are highly aggregated, involving the whole U.S. manufacturing industry; others are disaggregated at the two to four-digit SIC levels. Only in recent years have scholars devoted their attention to more disaggregated studies. Advances in production theory, conception of new computing techniques, and increasing availability of statistical packages for micro computers have made it easier in recent years to study input substitution using more sophisticated techniques not available a few years ago.

One of the first studies done in the field of capital-energy substitutability using translog cost functions concluded that capital and energy were complements.[5] The study used four inputs; capital (K), labor (L), material (M), and energy (E). The model was estimated using data from the U.S. manufacturing sector through the Iteractive Three Stage Least Squares (I3SLS) estimation procedure. The results of that study predicted a painful adjustment process to higher energy prices for the U.S. economy. As investment would decline in response to higher energy costs, unit costs of output would rise and unemployment would increase until the economy adjusted to a less energy intensive path.

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5. Berndt, Ernst and Wood, David; "Technology, Prices, and the Derived Demand for Energy," The Review of Economics and Statistics, August 1975.

Energy complementarity was also found by Hudson and Jorgenson.[6] at roughly the same time.

Griffin and Gregory,[7] in spite of questioning the existence of an aggregate cost function and the ability of econometric techniques to depict such a function if one existed, applied the same methodology used by Berndt and Wood to a cross-section data set and obtained the opposite result. The authors used pooled international data for the manufacturing industry in OECD countries. They argued that while short-run complementarity between energy and capital may exist as production increases along an expansion path, in the long run energy and capital are substitutes because new equipment could be designed to achieve higher thermal efficiency albeit at greater capital cost.

Other studies were as unsettling as these. Melvyn Fuss[8] found complementarity in Canadian manufacturing data pooled by region. Similar results were reported by Jan R.

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6. Hudson, E. and Jorgenson, D.; "U.S. Energy Policy and Economic Growth, 1975-2000," Bell Journal of Economics, Autumn, 1974, 5, pp 461-514.

7. Griffin, James and Gregory, Paul; "An Intercountry Translog Model of Energy Substitution Responses," American Economic Review, December, 1976.

8. Fuss, M. A., "The Demand for Energy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs," Journal of Econometrics, January 1977, 5, pp 89-116.

Magnus[9] using Dutch manufacturing data and by Paul Swaim and Gerhard Friede[10] using German data.

Humphrey and Moroney[11], using two-digit SIC data, reported potential substitution between labor and natural resources, and capital and natural resources in many industries. They reported results with both translog cost and translog production functions. This study was one of the first to use disaggregated data by certain industries and to estimate production functions. They also included nonenergy natural resource inputs. Moroney and Toevs[12], using three and four digits SIC data, estimated translog cost functions for several industries and found substitution between capital, labor, or both for industry specific natural resource inputs.

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9. Magnus, J. R., "Substitution Between Energy and Non-Energy Inputs in the Netherlands, 1950-1974," International Economic Review, 1979.

10. Friede, Gerhard, "Die Entwicklung des Energieverbrauchs der Bundes republik Deutschland und der Vereinigten Staaten von Amerika in Abhangigkeit von Preisen and Technologie," Karlsruhe: Institute fur Angewandte Systemanalyse, June 1976.

11. Humphrey, D. B. and Moroney, J. R., "Substitution Among Capital, Labor, and Natural Resources Products in American Manufacturing," Journal of Political Economy, 83, February 1975, pp 57-82.

12. Moroney, J. and Toevs A., "Factor Costs and Factor Use: An Analysis of Labor, Capital, and Natural Resources," Southern Economic Journal, 44, October 1977, pp. 222-239.

Robert Halvorsen and Jay Ford[13] found energy and non-energy inputs to be predominantly substitutes. They used data from the 1958 Census of Manufactures and estimated the elasticities for eight two-digit industries.

In 1979, Berndt and Wood[14] returned to their previous work of 1975 and tried to explain the disparity of results obtained by different authors but mainly with those of Griffin and Gregory. They distinguished between the econometric and engineering interpretations of energy-capital complementarity. Engineering studies supported the hypothesis of E-K substitutability. Basically, a new, more expensive machine may turn production less energy intensive. Energy input share would drop while capital input cost share would increase. The authors argued that their focus was on *net elasticities* while other studies, finding E-K substitutability, focused on gross elasticities.[15] Furthermore, they argued furthermore that the literature on the subject deals mainly with two inputs and in those circumstances only substitution is possible. They go on to state that the expansion effect may outweigh the

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13. Halvorsen, Robert and Ford, Jay, "Substitution Among Energy, Capital, and Labor Inputs in U.S. Manufacturing," in Advances in the Economics of Energy and Resources, Vol. 1, JAI Press, 1979, pp. 51-75.

14. Berndt, Ernst and Wood, David; "Engineering and Econometric Interpretations of Energy-Capital Complementarity," The American Economic Review, June 1979.

15. Net measures of elasticities are the appropriate ones to determine substitutability or complementarity. The gross elasticities include the expansion effect.

substitution effect;[16] a situation could emerge where E-K may be gross substitutes and net complements. In their view, this would be the most likely explanation for the disparity in findings. They emphasize that if E-K are found to be complements, a policy of reducing the price of capital with tax incentives to encourage energy conservation would increase the demand for energy instead of reducing it. This, in the context of a four input economy would mean lower demand for labor, materials, or both. There is no disagreement about policy implications among the scholars studying energy substitution. The burden of settling the question of substitutability/complementarity in the Berndt-Wood scenario is to a great extent transferred to the accuracy of the data. The available data are associated with a level of output, and the models up to now have no mechanisms to neutralize the output effect. The authors end up saying that the complementarity problem remains unsettled, largely because of the absence of models to explain the short and long run adjustment paths.

In 1981 James Griffin[17] provided his version of a reconciliation attempt. He acknowledged that the matter remained as unsettled as when the Griffin-Gregory results

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16. Quantities of inputs would be affected more by the effect of increase in production (expansion effect) than by the input substitution effect itself.

17. Griffin, James, "The Energy-Capital Complementarity Controversy: A Progress Report and Reconciliation Attempts," in Berndt and Field (eds), Modeling and Measuring Natural Resources Substitution, MIT Press, Cambridge, 1981.

were first presented. No breakthroughs were reported, but in Griffin's view, the essence of the controversy was:

1. E-K are complements or substitutes depending on whether a short or long-run production relationship is being measured. In the short-run, energy input per unit of machine hours tends to be fixed. If other inputs are substituted for energy and capital, capital and energy can be short-run complements. In the long run, energy and capital are expected to be substitutes.

2. It is argued that studies showing E-K substitution measure only gross elasticity because one or more factors have been omitted from the production function. Empirical results indicate that energy and capital are gross substitutes but net complements.

3. Capital is not separable from other aggregates as some studies have assumed. Capital should be disaggregated into working capital and physical capital. Energy would act as a complement to physical capital and a substitute for working capital, and vice-versa.

The Allen Elasticity of Substitution (AES)[18] between energy and capital range from +1.07 in Griffin and Gregory to +0.8 in Pindyck, and from -1.01 to +2.0 in Halvorsen and Ford. These estimates are very different from the Berndt-Wood estimate of -3.2. Consequently, Griffin argued that

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18. Allen, R. G. D., Mathematical Analysis of Economists London: Macmillan, 1938, 503-509.

pooled[19] data are more appropriate to measure elasticities because the price variations are greater not only among countries but also within the countries included in the study. In the US, the price variation in the periods studied is very small, and thereby unable to yield reliable results. In Griffin's view, econometric evidence does not reject a short and long run dichotomy; the gross/net elasticity distinction cannot offer a complete explanation.

Griffin questioned the wisdom of including working capital into the production function. He argued that the inclusion of working capital should be preceded by good theoretical reasons to do so. He ended his review by saying that E-K complementarity remained an unanswered but important policy question.

Several other authors contribute to the debate. David Stapleton[20] examined the results from cross-section and time series data, and concluded that cross-section data does not always yield long-run elasticities nor does time-series data always yield short-run elasticities. This study weakens Griffin's argument about the likely cause for divergent

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19. "Pooled data" refers to the procedure of using data from several countries to jointly estimate functions through dummy variable manipulation.

20. Stapleton, David, "Inferring Long-Term Substitution Possibilities from Cross-Section and Time-Series Data," in Berndt and Field (eds), Modeling and Measuring Natural Resources Substitution, MIT Press, Cambridge, 1981.

elasticity estimates. Charles Struckmeyer[21] argued that capital-energy complementarity is a short-run phenomenon reflecting the fixed ex post nature of factor employment in a putty-clay technology.[22] But if a specification is used to measure the ex ante choice of technique, capital and energy are found to be long-run substitutes. Struckmeyer argues, however, that neither the translog function nor the putty-clay model are adequate representations of technology. They do not capture the dynamic adjustments found in the data.

Several problems remain to be worked out in the methodology of estimating production and cost functions. In order to omit some of the input series, authors have assumed separability of inputs.[23] With the separability assumption the absence of one series would not affect the estimation of the parameters for the others. Several authors, however, argue that the separability assumption is not valid. In later studies tests have been devised to validate the separability assumption; results are mixed. Because separability depends on the functional form, if the true

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21. Struckmeyer, Charles, "The Putty-Clay Perspective on the Capital-Energy Complementarity Debate," The Review of Economics and Statistics, 1987.

22. "Putty-clay" is used to describe the fact that firms are free to choose the kind of technology they want to use. Once they exercised that choice, they cannot change it easily. So in a putty-clay technology model, inputs are ex-ante substitutes, but ex-post complements.

23. "Separability" means that the quantities of one input in the production function is independent of the quantity of the other inputs.

functional form is not known, or if the functional form being used is not a reasonable approximation, separability is a strong assumption.

The aggregation of inputs across firms bias the series because firms have different degrees of vertical integration. Anderson[24] argues that it does not make much sense to include intermediary inputs at the industry level. This is a valid procedure only at the firm level. Kopp and Smith[25] used disaggregated data to study the performance of translog functions. They argue that aggregated data in the translog function does not properly describe the technology, while disaggregated data provides a more appropriate representation. Chung[26] proposes an alternative way of estimating (AES) through a single cost-share equation. While the estimation process is made easier, it does not solve the basic problem of conflicting results. The estimates remain mixed; he obtains negative and positive parameters, similar to those already known.

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24. Anderson, Richard G., "On the Specification of Conditional Factor Demand Functions in Recent Studies of U.S. Manufacturing," in Modeling and Measuring Natural Resource Substitution, edited by Ernst Berndt and Barry C. Field, pp. 119-144. Cambridge, 1981, MIT Press.

25. Kopp, Raymond J.; and Smith, V. Kerry; "Measuring the Prospects for Resource Substitution under Input and Technology Aggregations," in Modeling and Measuring Natural Resources Substitution, Cambridge, MIT Press, 1981, pp. 145-173.

26. Chung, Jae Wan, "On The Estimation of Factor Substitution in the Translog Model," The Review of Economics and Statistics, 1987, pp. 409-417.

In a study involving several industries in Canada and the U.S., Denny, Fuss, and Waverman[27] found that in the U.S. paper industry, energy and capital are complements ($\sigma_{E,K}$ = -2.74), and energy and labor are substitutes ($\sigma_{E,L}$ = 5.48). The study, however, does not capture the effect of the energy price shock since it comprehends only the period 1948-1971. In the case of Canada, the range is 1962-1975, but still, it is not enough to capture the effect of the first oil shock. The study shows substitutability between energy and capital in the paper industry ($\sigma_{E,K}$ = 1.93); energy and labor are substitutes in the short run ($\sigma_{E,L}$ = 0.39), and complements in the long run ($\sigma_{E,L}$ = -2.61). For Canada, the authors disaggregated energy among electricity, fuel oil, coal, and natural gas. Significant complementarity is found between electricity and fuel oil ($\sigma_{E2,E3}$ = -0.299), substitutability between coal and fuel oil ($\sigma_{E2,CL}$ = 0.672), and substitutability between natural gas and fuel oil ($\sigma_{NG,E2}$ = 0.124).

Aggregation, it is seen, presents serious problems for the study of substitution of inputs. Different types of data have been aggregated which distort the parameters. Aggregation not only presents problems on the input side, but on the output side as well. Firms, responding to market

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27. Denny, M.; Fuss, M., and Waverman, L. "Substitution Possibilities for Energy: Evidence from U.S. and Canadian Manufacturing Industries," in Modeling and Measuring Natural Resource Substitution, edited by Ernst Berndt and Barry C. Field, 1981, Cambridge, MIT Press.

trends change the output mix. If energy prices double, for example, prices of energy intensive goods would rise more than the prices of less energy intensive goods. Demand for energy intensive products would drop, while demand for less energy intensive goods would rise. In order to respond to this change in demand, firms would increase the production of less energy intensive goods, and decrease production of more energy intensive products. Elasticities in this context could be misleading because two different outputs are being compared. The methodology being employed assumes that the same output is being analyzed.

Using the argument of changing output mix, John Solow[28] express serious doubts about the entire process of elasticity estimation as it is generally done. He looks at input substitution in a general equilibrium context, as opposed to a partial equilibrium approach, and concludes that input substitution is basically a micro phenomenon which cannot be analyzed using aggregated data. He argues that price-induced changes in the composition of output can cause either outcome in the aggregate -- substitution or complementarity -- even if no technical substitution is possible. Changes in the relative incomes of U.S. consumers as opposed to the rest of the world may be key in determining if energy and capital are to become substitutes or complements in the U.S..

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28. Solow, John, "The Capital-Energy Complementarity Debate Revisited," American Economic Review, September 1987, pp. 605-614.

Solow's article leaves two alternative ways of dealing with the problem: a) Look for other models in which aggregate data could be used to establish the relationship between capital and energy, or b) Search for data at the micro level and try to establish the elasticity estimates at that level. A third alternative, of course, is to abandon the effort altogether.

In the next chapter, the method used in the research will be described in detail.

CHAPTER 3

ECONOMETRIC MODELS AND ESTIMATING PROBLEMS

The use of aggregate models is always troublesome. Even the most sophisticated models cannot separate what is needed from what is available. This dissertation took the tack of studying input substitution at the micro level.

The search for data at the micro level is no easy task. Firms consider most of the data needed for production and cost function estimation as confidential and thus beyond the reach of academic researchers. The reports produced for public relations and stockholders do not have the necessary details. Many firms manufacture more than one product, so changes in the composition of output also occur at that level. To obtain reliable data, the researcher must be allowed free access to the books and internal reports, as well as consulting with the employees who understand them. Since this is always troublesome to them, it is not easy to arrange.

Studying micro data, in a complete capital, labor, materials and energy model (KLME) seemed, however, the most promising line of research. In order to accommodate the needs of the sponsor of my program, the approach was tried in Brazil first. More than a hundred letters were sent, and only six companies responded; four of them apologized because they could not provide that kind of data.

The results were discouraging; it seemed like a change in approach would be necessary. I started to look for data at the industry level, when, luckily, I was introduced to Indústrias Klabin de Papel e Celulose s/a in São Paulo, the holding company of a conglomerate involving paper, mining, and packaging divisions. After the matter was discussed with members of the Board of Directors, I was authorized to do research in three of their Brazilian paper firms which are fairly representative of the nation's paper industry. I personally visited two of the mills, one in the Western part of the Paraná State, and the other in Guaíba, Rio Grande do Sul State. I was allowed to talk with technical personnel, take notes, look at the internal reports, and books. I was to keep the data confidential and not publish without first consulting them. It was a unique opportunity to obtain valuable data which, hopefully, can bring new information to the study of energy-capital substitutability.

The most common method of measuring price responsiveness of demand for any input is to measure the price elasticity of demand. In its most simple form, in a production function $Y = f(X_1, X_2)$, where Y is the output and X_1 and X_2 are inputs. With prices P_1 and P_2, the elasticity of demand between the two inputs is given by $E_{12} = d\ln(X_1/X_2)/d\ln(P_2/P_1)$[1], output and other prices assumed to be unchanging. As E becomes larger, the substitutions are easier between the two inputs. If E > 1, the share of input 1 becomes larger relative to the share of input 2. If E < 1, the share of input 1 becomes smaller relative to the share of input 2. When there are only two inputs, $E_{1,2} = E_{2,1}$, and there is no ambiguity in the effects of a price change, they are substitutes, unless a Leontieff type of technology is deployed.[2]

The analysis of input substitution becomes more complicated when there are more than two inputs. In such cases, the elasticity measurement is not unambiguous since several partial derivatives are involved. A greater or lesser number of derivatives are assumed to change depending on *ceteris paribus* conditions. In this way, a large number

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1. Suppose the two inputs are K and L. Elasticities are derived in the following way:

$$E = \frac{\%K}{\%L} = \frac{dK/K}{dL/L} = \frac{L/K}{dL/dK} = \frac{L/K}{\frac{dL/dQ}{dK/dQ}} = \frac{L/K}{r/w}$$

where dK is the change in the amount of K, dL the change in the amount of L, and dQ the change in the amount of Q. Q is the output, r is cost of K, and w is the cost of L. Prices enter the elasticity calculation because the optimization condition requires that the marginal product of the factor be equal to its remuneration. The marginal products are dL/dQ and dK/dQ.

2. Inputs are used in fixed proportions. No substitution is possible.

of elasticity measures are possible. The most common elasticity concept used in cases of more than one input is the Allen Elasticity of Substitution (AES).[3]

It is standard in the literature to estimate the cost, or production functions, and from those parameters estimate the demand functions. The demand functions allow estimation of elasticities. Implicit in the procedure is the assumption that those functions exist. In order to validate the assumption, tests are performed with the data and the estimated parameters to check for their existence. When those tests are performed the existence is, of course, deferred to the accuracy of the data set.

While there are serious objections to the estimation of production and cost functions, particularly because some of the comparative statics hold only under optimization[4] conditions, the method is more appropriate in the context of a single firm than in the aggregate. The adjustments in production resulting from input price changes differ among firms. In some cases, taking a very long period, and in others, a short one. But in general, firms try to achieve the mix of inputs which minimize their cost, even when the adjustment process takes time. The problem is that most firms cannot change their equipment overnight. In the paper industry, for instance, it is common for a paper machine to

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3. Allen, op. cit., pp. 503-509.

4. The firms are assumed to be continuously maximizing profits or minimizing costs.

remain in use for more than 30 years. Even when energy prices go up, and the paper produced by that machine ends up being more expensive, liquidity constraints may prevent the firm from changing to a new machine. So, the firm keeps operating in a situation where it is not minimizing long run costs, although it may be minimizing costs given the technology in place. In order to compensate for higher production costs firms cut costs in other areas like overhead, for example. In such situations, the estimation of production and cost functions may not yield a fair representation of technology. Some inputs, in such situations, could present positive own price elasticities.

Another objection constantly raised is that the technology is restricted in scale. For example, in the translog function, the firm is assumed to exhibit constant returns to scale. In order to achieve general results, the assumption of constant, or decreasing returns to scale is essential. It is well known, by experience, that this is not the case. Firms may exhibit increasing returns to scale in a wide range of the output possibility path, which invalidates the comparative statics on which economics relies heavily.

To those objections, one could be added which is more serious: Successfully combining physical inputs to produce an output is not, in a great number of cases, the key to a firm's success. In the spectrum of decisions with which the manager is confronted with, the decision to substitute physical inputs is not the crucial one in many cases.[5] It is unnecessary to substitute inputs, if the product is not marketable, if the firm does not have an organization to reach the markets effectively, if the new input source is unreliable and unsustainable, or if the earnings vanish with inflation. In the context of LICs, it is not clear that energy, in the long run, is the only input in need of substitution. Organization, for example, is a scarce input. In many cases the survival of the firm is threatened by market conditions other than higher energy prices. In countries like Brazil, the development of mechanisms to cope with inflation is as important to the survival of the firm as the substitution of inputs whose prices have increased.

More profit is always better than less profit if all other things remain the same. It is logical to assume that decision makers, if confronted with such a naive proposition, would choose the alternative which brings more profit. This is relevant in the context of the firm but not as crucial as in neoclassical economics which relies heavily on this assumption. The manager compares alternatives under

5. In an interview with Dr. José Valentim Sartarelli, General Manager of Eli Lilly Corporation of Brazil, on July 26, 1988, he argued that for any firm to survive in an inflationary economy such as Brazil, where price levels increase at the rate of about 20% a month, the financial management of the firm takes the highest priority. Mismanagement in this area would make the profits vanish overnight. Production is to a great extent subordinate to financial management. Alternating in priority is the relationship with government bureaucracy vis-a-vis licensing procedures. This takes which takes top management personnel a lot of time and energy.

which conditions are different. The decision to choose between more profit as compared to less profit, other things being equal, is never faced. A decision, as such, would never reach higher management, it can be made by any employee which identifies such a possibility. Things do not remain the same when a choice is made; most choices involve alternatives which affect other variables. A great deal of time and effort is devoted to identifying the alternatives, establishing risks, and estimating returns. Decision-making process takes into account the actions of the competition, the actions of the government, the long-run objectives of the firm, the potentiality of the markets, etc., some of which may be more important than the combination of physical inputs.

By including only physical inputs in the production function important inputs are left out. This is easily demonstrated in the construction industry where several firms offer to build the same bridge, using the same technology, at a similar price. The reasons for choosing a particular firm are reputation, reliability, past history of litigation, and client satisfaction rates. These are intangible inputs which cannot be easily acquired. Even if energy prices go up, it is not within the reach of the firm's decision-makers to demand less energy and more "reliability," in the short run. Intangibles such as organization, reliability, reputation, and client satisfaction, for example, are long-term commitments which cannot be acquired in the short run. But they are clearly inputs in the production process, and a key to the survival of any business.

Suggestions to include other inputs in the production function have been made but the difficulty in dealing with the subject is holding back research. Meanwhile, it is necessary to be realistic and deal with what is available. This dissertation deals only with physical inputs in studying substitution between capital and energy. A whole spectrum of possibilities (substitution or complementarity) exist which are different for each industry and for particular firms within the industry. This is one of the first studies using translog functions at the firm level; consequently the method will also be evaluated. In addition to the basic treatment of energy-capital substitution, four inputs, K, L, E, M, will also be included making the separability assumption unnecessary.

Following the suggestion of Toevs (1980), both the translog cost and production functions will be estimated. This allows illustration of the disparity between methods. The translog function is widely used because the estimation process can be made simple. It is a second order approximation to any arbitrary function and offers possibilities for testing its existence and properties.

Cost functions assume that firms are minimizing total cost in the short-run, while production functions require

the more stringent assumption of profit maximization.[6] To calculate the AES between factor *i* and factor *j* from a cost function ($\sigma_{i,j}$), only the estimated parameters and cost shares of the production factors of the total cost are needed. To estimate the same elasticities from production functions (A_{ij}), the matrix of estimated coefficients must be inverted. Consequently, elasticity estimates from production functions involve more complex computations. Furthermore, if the data are not accurate, the distortions in the estimated elasticities are more serious due to greater manipulation of the data.

Hicks Elasticities of Complementarity (HEC) can be estimated from the production function parameters when the effect in factor prices caused by changes in quantities available is needed. The HEC is useful in comparing the effects of government policies. For example, when the government intervenes to increase the supply of a particular factor, the effects of that policy on the market prices of products can be determined. In investigations of individual firms, the HEC is not very useful, except for those situations where the firm has monopsonistic power.[7]

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6. Cost minimization requires the production function to be locally quasiconcave, while profit maximization requires the production function to be locally concave. See Varian, Hal, Microeconomic Analysis, Second Edition, W.W. Norton & Company, New York, 1984, pp. 21-25.

7. Monopsony is a situation where one economic agent is the exclusive buyer of one input. Such a case can be illustrated in the labor market by a large firm established in a small town, giving employment to the

The translog cost function[8] for four inputs, K, L, E, and M (with symmetry and constant returns to scale) can be specified as:

$$\begin{aligned}\ln C = {} & \ln(\alpha_0) + \ln(Y) + \alpha_K \ln(P_K) + \alpha_L \ln(P_L) + \alpha_E \ln(P_E) \\ & + \alpha_M \ln(P_M) + \tfrac{1}{2}\beta_{KK}(\ln P_K)^2 + \beta_{KL}\ln(P_K)\ln(P_L) \\ & + \beta_{KE}\ln(P_K)\ln(P_E) + \beta_{KM}\ln(P_K)\ln(P_M) \\ & + \tfrac{1}{2}\beta_{LL}(\ln P_L)^2 + \beta_{LE}\ln(P_L)\ln(P_E) \\ & + \beta_{LM}\ln(P_L)\ln(P_M) + \tfrac{1}{2}\beta_{EE}(\ln P_E)^2 + \\ & + \beta_{EM}\ln(P_E)\ln(P_M) + \tfrac{1}{2}\beta_{MM}(\ln P_M)^2 . \qquad (1)\end{aligned}$$

where:

C = total cost

Y = output level

P_K = price of capital

P_L = price of labor

P_E = price of energy

P_M = price of materials

ln = natural logarithm

β_{ij} = parameters

α = parameters

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majority of the local inhabitants. No major alternative employer is available nearby. In such a case the firm is said to enjoy monopsonistic power. The situation of the Klabin plant in the Paraná State resembles in many ways such a situation.

8. The translog functional form was first presented in Christensen, Laurits; Jorgenson, Dale; and Lau, Lawrence; "Transcendental Logarithmic Production Function Frontiers," The Review of Economics and Statistics, 55, February 1973, 29-45. Since the authors first defined this production function, variations of it have been the standard in the literature for estimation of input substitution.

The assumptions of linear homogeneity in prices and constant returns to scale, require that the following restrictions hold:

$$\alpha_K + \alpha_L + \alpha_E + \alpha_M = 1$$

$$\beta_{KK} + \beta_{KL} + \beta_{KE} + \beta_{KM} = 0$$

$$\beta_{KL} + \beta_{LL} + \beta_{LE} + \beta_{LM} = 0$$

$$\beta_{KE} + \beta_{LE} + \beta_{EE} + \beta_{EM} = 0$$

$$\beta_{KM} + \beta_{LM} + \beta_{EM} + \beta_{MM} = 0 \qquad (2)$$

Assuming a competitive market and cost minimization, using Shephard's Lemma[9]:

$$x_i = \frac{\delta C}{\delta P_i}, \qquad i = K, L, E, M.$$

where X_i is the demand for factor i.

Partial derivative of logarithms are equivalent to elasticities. So if natural logarithms are taken of the two sides of the cost function and the partial derivatives are taken of the cost function in relation to P_i (the price of factor i), the result will be the sensitivity of total cost with relation to the price of factor i (P_i):

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9. The Shepard's Lemma states that if $X_i(w,y)$ is the firm's conditional factor demand for input i, where y is the optimal output level, and w is the vector of input prices, if the cost function C is differentiable at (w,y), then:

$$X_i(w,y) = \frac{\delta C(w,y)}{\delta w_i}, \qquad i = 1,\ldots,n.$$

For a more detailed derivation see Varian, Hal R., Microeconomic Analysis, second edition, 1984, W.W. Norton & Company, New York, p. 54.

$$\frac{\delta \ln(C)}{\delta \ln(P_i)} = \frac{\delta C}{\delta P_i} \frac{P_i}{C} = \alpha_i + \sum_i \beta_{ij} \ln P_{j,i}$$

where j = K, L, E, M.

Substituting $\delta C/\delta P_i = X_i$ in the above equation:

$$\frac{P_i X_i}{C} = \alpha_i + \sum_i \beta_{ij} \ln P_{j,i}$$

As $P_i X_i /C$ is the share of the cost of input i, Si, in the total cost function, the following set of equations can be derived which are equivalent to the demand functions for each factor;

$$S_K = P_K K/C = \alpha_K + \beta_{KK} \ln(P_K) + \beta_{KL} \ln(P_L) + \beta_{KE} \ln(P_E) + \beta_{KM} \ln(P_M)$$

$$S_L = P_L L/C = \alpha_L + \beta_{KL} \ln(P_K) + \beta_{LL} \ln(P_L) + \beta_{LE} \ln(P_E) + \beta_{LM} \ln(P_M)$$

$$S_E = P_E E/C = \alpha_E + \beta_{KE} \ln(P_K) + \beta_{LE} \ln(P_L) + \beta_{EE} \ln(P_E) + \beta_{EM} \ln(P_M)$$

$$S_M = P_M M/C = \alpha_M + \beta_{KM} \ln(P_K) + \beta_{LM} \ln(P_L) + \beta_{EM} \ln(P_E) + \beta_{MM} \ln(P_M) \quad (3)$$

where the total cost is given by; $C = P_K K + P_L L + P_E E + P_M M$. S_i is the cost share of the input *i* in the total cost of producing Y.

The above equations are much easier to estimate because they are not complex algebraically and data about cost shares and prices are more readily available than the larger set needed to estimate directly a production or cost function. The restriction imposed by the complexity of the equations, however, has been greatly diminished in recent years with the increasing availability of statistical packages capable of handling simultaneous equation systems, and non linear models. Once the parameters of the above equations are estimated, elasticities of substitution can be calculated and substitutability of inputs analyzed.

The AES between inputs i and j can be calculated in the following way:

$$\sigma_{ij} = \frac{CC_{ij}}{C_i C_j}$$

where

$$Ci = \frac{\delta C}{\delta P_i}, \qquad C_{ij} = \frac{\delta^2 C}{\delta P_i \delta P_j} .$$

Because symmetry was imposed in the production function, by definition $\sigma_{ij} = \sigma_{ji}$. Using the translog cost function, the AES are defined as:

$$\sigma_{ii} = \frac{\beta_{ii} + (S_i)^2 - S_i}{(S_i)^2}, \qquad i = K, L, E, M. \tag{4}$$

$$\sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j}, \qquad i,j = K, L, E, M, i \neq j \tag{5}$$

The AES varies according to the cost share of each input. The price elasticity of demand ϵ_{ij} is defined as:

$$\epsilon_{ij} = \frac{\delta \ln(x_i)}{\delta \ln P_j},$$

and the price elasticities of demand are related to the AES elasticities in the following manner:

$$\epsilon_{ij} = S_j \sigma_{ij} .$$

In this way, even when $\sigma_{ij} = \sigma_{ji}$ by definition, price elasticity of demand varies according to the cost share of the input.

In the same fashion, the translog production function can be defined as:

$$\begin{aligned} \ln Y = & \ln(\alpha_0) + \alpha_K \ln(X_K) + \alpha_L \ln(X_L) + \alpha_E \ln(X_E) \\ & + \alpha_M \ln(X_M) + \tfrac{1}{2}\beta_{KK}(\ln X_K)^2 + \beta_{KL}\ln(X_K)\ln(X_L) \\ & + \beta_{KE}\ln(X_K)\ln(X_E) + \beta_{KM}\ln(X_K)\ln(X_M) \\ & + \tfrac{1}{2}\beta_{LL}(\ln X_L)^2 + \beta_{LE}\ln(X_L)\ln(X_E) \\ & + \beta_{LM}\ln(X_L)\ln(X_M) + \tfrac{1}{2}\beta_{EE}(\ln X_E)^2 + \\ & + \beta_{EM}\ln(X_E)\ln(X_M) + \tfrac{1}{2}\beta_{MM}(\ln X_M)^2. \qquad (6) \end{aligned}$$

where:

Y = total output

X_K = quantity of capital input

X_L = " labor input

X_E = " energy input

X_M = " material input

β_{ij} = parameters

α = parameters

ln = natural logarithm

Given profit maximization,

$$P_i = \frac{\delta Y}{\delta X_i}, \qquad i = K, L, E, M.$$

The logs of both sides taking derivatives is equivalent to finding elasticities. Thus:

$$\frac{\delta \ln(Y)}{\delta \ln(X_i)} = \frac{\delta Y}{\delta X_i}\frac{X_i}{Y} = \alpha_i + \sum_i \beta_{ij} \ln X_{j,i}$$

where j = K, L, E, M.

Since $\delta Y/\delta X_i = P_i$, substituting in the above we get:

$$P_i X_i / Y = \alpha_i + \sum_i \beta_{ij} \ln X_{j,i}$$

The equations below are equivalent to the factor's demand functions if we define $S_i = P_i X_i / Y$ with price of output normalized at 1:

$$S_K = P_K K/y = \alpha_K + \beta_{KK}\ln(X_K) + \beta_{KL}\ln(X_L) + \beta_{KE}\ln(X_E) + \beta_{KM}\ln(X_M)$$

$$S_L = P_L L/y = \alpha_L + \beta_{KL}\ln(X_K) + \beta_{LL}\ln(X_L) + \beta_{LE}\ln(X_E) + \beta_{LM}\ln(X_M)$$

$$S_E = P_E E/y = \alpha_E + \beta_{KE}\ln(X_K) + \beta_{LE}\ln(X_L) + \beta_{EE}\ln(X_E) + \beta_{EM}\ln(X_M)$$

$$S_M = P_M M/y = \alpha_M + \beta_{KM}\ln(X_K) + \beta_{LM}\ln(X_L) + \beta_{EM}\ln(X_E) + \beta_{MM}\ln(X_M) \qquad (7)$$

To reiterate, the production function $Y = f(X_K, X_L, X_E, X_M)$. S_i is the cost share of each input in the total output Y.

In the same way, the assumptions of linear homogeneity and constant returns to scale require that the following restrictions hold:

$$\alpha_K + \alpha_L + \alpha_E + \alpha_M = 1$$

$$\beta_{KK} + \beta_{KL} + \beta_{KE} + \beta_{KM} = 0$$

$$\beta_{KL} + \beta_{LL} + \beta_{LE} + \beta_{LM} = 0$$

$$\beta_{KE} + \beta_{LE} + \beta_{EE} + \beta_{EM} = 0$$

$$\beta_{KM} + \beta_{LM} + \beta_{EM} + \beta_{MM} = 0 \qquad (8)$$

According to the AES, inputs are complements or substitutes as $\sigma_{ij} < 0$ or $\sigma_{ij} > 0$ respectively. The AES will be calculated based on the production and cost functions. The AES from the production function will be A_{ij}, to distinguish it from the AES calculated from the cost function, σ_{ij}. The A_{ij} is obtained through the following procedure:[10]

$$A_{ij} = \frac{|F_{ij}|}{|F|}$$

where F_{ij} is the cofactor of f_{ij} in F, and F is the following determinant, in a four input model:

$$F = \begin{vmatrix} 0 & f_1 & f_2 & f_3 & f_4 \\ f_1 & f_{11} & f_{12} & f_{13} & f_{14} \\ f_2 & f_{21} & f_{22} & f_{23} & f_{24} \\ f_3 & f_{31} & f_{32} & f_{33} & f_{34} \\ f_4 & f_{41} & f_{42} & f_{43} & f_{44} \end{vmatrix}$$

where:

$f_i = S_i$

$f_{ii} = \beta_{ii} + S_i^2 - S_i$

$f_{ij} = \beta_{ij} + S_i S_j$

In order to make sure that the data conforms to a cost function, the test for positivity and concavity must be performed. These are requirements for the existence of the functions. The test for positivity is required to make sure

10. Hamermesh, Daniel and Grant, James; "Econometric Studies of Labor-Labor Substitution and Their Implications for Policy," The Journal of Human Resources, XIV, 4, Fall 1979.

that there are no negative costs. This situation would rule out the existence of a cost function. For the translog cost function this is done by fitting the equation and ensuring that there is no negative-fitted cost share.[11]

The test for concavity is needed to ensure that there are no increasing returns to scale. In the presence of increasing returns to scale the profit function may not have a maximum. When the assumption of profit maximization does not hold, the estimation of production functions and the elasticities originated from the procedure may not be valid.

For the cost function quasi-convacity must be ensured if the cost function is to have a minimum. Concavity/quasi-concavity requirements do not hold for the translog function globally, necessitating checks at every point.[12] One way to do this is to use a procedure called Cholesky decomposition, first used by Lau[13] in this context. A function is concave if the Hessian matrix of second partial

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11. Some authors like Jorgenson Dale, and Fraumeni, Barbara M.; "Relative Prices, and Technical Change" in Modeling and Measuring Natural Resource Substitution, edited by Ernst Berndt and Barry C. Field, Cambridge, MIT Press, 1981, pp. 17-47, consider satisfactions that the average shares are non-negative.

12. Peter Schmidt does not attach too much importance to the point by point check for concavity, probably because the translog is a second order approximation, and it does not satisfy concavity globally anyway.

13. Lau, Lawrence J., "Testing and Imposing Monotonicity, Convexity and Quasi-Convexity Constraints," in Production Economics: A Dual Approach to Theory and Applications, Vol 1, edited by Melvyn A. Fuss and Daniel Mcfadden, 1978, Amsterdam, North Holland, pp. 409-453.

derivatives is negative semi-definite. This requirement is achieved in the context of a translog cost function if all Cholesky values are less than or equal to zero at each sample point. An alternative way of doing it is to check for the eigenvalues. For quasi-concavity, the number of non-positive eigenvalues must be greater than or equal to (n-1) where n is the order of the symmetric matrix. For concavity, all eigenvalues must be non positive.

The share equations (S_i) derived from the cost and production functions, as a result of the mathematics of the derivation, are deterministic. There is no reason, however, to expect deterministic behavior from stochastic variables. The decision-makers in a firm make mistakes. A firm cannot adjust input mix overnight as a result of changes in prices and market conditions, and the data contain measurement errors which justify for adding error terms to the equations so that econometric techniques can be used to estimate the parameters. The error terms are assumed to have means of zero and constant variances across the sample. This may not always be the case, but small departures will not significantly distort the results.[14]

The error terms of the equations (3) and (7) above are correlated because the increase in the cost share of one input implies the reduction in the cost share of at least

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14. Chavas, Jean Paul and Segerson, Kathleen; "Stochastic Specification and Estimation of Share Equations Systems," Journal of Econometrics, July 1987, pp. 337-358.

one competing factor. In these cases, the ordinary least squares technique does not yield efficient estimates. The Zellner Seemingly Unrelated Regression Estimation (SURE) is used because it improves the efficiency of the estimates by plugging back the covariance matrix into the estimation process. When the covariances between the error terms are zero, SURE will be equivalent to OLS. The assumption of no serial correlation within equations must still hold.

As a brief summary of what has been done in the field, an updated synopsis taken from Chung[15] is presented in Appendix A.

15. Chung, op.cit..

CHAPTER 4

DATA AND ESTIMATION

The data used in this study refer to three paper enterprises of the Klabin Group in Brazil: Industrias Klabin de Papel e Celulose s/a (IKPC), Riocell s/a (RIOCELL), and Papel e Celulose Catarinense s/a (PCC). The first firm acts as a holding company for the Group in spite of the fact that this relationship is not formally defined in the structure. The headquarters of Klabin are located in São Paulo, and its plant is located in the Monte Alegre Farm in Telemaco Borba in the west of Paranå state. The Group controls several other firms besides PCC and RIOCELL; some of them in other states. In addition to its paper companies, the conglomerate has packaging, forestry, and mining divisions.

The three firms cited above were chosen from among the others in the group because the paper producing activity could be clearly separated from the other activity. The reason to limit the study to one activity, and one product is to minimize the phenomenon of changing output mix in response to market demand as described by Solow.[1] The

1. Solow, op.cit.

phenomenon, in this case, was minimized but could not be eliminated because even within paper manufacturing, there were variations in the product. For example, every plant produces at least four types of paper. The composition of the final output may also be changing over time. Paper production is, however, the most disaggregated level for which data can be readily obtained. It is possible to pick only one type of paper, but it would take a long time to determine the specific inputs used. Furthermore, those determinations would never be exact, because many inputs are jointly used.

The data were taken from internal management reports together with records of specific units in the plants, accounting records, and cost accounting reports. Data for more than five years were difficult to assemble because reports changed considerably; while more detailed data were included in recent years, some series of data were discontinued. There are very good cost accounting reports for the recent years, but similar data for earlier years are not available. Because this study relies on time series analysis, the length of the time series is important. This research concentrates on those series for which the longest period of time could be covered.

DATA

The three firms researched have different management teams and different reporting techniques. The data are necessarily in different degrees of completeness, accuracy, and aggregation. The most complete data set exists for the Klabin mill in Monte Alegre, Paraná. More time was spent in that plant and its offices reviewing reports. Time series were obtained for:

- -output levels
- -product prices
- -depreciation
- -financial costs
- -number of employees
- -cost of labor
- -electricity (prices and quantities)
- -coal (prices and quantities)
- -fuel oil (prices and quantities)
- -black liquor[2] (quantities)
- -firewood (prices and quantities)
- -wood (prices and quantities)
- -caustic soda (prices and quantities)
- -whitewash (prices and quantities)
- -sodium sulfate (prices and quantities)
- -chloro (prices and quantities)
- -water (prices and quantities)
- -sulphur (prices and quantities).

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2. Black liquor is a residual from the wood digesting process. One of the processes of decomposition of the wood for transforming it into paper is through the use of chemicals. When the wood is dissolved and the fibers finally separated, what remains is a chemical/wood residue which when treated can be effectively used as fuel.

The data were obtained (with the exception of a few series), for the period of January, 1982 to December, 1987.

The first major difficulty was the transformation of prices and values into a common, measurable monetary unit. Inflation in Brazil has been a problem for decades. In recent years, the inflation rates have been consistently above 100 per cent[3] and currency unit changes have been a common occurrence. This poses a dilemma for firms, because they cannot plan if they do not have a stable unit of value. Those firms which have a trained staff plan everything in dollars or in any of the various fixed value currencies the Government has created over the years. There are Standard Units of Capital (UPCs), Readjustable National Treasury Bonds (ORTNs), National Treasury Bonds (OTNs), Fiscal OTNs and Standard Reference Units (URPs) among others. Several index tables are available, each one with its own approach and directed to a specific sector or activity. The reports at IKPC company started with cruzeiros, went to ORTN, then cruzados, and finally dollars. These changes were either caused by an overhaul in currency denominations, or required by soaring inflation rates. Planning for the future has been done in dollars for several years, but reports remained in cruzeiros/cruzados until 1986. To report in dollars is a

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3. The World Bank, Brazil: A Macroeconomic Evaluation of the Cruzado Plan, Washington, 1987; Baer, Werner; "The Resurgence of Inflation in Brazil, 1974-86, World Development, Vol. 15, N.8, 1987.

more demanding task. The transformations must be made by trained people, or the numbers are grossly distorted.

All data used in this study were transformed into January, 1982 dollars. Brazilian firms need to maintain two accounting systems, one in local currency to comply with corporate tax laws and another which accurately reflects the real value of assets and profits. It was a monumental task to convert all values into 1982 dollars. Nevertheless, the transformed data are not free from distortions because they reflect the sharp internal price fluctuations caused by exchange rate lag. The official exchange rate is fixed by the Central Bank. Depending on how they practice catching up with inflation, prices are lowered or increased sharply. During strong inflationary periods, internal prices become very high if the Central Bank does not devalue the currency fast enough. If it devalues it faster than inflation, internal prices fall. The record shows that the Central Bank always plays tricks with the exchange rate to allow the government to achieve short run political goals.[4]

Planning in dollars does not solve a firm's problems because tricks with the exchange rate distort company operations in any circumstance. Swift movements in exchange rate cause sharp fluctuations in a firm's liquidity because those changes affect contracts already signed but not yet

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4. The President of the Central Bank is selected by the Finance Minister. So the Central Bank has no autonomy to follow a sound monetary policy. It has to yield to the interest of the politician in charge.

fulfilled. They also affect a firm's decision to buy locally or to buy imports, and its competitiveness in the international market.

It would be interesting to disaggregate labor and energy to see which segments of labor are being substituted for which group of inputs. This would provide a picture of the evolving labor market contrasted with patterns of energy use. A disaggregation, however, is not possible for labor because labor use reports by wage level use different criteria across the years. There are some reports classifying the labor force by wage level (minimum wages earned) but, because the wage rate fluctuates considerably, acute fluctuations in the numbers within each category occur. Minimum wage readjustments by the government do not coincide with the timing of wage rate readjustments for the industry. Thus, in the period preceding wage rate increases by firms in the paper industry, wage rates are very low (in terms of minimum wages earned), and the low-paying categories are inflated.[5] In months when pay rises, almost everybody moves up in the scale (they earn more minimum wage units) with the lower categories dropping sharply in numbers. So, an analysis of the labor force by skill level

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5. For example, minimum wages category X has an inordinately high number of employees because inflation has eroded wages, and government readjusted minimum wages before firms readjusted the salaries of their employees. Wage increases are normally intended to compensate for past inflation. In the months when the firms give a wage increase, fewer people will be classified in the category X.

will take considerable time to complete. The disaggregation of energy was possible in three categories, except for RIOCELL which was subdivided in only two categories.

In order to find a common factor for energy aggregation, all energy inputs were transformed into Tons of Oil Equivalent (TOE),[6] using the coefficients published by the Ministry of Mines and Energy.[7] A good share of electric power used in the plants is produced internally using fuel oil, coal, firewood, or black liquor. Only the electricity purchased from public utilities was included because the caloric content of the electricity produced internally was accounted for in the fuels used to generate it (coal, oil, firewood, etc.). Power shortages in this industry can be disastrous. Firms maintain several backup systems for power because the public utilities supplying energy are unreliable.

The other material inputs can also be disaggregated. But as was the case for labor, this task is beyond the scope of this study and will be left for a future undertaking.

The data used in the estimation process for each firm are: share of labor in total cost of production (S_L), share of energy (S_E), share of materials (S_M), share of capital (S_K); and levels of use of energy (X_E), materials (X_M), labor (X_L), and capital (X_K). For the materials series,

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6. The equivalency is in caloric content.

7. Balanço Energètico Nacional, 1987, Ministèrio das Minas e Energia, pp. 119-120.

inputs were added up in tons. In the labor series, the number of workers was used. For the physical capital series, a composite index to resemble the number of machine hours was calculated. The composite index was based on the level of output, total electricity used (acquired and generated internally), and tons of steam generated. Physical capital has been very stable in recent years, except for RIOCELL. For the others, there has been no major addition of equipment. There have been changes in boilers and a biomass plant[8] built at IKPC. The series, in index numbers format, are shown in Appendix B.

In order to estimate the parameters using SURE, the prices and quantities are transformed into index numbers and then into natural logarithms so that the data conform to the model.

The basic equations are estimated with the restriction that the elasticity between input i and j are the same as the elasticity between input j and i: $\sigma_{ij}=\sigma_{ji}$. This restriction, in fact, is part of the model because of the way the cost and production functions are set up. The demand equation systems to be estimated for each firm are:

Group 1. Cost Function - 4 inputs, K, L, E, and M.

(1) $S_K = \alpha_K + \beta_{KE} \ln P_E + \beta_{KK} \ln P_K + \beta_{KL} \ln P_L + \beta_{KM} \ln P_M + e_1$

(2) $S_M = \alpha_M + \beta_{ME} \ln P_E + \beta_{MK} \ln P_K + \beta_{ML} \ln P_L + \beta_{MM} \ln P_M + e_2$

8. This is a facility to prepare wood residues for burning.

(3) $S_E = \alpha_E + \beta_{EE} \ln P_E + \beta_{EK} \ln P_K + \beta_{EL} \ln P_L +$

$\beta_{EM} \ln P_M + e_3$

(4) $S_L = \alpha_L + \beta_{KM} \ln P_E + \beta_{LK} \ln P_K + \beta_{EM} \ln P_L +$

$\beta_{MM} \ln P_M + e_4$

The results of the estimation for the three firms are shown in Tables 1, 2, and 3.

Group 2. Production functions - 4 inputs; K, L, E, and M.

(1) $S_M = \alpha_K + \beta_{KK} \ln X_K + \beta_{KL} \ln X_L + \beta_{KE} \ln X_E$

$\beta_{KM} \ln X_M + e_1$

(2) $S_E = \alpha_L + \beta_{KL} \ln X_K + \beta_{LL} \ln X_L + \beta_{LE} \ln X_E +$

$\beta_{LM} \ln X_M + e_2$

(3) $S_K = \alpha_E + \beta_{KE} \ln X_K + \beta_{LE} \ln X_L + \beta_{EE} \ln X_E +$

$\beta_{EM} \ln X_M + e_3$

(4) $S_L = \alpha_M + \beta_{KM} \ln X_K + \beta_{LM} \ln X_L + \beta_{EM} \ln X_E +$

$\beta_{MM} \ln X_M + e_4$

The results of the estimation for the three firms are shown in Tables 4, 5, and 6.

Group 3. Cost Functions - 6 inputs with energy disaggregated in 3 categories: Biomass (E_1), Fossil fuels (E_2), Hydroelectricity (E_3), and K, L, M:

(1) $S_{E1} = \alpha_{E1} + \beta_{E1,E1} \ln(P_{E1}) + \beta_{E1,E2} \ln(P_{E2}) +$

$\beta_{E1,E3} \ln(P_{E3}) + \beta_{E1,K} \ln(P_K) + \beta_{E1,L} \ln(P_L) +$

$\beta_{E1,M} \ln(P_M) + e_1$

(2) $S_{E2} = \alpha_{E2} + \beta_{E2,E1} \ln(P_{E1}) + \beta_{E2,E2} \ln(P_{E2}) +$

$\beta_{E2,E3} \ln(P_{E3}) + \beta_{E2,K} \ln(P_K) + \beta_{E2,L} \ln(P_L) +$

$\beta_{E2,M} \ln(P_M) + e_2$

$$(3) \quad S_{E2} = \alpha_{E3} + \beta_{E3,E1}\ln(P_{E1}) + \beta_{E3,E2}\ln(P_{E2}) + \beta_{E3,E3}\ln(P_{E3}) + \beta_{E3,K}\ln(P_K) + \beta_{E3,L}\ln(P_L) + \beta_{E3,M}\ln(P_M) + e_3$$

$$(4) \quad S_K = \alpha_K + \beta_{K,E1}\ln(P_{E1}) + \beta_{K,E2}\ln(P_{E2}) + \beta_{K,E3}\ln(P_{E3}) + \beta_{K,K}\ln(P_K) + \beta_{K,L}\ln(P_L) + \beta_{K,M}\ln(P_M) + e_4$$

$$(5) \quad S_L = \alpha_L + \beta_{L,E1}\ln(P_{E1}) + \beta_{L,E2}\ln(P_{E2}) + \beta_{L,E3}\ln(P_{E3}) + \beta_{L,K}\ln(P_K) + \beta_{L,L}\ln(P_L) + \beta_{L,M}\ln(P_M) + e_5$$

$$(6) \quad S_M = \alpha_M + \beta_{M,E1}\ln(P_{E1}) + \beta_{M,E2}\ln(P_{E2}) + \beta_{M,E3}\ln(P_{E3}) + \beta_{M,K}\ln(P_K) + \beta_{M,L}\ln(P_L) + \beta_{M,M}\ln(P_M) + e_6$$

The results are presented in Tables 7, 8, and 9.

Group 4. Production Functions - 6 inputs, energy disaggregated as in item 3. For the production function, instead of prices quantities (X_i) are used in the share equations as regressors. The results are presented in Tables 10, 11, and 12.

Elasticity Estimates

The AESs are shown for each group (for the three firms) in Tables 13 to 24.

As important as estimating their elasticities is finding their significance. This procedure consists basically of estimating a confidence interval. One chooses the level of confidence that one wants to have about the probability that the estimated elasticity will fall within the interval; if it falls within the interval, "significance" is said to have been reached. The most common level of significance chosen in scientific research is 95 per cent (α=0.05).[9] This is called statistical significance, as opposed to a theoretical or conceptual significance. Statistical significance has a very narrow interpretation. If an α=0.05 is chosen, the statistical significance indicates that, given the sample used in the study, with 95 percent certainty, the coefficients are likely to be within the estimated interval. In the discussion below, the term significant and significance are used to refer to statistical significance.

The confidence interval may be estimated by several methods. The first, and most frequently used is to assume that the input shares in the total cost are not stochastic. This assumption simplifies significantly the computation of the variances, which can be obtained by the formula:

$$VAR(G_{ij}) = \left[\frac{1}{S_i S_j}\right]^2 VAR(\beta_{ij})$$

The shares, however, are clearly stochastic and the intervals generated by this formula are not appropriate. A more appropriate method assumes that the shares are stochastic. The estimated elasticity can be written as functions of the shares and the regression coefficients:

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9. α being the tail of the distribution. This is the area we want to exclude.

$$\hat{G}_{ij} = f(\hat{S}_i, \hat{S}_j, \hat{\beta}_{ij})$$

This is a non-linear relationship. Assuming that the function is continuous and twice differentiable in the neighborhood of the mean, the variance of the estimates can be approximated by:[10]

$$\mathrm{VAR}(\hat{G}_{ij}) \approx \Sigma \left[\frac{\delta f}{\delta \hat{\beta}_i}\right]^2 \mathrm{VAR}(\hat{\beta}_{ij}) + 2\sum_{j<i} \left[\frac{\delta f}{\delta \hat{\beta}_j}\right]\left[\frac{\delta f}{\delta \hat{\beta}_i}\right] \mathrm{COV}(\hat{\beta}_i, \hat{\beta}_j)$$

To any elasticity G_{ij}, this would be translated into:

$$\mathrm{VAR}(\hat{G}_{ij}) = \left[\frac{1}{\hat{S}_i \hat{S}_j}\right]^2 \mathrm{VAR}(\hat{\beta}_{ij}) + \left[\frac{-\hat{\beta}_{ij}}{\hat{S}_i^2 \hat{S}_j}\right]^2 \mathrm{VAR}(\hat{S}_i) + \left[\frac{-\hat{\beta}_{ij}}{\hat{S}_i \hat{S}_j^2}\right]^2$$

$$\mathrm{VAR}(\hat{S}_j) + 2\left[\frac{1}{\hat{S}_i \hat{S}_j}\right]\left[\frac{-\hat{\beta}_{ij}}{\hat{S}_i^2 \hat{S}_j}\right] \mathrm{COV}(\hat{\beta}_{ij}, \hat{S}_i)$$

$$+ 2\left[\frac{1}{\hat{S}_i \hat{S}_j}\right]\left[\frac{-\hat{\beta}_{ij}}{\hat{S}_i \hat{S}_j^2}\right] \mathrm{COV}(\hat{\beta}_{ij}, \hat{S}_j)$$

$$+ 2\left[\frac{-\hat{\beta}_{ij}}{\hat{S}_i^2 \hat{S}_j}\right]\left[\frac{-\hat{\beta}_{ij}}{\hat{S}_i \hat{S}_j^2}\right] \mathrm{COV}(\hat{S}_i, \hat{S}_j)$$

The $\mathrm{COV}(\hat{\beta}_{ij}, \hat{S}_i)$ and $\mathrm{COV}(\hat{\beta}_{ij}, \hat{S}_j)$ are assumed to be zero. In this case, three terms are left and the estimated variances are reasonable approximations.

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10. Kmenta, Jan; Elements of Econometrics, The MacMillan Company, New York, 1971, pp. 443-444.

In order to facilitate the task of connecting the results, Tables 25 and 26 summarize the results for the four-input estimates and six-input estimates respectively. To allow a brief comparison with selected results found in the literature, Table 27 presents the elasticities published in a few selected studies. This study is interested mainly in the energy-capital coefficients and elasticities, but a discussion of the other estimates is illustrative because it would tell something about the method itself. The other inputs estimates can be compared to theory and/or previous studies for disparities. If disparities are present, an explanation for that should be provided.

The Four Input Estimates

Cost Function

The input own price elasticities are expected to be negative, meaning that as the price of the input increases, the use of the input diminishes. For the cost function estimates, only eight from the twelve elasticities were negative. For the PCC company, the energy and materials own price elasticities ($\sigma_{E,E}$ and $\sigma_{M,M}$) have the wrong sign, while for the RIOCELL company, the energy and capital own elasticities ($\sigma_{E,E}$, and $\sigma_{K,K}$) are also positive. From the four estimates with wrong signs, only the capital elasticity for the RIOCELL company is significant at the 5 per cent level.

Two of the energy-capital ($\sigma_{E,K}$) elasticities are positive (IKPC and PCC companies) indicating substitution between energy and capital, while the same elasticity for the RIOCELL company is negative and significant indicating complementarity between the two inputs. Worth mentioning is the fact that the capital/labor elasticities ($\sigma_{K,L}$) are all positive and significant. The labor-materials ($\sigma_{L,M}$) elasticities are all positive but only for IKPC is it significant.

Production Function

The elasticities calculated from the production coefficients show that nine of the twelve input own price elasticities ($A_{i,i}$) are negative, and three of them have the wrong sign. The estimates of the IKPC company remain consistent with all input own price elasticities, that is, negative. For the PCC company, the energy estimate remains positive, but the capital estimate ($G_{K,K}$) turns from negative and significant in the cost function to positive but not significant in the production function. The case of the RIOCELL company remains consistent also. Only the capital elasticity is positive, repeating in the production function the result of the cost function estimation. In general, input demand is responsive to its own price increases, as indicated by the negative numbers of the input own price elasticities. In other words, as the relative price of an input rises, less of it is used.

The energy-capital ($G_{E,K}$) estimate for IKPC company remains consistent, that is, positive; reinforcing the case of substitutability of inputs in that company. The estimate for the PCC company shifted signs from positive to negative, but both of them are not significant. The case of RIOCELL remained negative and significant. Based on the cost and production functions, energy capital are substitutes in the IKPC company, complements in the RIOCELL company, and not defined in the PCC company.

For both IKPC and RIOCELL companies, the capital/labor estimates ($G_{K,L}$) change signs. Only the coefficient for IKPC is significant. These sign shifts are problematic and indicate that there are inconsistencies present in the method, or in the data. The signs for labor/materials ($G_{L,M}$) remain positive across methods.

All the energy/labor ($G_{E,L}$) estimates are not significant in the cost function while in the production function two of them are positive and significant. That is the case for PCC and RIOCELL companies, indicating that there is some degree of substitutability between energy and labor.

The Six Input Estimates

Cost Function

The transformation from four to six inputs is a result of the disaggregation of energy into three categories: E1 (fossil fuel), E2 (biomass), and E3 (hydroelectricity). This categorization is arbitrary; there is no special reason beyond the fact that fossil fuels are clearly non-renewable while biomass and hydro are usually considered renewable. In the case of RIOCELL company, hydroelectricity was dropped because it was negligible; there is some indication that the translog function method is sensitive to small input shares.

Twelve of the input own price elasticities are negative ($G_{i,i}$). Those not conforming with the theory are:

IKPC company

- Fossil fuels
- Biomass

PCC company

- Labor
- Materials

RIOCELL company

- Capital

Only the capital estimation for RIOCELL company is significant.

An interesting fact is that the energy own price elasticity for the IKPC company ($G_{E,E}$) was negative and significant when the estimation was done with four inputs. In the cost function with six inputs, the estimates for the three disaggregated series (E1, E2 and E3) are not significant, but only $G_{E3,E3}$ is negative. The remaining own input price elasticities are negative for IKPC.

The elasticities for fossil fuels/biomass ($G_{E1,E2}$) are positive for the PCC and RIOCELL companies indicating substitutability between the two energy groups in those companies. The same elasticity is negative for the IKPC company reflecting complementarity between the two energy groups.

Substitution between biomass and capital ($G_{E1,K}$) was found only in PCC and RIOCELL companies. The biomass-capital elasticity for the IKPC company is negative and not significant. All the elasticities between biomass and the other inputs ($G_{E1,L}$ and $G_{E1,M}$) for the three companies were not significant.

The elasticities between fossil fuels and hydroelectricity ($G_{E2,E3}$) were negative and significant for the two companies for which they were estimated (IKPC and PCC), indicating complementarity in the use of those two energy groups. Substitutability between fossil fuels and capital ($G_{E2,K}$) was found only in the IKPC company. For PCC and RIOCELL the elasticities were negative and significant, indicating complementarity for these companies.

The hydroelectricity/capital ($G_{E3,K}$) elasticities indicate substitutability between the two inputs for IKPC and PCC companies. The capital/labor elasticities ($G_{K,L}$) are positive for IKPC and RIOCELL, and negative but not significant for PCC. These results remain consistent with the literature which usually finds substitutability between capital and labor (Table 27). The elasticities between labor and material ($G_{L,M}$) are consistently positive across methods and disaggregations.

Production Function

Fourteen of the seventeen input own elasticities are negative, repeating the early results from the four-input model and the six-input cost function. The elasticities not conforming to the theory are:

IKPC company

- $G_{E3,E3}$
- $G_{K,K}$

PCC company

- $G_{E3,E3}$

Only the estimate for the IKPC company is significant.

All the elasticities between biomass and fossil fuels ($G_{E1,E3}$) are positive and significant, indicating substitutability between the two groups of inputs. The elasticities between biomass and hydroelectricity ($G_{E1,E3}$) are negative; it is significant only in the case of IKPC company. This gives a mixed result because, in the case of the cost function, the elasticities between biomass and hydroelectricity are different. The elasticity for PCC company is positive and significant, and for IKPC it is negative and not significant.

The elasticities between biomass and capital ($G_{E1,K}$) also provide mixed results. The estimates for the RIOCELL company remain consistent from the cost to the production function, indicating substitutability between biomass and capital; they are significant. The estimates for the IKPC company are negative in both the cost and production functions and are not significant. The estimates for the PCC company shift signs from positive and significant in the cost function to negative and significant in the production function.

The complementarity between fossil fuels and electricity ($G_{E2,E3}$) is once more shown by a negative and significant estimate for IKPC company. The same elasticity is positive for PCC, but not significant. This estimate does not exist for RIOCELL company because the hydroelectricity variable was dropped.

Another major shift in signs occurs for the PCC company in the case of the fossil fuels/capital ($G_{E2,K}$) elasticity. From negative and significant in the cost function, it shifts to positive and significant in the production function. The estimates for the RIOCELL company remain consistent with negative and significant elasticities across methods. In the case of the IKPC company, $G_{E2,K}$ is positive and significant in the cost function and negative and not significant in the production function--an ambiguous result. Also ambiguous are the results of biomass with the other labor and material inputs.

The estimation of the hydroelectricity/capital ($G_{E3,K}$) elasticities seem to be consistent across methods, revealing significant substitution between hydroelectricity and capital. The relationship between hydroelectricity and the other inputs, labor and materials, is not clear. Also, in the capital/labor elasticities ($G_{K,L}$), there seems to be a major shift in the case of the RIOCELL company. The significant estimates for $G_{K,L}$ have been primarily positive, but in the five-input case for RIOCELL, it shifts from positive and significant to negative and significant.

The only elasticity estimate which remains consistently positive across methods and firms is the labor/materials ($G_{L,M}$) elasticity. The substitutability between labor and materials seems unequivocally established in this study.

Comparing the results obtained here with those found in previous studies (Table 27), one can see that they are not very different. The labor/material elasticity has been found to be positive most of the time. The same applies to capital/materials and capital/ labor. But the results are not as consistent when the other elasticities estimated in this study are compared. From seven significant capital/materials ($G_{K,M}$) elasticities, only four are positive. From nine significant capital/labor ($G_{K,L}$) significant elasticities, only seven are positive.

The results in general are mixed and do not by themselves establish substitutability between inputs unambiguously. The study, however, does provide evidence that some assumptions underlying government policies in the energy sector are not warranted.

The tests required to check for the existence of cost and production functions (positivity and concavity) were performed. All the regressions satisfied the positivity requirement, but only the following regressions complied with the concavity requirements:[11]

RIOCELL - Production, 5 inputs

RIOCELL - Cost, 4 inputs

RIOCELL - Production, 4 inputs

PCC - Production, 6 inputs

PCC - Production, 4 inputs

All the test results for IKPC company were undefined. The test was also undefined for PCC company for the cost function with 4 and 6 inputs, and for RIOCELL company cost function with five inputs. This is reason enough for looking at the estimates from those regressions with care.

In the next chapter, the results will be further discussed and concluding comments presented.

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11. These tests are necessary to rule out negative costs and increasing returns to scale in the production function.

TABLE 1: IKPC
SURE PARAMETER ESTIMATES OF E, K, L, AND M - COST FUNCTION
JAN/82 to DEC/87 (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	R^2	F
(1) (S_E)	0.3040*	0.0980*	0.0767*	-0.1122*	-0.0630*	0.53	17.59
	(3.75)	(7.42)	(5.18)	(-14.40)	(-3.04)		
(2) (S_K)	0.1360*	0.0767*	-0.0948*	-4.0E-7	0.0180	0.27	9.92
	(20.17)	(5.18)	(-4.02)	(-0.05)	(0.62)		
(3) (S_L)	0.3060*	-0.1122*	-4.0E-7	0.1460*	-0.0338	0.61	39.05
	(78.87)	(-14.40)	(-0.05)	(12.34)	(-1.79)		
(4) (S_M)	0.2520*	-0.0640*	0.0180	-0.0330	0.0790*	0.37	8.03
	(42.62)	(-3.04)	(0.62)	(-1.79)	(4.20)		

i = E, K, L and M
* Significant at the 5 per unit level.

TABLE 2: PCC
SURE PARAMETER ESTIMATES OF E, K, L, AND M - COST FUNCTION
JAN/82 to DEC/87 (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	R^2	F
(1) (S_E)	0.3670*	0.2780*	-0.0090	-0.1540*	-0.1154*	0.89	125.55
	(4.15)	(30.14)	(-1.78)	(-14.58)	(-8.27)		
(2) (S_K)	0.0530*	-0.0090	-0.0025	-3.0E-6	0.0118*	0.02	1.61
	(26.44)	(-1.78)	(-0.49)	(-0.03)	(1.97)		
(3) (S_L)	0.4060*	-0.1540*	-3.0E-6	0.2048*	-0.0507*	0.75	73.67
	(108.75)	(-14.58)	(-0.03)	(15.10)	(-8.49)		
(4) (S_M)	0.1720*	-0.1155*	0.0118*	-0.0507*	0.1543*	0.78	44.00
	(71.90)	(-8.27)	(1.97)	(-8.49)	(18.78)		

i = E, K, L and M

* Significant at the 5 per unit level.

TABLE 3: RIOCELL
SURE PARAMETER ESTIMATES OF E, K, L, AND M - COST FUNCTION
JAN/82 to DEC/87 (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	R^2	F
(1) (S_E)	0.4720*	0.2240*	-0.1300*	-0.0434*	-0.0509	0.57	16.52
	(5.72)	(9.68)	(-4.96)	(-3.00)	(-1.55)		
(3) (S_K)	0.1470*	-0.1300*	0.2018*	-3.0E-7	-0.0716	0.33	10.73
	(6.13)	(-4.90)	(5.25)	(-0.03)	(-1.42)		
(2) (S_L)	0.1036*	-0.0434*	-3.0E-7	0.0480*	-0.0047	0.08	2.78
	(6.40)	(-3.00)	(-0.03)	(2.80)	(-0.17)		
(4) (S_M)	0.2770*	-0.0509	-0.0716	-0.0047	+0.1274*	0.09	2.04
	(16.90)	(-1.50)	(-1.42)	(-0.17)	(4.51)		

i = E, K, L and M
* Significant at the 5 per unit level.

TABLE 4: IKPC
SURE PARAMETER ESTIMATES OF E, K, L, AND M - PRODUCTION FUNCTION
JAN/82 to DEC/87 (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_E)	0.2820*	-0.0610	-0.0340*	0.0640*	0.0310	0.12	4.44
	(31.37)	(-1.21)	(-3.70)	(1.96)	(1.05)		
(2) (S_K)	0.1870*	-0.0340*	0.0700*	0.0027	-0.0387*	0.96	579.77
	(88.15)	(-3.70)	(23.88)	(0.31)	(-5.80)		
(3) (S_L)	0.3030*	0.0640*	0.0027	0.0241	-0.0910*	-0.03	0.22
	(36.51)	(1.96)	(0.31)	(0.72)	(-3.15)		
(4) (S_M)	0.2280*	0.0310	-0.0387	-0.0910	0.0980*	0.63	16.21
	(3.12)	(1.05)	(-5.80)	(-3.15)	(4.24)		

i = E, K, L and M
* Significant at the 5% level.

TABLE 5: PCC
SURE PARAMETER ESTIMATES OF E, K, L, AND M - PRODUCTION FUNCTION
JAN/82 to DEC/87 (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_E)	0.3090*	0.4690*	-0.0640*	-0.2170*	-0.1880*	0.58	34.41
	(31.20)	(9.67)	(-6.49)	(-5.13)	(-4.74)		
(2) (S_K)	0.0550*	-0.0640*	0.0814*	-0.0097	-0.0084*	0.69	55.51
	(27.67)	(-6.49)	(11.58)	(-0.97)	(-1.49)		
(3) (S_L)	0.4590*	-0.2170*	-0.0090	0.2170*	0.0090	0.26	9.49
	(44.98)	(-5.13)	(-0.97)	(4.51)	(0.21)		
(4) (S_M)	0.1770*	-0.1880*	-0.0080*	0.0090	0.1880*	0.51	10.36
	(2.11)	(-4.74)	(-1.49)	(0.21)	(10.70)		

i = E, K, L and M
* Significant at the 5% level.

TABLE 6: RIOCELL
SURE PARAMETER ESTIMATES OF E, K, L, AND M - PRODUCTION FUNCTION
JAN/82 to DEC/87** (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_E)	0.3770*	0.2130*	-0.1360*	-0.0124	-0.0650*	0.65	43.54
	(28.63)	(6.71)	(-10.79)	(-0.88)	(-4.49)		
(2) (S_K)	0.1860*	-0.1360*	0.2440*	-0.0350*	-0.0730*	0.93	325.66
	(27.18)	(-10.79)	(27.55)	(-5.42)	(-9.05)		
(3) (S_L)	0.2290*	-0.0124	-0.0350*	0.0670*	-0.0196*	0.47	21.25
	(24.74)	(-0.88)	(-5.42)	(7.28)	(-2.01)		
(4) (S_M)	0.2080*	-0.0650*	-0.0730*	-0.0196*	0.1576*	0.57	12.42
	(14.63)	(-4.49)	(-9.05)	(-2.01)	(18.21)		

i = E, K, L and M
** NOV/82, DEC/82, JAN/83, FEB/83 excluded from sample.
* Significant at the 5% level.

TABLE 7: IKPC
SURE PARAMETER ESTIMATES OF E1, E2, E3, K, L, AND M COST FUNCTION - ENERGY DISAGGREGATED JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E1}$	$\beta_{i,E2}$	$\beta_{i,E3}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_{E1})	0.1617*	0.2020*	-0.0858*	-0.0156*	-0.0235*	-0.0547*	-0.0226	0.64	27.34
		(35.04)	(12.22)	(-5.78)	(-2.05)	(-5.28)	(-6.46)	(-1.06)	
(2) (S_{E2})	0.0827*	-0.0858*	0.1193*	-0.0234*	0.0464*	-0.0297*	-0.0265*	-0.05	0.21
		(16.83)	(-5.78)	(7.53)	(-2.81)	(5.36)	(-3.94)	(-2.94)	
(3) (S_{E3})	0.0610*	-0.0156*	-0.0234*	0.0552*	0.0195*	-0.0235*	-0.0121*	0.51	16.33
		(22.70)	(-2.05)	(-2.81)	(7.58)	(3.40)	(-5.28)	(-2.20)	
(4) (S_K)	0.1330*	-0.0235*	0.0463*	0.0195*	-0.0354	0.0016	-0.0085	0.25	5.79
		(19.97)	(-5.28)	(5.36)	(3.40)	(-1.85)	(0.14)	(-0.28)	
(5) (S_L)	0.3070*	-0.0547*	-0.0297*	-0.0235*	0.0016	0.1386*	-0.0322	0.64	27.05
		(66.18)	(-6.46)	(-3.94)	(-5.28)	(0.14)	(11.78)	(-1.75)	
(6) (SM)	0.2530*	-0.0226	-0.0265	-0.0121	-0.0085	-0.0322	0.1020*	0.19	1.88
		(25.45)	(-1.06)	(-2.94)	(-2.20)	(-0.28)	(-1.75)	(3.13)	

i = E, K, L and M
* Significant at the 5% level.

TABLE 8: PCC
SURE PARAMETER ESTIMATES OF E_1, E_2, E_3, K, L, AND M COST FUNCTION - ENERGY DISAGGREGATED JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E1}$	$\beta_{i,E2}$	$\beta_{i,E3}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_{E1})	0.2730*	0.0710*	0.1470*	0.0100	0.0050	-0.1600*	-0.0720*	0.83	73.96
		(67.04)	(3.02)	(9.74)	(1.40)	(1.00)	(-12.33)	(-5.22)	
(2) (S_{E2})	0.0400*	0.1470*	-0.0219	-0.0177*	-0.0325*	-0.0226*	-0.0521*	0.04	1.71
		(11.92)	(9.74)	(-1.56)	(-3.15)	(-5.60)	(-2.31)	(-4.47)	
(3) (S_{E3})	0.0307*	0.0102	-0.0177*	0.0117	0.0101*	0.0052	-0.0195*	0.28	6.57
		(18.11)	(1.40)	(-3.15)	(1.84)	(2.33)	(1.00)	(-5.20)	
(4) (S_K)	0.0503*	0.0052	-0.0325*	0.0101*	0.0190*	-0.0281*	0.0261*	0.15	3.55
		(22.01)	(1.00)	(-5.60)	(2.33)	(2.69)	(-3.84)	(4.55)	
(5) (S_L)	0.4290*	-0.1600*	-0.0226*	0.0052	-0.0281*	0.2490*	-0.0435*	0.87	96.55
		(134.91)	(-12.33)	(-2.31)	(1.00)	(-3.82)	(19.09)	(-4.14)	
(6) (SM)	0.1770*	-0.0720*	-0.0521*	-0.0197*	0.0261*	-0.0435*	0.1612*	0.63	7.37
		( )	(-5.22)	(-4.47)	(-5.20)	(4.55)	(-4.14)	(17.08)	

i = E, K, L and M
* Significant at the 5% level.

TABLE 9: RIOCELL
SURE PARAMETER ESTIMATES OF E_1, E_2, K, L, AND M
COST FUNCTION - ENERGY DISAGGREGATED JAN/82 to DEC/87**
(Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E1}$	$\beta_{i,E2}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_{E1})	0.3140*	0.0420	0.0580*	0.0214	-0.0880*	-0.0329	0.29	7.91
		(21.44)	(1.08)	(2.14)	(0.71)	(-4.80)	(-1.16)	
(2) (S_{E2})	0.1530*	0.0580*	0.0617*	-0.1539*	0.0704*	-0.0362	0.15	4.08
		(12.06)	(2.14)	(2.46)	(-6.90)	(4.60)	(-1.56)	
(3) (S_K)	0.0810*	0.0214	-0.1539*	0.2106*	0.0069	-0.0850*	0.58	24.81
		(4.77)	(0.71)	(-6.90)	(5.41)	(0.32)	(-2.39)	
(4) (S_L)	0.1850*	-0.0880*	0.0704*	0.0069	0.0001	0.0115	0.39	12.02
		(16.93)	(-4.80)	(4.60)	(0.32)	(0.007)	(0.63)	
(5) (S_M)	0.2670*	-0.0329	-0.0362*	-0.0850*	0.0115	0.1426*	-0.09	0.56
		(2.06)	(-1.16)	(-1.56)	(-2.39)	(0.63)	(5.92)	

i = E, K, L and M
** NOV/82, DEC/82, JAN/83, FEB/83 excluded from sample.
* Significant at the 5% level.

TABLE 10: IKPC
SURE PARAMETER ESTIMATES OF E_1, E_2, E_3, K, L, AND M PRODUCTION FUNCTION - ENERGY DISAGGREGATED JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E1}$	$\beta_{i,E2}$	$\beta_{i,E3}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_{E1})	0.1390*	0.0430*	-0.0201*	-0.0258*	-0.0416*	0.0461*	-0.0022	0.06	1.98
		(17.16)	(2.04)	(-3.03)	(-2.26)	(-3.88)	(2.58)	(-0.08)	
(2) (S_{E2})	0.0673*	-0.02014*	0.0440*	-0.0091	-0.0083	0.0003	-0.0067	0.68	31.55
		(35.68)	(-3.03)	(6.32)	(-1.24)	(-0.91)	(0.045	(-1.35)	
(3) (S_{E3})	0.0640*	-0.0258*	-0.0091	0.0656*	-0.0149	-0.0417*	0.0260*	0.05	1.83
		(18.85)	(-2.26)	(-1.24)	(3.84)	(-0.98)	(-3.88)	(3.35)	
(4) (S_K)	0.1740*	-0.0416*	-0.0083	-0.0149	0.2770*	-0.0198	-0.1920*	0.83	72.00
		(45.96)	(-3.88)	(-0.91)	(-0.98)	(10.32)	(-0.98)	(-13.57)	
(5) (S_L)	0.3220*	0.0461*	0.0003	-0.0417*	-0.0198	0.0523	-0.0373	-0.07	0.05
		(35.82)	(2.58)	(0.04)	(-3.88)	(-0.98)	(1.90)	(-1.15)	
(6) (SM)	0.2319*	-0.0022	-0.0067	0.0260*	-0.1920*	-0.0373	0.2120*	0.43	3.87
		(2.52)	(-0.08)	(-1.35)	(3.35)	(-13.57)	(-1.15)	(7.74)	

i = E_1, E_2, E_3, K, L and M.
* Significant at 5% level.

TABLE 11: PCC
SURE PARAMETER ESTIMATES OF E_1, E_2, E_3, K, L, AND M
PRODUCTION FUNCTION - ENERGY DISAGGREGATED JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E1}$	$\beta_{i,E2}$	$\beta_{i,E3}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_{E1})	0.0400*	0.0428*	0.0352*	-0.0161*	-0.006*	-0.0470*	-0.0074	0.90	131.17
		(33.07)	(24.50)	(6.03)	(-8.48)	(-2.99)	(-7.10)	(-1.22)	
(2) (S_{E2})	0.2670*	0.0352*	0.5940*	-0.1850*	-0.0305*	-0.2740*	-0.1380*	0.71	36.81
		(45.72)	(6.03)	(16.91)	(-11.64)	(-3.14)	(-8.19)	(-4.50)	
(3) (S_{E3})	0.0191*	-0.0162*	-0.1857*	0.2350*	-0.0253*	-0.0067*	-0.0008	0.76	47.78
		(12.05)	(-8.48)	(-11.64)	(11.08)	(-4.49)	(-2.99)	(-0.22)	
(4) (S_K)	0.0532*	-0.0068*	-0.0305*	-0.0253*	0.0875*	0.0024	-0.0273*	0.69	33.49
		(29.96)	(-2.99)	(-3.14)	(-4.49)	(10.54)	(0.23)	(-4.81)	
(5) (S_L)	0.4560*	-0.0470*	-0.2740*	-0.0067*	0.0024	0.3130*	0.0135	0.50	15.47
		(65.62)	(-7.10)	(8.19)	(-2.99)	(0.24)	(7.26)	(0.39)	
(6) (S_M)	0.1632	-0.00736	-0.1380*	-0.0008	-0.0273*	0.0135	0.1599*	0.46	4.28
		(1.86)	(-1.22)	(-4.50)	(-0.22)	(-4.81)	(0.39)	(8.69)	

i = E_1, E_2, E_3, K, L and M.
* Significant at 5% level.

TABLE 12: RIOCELL
SURE PARAMETER ESTIMATES OF E_1, E_2, K, L, AND M
PRODUCTION FUNCTION - ENERGY DISAGGREGATED
JAN/82 to DEC/87** (Asymptotic t-ratios in parenthesis)

Equation	α_i	$\beta_{i,E1}$	$\beta_{i,E2}$	$\beta_{i,K}$	$\beta_{i,L}$	$\beta_{i,M}$	ADJ R^2	F
(1) (S_{E1})	0.3040*	0.1620*	-0.0380*	-0.0610*	-0.0134	-0.0480*	0.62	28.57
		(31.94)	(10.05)	(-4.54)	(-7.05)	(-1.36)	(-4.00)	
(2) (S_{E2})	0.0950*	-0.0380*	0.1130*	-0.0750*	0.0240*	-0.0243*	0.84	90.22
		(14.19)	(-4.54)	(12.93)	(-10.93)	(4.40)	(-4.19)	
(3) (S_K)	0.1880*	-0.0610*	-0.0750*	0.2590*	-0.0507*	-0.0721*	0.94	318.34
		(27.02)	(-7.05)	(-10.93)	(28.70)	(-8.08)	(-3.18)	
(4) (S_L)	0.2100*	-0.0134	0.0240*	-0.0507*	0.0600*	-0.0214	0.32	9.04
		(23.28)	(-1.36)	(4.40)	(-8.08)	(6.55)	(-1.93)	
(5) (SM)	0.2030*	-0.0480*	-0.0243*	-0.0721*	-0.0214	0.1658*	0.56	7.64
		(2.47)	(-4.00)	(-4.19)	(-3.18)	(-1.93)	(18.80)	

i = E_1, E_2, E_3, K, L and M.
* Significant at 5% level.
** NOV/82, DEC/82, JAN/83, FEB/83 excluded from sample.

TABLE 13: IKPC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
COST FUNCTION (E, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	MIN	MAX
σ_{EE}	-1.29 (-3.38)	1.54	-0.97
σ_{KK}	-21.88 (-3.15)	-44.22	-5.57
σ_{LL}	-0.67 (-1.83)	-0.71	-0.48
σ_{MM}	-1.58 (-3.77)	-2.15	-1.05
σ_{EK}	3.87 (3.43)	2.28	6.03
σ_{EL}	-0.23 (-1.52)	-0.61	0.07
σ_{EM}	0.15 (0.50)	-0.76	0.50
σ_{KL}	0.99 (3921.97)	0.99	0.99
σ_{KM}	1.67 (1.73)	1.37	2.18
σ_{LM}	0.61 (2.78)	0.42	0.73

* Significant at the 5% level.

TABLE 14: PCC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
COST FUNCTION (E, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	MIN	MAX
σ_{EE}	0.47 (0.55)	0.10	1.58
σ_{KK}	-20.19 (-10.29)	-38.76	-7.65
σ_{LL}	-0.18 (-0.52)	-0.22	-0.01
σ_{MM}	1.36 (0.54)	-0.48	5.08
σ_{EK}	0.49 (1.65)	0.06	0.76
σ_{EL}	-0.03 (-0.24)	-0.30	0.18
σ_{EM}	-1.07 (-2.56)	-1.89	-0.44
σ_{KL}	0.99 (238.69)	0.99	0.99
σ_{KM}	2.56 (2.92)	1.61	3.42
σ_{LM}	0.17 (0.74)	-0.51	0.52

* Significant at the 5% level.

TABLE 15: RIOCELL
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
COST FUNCTION (E, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	MIN	MAX
σ_{EE}	0.10 (0.14)	-0.11	1.36
σ_{KK}	34.48 (13.19)	-0.23	542.79
σ_{LL}	-3.45 (-2.83)	-4.20	-1.79
σ_{MM}	-0.82 (-0.90)	-17.07	-2.99
σ_{EK}	-1.61 (-3.31)	-15.34	-0.06
σ_{EL}	0.13 (0.41)	-0.22	0.66
σ_{EM}	0.35 (0.32)	-1.10	0.68
σ_{KL}	0.99 (3525.41)	0.99	0.99
σ_{KM}	-1.28 (-1.38)	-14.64	0.21
σ_{LM}	0.86 (1.18)	0.77	0.94

* Significant at the 5% level.

TABLE 16: IKPC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
PRODUCTION FUNCTION (E, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	AES	Estimate
$A_{E,E}$	-2.26* (-3.73)	$A_{E,L}$	0.63 (1.69)
$A_{K,K}$	-33.49* (-7.45)	$A_{E,M}$	-0.11 (-0.34)
$A_{L,L}$	-3.62* (-9.73)	$A_{K,L}$	-1.34* (-5.25)
$A_{M,M}$	-7.46* (-14.92)	$A_{K,M}$	9.73* (24.04)
$A_{E,K}$	4.75* (9.69)	$A_{L,M}$	3.62* (9.48)

* Significant at the 5% level.

TABLE 17: PCC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
PRODUCTION FUNCTION (E, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	AES	Estimate
$A_{E,E}$	0.31 (0.21)	$A_{E,L}$	1.63* (5.24)
$A_{K,K}$	26.22 (1.76)	$A_{E,M}$	-4.29* (-4.91)
$A_{L,L}$	-4.29* (-9.31)	$A_{K,L}$	2.48* (5.59)
$A_{M,M}$	-4.72* (-1.53)	$A_{K,M}$	-10.740* (-14.03)
$A_{E,K}$	-1.88 (-1.73)	$A_{L,M}$	7.30* (11.25)

* Significant at the 5% level.

TABLE 18: RIOCELL
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
PRODUCTION FUNCTION (E, K, L, AND M) JAN/82 to DEC/87**
(Asymptotic t-ratios in parenthesis)

AES	Estimate	AES	Estimate
$A_{E,E}$	-4.23* (-5.26)	$A_{E,L}$	2.17* (8.27)
$A_{K,K}$	8.23* (2.21)	$A_{E,M}$	9.93* (34.62)
$A_{L,L}$	-10.35* (-6.32)	$A_{K,L}$	-0.74* (-1.67)
$A_{M,M}$	-17.68* (-17.95)	$A_{K,M}$	-0.10* (-0.21)
$A_{E,K}$	-5.15* (-10.48)	$A_{L,M}$	4.19* (13.44)

** NOV/82, DEC/82, JAN/83, FEB/83 excluded from sample.
* Significant at the 5% level.

TABLE 19: IKPC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
COST FUNCTION DISAGGREGATED ENERGY INPUT
(E_1, E_2, E_3, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	MIN	MAX
$\sigma_{E1,E1}$	4.07 (1.03)	0.43	20.16
$\sigma_{E2,E2}$	31.92 (1.54)	8.38	89.05
$\sigma_{E3,E3}$	-1.77 (-0.50)	-3.41	3.93
$\sigma_{K,K}$	-13.98* (-4.87)	-26.24	-4.31
$\sigma_{L,L}$	-0.74* (-2.16)	-0.80	-0.55
$\sigma_{M,M}$	-1.24* (-2.06)	-1.45	-0.88
$\sigma_{E1,E2}$	-10.94* (-2.63)	-29.78	-4.33
$\sigma_{E1,E3}$	-0.52 (-0.66)	-2.53	0.15
$\sigma_{E1,K}$	-0.64 (-0.98)	-1.87	0.38
$\sigma_{E1,L}$	-0.13 (-0.50)	-0.80	0.28
$\sigma_{E1,M}$	0.43 (0.86)	-0.45	0.71
$\sigma_{E2,E3}$	-5.71* (-2.10)	-13.49	-2.49
$\sigma_{E2,K}$	11.18* (2.28)	3.99	19.56
$\sigma_{E2,L}$	-0.83 (-1.45)	-1.57	-0.20
$\sigma_{E2,M}$	-0.91 (-1.29)	-2.35	-0.19
$\sigma_{E3,K}$	3.85* (3.30)	2.37	5.93
$\sigma_{E3,L}$	-0.03 (-0.12)	-0.47	0.27
$\sigma_{E3,M}$	0.36 (1.13)	-0.12	0.62
$\sigma_{K,L}$	1.05* (3.26)	1.01	1.11
$\sigma_{K,M}$	0.68 (0.70)	0.45	0.82
$\sigma_{L,M}$	0.63* (3.02)	0.46	0.75

* Significant at the 5% level.

TABLE 20: PCC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
COST FUNCTION - ENERGY DISAGGREGATED
(E_1, E_2, E_3, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	MIN	MAX
$\sigma_{E1,E1}$	-1.74* (-3.03)	-2.51	-0.89
$\sigma_{E2,E2}$	-61.90* (-4.92)	-318.90	-10.14
$\sigma_{E3,E3}$	-17.29* (-0.37)	-20.35	-13.08
$\sigma_{K,K}$	-10.94* (-2.66)	-12.15	-6.10
$\sigma_{L,L}$	0.06 (0.17)	-0.004	0.51
$\sigma_{M,M}$	1.48 (0.60)	-0.36	5.66
$\sigma_{E1,E2}$	19.92* (2.73)	5.31	79.16
$\sigma_{E1,E3}$	2.11* (2.68)	1.61	3.20
$\sigma_{E1,K}$	1.37* (3.69)	1.20	1.75
$\sigma_{E1,L}$	-0.45 (-1.67)	-1.33	-0.09
$\sigma_{E1,M}$	-0.73 (-1.66)	-1.68	-0.20
$\sigma_{E2,E3}$	-14.67* (-2.09)	-45.16	-2.13
$\sigma_{E2,K}$	-18.96* (-2.18)	-55.19	-3.05
$\sigma_{E2,L}$	-0.59 (-0.81)	-3.60	0.47
$\sigma_{E2,M}$	-8.88* (-2.23)	-27.17	-1.45
$\sigma_{E3,K}$	6.82* (2.32)	3.29	13.98
$\sigma_{E3,L}$	1.36* (3.94)	1.20	1.78
$\sigma_{E3,M}$	-2.69 (-1.94)	-6.05	-0.62
$\sigma_{K,L}$	-0.31 (-0.68)	-1.26	0.42
$\sigma_{K,M}$	4.31* (3.48)	2.35	6.35
$\sigma_{L,M}$	0.32 (1.41)	-0.30	0.59

* Significant at the 5% level.

TABLE 21: RIOCELL
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
COST FUNCTION DISAGGREGATED ENERGY INPUT
(E_1, E_2, E_3, K, L, AND M) JAN/82 to DEC/87**
(Asymptotic t-ratios in parenthesis)

AES	Estimate	MIN	MAX
$\sigma_{E1,E1}$	-2.57* (-3.24)	-4.27	-0.99
$\sigma_{E2,E2}$	-2.45 (-0.62)	-3.05	4.03
$\sigma_{K,K}$	36.29* (11.10)	-0.18	568.79
$\sigma_{L,L}$	-5.85* (-8.13)	-9.59	-2.32
$\sigma_{M,M}$	-0.52 (-0.54)	-0.75	-2.96
$\sigma_{E1,E2}$	3.46* (2.51)	1.91	6.61
$\sigma_{E1,K}$	1.64* (3.05)	1.21	4.52
$\sigma_{E1,L}$	-1.64 (-1.60)	-3.38	0.11
$\sigma_{E1,M}$	0.36 (0.87)	-1.23	0.74
$\sigma_{E2,K}$	-10.60* (-4.48)	-135.54	-2.20
$\sigma_{E2,L}$	5.46* (2.65)	2.10	7.73
$\sigma_{E2,M}$	-0.47 (-0.48)	-3.21	0.51
$\sigma_{K,L}$	1.33* (2.33)	1.06	3.51
$\sigma_{K,M}$	-1.71* (-2.09)	-17.57	0.07
$\sigma_{L,M}$	1.33* (2.72)	1.12	1.56

** Nov/82, Dec/82, Jan/83, and Feb/83 excluded from the sample.
* Significant at the 5% level.

TABLE 22: IKPC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
PRODUCTION FUNCTION DISAGGREGATED ENERGY INPUT
(E_1, E_2, E_3, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	AES	Estimate
$A_{E1,E1}$	-13.71* (-14.97)	$A_{E2,E3}$	-44.50* (-22.13)
$A_{E2,E2}$	-197.26* (-29.80)	$A_{E2,K}$	-0.90 (-0.51)
$A_{E3,E3}$	54.04* (11.39)	$A_{E2,L}$	17.13* (37.83)
$A_{K,K}$	3.49 (0.20)	$A_{E2,M}$	-1.76* (-5.14)
$A_{L,L}$	-0.62 (-2.44)	$A_{E3,K}$	9.04* (4.53)
$A_{M,M}$	-1.69 (-2.09)	$A_{E3,L}$	-10.84* (-21.64)
$A_{E1,E2}$	54.47* (60.60)	$A_{E3,M}$	9.64* (19.09)
$A_{E1,E3}$	-11.06* (-10.24)	$A_{K,L}$	-0.52 (-0.89)
$A_{E1,K}$	-2.01 (-1.91)	$A_{K,M}$	-1.77 (-1.11)
$A_{E1,L}$	0.73 (2.06)	$A_{L,M}$	0.12 (0.35)
$A_{E1,M}$	0.22 (0.36)		

* Significant at 5% level.

TABLE 23: PCC
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
PRODUCTION FUNCTION - DISAGGREGATED ENERGY INPUT
(E_1, E_2, E_3, K, L, AND M) JAN/82 to DEC/87
(Asymptotic t-ratios in parenthesis)

AES	Estimate	AES	Estimate
$A_{E1,E1}$	-251.26* (-11.37)	$A_{E2,E3}$	1.02 (0.17)
$A_{E2,E2}$	-1.96 (-0.55)	$A_{E2,K}$	5.89* (6.82)
$A_{E3,E3}$	5.84 (0.06)	$A_{E2,L}$	-3.82* (-8.18)
$A_{K,K}$	-1.89 (-0.11)	$A_{E2,M}$	2.98* (3.74)
$A_{L,L}$	-7.92* (-13.51)	$A_{E3,K}$	0.32 (0.05)
$A_{M,M}$	-19.68* (-7.43)	$A_{E3,L}$	0.33 (1.72)
$A_{E1,E2}$	29.70* (17.40)	$A_{E3,M}$	-4.22* (-0.60)
$A_{E1,E3}$	0.02 (0.004)	$A_{K,L}$	13.26* (27.75)
$A_{E1,K}$	-62.67* (-30.34)	AK,M	-27.21* (-10.88)
$A_{E1,L}$	32.13* (25.63)	$A_{L,M}$	14.22* (33.81)
$A_{E1,M}$	-46.40* (-53.60)		

* Significant at 5% level.

TABLE 24: RIOCELL
SURE ESTIMATED ALLEN ELASTICITIES OF SUBSTITUTION. (AES)
PRODUCTION FUNCTION - DISAGGREGATED ENERGY INPUT
(E_1, E_2, E_3, K, L, AND M) JAN/82 to DEC/87**
(Asymptotic t-ratios in parenthesis)

AES	Estimate	AES	Estimate
$A_{E1,E1}$	-87.86* (-55.86)	$A_{E1,L}$	18.49* (62.19)
$A_{E2,E2}$	-152.86* (-23.33)	$A_{E1,M}$	-29.48* (-84.08)
$A_{K,K}$	-34.48* (-8.70)	$A_{E2,K}$	-82.53* (-73.22)
$A_{L,L}$	-12.84* (-8.61)	$A_{E2,L}$	-23.37* (-31.76)
$A_{M,M}$	-47.61* (-45.79)	$A_{E2,M}$	69.44 (157.83)
$A_{E1,E2}$	103.98* (141.04)	$A_{K,L}$	-15.60* (-25.84)
$A_{K,M}$	31.96* (52.51)	$A_{L,M}$	16.97* (48.25)
$A_{E1,K}$	53.55* (131.69)		

** NOV/82 to FEB/82 excluded from sample.
* Significant at 5% level.

TABLE 25: SUMMARY - FOUR INPUTS (E, K, L, AND M)
Summary of Allen Elasticities from the Cost and Production Functions IKPC, PCC, RIOCELL

Elasticity	Cost			Production		
	IKPC	PCC	RIOCELL	IKPC	PCC	RIOCELL
$G_{E,E}$	-1.29*	0.47	0.10	-2.26*	0.31	-4.23*
$G_{K,K}$	-21.88*	-20.19*	34.48*	-33.49*	26.23	8.23*
$G_{L,L}$	-0.67	-0.18	-3.45*	-3.62*	-4.30*	-10.35*
$G_{M,M}$	-1.58*	1.36	-0.82	-7.46*	-4.72*	-17.68*
$G_{E,K}$	3.87*	0.49	-1.61*	4.75*	-1.88	-5.15*
$G_{E,L}$	-0.23	-0.03	0.13	0.63	1.63*	2.17*
$G_{E,M}$	0.15	-1.07*	0.35	-0.11	-4.30*	9.93*
$G_{K,L}$	0.99*	0.99*	0.99*	-1.34*	2.48*	-0.74
$G_{K,M}$	1.67	2.56*	-1.28	9.73*	-10.75*	-0.10
$G_{L,M}$	0.61*	0.17	0.86	3.63*	7.31*	4.19*

TABLE 26: SUMMARY - SIX INPUTS (E_1, E_2, E_3, K, L, AND M)**
Allen Elasticities from the Cost and Production Functions
IKPC, PCC, RIOCELL

Elasticity	Cost			Production		
	IKPC	PCC	RIOCELL	IKPC	PCC	RIOCELL
$G_{E1,E1}$	4.07	-1.74*	-2.57*	-13.71*	-251.26*	-87.87*
$G_{E2,E2}$	31.92	-61.90*	-2.45	-197.26*	-1.96	-152.87*
$G_{E3,E3}$	-1.77	-17.29	-	54.04*	5.84	-
$G_{K,K}$	-13.98*	-10.94*	36.29*	3.49	-1.89	-34.49*
$G_{L,L}$	-0.74*	0.06	-5.85*	-0.62*	-7.92*	-12.84*
$G_{M,M}$	-1.24*	1.47	-0.52	-1.69	-19.68*	-47.61*
$G_{E1,E2}$	-10.94*	19.97*	3.46*	54.47*	29.70*	103.98*
$G_{E1,E3}$	-0.52	2.11*	-	-11.06*	0.02	-
$G_{E1,K}$	-0.64	1.37*	1.64*	-2.01	-62.67*	53.55*
$G_{E1,L}$	-0.13	-0.45	-1.64	0.79	32.13*	18.49*
$G_{E1,M}$	0.43	-0.73	0.36	0.22	-46.40*	-29.49*
$G_{E2,E3}$	-5.71*	-14.67*	-	-44.50*	1.02	-
$G_{E2,K}$	11.18*	-18.96*	-10.60*	-0.90	5.89*	-82.53*
$G_{E2,L}$	-0.83	-0.59	5.46*	17.13*	-3.82*	-23.37*
$G_{E2,M}$	-0.91	-8.88*	-0.47	-1.76*	2.98*	69.44*
$G_{E3,K}$	3.85*	6.82*	-	9.04*	0.32	-
$G_{E3,L}$	-0.03	1.36*	-	-10.84*	0.33	-
$G_{E3,M}$	0.36	-2.69*	-	9.64*	-4.22*	-
$G_{K,L}$	1.05*	-0.31	1.33*	-0.52	13.26*	-15.60*
$G_{K,M}$	0.68	4.31*	-1.71*	-1.77	-27.21*	31.96*
$G_{L,M}$	0.63*	0.32	1.33*	0.12	14.22*	16.97*

** For RIOCELL E_3 was dropped because it was negligible.
* Significant at 5% level.

Table 27
Elasticities of Substitution Reported in the Literature

Elasticity	Charles Struckmeyer Standard Translog A	Charles Struckmeyer Standard Translog B	Charles Struckmeyer Putty Clay A	Charles Struckmeyer Putty Clay B	Berndt & Wood	Brown & Christen	Gregory & Griffin Belgim	Gregory & Griffin Denmark	Gregory & Griffin France	Gregory & Griffin W.Germany	Gregory & Griffin Italy	Gregory & Griffin Netherlands	Gregory & Griffin Norway	Gregory & Griffin UK	Gregory & Griffin US	Alden Toevs Industries 2011	Alden Toevs Industries 202	Alden Toevs Industries 2041-43	Alden Toevs Industries 2911	Alden Toevs Industries 3241	Alden Toevs Industries 3275	Alden Toevs Industries 3333
σ_{EE}	0.77	-3.30	-48.06	-47.66	-10.67																	
σ_{KK}	-2.17	-1.79	-7.99	-8.22	-8.77	-0.05										-16.73	-2.16	0.18	1.70	-0.70	-0,69	145.91
σ_{LL}	-0.72	-0.31	-3.66	-3.55	-1.66	-0.65										-29.14	11.80	-10.91	25.03	-2.85	-3.35	81.47
σ_{MM}	-0.24	-0.30	-0.49	-0.60	-0.36	-0.19										-0.35	-0.82	0.14	0.04	-9.84	-14.82	35.18
σ_{EK}	-0.23	-0.12	2.03	2.54	-3.24		1.02	1.04	1.05	1.03	1.03	1.02	1.02	1.04	1.07							
σ_{EL}	0.30	0.02	0.30	-0.11	0.64		0.87	0.72	0.82	0.78	0.85	0.86	0.86	0.84	0.87							
σ_{EM}	-0.08	0.11	0.75	0.93	0.75																	
σ_{KL}	-0.41	-0.69	2.27	2.62	1.01	0.35	0.39	0.52	0.41	0.50	0.43	0.41	0.40	0.39	0.06	6.51	1.91	3.09	-9.15	0.74	0.75	112.92
σ_{KM}	0.59	0.72	0.67	0.67	0.54	0.05										0.59	0.24	-0.55	0.71	1.56	1.67	-72.16
σ_{LM}	0.34	0.29	0.91	0.95	0.59	1.25										2.75	2.61	0.47	-1.34	1.87	3.37	54.11

CHAPTER 5

COMMENTS AND CONCLUSION

One important implication here is that policy-makers cannot, in general, rely only on estimated elasticities as a point of departure for macroeconomic policies.[1] Those estimates can at best provide some guidance for sector-specific policy-making. Elasticities vary from firm to firm even when they belong to the same industry. A wide spectrum of input mixes is available to firms in spite of the fact that in many cases the core technology is the same. The realm of feasible input mixes widens with the degree of integration of the firms. Firms with a high degree of integration in their activities have more options in the combination of inputs. This will become clear as the structure of the activities in the firm is further explained.

The production function being studied here is ex-post in nature. The core equipment is in place, and this means that the process cannot be fundamentally changed. In

1. Macroeconomic policies generally assume elasticities are in the extremes (0 or ∞), or 1. If the true elasticities were known, they could provide some guidance to policy making. Since we are not positive about the range of elasticities, other parameters must be also used.

economics jargon, it is a putty-clay technology meaning that ex-ante the inputs are substitutable, but ex-post they are fixed. This study refers to actual data of production, which means that the technology has been chosen. The option of choosing an alternative production technique is not being considered. In highly integrated firms, however, even when the core technology is in place, input mix can be changed significantly. To illustrate the point, the paper industry itself can be used as an example.

The paper industry is very integrated vertically. The production process starts with a natural resource (trees) and ends with the manufactured product ready for consumption (paper). The basic output can be further transformed into more elaborate products like specialty papers, packaging, and cardboards among others. The major transformation, however, occurs within the paper mill.

Even if the paper machine, the single most important piece of equipment in the firm, is chosen to represent the technology being used, there remains room for change in the associated activities. The firm has different ways of performing several activities such as:

1. The transport of the pulverized wood from the grinding unit to the cooking/digesting unit which can be done by trucks or by conveyor belts.

2. The wood segments can be transported from the storage path to the grinding unit by trucks or by conveyor belts.

3. Tree branches may be left in the forest as fertilizer, or used as fuel.

4. The digesting process can be done through chemical or heating processes.

5. The residues of chemical decomposition can be treated and used as a fuel, or released into the environment.

6. Electric power can be generated internally or purchased from public utilities.

7. The wood/chemical residues may go through a process of secondary recovery from which additional paper fiber could be generated.

8. A variety of fuels may be chosen to generate steam: coal, fuel oil, firewood, black liquor, wood residues, tall oil, diesel, and gas.

The above illustrates the fact that even when the core technology is the same, several jobs can be done differently. Depending on how these tasks are performed, a different input mix will emerge.

Because of the ex-post nature of the production function being studied, the capital productivity is not captured in the estimation process. Except for the RIOCELL company, no major addition of equipment was made in the period studied. The addition of one paper machine, for example, would produce a sharp increase in the output. Major increases in the output are not possible with only changes in how some tasks are performed. The latter is rather associated with input substitution. The addition of a secondary recovery process would increase the use of capital, and reduce the input of raw material (wood). This is shown by the estimated AES for the IKPC company whose major changes were the installation of a recovery boiler and a biomass plant. The capital/materials ($G_{K,M}$) elasticity is positive in the cost and the production functions, indicating substitutability between capital and materials. The $G_{K,M}$ for the RIOCELL and PCC companies is ambiguous. The labor/materials ($G_{L,M}$) elasticity is positive throughout the methods, indicating easy substitution between labor and materials. The above elasticities indicate that substitution of inputs is possible even in an ex-post production function. The putty-clay characterization of technology is not appropriate in cases of highly integrated activities.

A general pattern of input substitution cannot be established. The paper industry operates with long time horizons, adjusting slower to economic changes than any other industry. Equipment has a life span of more than 20 years, and major equipment substitutions have to be planned years ahead. The paper industry is an excellent representation of an industry in which input substitution is difficult and slow. The present study encompasses only five years; a short span for analysis of the industry. Studies of less capital and energy intensive industries may find more substitutability between energy and capital, as well as among other inputs.

There are a number of discrepancies between the methods of estimating demand functions originating from cost and production functions. These might be an indication of problems with the method, and/or problems with the data. The number of inconsistencies, however, is rather small considering the number of parameters estimated; especially when one considers that the translog cost and production functions are not duals of one another.

Estimating of elasticities of substitution from demand functions based on production and cost functions is an attempt to measure how much the use of one input is affected by the price of other inputs. This in turn should facilitate the development of more accurate predictions of demand for inputs. Energy demand forecasts based on energy consumption as a fixed proportion of output (E/Y)[2] have not fared well because they do not take into account substitutability among inputs. In this regard, econometric studies undertaken in the past several years provide some guidance about energy-capital substitutability possibilities. The studies have also provided consistent estimates of capital/labor substitutability, and similar measures of the effects on demand of changes in input own prices.

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2. E = energy, Y = output.

The controversy about energy and capital substitutability has been going on for about 13 years. Many studies have tried to establish substitutability in the aggregate for the whole manufacturing industry, for specific sectors, or industries. The studies do not produce unambiguous estimates of energy-capital substitutability.

The recent argument by John Solow that estimating production and cost functions with aggregate data may be invalid, must be taken into account. That is one of the reasons why this study focuses primarily at the micro level; another reason is the difficulty of obtaining data in LICs at the macro or industry level. However, the ambiguity observed in aggregate level studies remains at the micro level. While it is evident that demand is responsive to price changes, the substitutability between energy and capital could not be unambiguously established in the sample.

The estimation of production and cost functions is sensitive to the level of disaggregation. Highly disaggregated models make studies more interesting because there is a clearer distinction between substitutes, and the method is more precise. But computation costs may increase significantly. In this study, for example, if energy in Group 2 were disaggregated into coal and fuel oil, the elasticities would have been evaluated differently because fuel oil is heavily substituted for coal in this industry. Once these two fuels are aggregated, the process of substitution is not captured. Furthermore, elasticities calculated from the disaggregated cost function (6 inputs) are not comparable to elasticities found in the cost function (4 inputs) for those inputs which remain unchanged. Changes in elasticities should be analyzed longitudinally, that is, how they change in time instead of how they change across aggregations. Each elasticity bear a relationship with the others, and disaggregation into more inputs generate conceptually different elasticities.

Energy groups are physical substitutes. This can be seen in Figures 2, 3, and 4, for the IKPC, PCC and RIOCELL companies. The installation of a new coal burning boiler in the RIOCELL company explains the sharp increase in the consumption of fossil fuels. The elasticities being calculated in this study measure these relative changes in energy consumption against changes in relative prices. The pattern of physical substitution should provide an idea of the trend in relative price changes. There are situations, however, in which this is not the case, as explained below.

Since investment in IKPC and PCC companies was very low in the past years, there was not much potential for energy/capital substitution. The investment made in the RIOCELL company was not related to a technological improvement, but rather to the addition of a whitening facility. Before 1983, RIOCELL produced only natural paper. In other words, there was a change in the output mix in this company in 1983.

FIGURE 2: IKPC
ENERGY/OUTPUT RELATIONSHIP
JANUARY, 1982 THROUGH DECEMBER, 1987

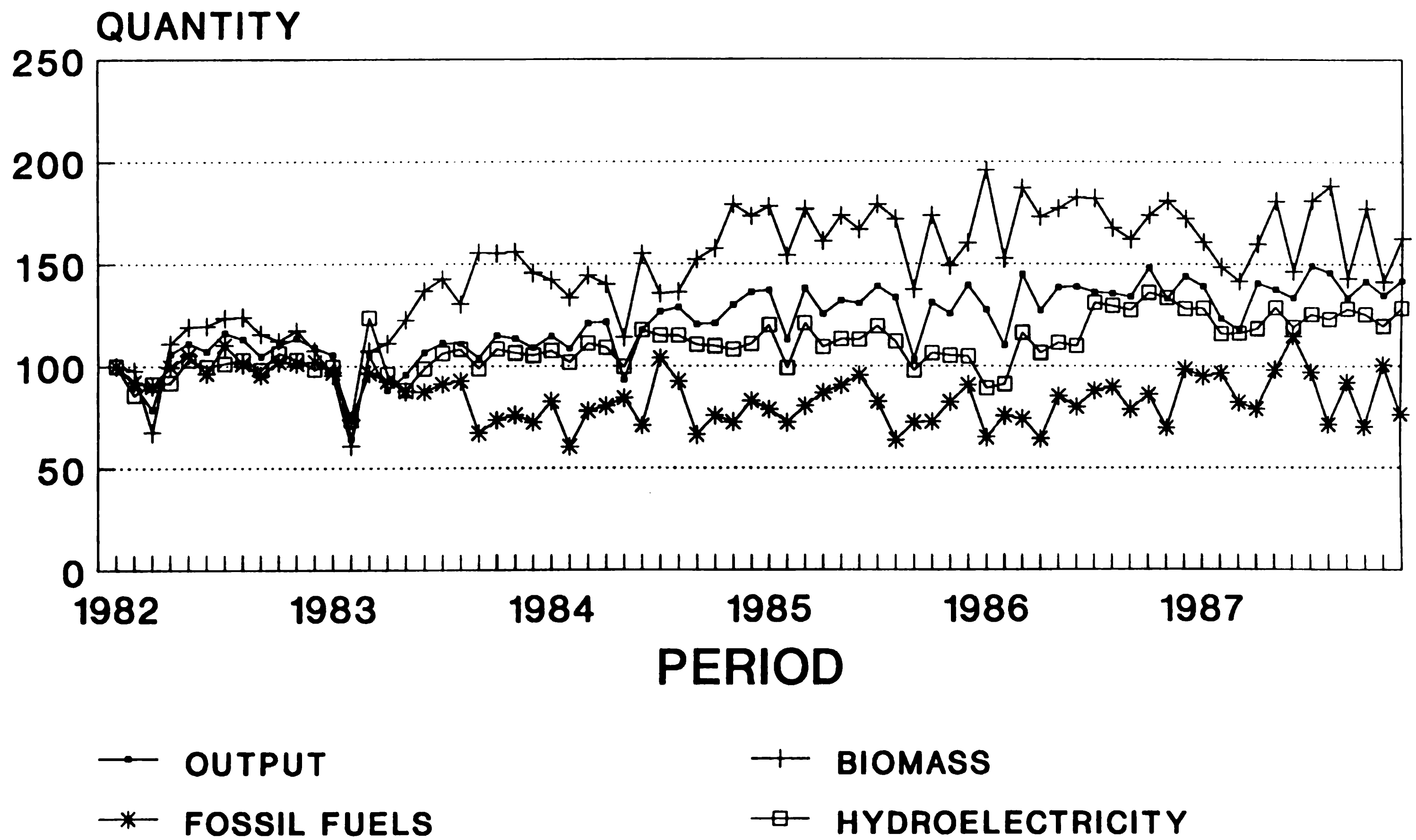


FIGURE 3: PCC

ENERGY/OUTPUT RELATIONSHIP

JANUARY, 1982 THROUGH DECEMBER, 1987

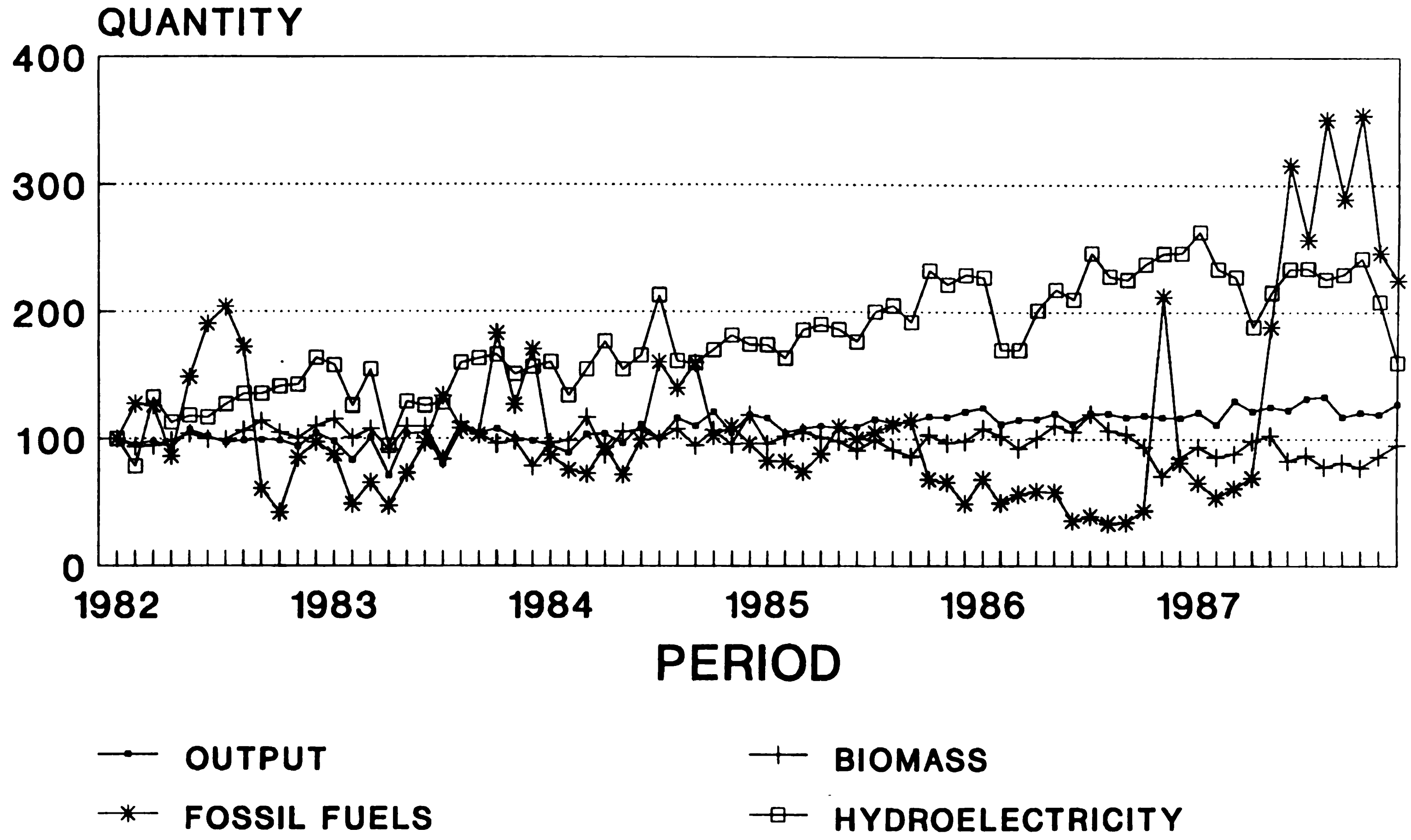
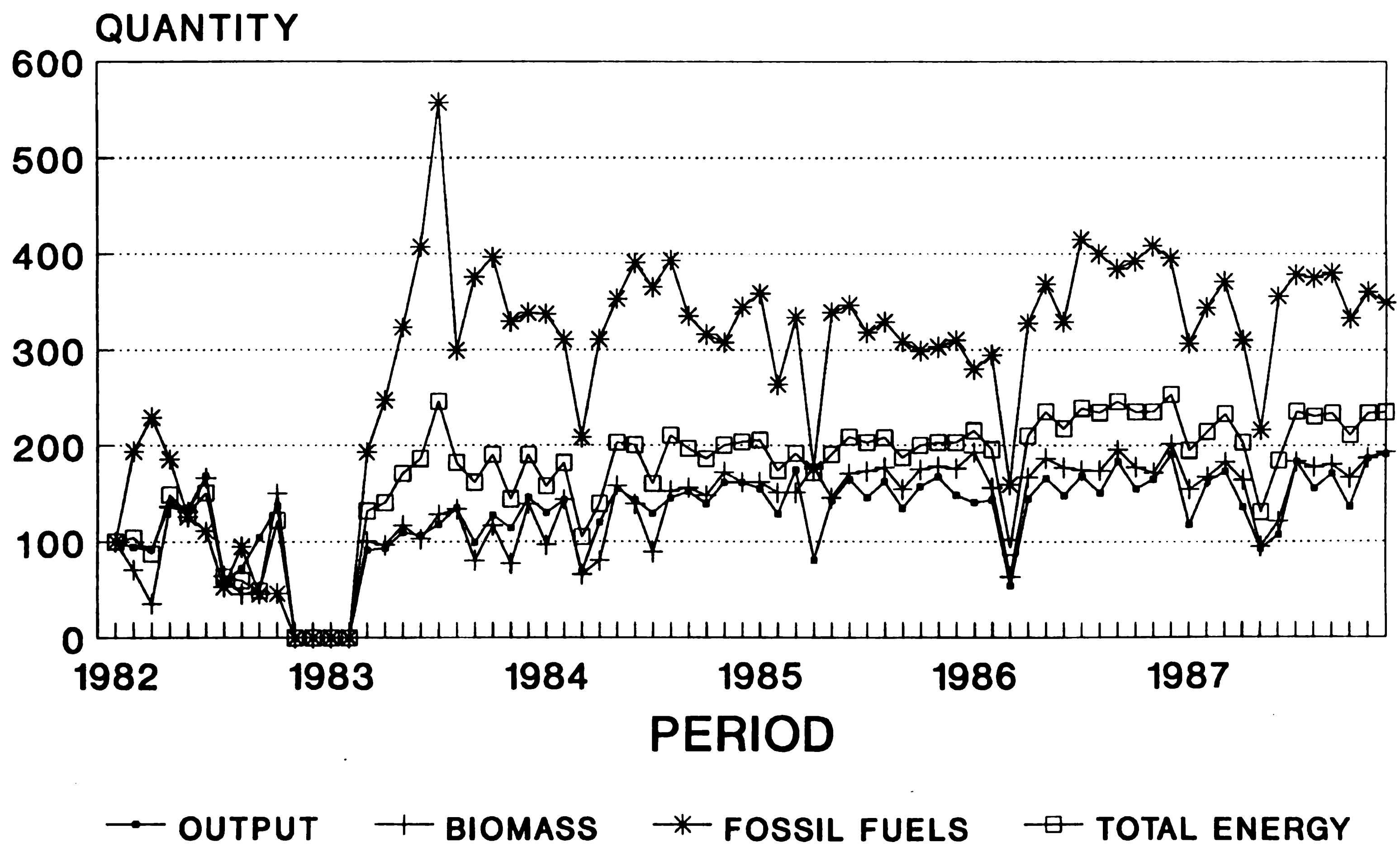


FIGURE 4: RIOCELL
ENERGY/OUTPUT RELATIONSHIP
JANUARY, 1982 THROUGH DECEMBER, 1987



In order to take advantage of the exceptionally good market conditions for paper in the last few years, the Klabin group has chosen to acquire existing firms. They reorganize them to conform with the management style of the holding company which tries to achieve higher input productivity.[3] As a major paper producer, the Klabin group has no problem in marketing its products. It has a significant market share within the country and it has expanded considerably in foreign markets in recent years. Its production capacity has reached its limit and it still has the potential to capture more markets. That is why it makes sense to acquire other firms. Investment in new equipment might take several years to be transformed into increased production. By then, market conditions may not be as good. This strategy allows the group to take immediate advantage of increased demand and higher paper prices. This strategy also affects the composition of factors within the firm, as new externally acquired capacity is not reflected in the firm's production. Instead capital is being diverted from the internal operations of one firm to the other. To have a better picture, the whole group should be analyzed as

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3. Those are smaller firms, and they are in such a situation because they could not compete effectively in international markets when the country entered into the recent crisis. As the internal market shrunk because of the crisis, they found themselves in an increasingly weak position. Those firms which could compete effectively in foreign markets gained strength and are now in a position to acquire the smaller. The smaller ones have neither the structure nor the organization to venture into foreign markets.

one producing unit. But in this case, there would be no homogeneity in the output. The estimation process would also be running into the problem of changing output mixes pointed out by Solow.[4]

As previously mentioned, some of the estimated functions do not comply with concavity requirements. This may cast some doubts on the estimates of those functions. This situation indicates that the method needs to be perfected. The data should not be forced to fit into an existing model. Rather, the model should be broad enough to explain the dynamics contained in the data. The data should not be made to conform with a concave function if in reality the function is non-concave. The method is not appropriate in such cases because it cannot explain the behavior of the variables.

In several occasions, the behavior of the firms do not conform to the theory. Thus, the analysis must be complemented in order to provide a better understanding of why this is the case. Following are some explanations for non-concavity of some functions; and each one will be further explained later:

1. Late reaction to higher oil prices due to lags in the firms adjustment process.
2. The market price of oil does not reflect the true cost of using oil.

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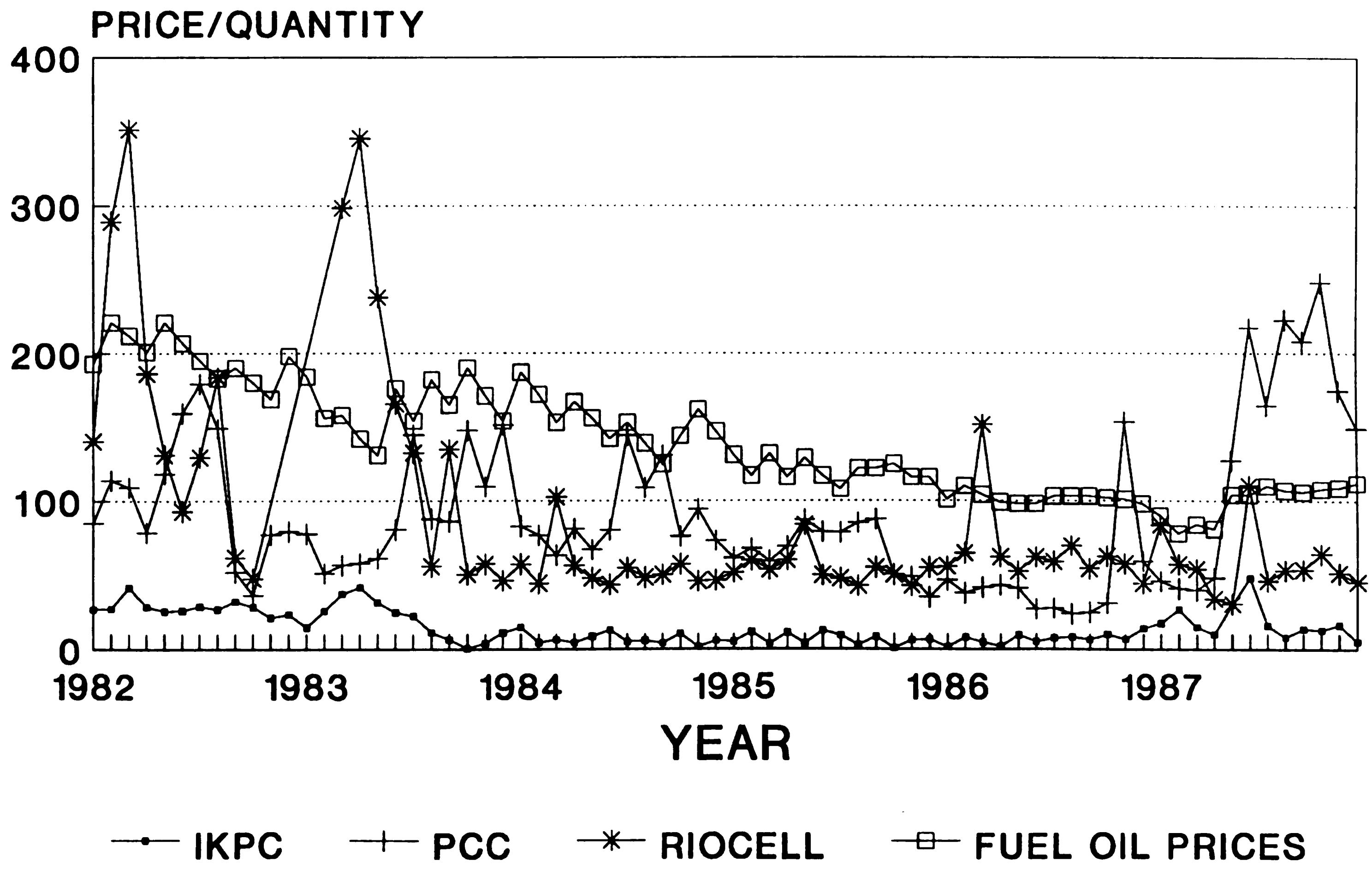
4. Solow, op.cit., 1987.

3. Technological change takes a long time to implement. It is not induced by short-term price fluctuations but, rather, the long-run trend in relative factor prices.
4. Increased local demand for biomass and coal pushed up their relative prices.
5. Presence of increasing returns to scale in the production functions.

The late reaction to oil price increases may be explained by the firms' continued effort to substitute oil for other energy sources, even when oil prices were going down. This can be seen in Figure 5 for the IKPC company which shows decline in the use of oil at the same time that oil prices were declining. This happens because the affected companies could not do much in the short-run. They took measures to substitute oil, but these measures take several years to be operationalized. When the changes began to be operational, oil prices started to go down. Thus, adjustment lags explain why substitution happened in a period when it was not justifiable economically.

An alternative explanation is that entrepreneurs were adjusting the prices of oil by an uncertainty premium. The supply of oil has greater probability of being disrupted in Brazil than in other countries because of the debt crisis. Firms were taking this risk into consideration when they decided to substitute oil for biomass. Oil prices were being adjusted by an additional risk premium.

FIGURE 5: FUEL OIL USE AND PRICES
IKPC, PCC, AND RIOCELL



Kilogram of fuel oil per ton of paper

A paper machine may remain in use for about 30 years. This may explain the slow reaction of this industry to sharp input price fluctuations. Decisions to change technology take several years to be implemented. By the time the new equipment starts to affect production, conditions may have changed. This happened to some degree in the decision to substitute fuel oil.

The fact that many industries were looking for domestic sources of energy may have pushed up the prices of local inputs since increased demand for any input drives prices up. More biomass was being used by the companies in a period when biomass prices were going up; less fuel oil was being used at a time when oil prices were going down. This behavior goes against the core of neoclassical economic theory, but it can still be rationally explained.

The results may be further distorted because the firms may be operating in a range of increasing returns to scale. Estimation of a simple Cobb-Douglas production function with four inputs (K, L, E, and M) using non-linear least squares as expressed by the formula:

$$Y = AE^{\alpha}K^{\beta}L^{\tau}M^{\delta}$$

where:

Y = output

E = energy

K = capital

L = labor

M = materials;

with aggregated data for the three firms results in the following parameter:

$$A = 0.16$$

$$\alpha = 0.60^{*}$$

$$\beta = 0.05^{**}$$

$$\tau = 0.29^{*}$$

$$\Phi = 0.45^{*}$$

where:

* = significant at the 1 percent level,

** = significant at the 5 percent level, and

*** = significant at the 10 percent level.

The four marginal products sum to 1.39, indicating the presence of increasing returns to scale.[5] The input with the highest marginal product is energy, followed by materials and labor. The input with the lowest marginal product is capital. This is explained by the ex-post nature of the production function. The machinery is already installed and operating with little room for changes in the technology. But this is not saying that the input mix cannot be changed.

Estimation of the Cobb-Douglas function in its linearized form:

$$\ln Y = \ln A + \alpha \ln E + \beta \ln K + \tau \ln L + \Phi \ln M$$

yields results similar to the non-linear form:

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5. If the sum of the marginal products is more than one, that means increasing returns to scale. If they sum to one, it represents constant returns to scale, and if they sum less than one, the firm is in a range of decreasing returns to scale.

$$\ln A = -2.35^{*}$$

$$\alpha = 0.59^{*}$$

$$\beta = 0.06^{**}$$

$$\tau = 0.36^{*}$$

$$\Phi = 0.48^{*}$$

The presence of increasing returns to scale is confirmed by the sum of marginal products (1.49).

If energy is disaggregated into biomass (E_1), oil derivates (E_2), hydroelectricity (E_3), and coal (E_4), the production function becomes:

$$\ln Y = \ln A + \alpha_1 \ln E_1 + \alpha_2 \ln E_2 + \alpha_3 \ln E_3 + \alpha_4 \ln E_4 + \beta \ln K + \tau \ln L + \Phi \ln M$$

and the estimates are:

$$\ln A = -2.09^{**}$$

$$\alpha_1 = 0.37^{*}$$

$$\alpha_2 = 0.02$$

$$\alpha_3 = 0.13^{***}$$

$$\alpha_4 = 0.04$$

$$\beta = 0.06^{**}$$

$$\tau = 0.33^{*}$$

$$\Phi = 0.47^{*}$$

In such a case, materials become the input with the higher marginal product. Again, the sum of marginal products is higher than one (1.42). In an <u>ex-ante</u> production function, the marginal product of capital is likely to increase considerably.

One reason why the firms are exhibiting increasing returns to scale may be the fact that the managers are making a great effort to increase labor productivity. All three firms have been increasing labor productivity over the past years, as shown in Table 28.

Table 28
Input Productivity. Aggregated Data
(IKPC, PCC and RIOCELL)
1982-1987

	Labor*	Capital**	Materials***	Energy+
1982	6.66	0.021	0.210	1.31
1983	7.49	0.025	0.189	1.13
1984	10.29	0.031	0.193	1.26
1985	10.88	0.033	0.191	1.26
1986	10.99	0.030	0.189	1.24
1987	11.13	0.026	0.193	1.28

* Tons of paper per worker.
** Tons of paper per dollars.
*** Tons of paper for ton of materials.
\+ Tons of paper per ton of oil equivalent (TOE).

Energy efficiency declined slightly from 1982 to 1987. The efficiency of materials declined from 1982 to 1983, and remained roughly constant for the remaining years. Capital productivity increased over the period. The increases in productivity of labor combined with increasing capital productivity, and roughly unchanging productivity of the other factors, explain why the Cobb-Douglas production function captures increasing returns to scale in the data. Average product per worker has been increasing over the years. This means that marginal product has been on the rise, and wage rates should have risen. According to economic theory, firms pay workers their marginal product. This is the case for the aggregated data (all three firms), as shown in Table 29, in spite of not being the case when each firm is analyzed individually.

Table 29
Wage Rate
Average Cost Per Worker
JANUARY, 1982 Dollars

Year	Cost
1982	$654.50
1983	$633.85
1984	$635.48
1985	$664.63
1986	$703.42
1987	$710.42

A competing explanation for the inconsistency between the disaggregated and aggregated data is provided by organization theory. Any organization tends to deteriorate over time. People tend to do things in the way in which they are accustomed, they tend to resist change, and they tend to not accept new assignments which are interpreted as an increase in the amount of work they have to do. In order to take care of new tasks, the organization tends to hire new people. Over time, the organization becomes inefficient because there is duplication of effort, lack of coordination, and conflicts over authority. In order to remedy this, reorganization is necessary from time to time to increase efficiency. In these reorganizations, many duplicated tasks and tasks which are no longer necessary are eliminated. In such situations, jobs are cut and workers are reassigned. The paper firms in this study are in the process of reorganization.

In the more capital intensive firms, labor productivity should be higher because each employee has more machinery available with which to work. This is found to be the case in the firms studied, as shown in Table 30. The Riocell company is the most capital intensive, followed by IKPC and PCC companies.

TABLE 30

LABOR PRODUCTIVITY
(Tons per worker)
1982-1987

YEAR	IKPC	PCC	RIOCELL
1982	6.71	3.68	11.16
1983	7.15	3.92	16.54
1984	9.19	5.11	20.61
1985	9.73	5.34	22.14
1986	10.44	5.42	18.22
1987	10.8	5.53	17.45

Accordingly, the wage rate should be higher in the firms where labor productivity is higher. This is not the case, as shown in Table 31. Starting in 1983, relative wages in the RIOCELL and PCC companies reflect their relative capital intensity, but IKPC company is still out of line. The explanation for this may be due to the labor market since the companies are located in different regions. The headquarters of the IKPC company is located in the more competitive labor market of São Paulo. Furthermore, overhead, which should be part of a separate holding company is part of the IKPC payroll. This pushes the average wage up because overhead salaries are above average.

TABLE 31

WAGE RATE
AVERAGE COST PER WORKER
(January, 1982 Dollars)

YEAR	PCC	RIOCELL	IKPC
1982	726	503	820
1983	498	597	671
1984	442	510	585
1985	461	602	617
1986	569	639	759
1987	588	723	748

The method used in this study does not capture the dynamics of the data. Thus, the search for new methods to explain the mechanism of adjustment among inputs and prices must continue. The estimation of energy demand through the use of production and cost functions represents, however, an improvement over estimates based on energy consumption as a fixed ratio of output. It has been shown that energy demand is responsive to price changes, and fitted demand equations predict future energy demand quite well. This is shown in Figures 1 through 34 in Appendix C. The assumption that energy and capital are substitutes underlying macroeconomic policies aimed at lowering the price of capital to promote its use and reduce the use of energy is not warranted. Similarly, the assumption that energy and capital are complements underlying policies aimed at lowering the prices of fuels to promote capital spending is not warranted. Furthermore, the assumption that energy groups are substitutes, underlying policies aimed at promoting the substitution of a particular fuel for another is not warranted. Some fuel groups show complementarity rather than substitutability.

Since the results provide inconclusive evidence of energy-capital substitution, it is not correct to assume either energy-capital complementarity or substitutability in the formulation of macroeconomic policies. This assumption underlies some government policies in the energy sector of OILICS like the subsidy to some types of energy, when their prices go up, to avoid a recession. The assumption behind this policy is that energy and capital are complements. Furthermore, factor prices manipulation distorts the choice of appropriate factor proportions.[6]

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6. White, Lawrence J.; "The Evidence on Appropriate Factor Proportions for Manufacturing in Less Developed Countries: A Survey," Economic Development and Cultural Change, October 1978.

In Brazil, for example, the government subsidizes hydroelectricity. The assumption behind it is that fossil fuels and hydroelectricity are substitutes. If the conclusions of this study are correct, subsidizing electricity to induce substitution of oil would lead to an increase in oil consumption as fossil fuels and hydroelectricity are shown to be complements.[7] Three out of four $G_{E2,E3}$ are negative, and the only positive one (PCC) is not significant at the 5 per cent level. These results are consistent with the findings of Denny et. al.[8] in their study of the Canadian paper industry. In that case, the effect of a decline in the price of electricity entailed an increase in the use of electricity associated with an increase in the use of oil. These results indicate that subsidizing the price of hydroelectricity in order to encourage the substitution of fuel oil for hydroelectricity, would not work in the Brazilian paper industry. Policies aimed at promoting the substitution of oil would work better if coal was used to replace oil, as the Canadian study shows. The present study did not disaggregate oil from coal, but the data show that there is considerable substitution between the two energy sources. Hydroelectricity and capital $(G_{E3,K})$ are found to be

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7. The Brazilian policy of subsidizing alcohol to encourage substitution of oil did not produce the expected results. It is not known if a substitution analyses was conducted prior to the adoption of the policy.

8. Denny et al. op. cit., 1981.

substitutes. The policy of subsidizing electricity would only delay technological changes, because firms would withhold capital spending during the period they enjoy a lower electricity cost.

Another implication of this study is that capital and labor are shown to be substitutes. Thus government policies aimed ar lowering the cost of labor would increase the share of labor, and decrease the share of capital in the industry. Again, this is not the policy followed by the Brazilian government which through increasing payroll taxation is making labor more expensive, encouraging the use of capital, and discouraging the use of labor.

Elasticities vary across firms, industries, countries, and time. This is partially illustrated by the energy-capital elasticity of the three firms in this study (Figures 6, 7, and 8). Only a constantly updated table of elasticities would provide a useful guide for sector-specific policy-making. Elasticities are also affected by the share of each input in total cost, and by structural changes occurring at any particular time and place.

The study of elasticities should be more useful for policymakers if they were calculated for long periods of time for any given industry. The number and types of inputs should be kept constant in order to make the estimates comparable. In such a case, the policy-maker would have access to a vast number of elasticity estimates so as to evaluate the impact of policies for different sectors. This

FIGURE 6: IKPC
ELASTICITY OF SUBSTITUTION
ENERGY/CAPITAL

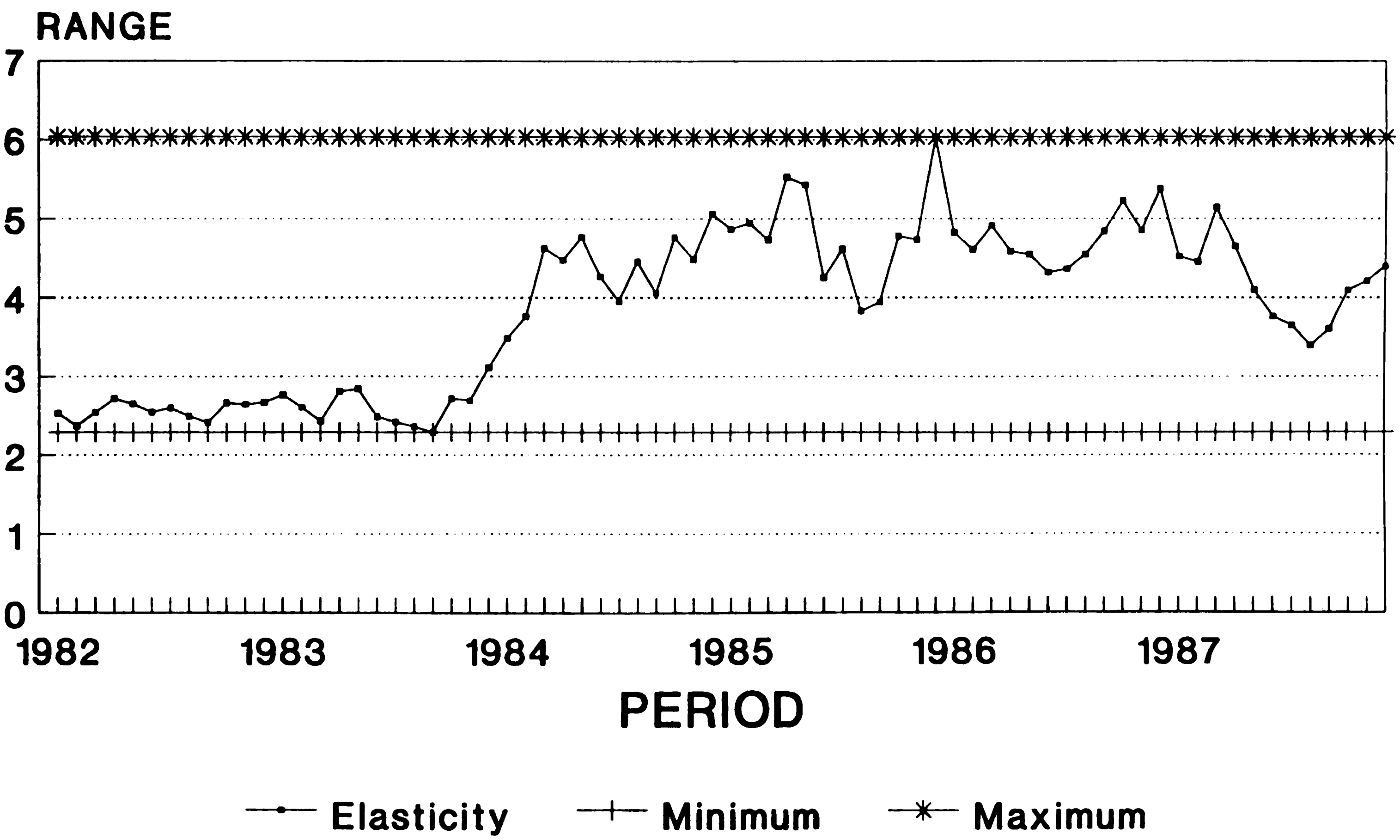


FIGURE 7: PCC
ELASTICITY OF SUBSTITUTION
ENERGY/CAPITAL

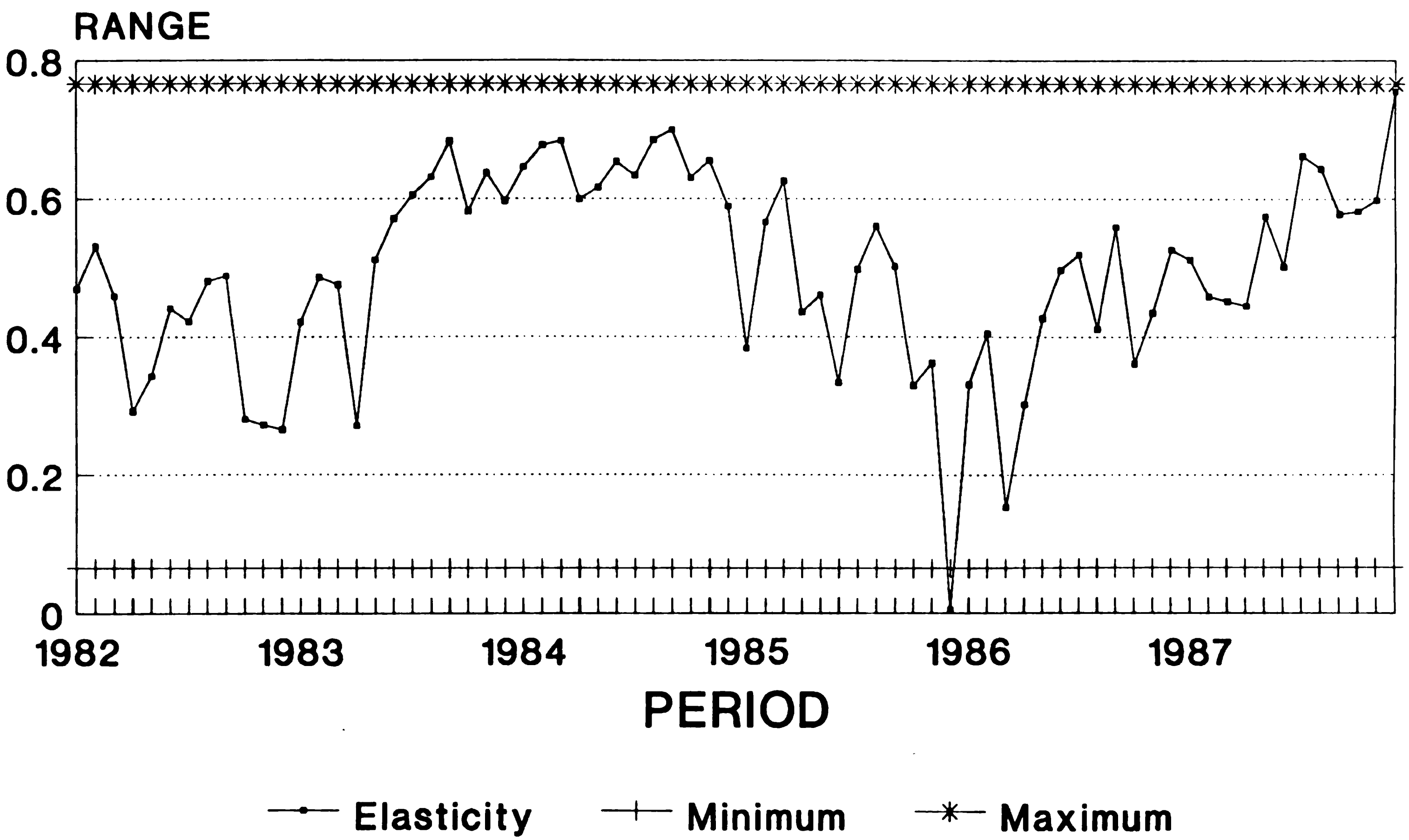
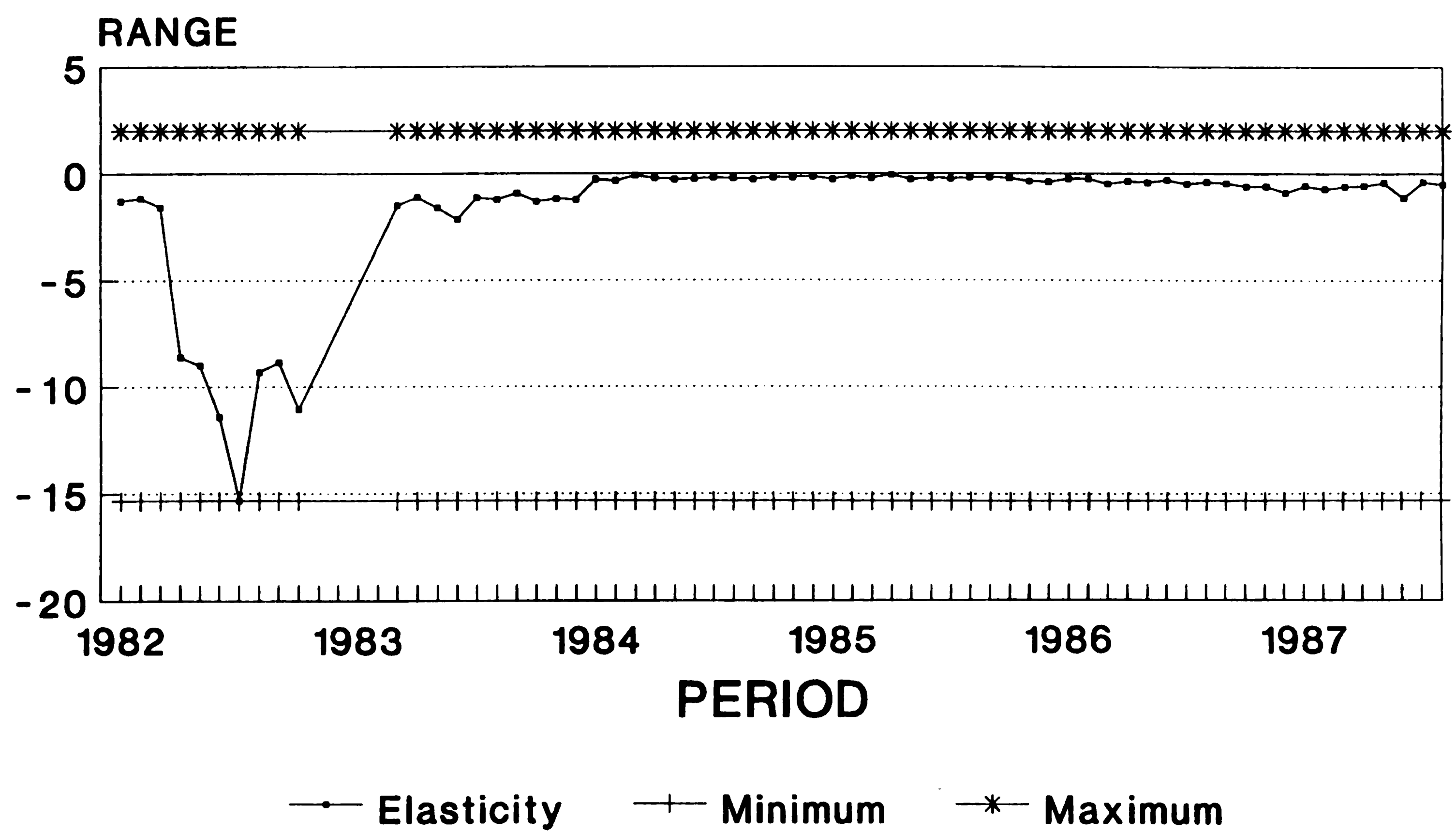


FIGURE 8: RIOCELL
ELASTICITY OF SUBSTITUTION ENERGY/CAPITAL



Between Nov/82 and Feb/83 the plant was paralized.

can be done with a computer program which would automatically calculate the elasticities once the data were entered into the system.

Research should be done within specific industries to check for similarities and differences among them in the pattern of input substitution, with special focus on the capital/energy coefficients. More importantly, however, research which includes intangible inputs into the production function is needed along with a more intensive search for methods allowing the exitence of non-concavity and discontinuity in the production function.

APPENDIX A

Table 1. - Selected Studies on Factor Substitution: Findings and Methodology

Author	Country and Industry	Data and Observations	Assumptions and Production or Cost Function	Test on VA Separability	Type of Equation and Method of Estimation	Main Results
Berndt and Christensen (1973)	U.S. manufacturing	Time series 1929-68	Linear homogeneous and separable [f(K_i, K_j, L), X]	NA	SURE I3SLS IZEF	(K_i, K_j), (K_i or K_j: L) : substitutes
Hudson and Jorgenson (1974)	U.S. 9 industrial sectors	Time series 1947-71	Homogeneous and separable [K, L, E, M]	NA	SURE MMDE	(K:E) : complements (L:E) : substitutes
Berndt and Wood (1975)	U.S. manufacturing	Time series 1947-71	Linear homogeneous and separable [K, L, E, M]	VAS under LSR	SURE I3SLS	(K:L),(K:M),(L:E), (L:M),(E:M) : substitutes (K:E) : complements
Humphrey and Moroney (1975)	U.S. 2-digit manufacturing	Cross section 1963	Linear homogeneous and separable [f(K, L, N), I]	NA	SURE IZEF	(K:L),(K:N),(L:N) : substitutes
Griffin and Gregory (1976)	Cross-country (9) manufacturing	Pooled data in 1955, '60, '65 and '69	Homothetic and separable [Y, ϕ(P_K, P_L, P_E), P_m, t]	VAS	SURE IZEF	(K:L),(K:E),(L:E), : substitutes in L-R (K:E) : complements in S-R
Halvorsen (1977)	U.S. 2-digit manufacturing	Cross section 1971	Linear homogeneous and separable [E, 4 energy costs]	NA	SURE IZEF	(E_i:E_j) : substitutes
Fuss (1977)	Canada manufacturing	Pooled data 1961-71	Homothetic and separable [K, L, M, E(6)]	NA	SURE IZEF EIV	(K:L),(K:M),(L:E),(L:M), (E_i:E_j) : substitutes (K:E),(E:M) : complements
Halvorsen and Ford (1979)	U.S. 2-digit manufacturing	Cross section 1958	Homothetic and separable [f(K, L_i, L_j, E(3)), X]	NA	SURE IZEF	(E_i:E_j),(E:X) : substitutes
Pindyck (1979)	Cross-country (10)	Pooled data 1963-73	Homothetic and separable [f(K, L, E(4)), M]	NA	SURE IZEF	(K:L),(K:E),(L:E) : substitutes (E_i:E_j) : mixed results
Field and Grebenstein (1980)	U.S. 2-digit manufacturing	Cross section 1971	Linear homogeneous and separable [f(K_i, K_j, L, E), M]	NA	SURE IZEF	(K_i:E) : complements (K_j:E) : substitutes
Viton (1981)	U.S. urban transportation	Cross section 1958	Homothetic and separable [R, L, F]	NA	SURE IZEF	(L:F) : substitutes
Hazilla and Kopp (1984)	U.S. 34 producing sector	Time series 1958-74	Homothetic and separable [K( ), L( ), E( ), M( )]	NA	SURE IZEF	(E:K),(E:L),(E:I) : mixed results

Kulatilaka (1985)	U.S. manufacturing	Time series 1947-71	NA [K; L, E, I]	NA	SE NIV	NA[c]
Chung (1987)	U.S. manufacturing	Time series 1947-71	Non-homogeneous and separable [K, L, E, M]	VAS under LSR and NSR	SE DTM IZEF	(K:L),(K:E),(K:M) (L:E),(L:M),(E:M) : substitutes

Notes:

Type of Equation:

SURE : seemingly unrelated equations

SE : single equation

Method of Estimation:

EIV : Efficient instrumental variable method

I3SLS : iteractive three-stage least squares method

IZEF : Zellner's iteractive efficient method

MMDE : Malinvaud's minimum distance estimator method

ZEF : Zellner's efficient method

NIV : non-linear instrumental variable technique

DTM : Durbin's two-stage method

Variable:

K : capital

K_i : capital i (i : equipment or structures in case of Berndt and Christensen; physical capital or working capital in case of Field and Grebenstein)

K : quasi-fixed capital

L : labor

L_i : Labor i (i : production workers or non-production workers in case of Halvorsen and Ford)

E : energy

E_i : energy i (i : coal, liquid petroleum, fuel oil, natural gas, electricity, and motor gasoline in case of Fuss; electricity, fuel oil, and gas in case of Halvorsen and Ford; oil, gas, coal, and electricity in case of Pindyck)

F : fuel

M : materials

N : natural resources

N_i : natural resources i (nonfuel minerals)

I : nonresource intermediate inputs

R : rolling stock

O,X : Other inputs

Separability:

VAS : value-added separability

LSR : linear separability restrictions

NSR : nonlinear separability restrictions

NA : not available

a In general, a cross section analysis yields long-run effects, whereas a time series analysis yields short-run effects.

b This column takes no account of other separability tests.

c The estimation of factor substitutions is not a primary concern in this paper, Kulatilaka rejects the validity of the full static (long-run) equilibrium approach taken by all of the previous studies.

APPENDIX B

TABLE 1: IKPC
FOUR INPUTS

Mth/yr	PE	PK	PL	PM	SHARE	SHARK	SHARL	SHARM	E	K	L	M
1982	100.00	100.00	100.00	100.00	0.27	0.18	0.31	0.23	100.00	100.00	100.00	100.00
	111.98	97.50	93.67	99.34	0.29	0.19	0.29	0.23	92.16	99.31	99.51	93.05
	94.40	97.02	91.08	139.57	0.24	0.21	0.32	0.23	81.51	99.70	99.98	62.78
	100.94	107.11	118.02	72.34	0.26	0.17	0.34	0.22	101.39	99.79	100.74	101.59
	106.68	103.29	115.73	104.19	0.28	0.16	0.32	0.23	109.83	100.82	100.68	107.73
	103.55	95.99	104.55	94.25	0.29	0.17	0.31	0.23	106.56	98.37	100.66	103.38
	103.89	105.37	111.87	101.19	0.29	0.17	0.31	0.23	112.26	100.10	100.60	110.78
	98.55	107.04	95.70	95.88	0.29	0.18	0.29	0.24	110.82	97.85	100.86	109.05
	101.63	116.31	83.98	101.48	0.30	0.18	0.28	0.24	104.04	94.75	101.63	102.00
	94.54	111.39	111.85	98.41	0.27	0.17	0.34	0.22	107.16	97.67	102.08	101.74
	92.58	110.44	112.54	95.22	0.27	0.18	0.34	0.21	107.79	97.11	100.84	102.23
	107.49	105.59	112.87	113.87	0.28	0.17	0.32	0.23	102.68	97.39	100.21	104.07
1983	98.30	93.57	116.54	101.73	0.25	0.17	0.35	0.23	97.22	97.15	99.47	96.90
	85.13	104.01	93.82	85.08	0.22	0.22	0.40	0.17	68.69	86.11	99.40	57.37
	78.62	89.57	77.89	74.66	0.31	0.18	0.31	0.21	109.90	72.48	98.79	100.24
	74.35	93.07	98.41	128.70	0.25	0.17	0.38	0.20	101.56	72.57	98.21	79.92
	73.46	103.24	100.64	81.91	0.25	0.17	0.38	0.20	102.64	71.48	96.60	94.97
	79.57	84.86	80.53	104.45	0.30	0.17	0.31	0.22	112.19	69.97	93.52	94.06
	75.46	90.30	73.58	86.87	0.32	0.17	0.30	0.21	117.97	68.05	89.44	102.52
	81.58	101.53	68.47	110.09	0.35	0.16	0.26	0.23	113.31	62.43	87.55	99.27
	78.01	88.29	59.83	95.72	0.34	0.18	0.25	0.24	115.28	62.52	86.96	99.54
	80.20	86.80	86.60	106.46	0.32	0.14	0.31	0.23	120.02	56.82	86.05	103.64
	78.48	106.69	80.52	93.46	0.34	0.14	0.30	0.23	119.87	52.16	84.65	105.05
	71.57	109.77	76.71	111.78	0.31	0.12	0.31	0.27	115.17	41.33	83.66	98.72
1984	88.21	100.49	65.64	101.54	0.37	0.08	0.26	0.29	116.83	30.07	85.35	107.01
	86.60	90.89	60.43	106.68	0.36	0.08	0.25	0.31	105.79	25.97	83.68	101.38
	75.48	99.97	54.54	114.47	0.34	0.06	0.21	0.39	117.85	22.50	83.52	117.10
	78.40	104.07	84.12	67.24	0.35	0.06	0.34	0.25	115.87	21.65	83.15	107.60
	75.77	104.40	77.40	142.51	0.32	0.06	0.33	0.29	102.32	21.00	83.54	85.14
	73.40	102.81	76.59	70.86	0.36	0.07	0.31	0.27	121.75	22.71	83.60	113.85
	73.24	98.50	78.42	103.23	0.36	0.07	0.31	0.26	120.75	25.88	83.72	112.49
	71.01	97.29	70.66	114.06	0.34	0.07	0.28	0.32	118.95	23.27	83.95	118.07
	67.89	100.63	61.66	89.74	0.33	0.08	0.30	0.30	119.62	22.31	84.40	103.59
	74.29	99.55	86.50	96.65	0.33	0.06	0.35	0.27	122.95	22.08	84.24	114.71
	81.11	110.24	76.83	109.34	0.36	0.06	0.30	0.29	131.05	22.60	83.99	116.44
	72.38	107.69	96.92	90.05	0.31	0.06	0.36	0.26	132.31	22.85	83.95	123.35
1985	67.84	99.57	74.02	126.86	0.31	0.06	0.29	0.34	139.32	23.23	84.16	121.44
	66.14	109.48	64.34	92.02	0.31	0.06	0.30	0.33	120.13	18.87	84.09	105.38
	68.42	99.26	58.92	98.32	0.35	0.06	0.25	0.34	139.07	19.55	84.61	122.12
	60.54	126.63	87.61	90.95	0.29	0.06	0.37	0.28	130.18	19.62	84.34	113.44
	59.62	115.62	78.46	117.40	0.29	0.06	0.32	0.33	137.92	20.51	84.14	113.61
	56.08	113.54	70.51	87.03	0.29	0.08	0.31	0.32	136.13	25.88	84.34	118.45
	55.51	107.78	73.98	103.42	0.27	0.08	0.30	0.35	140.82	27.77	85.66	137.93
	64.21	90.69	68.71	88.17	0.31	0.09	0.31	0.29	130.42	27.63	85.66	117.00
	62.24	117.63	63.99	127.79	0.28	0.09	0.31	0.31	112.52	26.97	86.09	90.71
	65.74	111.20	95.06	81.99	0.28	0.07	0.38	0.27	131.90	26.92	86.98	120.64
	63.18	87.49	83.73	112.98	0.28	0.07	0.34	0.30	121.74	26.07	87.02	117.78
	63.06	94.12	118.16	105.29	0.24	0.06	0.41	0.29	129.31	26.29	86.75	123.39

Month	PE	PK	PL	PM	SHARE	SHARK	SHARL	SHARM	E	K	L	M
1986	61.09	72.32	112.13	84.82	0.23	0.09	0.44	0.25	129.69	32.47	86.32	111.29
	60.10	51.82	80.45	109.92	0.27	0.08	0.37	0.28	114.78	24.59	85.08	97.94
	55.96	115.41	83.38	90.62	0.27	0.07	0.35	0.31	137.84	25.03	85.21	129.09
	56.24	111.94	80.26	110.08	0.25	0.08	0.34	0.32	126.00	28.51	85.64	118.49
	57.14	107.70	81.70	88.46	0.28	0.08	0.34	0.30	134.38	26.41	85.37	126.43
	55.63	106.95	89.32	116.26	0.24	0.09	0.34	0.32	134.87	35.17	85.23	126.35
	57.37	109.53	89.61	83.86	0.28	0.08	0.36	0.28	144.44	29.11	85.08	128.53
	56.45	109.17	90.13	109.40	0.27	0.08	0.35	0.30	137.49	29.10	84.53	127.49
	56.71	111.89	106.25	105.19	0.25	0.08	0.38	0.29	131.61	29.99	79.16	122.79
	55.12	106.14	118.04	104.16	0.25	0.07	0.38	0.30	141.33	30.39	78.89	131.35
	57.25	103.07	110.10	108.40	0.26	0.08	0.37	0.30	139.45	30.36	78.05	114.31
	53.82	94.16	111.28	101.13	0.24	0.07	0.36	0.33	140.97	29.98	78.25	131.72
1987	48.28	99.19	92.38	97.06	0.24	0.09	0.33	0.34	135.40	34.04	78.85	125.38
	44.83	128.20	108.24	94.72	0.20	0.11	0.39	0.30	126.50	40.40	79.71	115.91
	47.37	90.06	110.16	139.81	0.18	0.10	0.37	0.34	120.13	39.99	80.27	102.60
	48.67	82.26	102.30	82.41	0.20	0.10	0.35	0.35	127.85	41.46	80.56	127.51
	58.80	89.97	98.22	95.91	0.27	0.09	0.33	0.31	145.25	37.47	81.03	120.68
	63.08	72.10	87.38	86.56	0.30	0.09	0.32	0.29	130.65	34.31	80.91	118.12
	64.76	101.91	77.93	111.36	0.30	0.10	0.26	0.34	142.34	39.48	81.11	138.73
	62.84	123.21	82.70	143.06	0.30	0.11	0.30	0.29	138.07	39.44	81.42	73.96
	63.39	103.60	79.73	73.27	0.28	0.11	0.28	0.33	126.70	40.77	81.73	121.16
	62.13	95.85	95.89	104.12	0.26	0.09	0.31	0.33	133.70	39.61	81.65	125.49
	66.09	96.61	92.99	117.46	0.26	0.09	0.29	0.36	124.77	40.90	82.06	120.95
	63.00	93.31	108.28	87.93	0.24	0.09	0.34	0.33	130.89	41.01	82.00	127.62

TABLE 2: PCC
FOUR INPUTS

Mth/yr	PE	PK	PL	PM	SHARE	SHARK	SHARL	SHARM	E	K	L	M
1982	100.00	100.00	100.00	100.00	0.33	0.05	0.44	0.17	100.00	100.00	100.00	100.00
	113.28	97.50	87.94	115.58	0.37	0.05	0.40	0.18	94.92	95.54	99.31	86.66
	110.83	97.02	93.53	120.04	0.35	0.05	0.40	0.20	99.26	101.11	100.81	101.56
	103.23	107.11	126.67	102.67	0.30	0.04	0.50	0.16	98.55	96.38	100.87	103.45
	116.88	103.29	123.35	105.15	0.35	0.04	0.46	0.15	107.85	101.10	101.75	104.60
	119.20	95.99	112.07	96.69	0.38	0.04	0.46	0.12	106.93	98.46	102.49	81.51
	110.35	105.37	103.38	111.34	0.36	0.04	0.43	0.17	108.16	97.85	102.87	95.51
	102.47	107.04	101.46	86.96	0.38	0.05	0.45	0.13	112.67	98.89	102.49	86.08
	100.09	116.31	93.35	85.74	0.37	0.05	0.42	0.15	111.68	99.02	102.12	105.17
	99.01	111.39	128.61	81.19	0.30	0.04	0.52	0.13	103.04	99.41	103.68	107.93
	92.07	110.44	122.61	96.68	0.29	0.04	0.52	0.15	102.52	97.74	103.55	99.86
	109.72	105.59	137.43	92.50	0.33	0.04	0.50	0.13	112.96	103.55	103.80	103.80
1983	103.43	93.57	101.17	93.80	0.37	0.04	0.43	0.16	116.31	99.72	103.62	109.08
	86.51	104.01	80.36	72.85	0.35	0.05	0.45	0.15	99.07	85.68	103.43	94.75
	77.23	89.57	66.35	70.76	0.37	0.05	0.41	0.18	108.07	87.79	103.18	108.22
	76.54	93.07	88.71	70.68	0.29	0.04	0.51	0.16	88.43	70.86	102.00	102.64
	67.80	103.24	80.55	63.43	0.33	0.06	0.49	0.13	108.30	94.62	102.31	87.64
	80.11	84.86	74.47	70.18	0.38	0.05	0.44	0.12	109.80	93.89	101.87	74.98
	83.26	90.30	77.25	71.09	0.38	0.06	0.44	0.12	90.07	84.69	86.66	66.48
	90.85	101.53	63.93	76.87	0.47	0.05	0.32	0.16	115.42	95.38	83.92	91.44
	87.43	88.29	54.48	74.86	0.47	0.06	0.31	0.16	107.95	95.71	84.29	82.68
	82.74	86.80	78.82	79.26	0.40	0.05	0.40	0.15	106.51	97.57	84.04	82.95
	91.38	106.69	72.39	60.50	0.45	0.06	0.38	0.11	103.75	92.63	84.41	78.35
	91.07	109.77	74.08	61.63	0.39	0.06	0.40	0.15	89.67	92.70	84.48	99.90
1984	97.41	100.49	62.22	65.68	0.49	0.05	0.32	0.13	100.57	86.42	78.18	80.02
	98.15	90.89	57.60	59.75	0.51	0.05	0.32	0.12	99.29	81.38	78.18	71.59
	87.45	99.97	53.31	57.30	0.53	0.05	0.29	0.12	116.56	88.31	78.43	80.97
	99.03	104.07	80.05	62.58	0.44	0.05	0.40	0.11	93.75	92.08	78.43	70.15
	98.88	104.40	73.90	63.65	0.48	0.05	0.35	0.11	106.68	87.27	78.62	76.74
	100.38	102.81	64.67	59.43	0.52	0.05	0.32	0.11	110.17	93.15	78.12	78.14
	93.82	98.50	67.34	61.31	0.50	0.05	0.33	0.12	111.66	93.87	78.12	81.64
	107.35	97.29	58.94	61.50	0.56	0.05	0.28	0.11	113.28	96.99	78.30	77.52
	98.49	100.63	53.68	58.22	0.52	0.06	0.29	0.14	103.34	95.09	78.87	89.10
	86.03	99.55	78.60	56.58	0.43	0.06	0.38	0.14	110.60	104.19	79.18	104.68
	96.29	110.24	73.08	53.48	0.47	0.06	0.37	0.10	102.38	96.34	79.36	78.81
	86.09	107.69	87.71	59.45	0.44	0.05	0.39	0.11	121.08	100.51	79.43	87.22
1985	87.19	99.57	64.51	62.25	0.46	0.03	0.36	0.14	100.65	78.90	79.80	84.91
	92.35	109.48	55.58	59.90	0.51	0.04	0.31	0.13	104.78	79.81	79.43	80.40
	83.97	99.26	56.56	55.18	0.48	0.05	0.32	0.15	108.68	90.11	79.55	100.91
	72.03	126.63	78.64	58.63	0.40	0.04	0.43	0.13	106.60	85.11	79.36	85.17
	69.53	115.62	77.75	51.23	0.38	0.04	0.43	0.14	104.96	86.05	79.55	102.76
	65.07	113.54	66.77	60.79	0.38	0.04	0.42	0.16	97.60	76.97	79.74	87.47
	68.20	107.78	69.91	53.40	0.40	0.04	0.42	0.14	106.50	88.70	80.17	89.68
	70.76	90.69	63.58	57.41	0.40	0.05	0.39	0.16	100.59	91.84	81.23	93.80
	71.88	117.63	59.33	64.19	0.39	0.05	0.37	0.19	95.51	87.18	81.61	100.46
	65.07	111.20	85.74	61.60	0.34	0.04	0.45	0.17	109.83	93.09	81.11	111.14
	71.26	87.49	80.51	58.84	0.37	0.04	0.44	0.16	103.59	90.37	81.30	105.47
	67.09	94.12	86.69	67.83	0.34	0.03	0.46	0.18	104.24	84.53	80.92	104.76

Month	PE	PK	PL	PM	SHARE	SHARK	SHARL	SHARM	E	K	L	M
1986	64.94	72.32	76.78	70.52	0.37	0.04	0.42	0.18	113.86	92.25	81.67	99.56
	60.82	51.82	65.28	70.15	0.36	0.04	0.40	0.20	103.73	82.52	81.61	96.78
	52.92	115.41	82.67	64.45	0.28	0.04	0.49	0.19	95.63	82.06	81.80	105.11
	55.14	111.94	85.44	57.31	0.30	0.04	0.48	0.17	104.97	90.07	81.86	114.13
	53.15	107.70	82.23	62.50	0.31	0.05	0.45	0.18	114.71	99.18	81.30	112.15
	53.84	106.95	75.82	74.42	0.30	0.06	0.42	0.22	108.25	101.74	81.36	110.38
	54.96	109.53	83.22	70.64	0.31	0.06	0.42	0.21	123.18	114.22	82.54	126.82
	53.04	109.17	98.20	76.44	0.26	0.06	0.48	0.20	110.43	112.66	83.04	115.48
	54.63	111.89	88.45	60.45	0.28	0.07	0.47	0.17	107.76	117.05	83.23	112.97
	62.43	106.14	105.23	74.97	0.25	0.06	0.47	0.22	100.59	114.24	83.10	138.39
	70.19	103.07	96.78	72.84	0.29	0.05	0.49	0.17	92.11	108.97	83.54	98.98
	62.09	94.16	102.80	71.73	0.27	0.07	0.52	0.14	96.15	121.38	83.29	85.41
1987	55.59	99.19	93.40	68.09	0.27	0.07	0.49	0.17	103.68	121.35	83.85	106.06
	59.40	128.20	100.52	61.01	0.26	0.06	0.53	0.15	94.08	111.41	83.98	101.69
	58.84	90.06	100.78	88.85	0.24	0.07	0.48	0.21	96.36	126.65	84.10	111.19
	65.56	82.26	87.93	93.46	0.29	0.06	0.42	0.23	102.81	109.55	85.10	114.96
	68.66	89.97	89.80	80.69	0.34	0.06	0.43	0.17	116.25	118.30	84.41	96.24
	76.51	72.10	82.51	82.74	0.35	0.05	0.40	0.20	108.63	109.81	84.98	111.42
	71.84	101.91	72.83	80.05	0.34	0.08	0.37	0.21	108.50	132.58	85.35	116.15
	73.26	123.21	76.51	73.61	0.35	0.07	0.39	0.19	106.27	128.01	85.10	114.48
	70.57	103.60	88.69	94.92	0.30	0.07	0.41	0.21	105.30	125.71	85.29	105.80
	74.65	95.85	106.27	84.98	0.30	0.07	0.45	0.18	107.03	136.34	85.66	107.85
	73.29	96.61	82.91	82.49	0.33	0.07	0.41	0.20	105.21	120.49	86.35	109.91
	80.25	93.31	96.17	79.89	0.32	0.12	0.41	0.16	108.30	174.71	86.60	105.70

TABLE 3: RIOCELL
FOUR INPUTS

Mth/yr	PE	PK	PL	PM	SHARE	SHARK	SHARL	SHARM	E	K	L	M
Jan 82	100.00	100.00	100.00	100.00	0.44	0.13	0.20	0.23	100.00	100.00	100.00	100.00
	114.28	97.50	99.44	99.10	0.49	0.12	0.19	0.20	104.14	98.20	100.33	91.52
	109.54	97.02	87.05	103.27	0.46	0.11	0.20	0.23	87.73	80.97	100.88	87.78
	104.46	107.11	117.10	89.34	0.53	0.03	0.19	0.25	148.53	61.24	100.28	156.94
	114.70	103.29	116.45	92.06	0.53	0.02	0.18	0.26	129.34	59.06	92.92	152.15
	107.79	95.99	118.08	85.99	0.54	0.02	0.14	0.30	150.50	67.28	77.06	200.14
	99.79	105.37	121.86	114.52	0.43	0.02	0.30	0.25	63.43	30.48	77.34	60.68
	94.39	107.04	112.35	99.07	0.37	0.03	0.27	0.33	59.60	44.26	77.45	95.81
	97.25	116.31	104.20	86.84	0.35	0.04	0.27	0.34	49.03	44.29	75.18	102.83
	93.62	111.39	145.43	94.73	0.51	0.02	0.22	0.25	122.16	44.55	72.03	114.94
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan 83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	80.05	89.57	150.37	72.02	0.44	0.12	0.18	0.26	132.02	114.54	62.30	165.82
	72.06	93.07	180.96	74.72	0.45	0.14	0.24	0.17	140.30	101.70	63.24	99.60
	62.19	103.24	152.74	71.86	0.41	0.12	0.17	0.30	170.95	130.62	62.41	205.90
	67.97	84.86	138.06	69.62	0.47	0.09	0.15	0.29	186.30	116.02	62.35	217.87
	60.29	90.30	123.66	67.59	0.50	0.12	0.12	0.25	246.03	141.38	62.41	212.08
	73.08	101.53	107.75	62.46	0.47	0.13	0.11	0.30	182.10	150.17	61.97	255.74
	62.06	88.29	105.18	69.24	0.44	0.15	0.13	0.28	161.62	130.39	59.26	173.94
	66.40	86.80	143.77	64.39	0.46	0.12	0.14	0.27	190.26	136.67	58.87	219.69
	59.61	106.69	130.39	60.68	0.39	0.15	0.16	0.29	144.03	131.18	58.21	199.16
	60.88	109.77	115.10	58.10	0.45	0.13	0.12	0.29	190.08	136.56	58.65	244.48
Jan 84	72.52	100.49	113.74	67.82	0.37	0.28	0.10	0.25	157.36	253.90	59.15	218.51
	72.11	90.89	106.26	72.89	0.41	0.24	0.09	0.26	181.82	227.90	60.25	213.65
	61.95	99.97	107.68	79.34	0.29	0.40	0.14	0.17	104.56	232.19	59.98	87.64
	62.22	104.07	131.19	48.45	0.32	0.33	0.14	0.21	139.04	257.02	59.65	221.93
	64.96	104.40	135.93	61.98	0.38	0.27	0.11	0.24	203.20	274.00	58.37	255.67
	55.97	102.81	121.03	62.74	0.36	0.29	0.11	0.24	200.59	271.49	58.65	233.99
	56.89	98.50	106.53	56.30	0.33	0.33	0.11	0.23	159.93	269.28	59.26	213.99
	57.11	97.29	117.41	62.13	0.37	0.28	0.10	0.24	210.43	274.91	58.65	236.63
	54.09	100.63	107.10	55.46	0.37	0.28	0.10	0.25	196.75	246.16	58.54	244.11
	61.92	99.55	125.18	47.39	0.38	0.29	0.11	0.21	186.15	264.94	58.26	260.19
	69.51	110.24	140.67	50.13	0.42	0.27	0.12	0.20	200.21	270.21	58.49	252.31
	61.04	107.69	128.18	52.68	0.40	0.29	0.11	0.20	203.61	274.77	58.60	229.71
Jan 85	58.03	99.57	140.65	50.54	0.37	0.28	0.12	0.23	205.60	272.39	58.76	277.89
	54.60	109.48	140.58	51.22	0.34	0.34	0.13	0.19	173.71	279.55	57.99	198.46
	57.90	99.26	123.41	48.46	0.36	0.30	0.11	0.23	191.52	281.55	58.49	277.67
	55.09	126.63	145.87	52.22	0.40	0.30	0.17	0.12	171.76	196.64	59.37	104.26
	54.46	115.62	164.27	45.00	0.34	0.30	0.15	0.21	190.63	274.13	59.48	274.39
	49.39	113.54	129.57	47.29	0.35	0.31	0.12	0.22	208.79	276.83	58.54	263.19
	46.74	107.78	127.12	44.81	0.33	0.31	0.12	0.23	202.93	269.97	57.77	277.17
	52.81	90.69	137.61	46.59	0.35	0.31	0.12	0.22	208.28	286.79	58.43	275.44
	53.01	117.63	131.40	46.64	0.35	0.32	0.13	0.21	187.12	267.29	58.54	237.97
	55.56	111.20	140.77	50.92	0.37	0.29	0.13	0.21	199.77	269.93	58.71	242.37
	51.78	87.49	170.33	49.98	0.34	0.28	0.15	0.23	202.78	271.66	58.60	272.01
	51.53	94.12	150.10	53.24	0.33	0.28	0.13	0.25	203.09	270.70	59.15	280.87

Month	PE	PK	PL	PM	SHARE	SHARK	SHARL	SHARM	E	K	L	M
Jan 86	45.44	72.32	138.76	47.62	0.31	0.33	0.15	0.20	215.20	307.26	72.53	257.40
	48.04	51.82	127.05	50.62	0.31	0.34	0.14	0.21	195.64	295.10	72.91	237.98
	44.86	115.41	151.97	52.02	0.21	0.42	0.25	0.12	93.75	223.04	72.36	85.99
	43.14	111.94	149.96	50.14	0.29	0.33	0.16	0.22	209.82	298.39	71.59	256.29
	42.50	107.70	146.37	52.94	0.30	0.30	0.15	0.24	234.99	302.35	71.09	288.86
	43.06	106.95	133.41	53.61	0.29	0.35	0.14	0.23	217.40	321.54	73.36	260.26
	43.03	109.53	147.36	54.72	0.30	0.29	0.15	0.26	238.62	301.26	72.80	309.30
	43.43	109.17	145.47	56.11	0.31	0.30	0.15	0.24	234.28	297.75	73.30	262.83
	44.22	111.89	140.80	58.77	0.31	0.29	0.14	0.26	245.91	300.36	74.41	289.11
	43.03	106.14	162.54	57.03	0.29	0.28	0.16	0.26	235.12	296.13	74.85	307.44
	42.33	103.07	188.24	63.67	0.29	0.28	0.19	0.23	235.21	295.11	75.40	241.59
	41.89	94.16	175.65	64.93	0.28	0.25	0.16	0.31	253.47	298.14	75.57	348.51
Jan 87	39.60	99.19	177.79	54.48	0.23	0.35	0.19	0.22	195.14	334.05	75.90	257.50
	35.35	128.20	206.66	54.57	0.22	0.34	0.21	0.23	214.62	341.30	74.52	274.66
	36.67	90.06	171.49	57.66	0.25	0.33	0.17	0.25	233.20	337.44	74.90	285.93
	35.33	82.26	127.28	51.61	0.24	0.35	0.15	0.26	203.57	312.64	75.68	292.76
	43.71	89.97	152.53	65.90	0.23	0.40	0.21	0.16	130.78	279.19	75.68	115.82
	45.92	72.10	203.40	83.65	0.24	0.26	0.20	0.30	184.76	270.86	75.18	246.55
	47.99	101.91	121.30	59.96	0.31	0.30	0.12	0.27	235.62	333.70	76.78	312.95
	46.22	123.21	131.72	68.00	0.29	0.30	0.13	0.28	230.75	324.23	78.05	284.28
	45.63	103.60	135.81	78.64	0.28	0.28	0.13	0.31	233.87	322.94	78.50	284.59
	47.32	95.85	216.66	70.18	0.26	0.27	0.21	0.27	211.04	308.03	78.77	278.13
	48.56	96.61	238.07	82.40	0.27	0.24	0.21	0.29	233.81	307.27	77.72	280.20
Dec 87	49.82	93.31	161.46	74.15	0.29	0.23	0.15	0.33	234.72	299.12	78.72	350.62

TABLE 4: IKPC
SIX INPUTS

Month	E1	E2	E3	K	L	M	SHARE1	SHARE2	SHARE3
Jan 82	100.00	100.00	100.00	100.00	100.00	100.00	0.14	0.08	0.06
	97.92	92.17	85.67	94.41	99.51	93.05	0.16	0.07	0.06
	67.44	90.18	91.26	85.44	100.19	62.78	0.10	0.07	0.06
	110.92	99.46	91.67	101.22	100.72	101.59	0.14	0.07	0.05
	119.15	105.31	102.82	104.88	100.68	107.73	0.16	0.07	0.06
	119.48	96.37	99.50	101.33	100.86	103.38	0.16	0.06	0.06
	123.41	110.00	101.14	106.73	100.60	110.78	0.15	0.07	0.06
	123.91	101.02	102.87	104.57	100.86	109.05	0.15	0.07	0.07
	115.48	95.46	98.01	99.33	101.63	102.00	0.16	0.07	0.07
	112.21	101.96	106.16	103.39	102.08	101.74	0.13	0.06	0.07
	117.14	101.20	102.80	102.06	100.84	102.23	0.14	0.06	0.07
	107.32	101.99	98.44	102.92	100.21	104.07	0.15	0.07	0.06
Jan 83	95.40	96.76	99.59	98.51	99.47	95.90	0.12	0.06	0.06
	60.88	73.70	73.59	72.50	99.40	57.37	0.09	0.06	0.06
	107.24	96.46	123.62	89.76	98.79	100.24	0.16	0.07	0.08
	110.89	92.57	95.86	82.10	98.21	79.92	0.13	0.06	0.06
	122.46	87.58	88.19	87.50	96.60	94.97	0.13	0.05	0.06
	136.66	87.32	98.56	90.56	93.52	94.05	0.17	0.06	0.06
	142.60	91.19	106.07	93.55	89.44	102.52	0.18	0.07	0.06
	130.35	92.60	108.11	90.12	87.55	99.27	0.22	0.07	0.07
	155.42	67.14	98.75	88.88	86.96	99.54	0.22	0.05	0.07
	155.16	73.52	108.17	90.06	86.05	103.64	0.22	0.04	0.06
	155.76	75.98	106.30	88.43	84.65	105.05	0.21	0.04	0.07
	145.56	72.40	105.09	82.31	83.66	98.72	0.19	0.05	0.07
Jan 84	142.11	82.61	107.31	79.70	85.35	107.01	0.23	0.07	0.07
	133.59	60.48	101.73	71.85	83.68	101.38	0.22	0.05	0.08
	144.31	77.88	110.99	78.02	83.52	117.10	0.20	0.05	0.07
	140.02	80.34	108.96	77.88	83.15	107.60	0.22	0.06	0.07
	113.94	84.28	99.46	67.06	83.54	85.14	0.18	0.06	0.08
	154.92	70.82	117.55	79.57	83.60	113.85	0.21	0.05	0.09
	135.40	103.79	114.72	81.49	83.72	112.49	0.21	0.07	0.07
	136.21	92.47	114.72	81.66	83.95	118.07	0.19	0.06	0.08
	152.14	66.22	110.27	77.59	84.40	103.59	0.17	0.05	0.09
	157.42	75.51	109.59	80.12	84.18	114.71	0.19	0.05	0.07
	179.01	72.38	107.97	82.81	83.99	116.44	0.22	0.04	0.08
	173.29	82.83	110.71	84.83	83.95	123.35	0.19	0.05	0.07
Jan 85	178.06	78.64	119.82	86.67	84.16	121.44	0.17	0.05	0.08
	154.01	72.31	98.93	73.53	84.09	105.38	0.17	0.06	0.08
	176.74	80.40	120.85	84.87	84.47	122.12	0.20	0.05	0.09
	161.10	86.83	109.23	79.29	84.36	113.44	0.16	0.05	0.07
	173.55	90.57	112.99	84.94	84.14	113.61	0.17	0.05	0.07
	166.81	95.44	112.76	85.88	84.34	118.45	0.16	0.05	0.07
	179.02	82.53	119.38	90.41	85.66	137.93	0.15	0.04	0.07
	171.87	63.78	111.75	88.86	85.66	117.00	0.18	0.04	0.08
	137.39	72.32	97.69	74.66	86.09	90.71	0.14	0.05	0.08
	173.65	72.64	106.26	88.79	86.98	120.64	0.15	0.04	0.07
	148.97	82.25	105.07	83.02	87.02	117.78	0.15	0.04	0.08
	160.23	90.67	104.63	89.05	86.75	123.39	0.13	0.04	0.07

Month	E1	E2	E3	K	L	M	SHARE1	SHARE2	SHARE3
Jan 86	195.75	65.04	89.05	89.59	86.32	111.29	0.14	0.03	0.05
	152.57	75.48	91.03	74.42	85.08	97.94	0.14	0.05	0.07
	186.95	74.08	116.20	87.90	85.21	129.09	0.14	0.04	0.07
	173.03	64.39	106.28	83.70	85.64	118.49	0.13	0.04	0.07
	177.05	85.17	111.29	88.58	85.37	126.43	0.14	0.05	0.08
	182.47	79.91	109.64	91.16	85.23	126.35	0.13	0.04	0.07
	182.03	87.91	130.98	93.20	85.08	128.53	0.14	0.05	0.09
	167.71	89.71	129.40	90.15	84.53	127.49	0.14	0.05	0.08
	162.12	78.70	127.40	86.93	79.16	122.79	0.12	0.04	0.08
	173.93	86.05	135.94	94.03	78.89	131.35	0.12	0.04	0.08
	180.93	69.77	133.48	88.05	78.05	114.31	0.12	0.03	0.09
	172.33	98.47	128.05	91.42	78.25	131.72	0.12	0.04	0.06
Jan 87	160.80	95.09	128.33	91.75	78.85	125.38	0.12	0.05	0.06
	148.45	96.58	115.81	87.39	79.71	115.91	0.09	0.05	0.05
	141.56	82.13	116.00	82.58	80.27	102.60	0.08	0.03	0.06
	159.87	78.99	118.27	92.71	80.56	127.51	0.10	0.03	0.06
	180.81	98.12	128.68	93.51	81.03	120.68	0.12	0.05	0.08
	146.45	114.68	119.00	91.14	80.93	118.12	0.13	0.08	0.09
	181.09	96.91	125.21	98.68	81.11	138.73	0.14	0.05	0.09
	188.16	71.12	122.94	97.01	81.42	73.96	0.15	0.04	0.10
	143.02	91.83	127.92	91.38	81.73	121.16	0.13	0.05	0.09
	177.30	69.93	125.18	96.05	81.65	125.49	0.13	0.04	0.08
	141.41	100.46	119.48	91.81	82.06	120.95	0.11	0.05	0.08
Dec 87	162.46	75.98	128.20	96.30	82.00	127.62	0.12	0.04	0.07

Month	SHARK	SHARL	SHARM	PE1	PE2	PE3	PK	PL	PM
Jan 82	0.18	0.31	0.23	100.00	100.00	100.00	100.00	100.00	100.00
	0.19	0.29	0.23	113.25	98.59	110.20	97.50	89.79	99.34
	0.21	0.32	0.23	109.62	91.86	108.16	97.02	91.08	139.57
	0.17	0.34	0.22	103.89	95.61	97.96	107.11	118.02	72.34
	0.16	0.32	0.23	113.87	91.98	114.69	103.29	115.37	104.19
	0.17	0.31	0.23	107.56	87.23	116.73	95.99	104.55	94.25
	0.17	0.31	0.23	101.10	96.36	117.96	105.37	110.50	101.19
	0.18	0.29	0.24	95.01	90.46	118.37	107.04	95.70	95.88
	0.18	0.28	0.24	99.16	86.10	117.96	116.31	83.98	101.48
	0.17	0.34	0.22	94.17	81.38	117.14	111.39	111.85	98.41
	0.18	0.34	0.21	88.70	82.55	116.33	110.44	112.54	95.22
	0.17	0.32	0.23	104.17	95.39	115.51	105.59	112.87	113.87
Jan 83	0.17	0.35	0.23	96.74	88.74	113.06	93.57	116.54	101.73
	0.22	0.40	0.17	82.12	74.14	111.02	104.01	93.82	85.08
	0.18	0.31	0.21	81.73	62.44	82.45	89.57	77.89	74.66
	0.17	0.38	0.20	74.94	57.45	91.02	93.07	98.41	128.70
	0.17	0.39	0.20	67.97	60.76	94.82	103.24	100.64	81.91
	0.17	0.31	0.22	89.99	60.80	84.90	84.86	80.53	104.45
	0.17	0.30	0.21	78.91	66.64	75.92	90.30	80.19	86.87
	0.16	0.26	0.23	92.91	66.35	77.55	101.53	68.47	110.09
	0.18	0.25	0.24	84.88	61.76	78.78	88.29	59.83	95.72
	0.14	0.31	0.23	96.67	58.70	68.16	86.80	86.60	106.46
	0.14	0.30	0.23	87.43	57.41	84.08	106.69	80.52	93.46
	0.12	0.31	0.27	79.03	54.39	76.33	109.77	76.71	111.78

Month	SHARK	SHARL	SHARM	PE1	PE2	PE3	PK	PL	PM
Jan 84	0.08	0.26	0.29	95.96	70.68	71.02	100.49	65.64	101.54
	0.08	0.26	0.31	89.95	64.38	87.35	90.89	60.43	106.68
	0.06	0.22	0.39	81.52	58.69	74.69	99.97	54.54	114.47
	0.06	0.34	0.25	89.39	59.91	68.57	104.07	84.12	67.24
	0.06	0.33	0.29	85.98	57.70	82.86	104.40	77.40	142.51
	0.07	0.32	0.27	78.67	53.74	78.78	102.81	76.59	70.86
	0.07	0.31	0.26	83.87	57.64	74.29	98.50	78.42	103.23
	0.07	0.29	0.32	76.35	55.22	81.22	97.29	70.66	114.06
	0.08	0.30	0.30	68.21	52.27	78.78	100.63	61.66	89.74
	0.06	0.35	0.27	78.63	57.31	69.80	99.55	86.50	96.65
	0.06	0.31	0.29	87.66	56.30	81.63	110.24	76.83	109.34
	0.06	0.37	0.27	76.98	52.00	71.84	107.69	96.92	90.05
Jan 85	0.06	0.29	0.34	69.22	58.88	74.69	99.57	74.02	126.86
	0.06	0.30	0.33	63.59	56.09	77.14	109.48	64.34	92.02
	0.06	0.26	0.35	70.23	55.24	75.92	99.26	59.02	98.32
	0.06	0.37	0.29	61.97	48.47	71.84	126.63	87.59	90.95
	0.06	0.33	0.33	68.34	44.95	62.45	115.62	78.46	117.40
	0.08	0.31	0.32	62.07	41.21	62.86	113.54	70.51	87.03
	0.08	0.31	0.35	57.73	40.65	65.31	107.78	73.98	103.42
	0.09	0.32	0.29	65.44	45.96	71.43	90.69	68.71	88.17
	0.09	0.32	0.31	64.85	47.59	78.37	117.63	63.99	127.79
	0.07	0.39	0.27	65.30	48.35	77.96	111.20	95.06	81.99
	0.07	0.34	0.31	61.19	46.80	87.35	87.49	83.73	112.98
	0.06	0.41	0.29	61.19	45.77	85.71	94.12	118.16	105.29
Jan 86	0.09	0.44	0.25	54.13	45.25	67.76	72.32	112.13	84.82
	0.08	0.37	0.29	59.05	48.72	76.33	51.82	80.45	109.92
	0.07	0.35	0.32	55.31	44.88	68.16	115.41	83.38	90.62
	0.09	0.35	0.33	52.88	44.58	72.65	111.94	80.26	110.08
	0.08	0.35	0.30	53.29	44.37	75.92	107.70	81.70	88.46
	0.10	0.35	0.32	53.53	44.21	70.20	106.96	89.32	116.26
	0.08	0.36	0.28	54.79	44.20	77.96	109.53	89.61	83.86
	0.08	0.35	0.30	55.18	44.20	75.51	109.17	90.13	109.40
	0.08	0.38	0.30	55.49	44.04	75.10	111.89	106.25	105.19
	0.08	0.39	0.31	56.71	43.50	71.84	106.14	118.04	104.16
	0.08	0.38	0.30	55.72	43.87	79.18	103.07	110.10	108.40
	0.07	0.36	0.34	55.74	42.40	65.31	94.16	111.28	101.13
Jan 87	0.09	0.34	0.35	50.37	40.68	56.33	99.19	92.38	97.06
	0.11	0.40	0.30	45.97	40.82	49.39	128.20	108.24	94.72
	0.10	0.38	0.35	53.03	38.76	59.59	90.06	110.16	139.81
	0.11	0.35	0.35	46.57	38.71	63.67	82.26	102.30	82.41
	0.09	0.33	0.32	57.60	48.47	77.14	89.97	98.22	95.91
	0.09	0.32	0.29	59.13	53.75	86.94	72.10	87.35	86.56
	0.10	0.27	0.35	63.81	51.68	93.47	101.91	77.93	111.36
	0.11	0.31	0.29	60.55	49.14	90.20	123.21	82.70	143.06
	0.11	0.29	0.34	60.22	47.59	88.98	103.60	79.73	73.27
	0.10	0.32	0.33	61.35	49.93	85.71	95.85	95.89	104.12
	0.09	0.30	0.36	63.24	52.75	93.88	96.61	92.99	117.46
Dec 87	0.09	0.34	0.33	62.16	53.01	78.78	93.31	108.28	87.93

TABLE 5: PCC
SIX INPUTS

Month	PE1	PE2	PE3	PK	PL	PM	SHARE1	SHARE2	SHARE3
1982	100.00	100.00	100.00	100.00	100.00	100.00	0.28	0.04	0.02
	111.64	115.87	110.20	97.50	87.94	115.58	0.29	0.06	0.02
	110.38	110.04	108.16	97.02	93.53	120.04	0.27	0.05	0.03
	105.95	104.32	97.96	107.11	126.67	102.67	0.25	0.03	0.02
	116.34	115.88	114.69	103.29	123.35	105.15	0.27	0.06	0.02
	118.19	110.75	116.73	95.99	112.07	96.69	0.28	0.07	0.02
	105.36	104.30	117.96	105.37	103.38	111.34	0.26	0.08	0.03
	99.03	97.84	118.37	107.04	101.46	86.96	0.28	0.07	0.03
	100.29	100.22	117.96	116.31	93.35	85.74	0.32	0.02	0.03
	103.58	95.14	117.14	111.39	128.61	81.19	0.26	0.01	0.03
	88.18	89.39	116.33	110.44	122.61	96.68	0.23	0.03	0.03
	110.22	103.75	115.51	105.59	137.43	92.50	0.27	0.03	0.03
1983	97.87	98.16	113.06	93.57	101.17	93.80	0.29	0.03	0.03
	81.08	81.85	111.02	104.01	80.36	72.85	0.29	0.02	0.03
	71.19	83.30	82.45	89.57	66.35	70.76	0.30	0.03	0.03
	69.51	75.24	91.02	93.07	88.71	70.68	0.24	0.02	0.02
	60.98	69.42	94.82	103.24	80.55	63.43	0.26	0.03	0.03
	70.93	90.83	84.90	84.86	74.47	70.18	0.30	0.05	0.03
	77.76	83.05	7[illegible].92	90.30	77.25	71.09	0.26	0.07	0.03
	86.77	97.55	77.55	101.53	63.93	76.87	0.36	0.06	0.03
	84.94	88.99	78.78	88.29	54.48	74.86	0.36	0.06	0.04
	78.58	79.33	68.16	86.80	78.82	79.26	0.27	0.08	0.03
	87.39	92.67	84.08	106.69	72.39	60.50	0.33	0.07	0.03
	88.75	85.26	76.33	109.77	74.08	61.63	0.26	0.09	0.03
1984	96.21	102.78	71.02	100.49	62.22	65.68	0.38	0.06	0.03
	99.73	92.39	87.35	90.89	57.60	59.75	0.41	0.05	0.04
	85.65	82.05	74.69	99.97	53.31	57.30	0.44	0.04	0.03
	103.70	90.49	68.57	104.07	80.05	62.58	0.34	0.05	0.03
	100.07	82.88	82.86	104.40	73.90	63.65	0.40	0.03	0.03
	101.13	90.79	78.78	102.81	64.67	59.43	0.42	0.05	0.04
	94.02	81.97	74.29	98.50	67.34	61.31	0.36	0.08	0.04
	106.06	96.28	81.22	97.29	58.94	61.50	0.43	0.08	0.03
	98.21	86.71	78.78	100.63	53.68	58.22	0.38	0.09	0.04
	84.99	77.68	69.80	99.55	78.60	56.58	0.33	0.05	0.03
	95.91	85.38	81.63	110.24	73.08	53.48	0.35	0.06	0.04
	79.55	96.80	71.84	107.69	87.71	59.45	0.34	0.05	0.03
1985	85.92	87.43	74.69	99.57	64.51	62.25	0.35	0.05	0.04
	89.45	99.06	77.14	109.48	55.58	59.90	0.40	0.05	0.04
	82.35	89.21	75.92	99.26	56.56	55.18	0.37	0.04	0.04
	66.33	78.30	71.84	126.63	78.64	58.63	0.29	0.04	0.04
	66.79	70.25	62.45	115.62	77.75	51.23	0.28	0.05	0.04
	62.94	63.84	62.86	113.54	66.77	60.79	0.27	0.05	0.04
	64.92	70.17	65.31	107.78	69.91	53.40	0.29	0.05	0.04
	68.12	69.61	71.43	90.69	63.58	57.41	0.28	0.05	0.05
	66.35	70.53	78.37	117.63	59.33	64.19	0.27	0.06	0.05
	70.42	70.08	77.96	111.20	85.74	61.60	0.25	0.03	0.05
	80.85	71.66	87.35	87.49	80.51	58.84	0.26	0.03	0.06
	79.55	71.22	85.71	94.12	86.69	67.83	0.24	0.02	0.06

Month	PE1	PE2	PE3	PK	PL	PM	SHARE1	SHARE2	SHARE3
1986	77.44	70.29	67.76	72.32	76.78	70.52	0.27	0.03	0.04
	72.75	59.73	76.33	51.82	65.28	70.15	0.27	0.02	0.04
	58.00	51.26	68.16	115.41	82.67	64.45	0.21	0.02	0.04
	66.34	51.30	72.65	111.94	85.44	57.31	0.22	0.02	0.04
	63.10	51.22	75.92	107.70	82.23	62.50	0.23	0.02	0.05
	65.79	56.20	70.20	106.95	75.82	74.42	0.23	0.01	0.04
	64.82	56.19	77.96	109.53	83.22	70.64	0.23	0.01	0.05
	64.04	56.08	75.51	109.17	98.20	76.44	0.19	0.01	0.04
	63.85	55.81	75.10	111.89	88.45	60.45	0.21	0.01	0.05
	73.33	55.24	71.84	106.14	105.23	74.97	0.19	0.01	0.04
	96.57	54.65	79.18	103.07	96.78	72.84	0.16	0.06	0.05
	88.62	52.95	65.31	94.16	102.80	71.73	0.19	0.02	0.04
1987	74.65	47.29	56.33	99.19	93.40	68.09	0.20	0.02	0.04
	83.70	53.71	49.39	128.20	100.52	61.01	0.20	0.02	0.03
	74.37	47.91	59.59	90.06	100.78	88.85	0.18	0.01	0.03
	79.03	58.80	63.67	82.26	87.93	93.46	0.22	0.02	0.03
	81.64	57.69	77.14	89.97	89.80	80.69	0.23	0.06	0.04
	97.24	62.17	86.94	72.10	82.51	82.74	0.19	0.10	0.05
	84.39	59.78	93.47	101.91	72.83	80.05	0.19	0.08	0.06
	96.04	57.50	90.20	123.21	76.51	73.61	0.17	0.11	0.05
	79.05	57.30	88.98	103.60	88.69	94.92	0.16	0.08	0.05
	94.66	58.16	85.71	95.85	106.27	84.98	0.15	0.09	0.04
	88.94	58.33	93.88	96.61	82.91	82.49	0.19	0.07	0.05
	99.15	68.18	78.78	93.31	96.17	79.89	0.21	0.07	0.03

Month	SHARK	SHARL	SHARM	E1	E2	E3	K	L	M
1982	0.05	0.44	0.17	100.00	100.00	100.00	100.00	100.00	100.00
	0.05	0.40	0.18	127.53	93.77	94.92	95.54	99.31	86.66
	0.05	0.40	0.20	125.83	94.58	99.26	101.11	100.81	101.56
	0.04	0.50	0.16	86.18	98.36	98.55	96.38	100.87	103.45
	0.04	0.46	0.15	148.57	103.96	107.85	101.10	101.75	104.60
	0.04	0.46	0.12	190.47	99.81	106.93	98.46	102.49	81.51
	0.04	0.43	0.17	203.87	99.39	108.16	97.85	102.87	95.51
	0.05	0.45	0.13	172.51	106.31	112.67	98.89	102.49	86.08
	0.05	0.42	0.15	60.46	113.65	111.68	99.02	102.12	105.17
	0.04	0.52	0.13	41.98	104.58	103.04	99.41	103.68	107.93
	0.04	0.52	0.15	85.04	100.60	102.52	97.74	103.55	99.86
	0.04	0.50	0.13	97.02	110.08	112.96	103.55	103.80	103.80
1983	0.04	0.44	0.16	87.54	115.12	116.31	99.72	103.62	109.08
	0.05	0.46	0.15	48.85	100.70	99.07	85.68	103.43	94.75
	0.05	0.42	0.18	65.45	107.54	108.07	87.79	103.18	108.22
	0.04	0.52	0.16	47.34	91.08	88.43	70.86	102.00	102.64
	0.06	0.50	0.13	72.81	109.31	108.30	94.62	102.31	87.64
	0.06	0.45	0.12	96.76	109.49	109.80	93.89	101.87	74.98
	0.06	0.45	0.12	133.54	83.71	90.07	84.69	85.66	66.48
	0.05	0.33	0.17	107.89	112.41	115.42	95.38	83.92	91.44
	0.06	0.32	0.16	103.17	103.86	107.95	95.71	84.29	82.68
	0.06	0.41	0.16	182.96	95.90	106.51	97.57	84.04	82.95
	0.06	0.39	0.12	126.56	98.23	103.75	92.63	84.41	78.35
	0.06	0.41	0.16	170.32	78.17	89.67	92.70	84.48	99.90

Month	SHARK	SHARL	SHARM	E1	E2	E3	K	L	M
1984	0.05	0.33	0.14	86.94	96.78	100.57	86.42	78.18	80.02
	0.06	0.33	0.12	75.48	98.31	99.29	81.38	78.18	71.59
	0.06	0.30	0.13	72.39	116.84	116.56	88.31	78.43	80.97
	0.05	0.41	0.11	93.31	87.11	93.75	92.08	78.43	70.15
	0.05	0.36	0.12	71.66	105.46	106.68	87.27	78.62	76.74
	0.05	0.33	0.12	98.77	106.56	110.17	93.15	78.12	78.14
	0.05	0.34	0.12	160.24	99.78	111.66	93.87	78.12	81.64
	0.05	0.29	0.12	139.87	107.40	113.28	96.99	78.30	77.52
	0.06	0.30	0.14	159.70	94.51	103.34	95.09	78.87	89.10
	0.06	0.39	0.14	102.22	106.43	110.60	104.19	79.18	104.68
	0.06	0.38	0.11	109.32	95.46	102.38	96.34	79.36	78.81
	0.05	0.41	0.12	96.04	118.71	121.08	100.51	79.43	87.22
1985	0.03	0.38	0.15	82.48	96.11	100.65	78.90	79.80	84.91
	0.04	0.33	0.14	82.10	101.77	104.78	79.81	79.43	80.40
	0.05	0.33	0.16	74.12	105.08	108.68	90.11	79.55	100.91
	0.04	0.45	0.14	88.18	101.27	106.60	85.11	79.36	85.17
	0.05	0.45	0.15	109.28	98.07	104.96	86.05	79.55	102.76
	0.04	0.44	0.17	100.15	91.01	97.60	76.97	79.74	87.47
	0.05	0.43	0.14	105.10	99.05	106.50	88.70	80.17	89.68
	0.05	0.40	0.16	110.99	91.36	100.59	91.84	81.23	93.80
	0.05	0.38	0.20	114.60	86.27	95.51	87.18	81.61	100.46
	0.04	0.46	0.17	68.23	103.05	109.83	93.09	81.11	111.14
	0.04	0.45	0.16	65.95	96.90	103.59	90.37	81.30	105.47
	0.03	0.47	0.18	49.22	98.30	104.24	84.53	80.92	104.76
1986	0.04	0.43	0.19	68.45	108.13	113.86	92.25	81.67	99.56
	0.04	0.42	0.20	49.84	102.44	103.73	82.52	81.61	96.78
	0.04	0.51	0.19	56.43	92.57	95.63	82.06	81.80	105.11
	0.04	0.50	0.18	58.76	100.68	104.97	90.07	81.86	114.13
	0.05	0.47	0.19	58.18	110.65	114.71	99.18	81.30	112.15
	0.06	0.43	0.22	35.68	105.51	108.25	101.74	81.36	110.38
	0.06	0.43	0.22	39.17	119.59	123.18	114.22	82.54	126.82
	0.06	0.49	0.20	33.55	106.74	110.43	112.66	83.04	115.48
	0.07	0.49	0.17	34.32	103.80	107.76	117.05	83.23	112.97
	0.06	0.48	0.22	43.63	93.82	100.59	114.24	83.10	138.39
	0.06	0.50	0.17	212.15	70.56	92.11	108.97	83.54	98.98
	0.07	0.53	0.15	81.25	85.13	96.15	121.38	83.29	85.41
1987	0.07	0.50	0.18	65.55	93.68	103.68	121.35	83.86	106.06
	0.06	0.54	0.15	53.91	85.81	94.08	111.41	83.98	101.69
	0.07	0.49	0.22	61.08	88.43	96.36	126.65	84.10	111.19
	0.06	0.43	0.24	69.42	98.42	102.81	109.55	85.10	114.96
	0.06	0.44	0.17	188.49	102.75	116.25	118.30	84.41	96.24
	0.05	0.41	0.21	315.51	82.83	108.63	109.81	84.98	111.42
	0.08	0.37	0.22	257.14	87.06	108.50	132.58	85.35	116.15
	0.07	0.40	0.20	351.38	78.02	106.27	128.01	85.10	114.48
	0.07	0.42	0.21	289.33	81.29	105.30	125.71	85.29	105.80
	0.07	0.46	0.18	354.68	77.34	107.03	136.34	85.66	107.85
	0.07	0.41	0.20	246.67	86.18	105.21	120.49	86.35	109.91
	0.12	0.42	0.16	225.14	95.26	108.30	174.71	86.60	105.70

TABLE 6: RIOCELL
FIVE INPUTS

Month	PE1	PE2	PK	PL	PM	SHARE1	SHARE2	SHARK
Jan 82	100.00	100.00	100.00	100.00	100.00	0.32	0.12	0.13
	114.51	114.51	97.50	99.44	99.10	0.25	0.24	0.12
	109.84	109.84	97.02	87.05	103.27	0.14	0.32	0.11
	104.15	104.15	107.11	117.10	89.34	0.36	0.18	0.03
	114.51	114.51	103.29	116.45	92.06	0.39	0.14	0.02
	107.25	107.25	95.99	118.08	85.99	0.43	0.11	0.02
	101.04	101.04	105.37	121.86	114.52	0.33	0.10	0.02
	94.82	94.82	107.04	112.35	99.07	0.21	0.16	0.03
	98.45	98.45	116.31	104.20	86.84	0.26	0.09	0.04
	93.26	93.26	111.39	145.43	94.73	0.45	0.05	0.02
Oct 82	81.87	82.86	89.57	150.37	72.02	0.26	0.18	0.12
Mar 83	73.58	71.46	93.07	180.96	74.72	0.24	0.21	0.14
	67.88	55.85	103.24	152.74	71.86	0.22	0.19	0.12
	91.19	53.00	84.86	138.06	69.62	0.26	0.21	0.09
	79.79	49.32	90.30	123.66	67.59	0.25	0.25	0.12
	94.30	49.63	101.53	107.75	62.46	0.33	0.14	0.13
	85.49	49.63	88.29	105.18	69.24	0.22	0.22	0.15
	98.45	40.86	86.80	143.77	64.39	0.31	0.16	0.12
	88.60	41.37	106.69	130.39	60.68	0.23	0.17	0.15
	79.79	39.03	109.77	115.10	58.10	0.32	0.14	0.13
Jan 84	96.89	51.66	100.49	113.74	67.82	0.22	0.15	0.28
	89.12	46.50	90.89	106.26	72.89	0.29	0.12	0.24
	79.27	46.70	99.97	107.68	79.34	0.18	0.12	0.40
	86.53	43.88	104.07	131.19	48.45	0.19	0.13	0.33
	80.83	42.00	104.40	135.93	61.98	0.27	0.11	0.27
	73.58	36.80	102.81	121.03	62.74	0.24	0.12	0.29
	79.27	41.09	98.50	106.53	56.30	0.19	0.14	0.33
	72.02	38.84	97.29	117.41	62.13	0.25	0.13	0.28
	64.77	37.35	100.63	107.10	55.46	0.26	0.12	0.28
	74.61	41.98	99.55	125.18	47.39	0.27	0.12	0.29
	83.94	42.15	110.24	140.67	50.13	0.32	0.10	0.27
	76.17	37.80	107.69	128.18	52.68	0.29	0.11	0.29
Jan 85	67.88	41.61	99.57	140.65	50.54	0.25	0.12	0.28
	60.62	40.70	109.48	140.58	51.22	0.24	0.10	0.34
	68.39	40.64	99.26	123.41	48.46	0.24	0.12	0.30
	60.10	35.55	126.63	145.87	52.22	0.33	0.07	0.30
	66.84	36.63	115.62	164.27	45.00	0.23	0.11	0.30
	60.62	30.48	113.54	129.57	47.29	0.25	0.09	0.31
	55.96	29.15	107.78	127.12	44.81	0.25	0.09	0.31
	63.21	33.17	90.69	137.61	46.59	0.26	0.09	0.31
	63.21	34.89	117.63	131.40	46.64	0.25	0.10	0.32
	64.77	36.20	111.20	140.77	50.92	0.27	0.09	0.29
	60.10	33.99	87.49	170.33	49.98	0.25	0.09	0.28
	60.10	33.92	94.12	150.10	53.24	0.25	0.09	0.28

Month	PE1	PE2	PK	PL	PM	SHARE1	SHARE2	SHARK
Jan 86	52.33	33.13	72.32	138.76	47.62	0.23	0.08	0.33
	56.99	36.59	51.82	127.05	50.62	0.22	0.10	0.34
	53.89	37.58	115.41	151.97	52.02	0.13	0.08	0.42
	51.30	32.64	111.94	149.96	50.14	0.20	0.09	0.33
	50.78	31.85	107.70	146.37	52.94	0.21	0.09	0.30
	50.78	32.45	106.95	133.41	53.61	0.20	0.09	0.35
	53.37	32.04	109.53	147.36	54.72	0.20	0.10	0.29
	53.37	32.47	109.17	145.47	56.11	0.21	0.10	0.30
	53.37	32.31	111.89	140.80	58.77	0.22	0.09	0.29
	52.85	31.70	106.14	162.54	57.03	0.20	0.09	0.28
	52.33	31.66	103.07	188.24	63.67	0.19	0.10	0.28
	50.78	30.30	94.16	175.65	64.93	0.20	0.08	0.25
Jan 87	46.63	30.53	99.19	177.79	54.48	0.16	0.07	0.35
	40.41	29.26	128.20	206.66	54.57	0.14	0.08	0.34
	43.52	28.10	90.06	171.49	57.66	0.17	0.08	0.33
	41.97	26.47	82.26	127.28	51.61	0.17	0.07	0.35
	53.89	33.22	89.97	152.53	65.90	0.15	0.08	0.40
	53.89	39.42	72.10	203.40	83.65	0.13	0.10	0.26
	56.99	36.99	101.91	121.30	59.96	0.21	0.10	0.30
	55.44	35.21	123.21	131.72	68.00	0.20	0.10	0.30
	54.92	34.48	103.60	135.81	78.64	0.19	0.09	0.28
	55.96	36.39	95.85	216.66	70.18	0.18	0.08	0.27
	56.48	38.27	96.61	238.07	82.40	0.18	0.09	0.24
Dec	58.03	38.28	93.31	161.46	74.15	0.20	0.09	0.23

Month	SHARL	SHARM	E1	E2	K	L	M
Jan 82	0.20	0.23	100.00	100.00	100.00	100.00	100.00
	0.19	0.20	71.17	194.00	98.20	100.33	91.52
	0.20	0.23	35.84	229.33	80.97	100.88	87.78
	0.19	0.25	136.20	185.69	61.24	100.28	156.94
	0.18	0.26	131.14	125.73	59.06	92.92	152.15
	0.14	0.30	166.28	111.20	67.28	77.06	200.14
	0.30	0.25	64.83	53.42	30.48	77.34	60.68
	0.27	0.33	45.74	94.84	44.26	77.45	95.81
	0.27	0.34	48.46	45.73	44.29	75.18	102.83
	0.22	0.25	150.16	46.49	44.55	72.03	114.94
Oct 82	0.18	0.26	100.51	193.02	114.54	62.30	165.82
Mar 83	0.24	0.17	96.59	247.23	101.70	63.24	99.60
	0.17	0.30	116.72	323.17	130.62	62.41	205.90
	0.15	0.29	102.99	407.20	116.02	62.35	217.87
	0.12	0.25	128.05	557.16	141.38	62.41	212.08
	0.11	0.30	133.83	299.17	150.17	61.97	255.74
	0.13	0.28	80.42	375.78	130.39	59.26	173.94
	0.14	0.27	116.61	396.10	136.67	58.87	219.69
	0.16	0.29	77.43	329.28	131.18	58.21	199.16
	0.12	0.29	139.24	338.35	136.56	58.65	244.48

Month	SHARL	SHARM	E1	E2	K	L	M
Jan 84	0.10	0.25	96.64	337.08	253.90	59.15	218.51
	0.09	0.26	143.43	310.57	227.90	60.25	213.65
	0.14	0.17	66.05	208.32	232.19	59.98	87.64
	0.14	0.21	80.20	310.61	257.02	59.65	221.93
	0.11	0.24	157.90	352.93	274.00	58.37	255.67
	0.11	0.24	138.89	390.54	271.49	58.65	233.99
	0.11	0.23	89.01	365.17	269.28	59.26	213.99
	0.10	0.24	152.42	393.15	274.91	58.65	236.63
	0.10	0.25	155.69	335.32	246.16	58.54	244.11
	0.11	0.21	147.81	316.05	264.94	58.26	260.19
	0.12	0.20	171.82	307.66	270.21	58.49	252.31
	0.11	0.20	161.72	344.88	274.77	58.60	229.71
Jan 85	0.12	0.23	161.63	358.72	272.39	58.76	277.89
	0.13	0.19	150.85	263.63	279.55	57.99	198.46
	0.11	0.23	150.85	334.09	281.55	58.49	277.67
	0.17	0.12	177.97	175.67	196.64	59.37	104.26
	0.15	0.21	145.23	338.96	274.13	59.48	274.39
	0.12	0.22	170.41	346.61	276.83	58.54	263.19
	0.12	0.23	172.86	317.96	269.97	57.77	277.17
	0.12	0.22	176.57	328.83	286.79	58.43	275.44
	0.13	0.21	153.99	308.22	267.29	58.54	237.97
	0.13	0.21	174.87	298.72	269.93	58.71	242.37
	0.15	0.23	178.06	302.71	271.66	58.60	272.01
	0.13	0.25	175.91	309.76	270.70	59.15	280.87
Jan 86	0.15	0.20	192.61	279.46	307.26	72.53	257.40
	0.14	0.21	155.71	294.18	295.10	72.91	237.98
	0.25	0.12	63.57	159.02	223.04	72.36	85.99
	0.16	0.22	166.55	327.58	298.39	71.59	256.29
	0.15	0.24	186.50	368.57	302.35	71.09	288.86
	0.14	0.23	177.10	329.05	321.54	73.36	260.26
	0.15	0.26	174.09	414.62	301.26	72.80	309.30
	0.15	0.24	173.76	399.92	297.75	73.30	262.83
	0.14	0.26	195.60	384.60	300.36	74.41	289.11
	0.16	0.26	177.70	392.33	296.13	74.85	307.44
	0.19	0.23	171.92	408.05	295.11	75.40	241.59
	0.16	0.31	201.82	395.38	298.14	75.57	348.51
Jan 87	0.19	0.22	154.91	306.88	334.05	75.90	257.50
	0.21	0.23	167.66	344.18	341.30	74.52	274.66
	0.17	0.25	183.08	371.20	337.44	74.90	285.93
	0.15	0.26	164.56	310.22	312.64	75.68	292.76
	0.21	0.16	94.95	216.54	279.19	75.68	115.82
	0.20	0.30	121.36	355.81	270.86	75.18	246.55
	0.12	0.27	183.54	378.41	333.70	76.78	312.95
	0.13	0.28	177.75	375.35	324.23	78.05	284.28
	0.13	0.31	180.30	380.18	322.94	78.50	284.59
	0.21	0.27	166.54	333.16	308.03	78.77	278.13
	0.21	0.29	187.14	360.38	307.27	77.72	280.20
Dec	0.15	0.33	193.38	349.33	299.12	78.72	350.62

APPENDIX C

FIGURE 1: IKPC

ENERGY - FITTED EQUATION
COST FUNCTION - 4 INPUTS

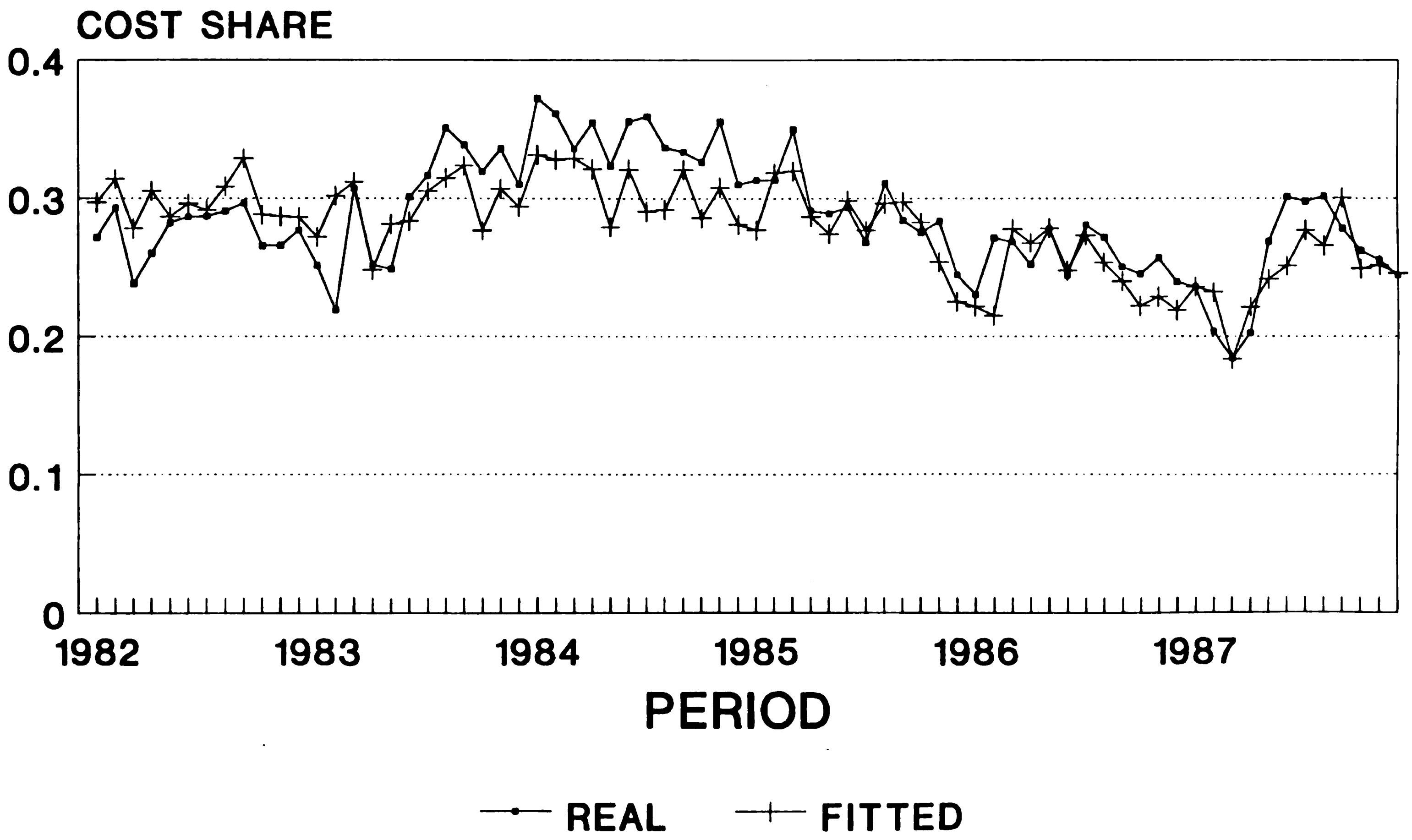


FIGURE 2: IKPC
ENERGY - FITTED EQUATION
PRODUCTION FUNCTION - 4 INPUTS

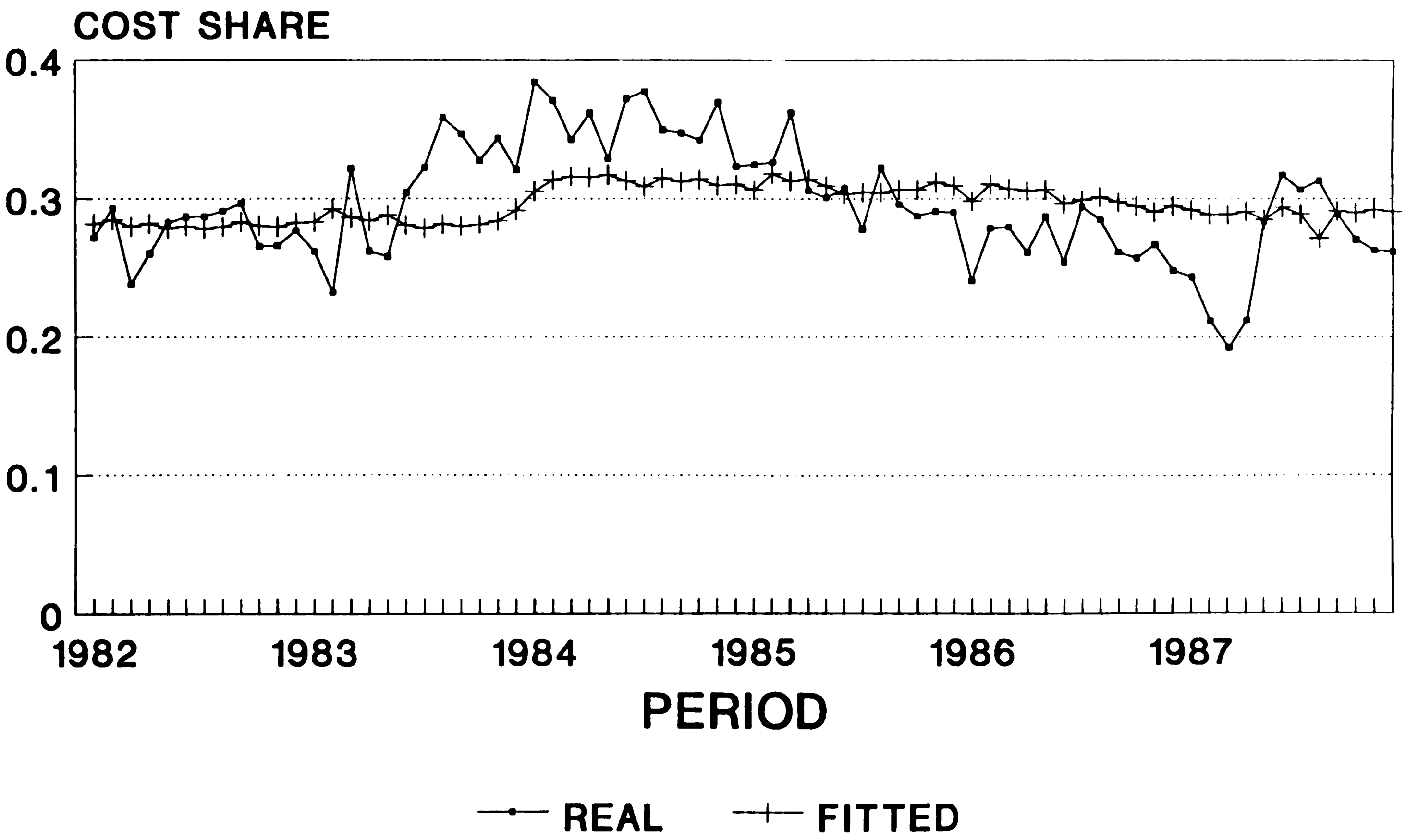


FIGURE 3: IKPC
CAPITAL - FITTED EQUATION
COST FUNCTION - 4 INPUTS

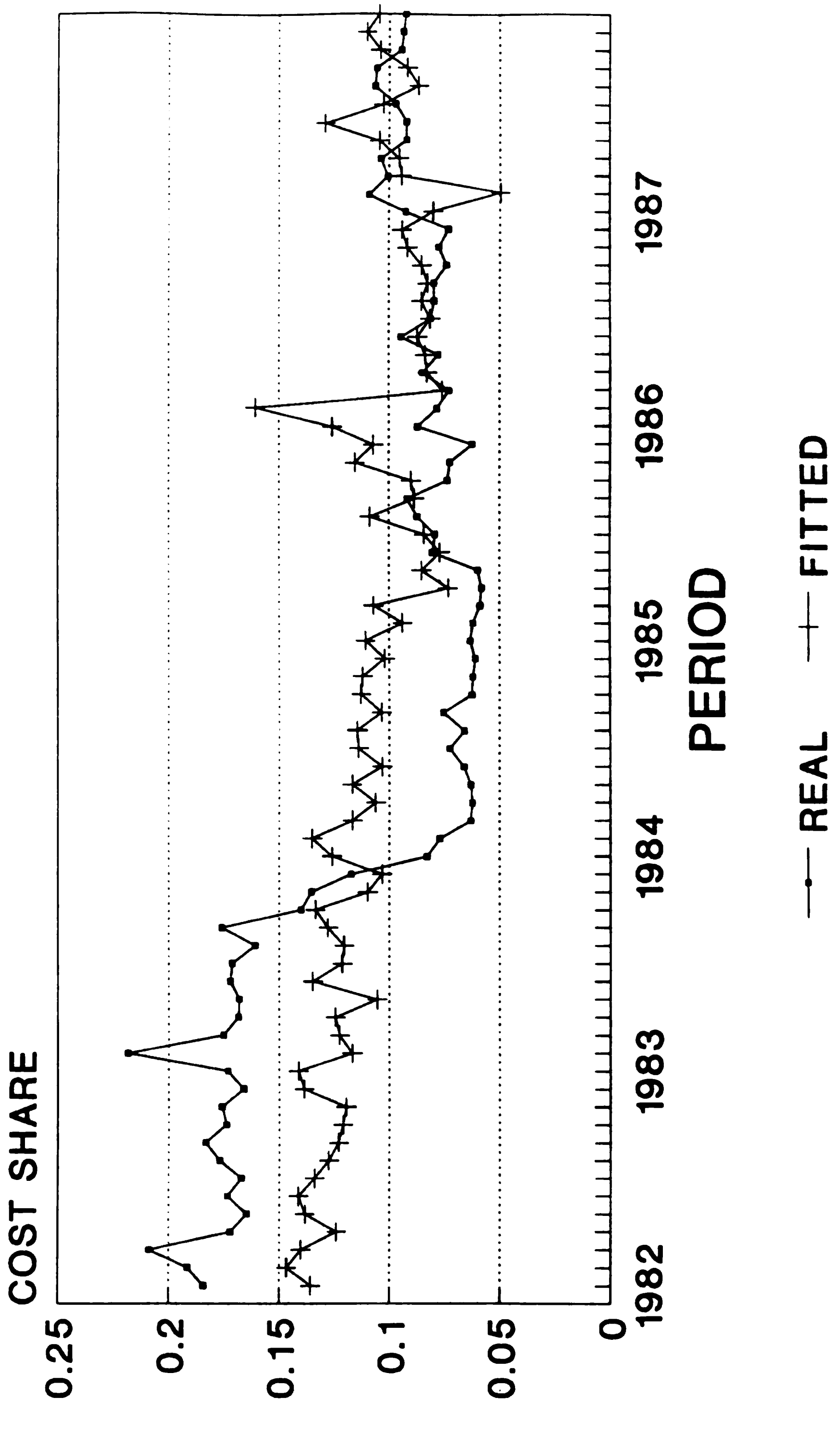


FIGURE 4: IKPC

CAPITAL - FITTED EQUATION
PRODUCTION FUNCTION - 4 INPUTS

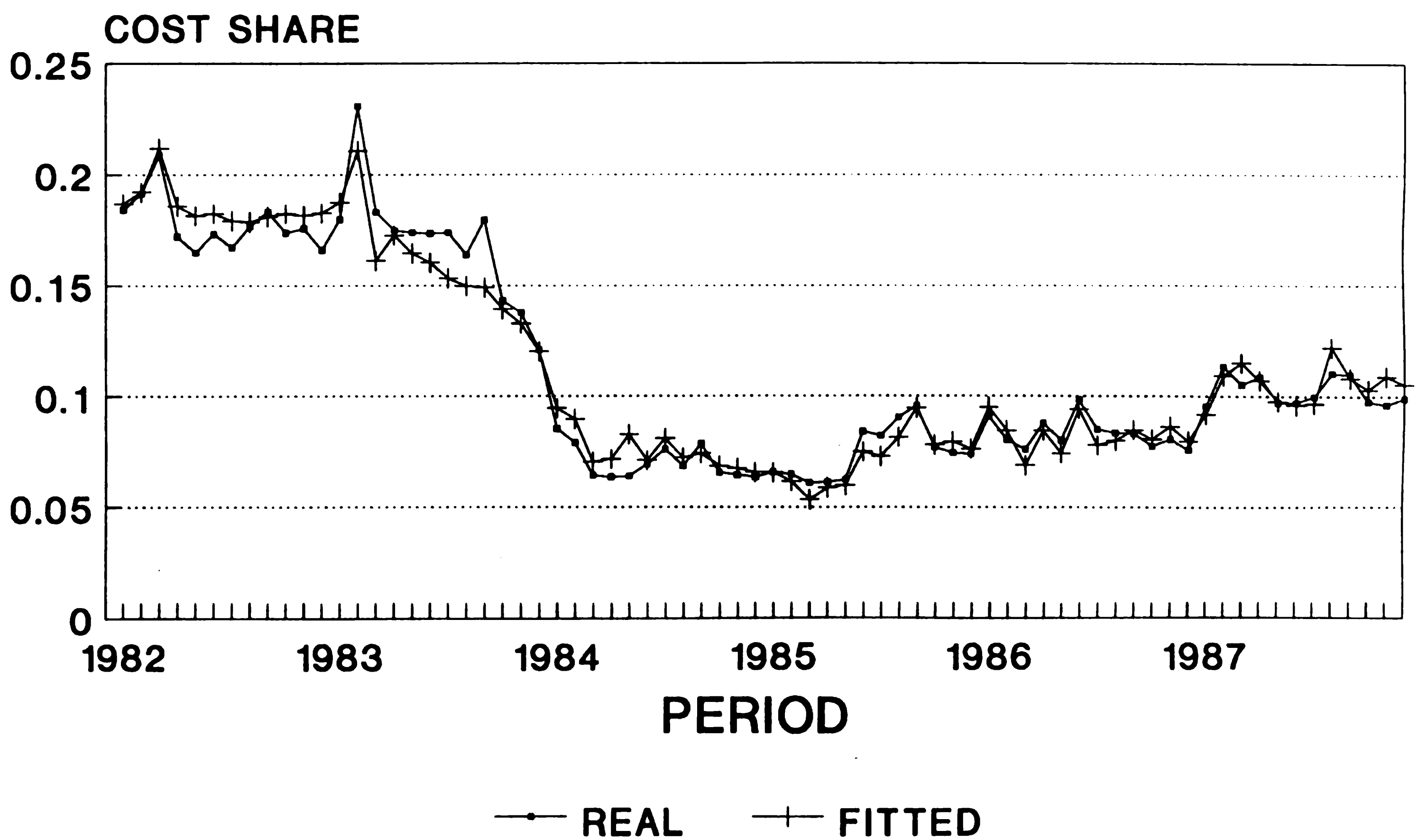


FIGURE 5: PCC

ENERGY - FITTED EQUATION
COST FUNCTION - 4 INPUTS

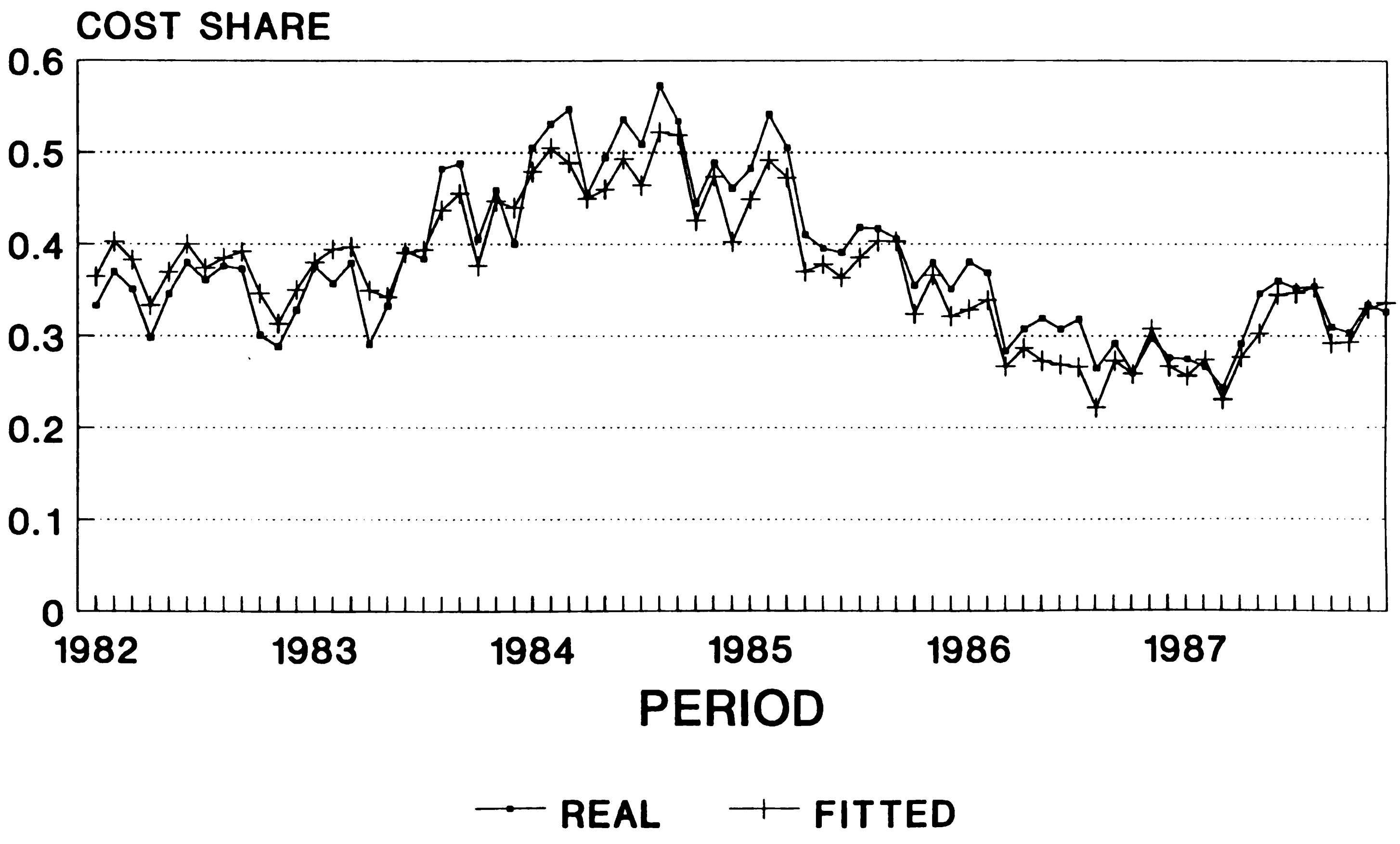


FIGURE 6: PCC

ENERGY - FITTED EQUATION
PRODUCTION FUNCTION 4 INPUTS

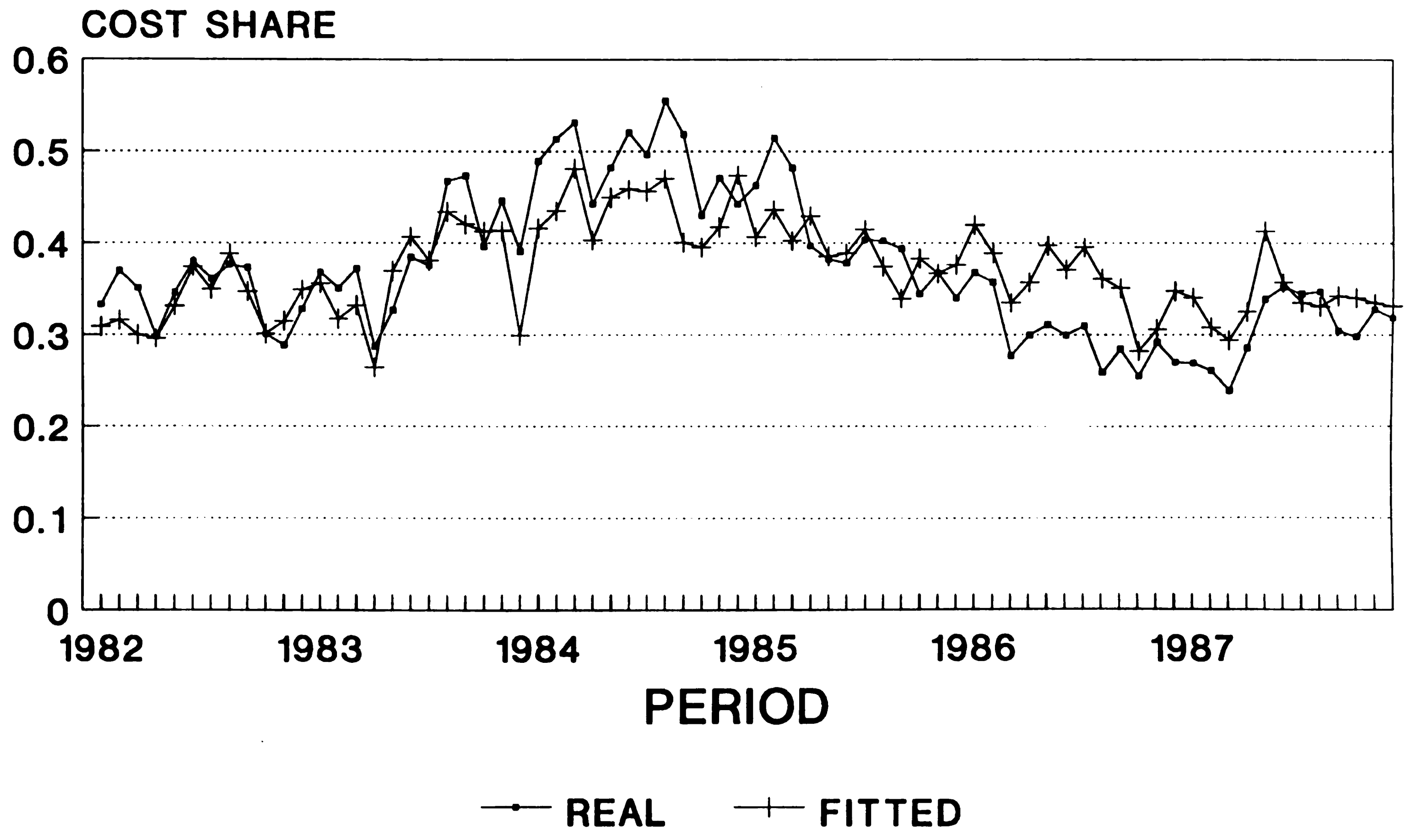


FIGURE 7: PCC
CAPITAL - FITTED EQUATION
COST FUNCTION - 4 INPUTS

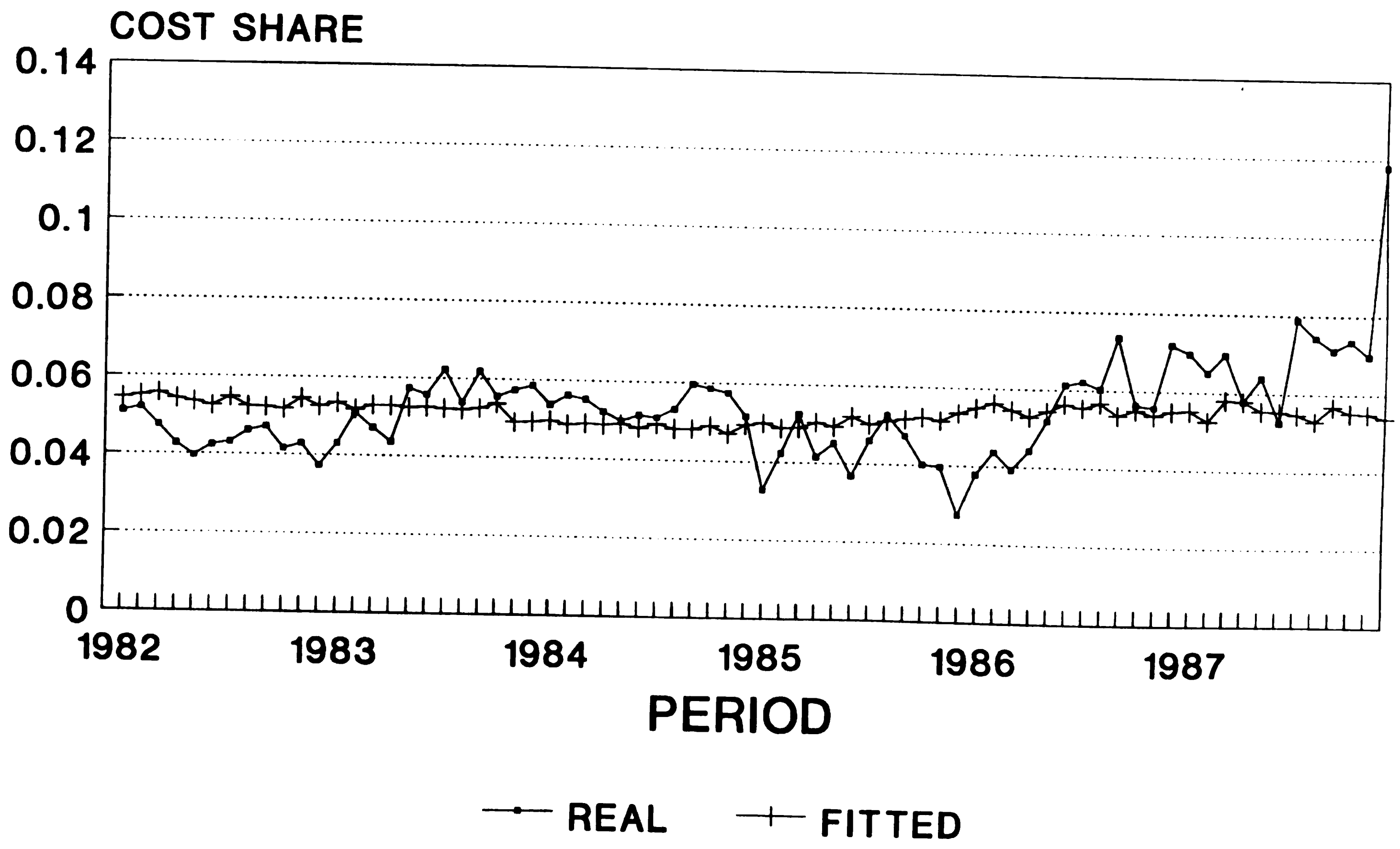


FIGURE 7: PCC

CAPITAL - FITTED EQUATION
COST FUNCTION - 4 INPUTS

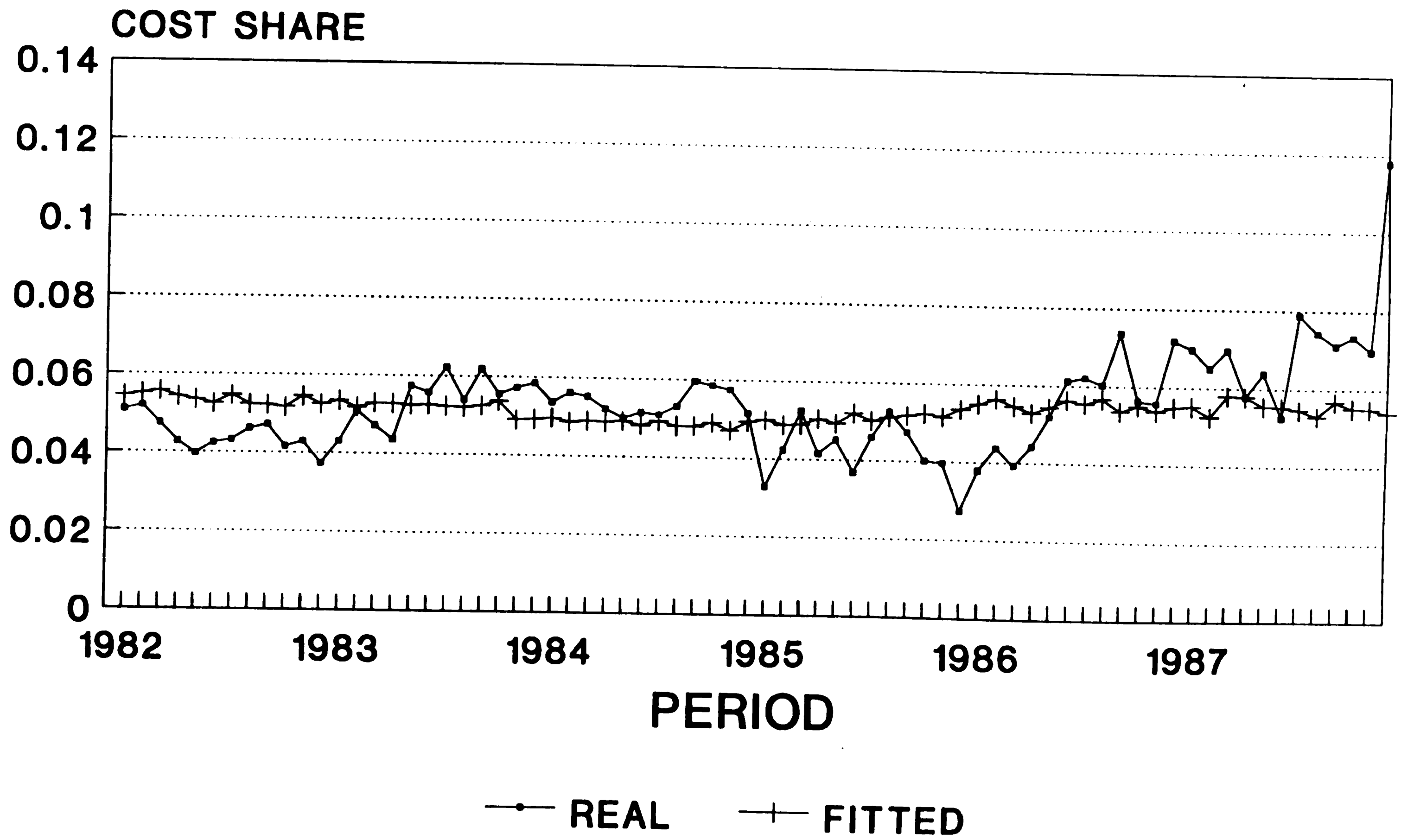


FIGURE 9: RIOCELL

ENERGY - FITTED EQUATION
COST FUNCTION - 4 INPUTS

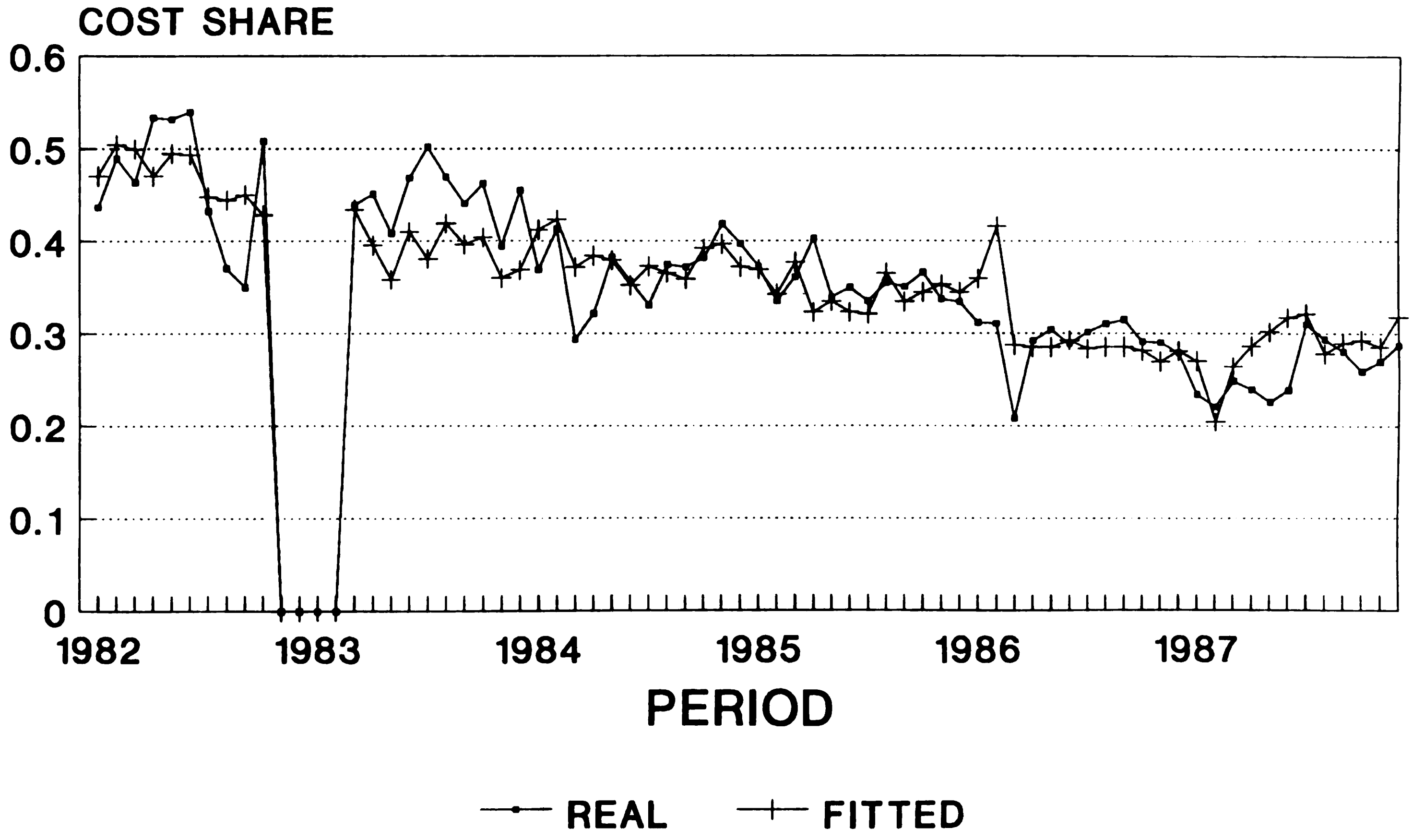


FIGURE 9: RIOCELL
ENERGY - FITTED EQUATION
COST FUNCTION - 4 INPUTS

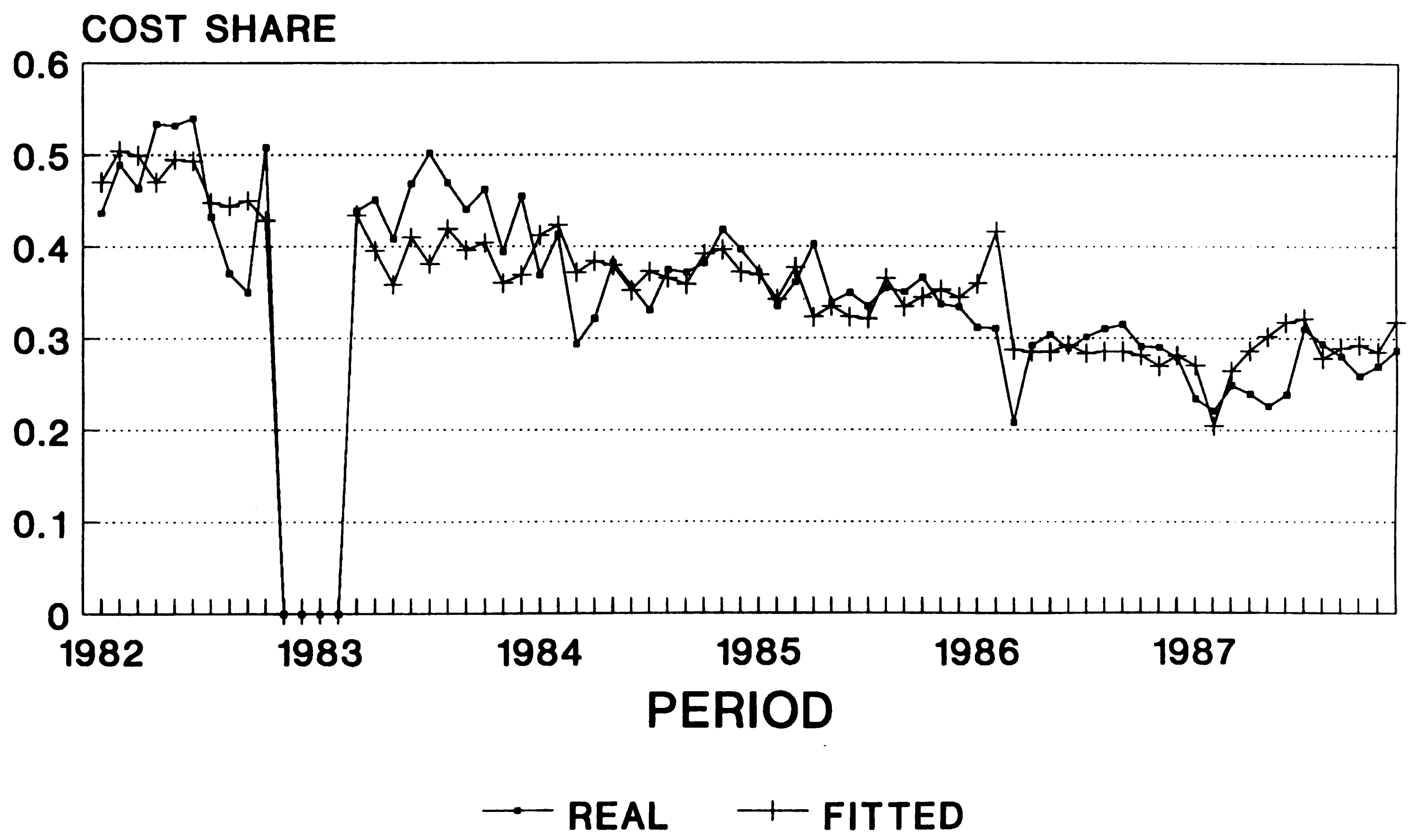


FIGURE 10: RIOCELL
ENERGY - FITTED EQUATION
PRODUCTION FUNCTION - 4 INPUTS

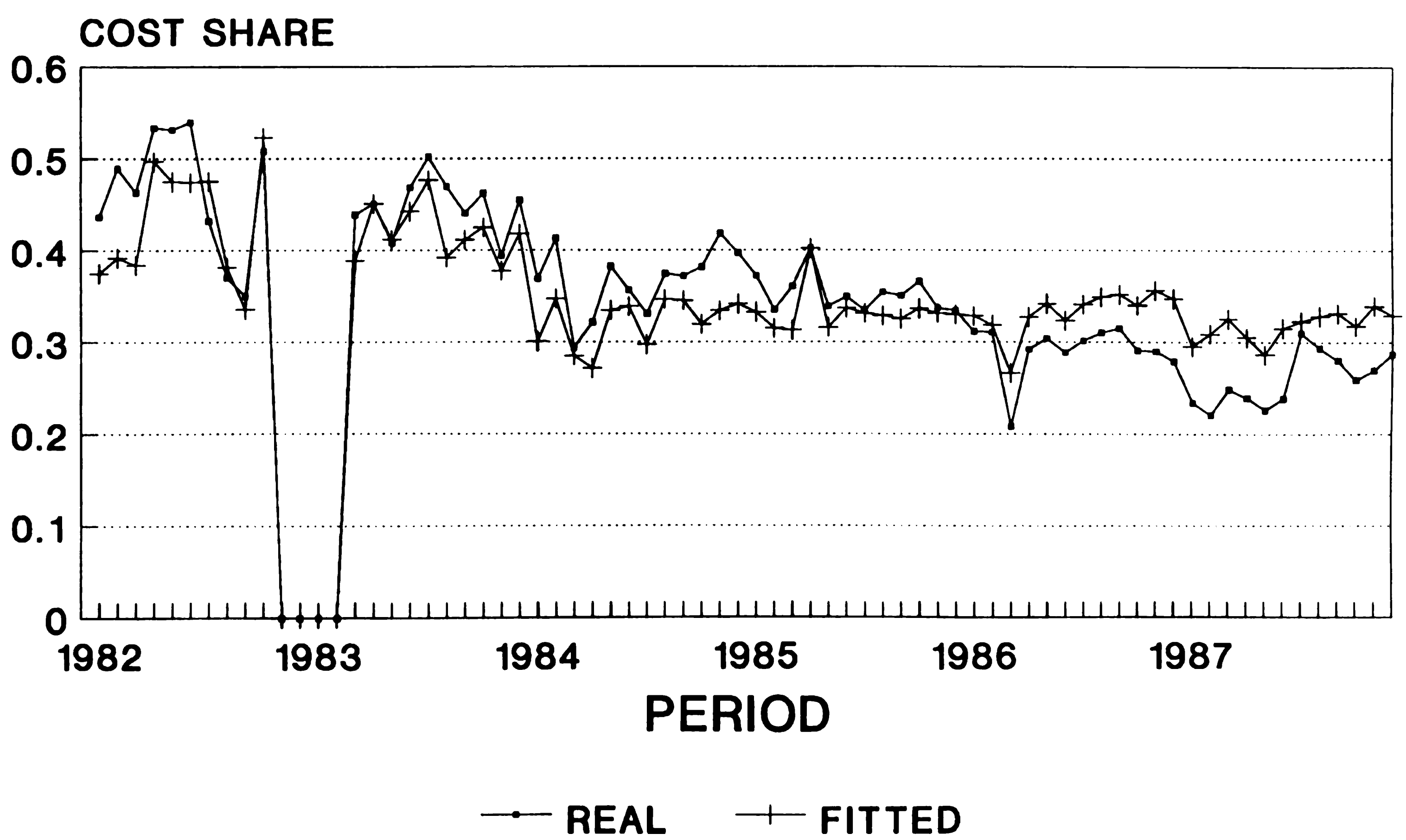


FIGURE 11: RIOCELL
CAPITAL - FITTED EQUATION
COST FUNCTION - 4 INPUTS

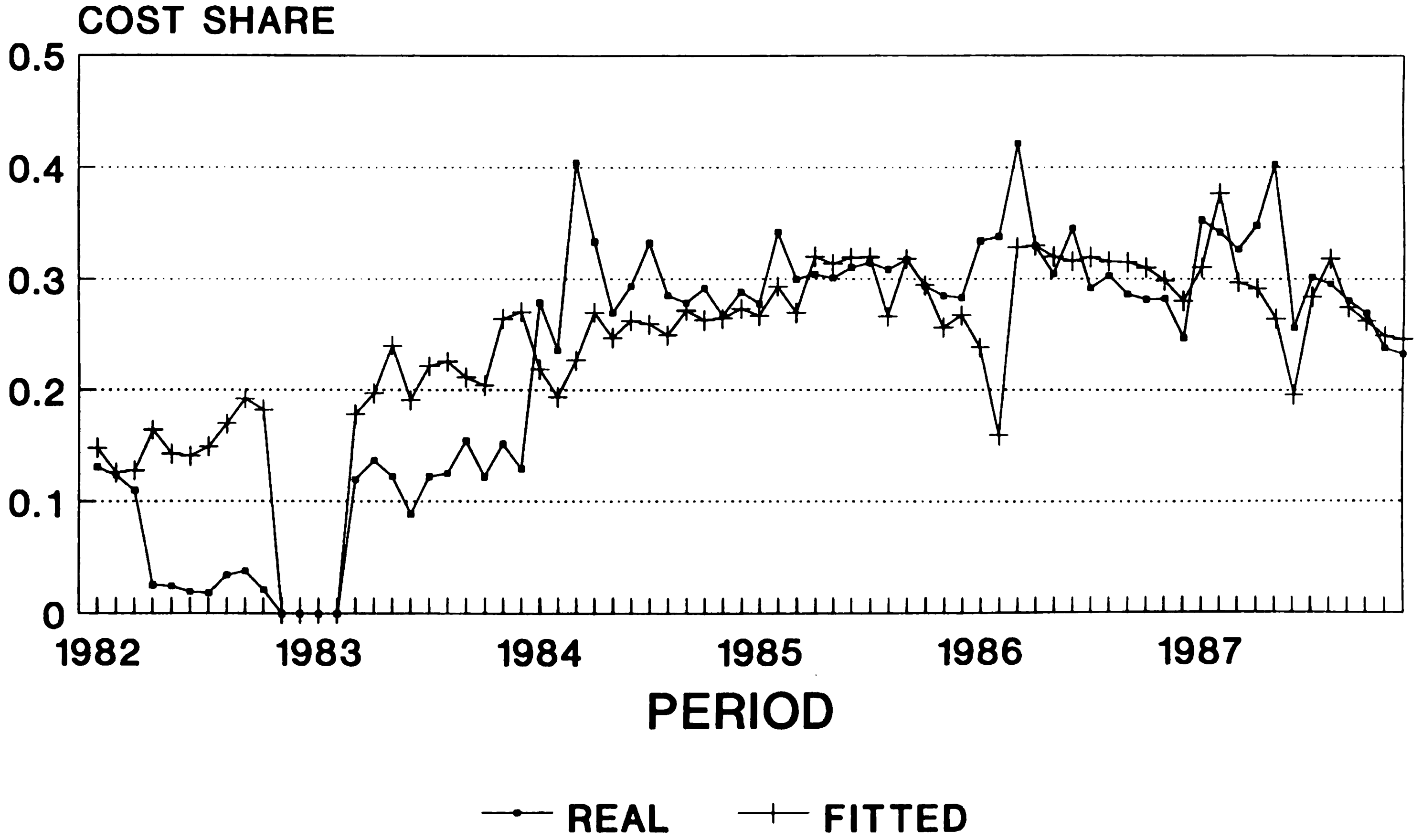


FIGURE 12: RIOCELL
CAPITAL - FITTED EQUATION
PRODUCTION FUNCTION - 4 INPUTS

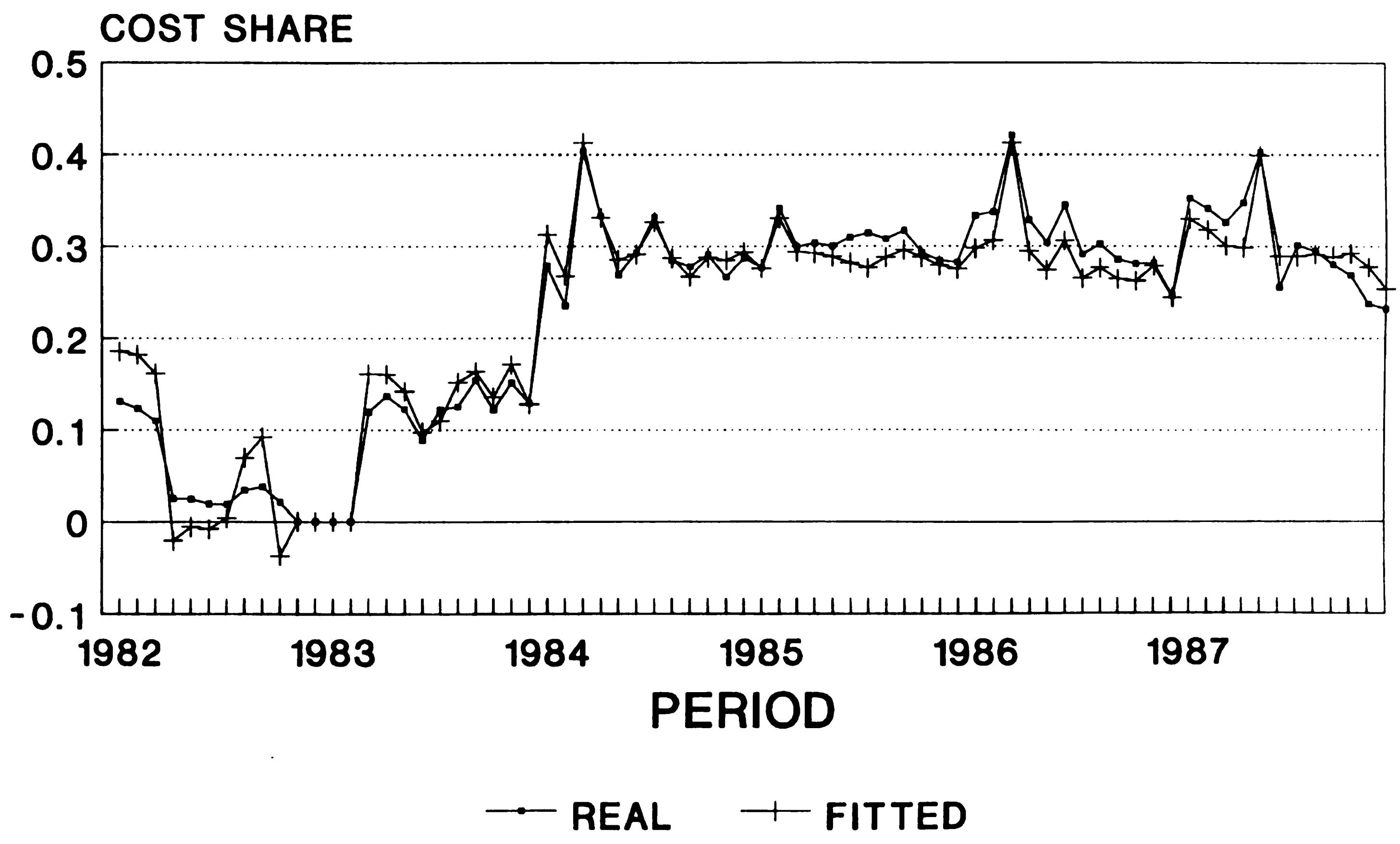


FIGURE 13: IKPC
BIOMASS - FITTED EQUATION
COST FUNCTION - 6 INPUTS

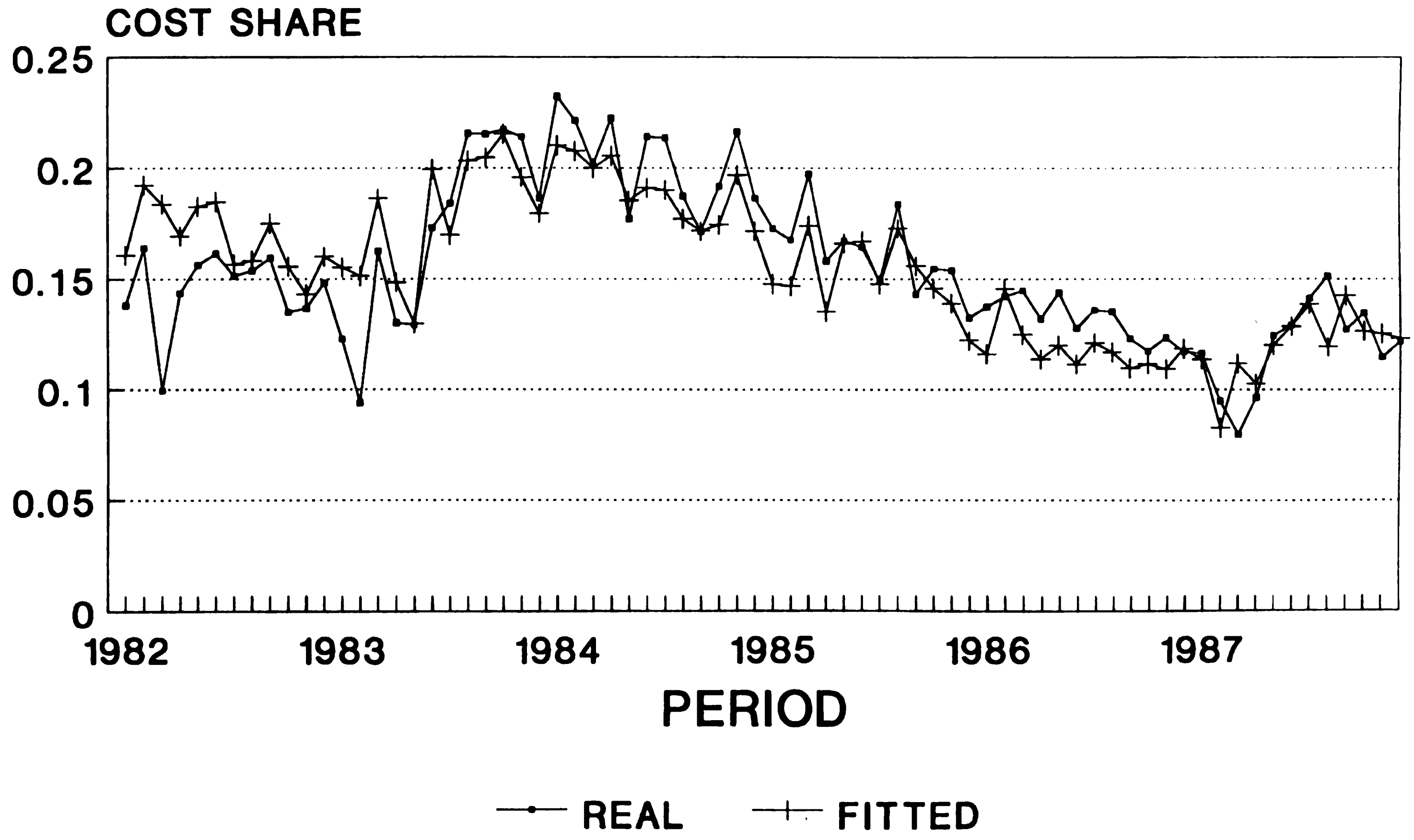


FIGURE 13: IKPC

BIOMASS - FITTED EQUATION
COST FUNCTION - 6 INPUTS

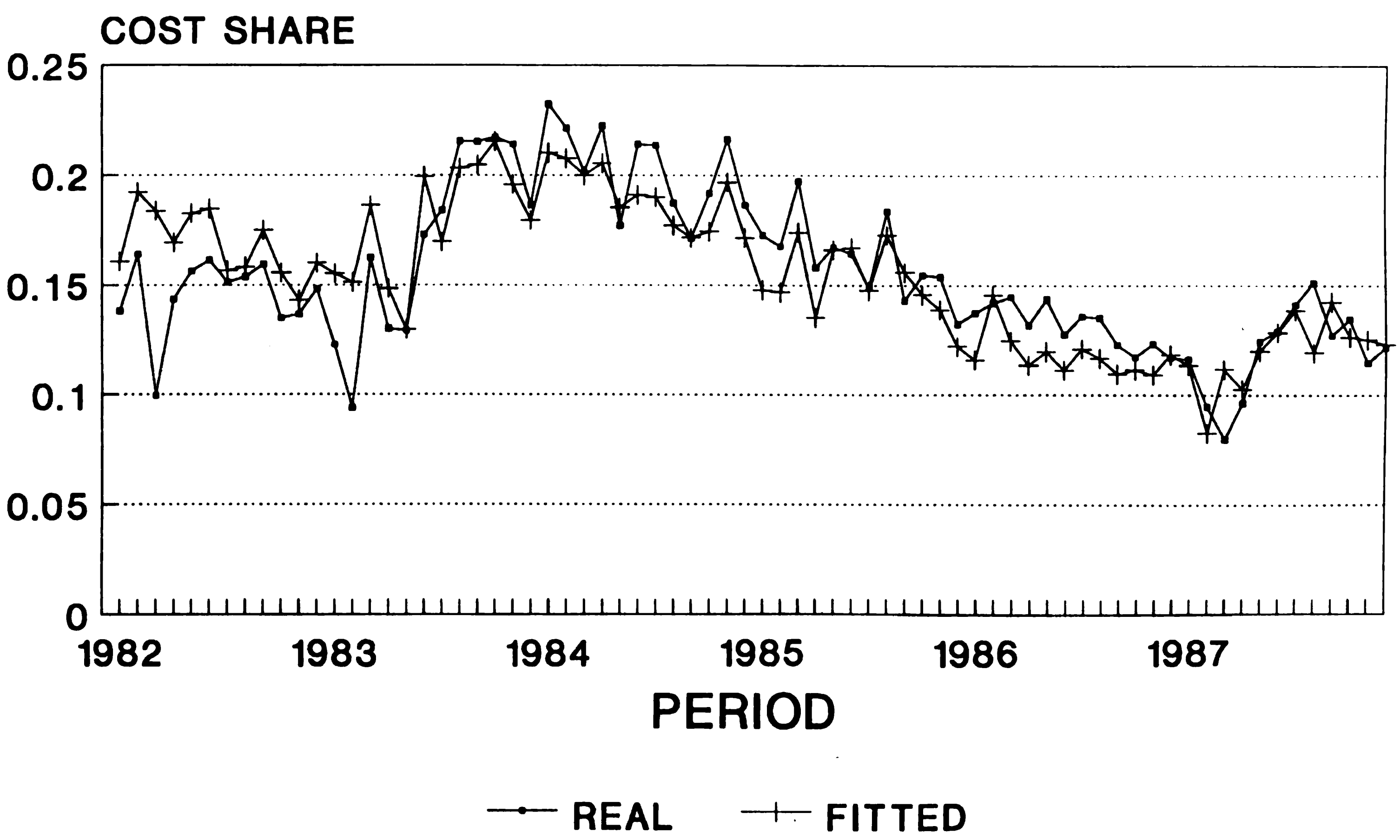


FIGURE 14: IKPC

BIOMASS - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

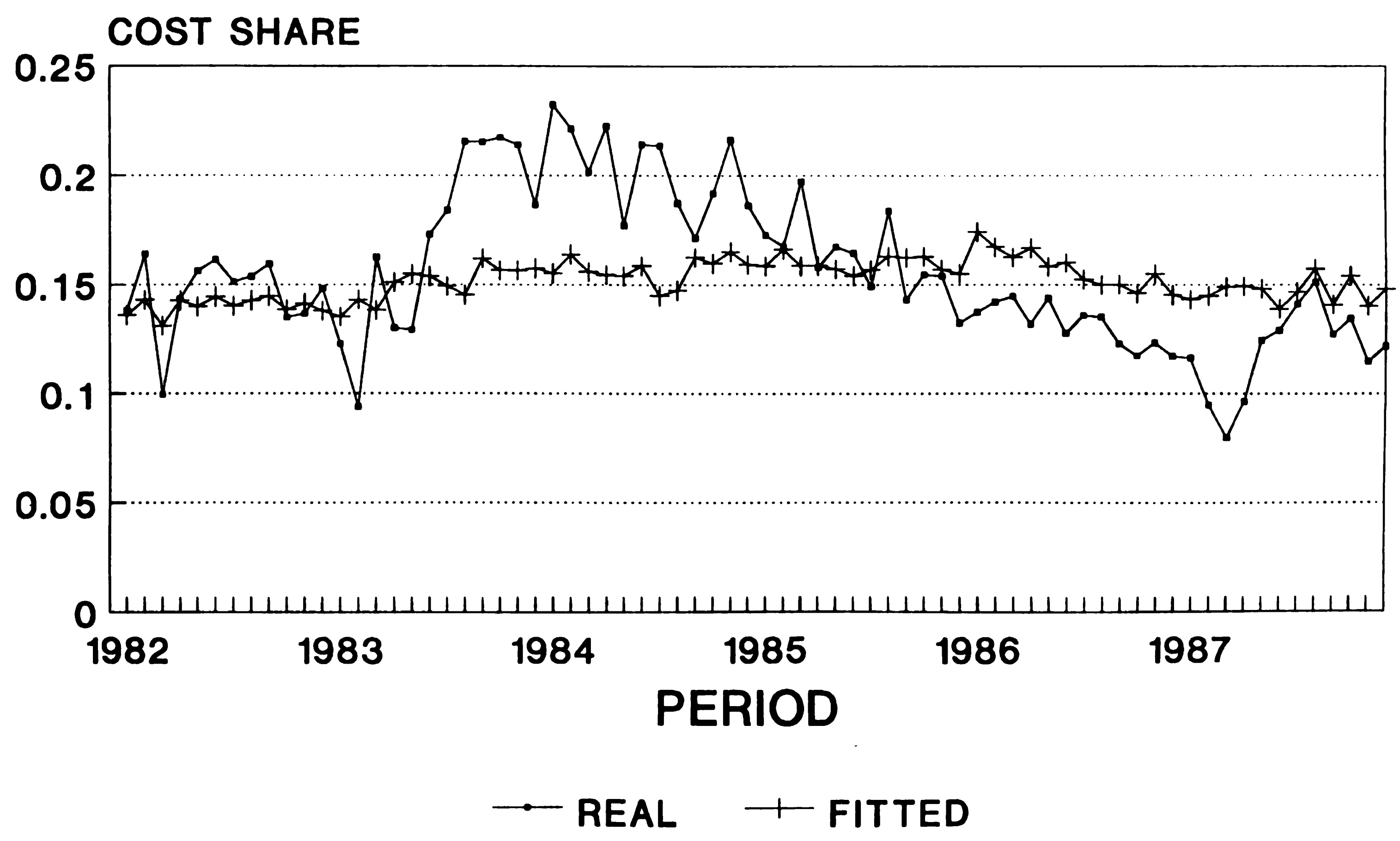


FIGURE 15: IKPC
FOSSIL FUELS - FITTED EQUATION
COST FUNCTION - 6 INPUTS

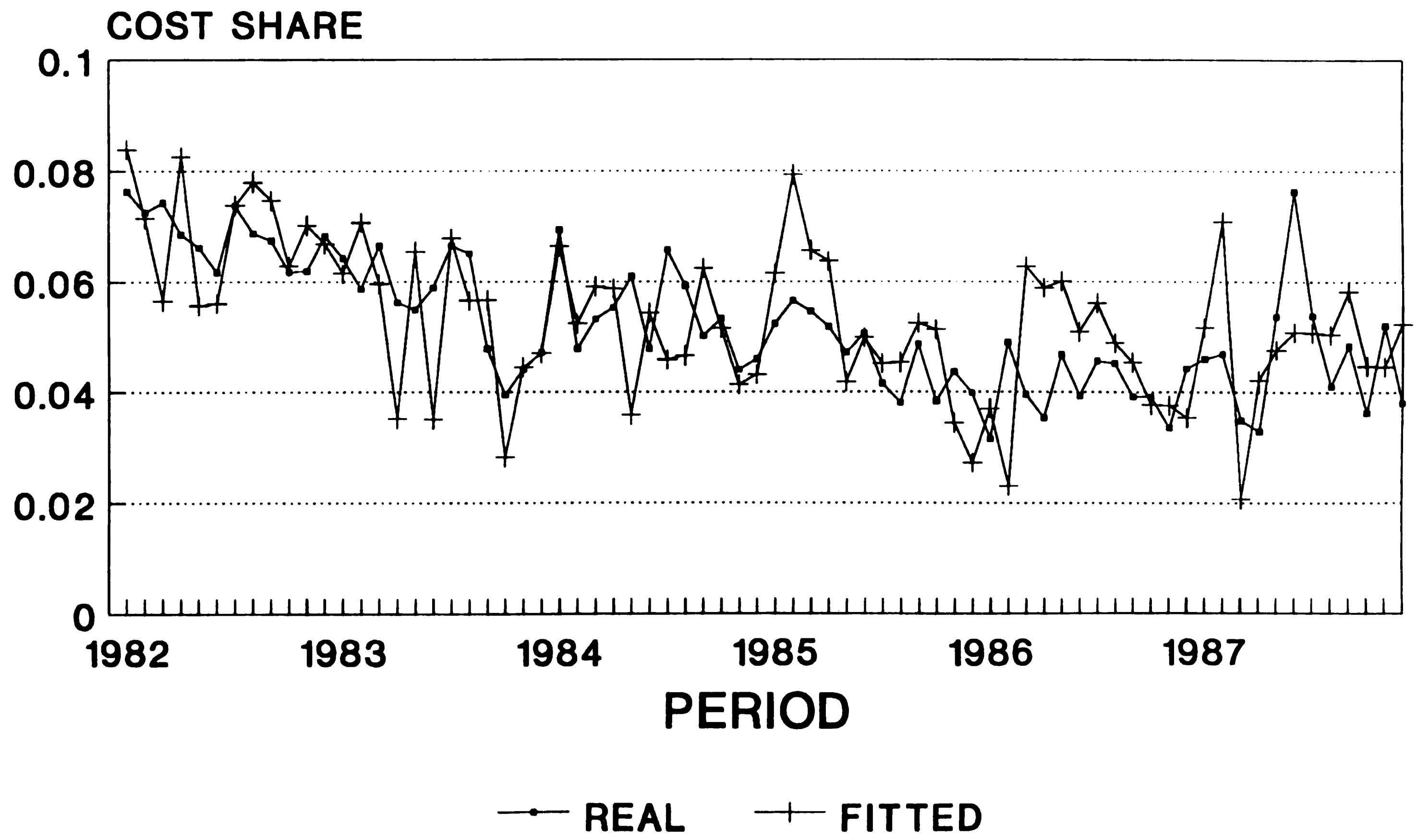


FIGURE 15: IKPC

FOSSIL FUELS - FITTED EQUATION
COST FUNCTION - 6 INPUTS

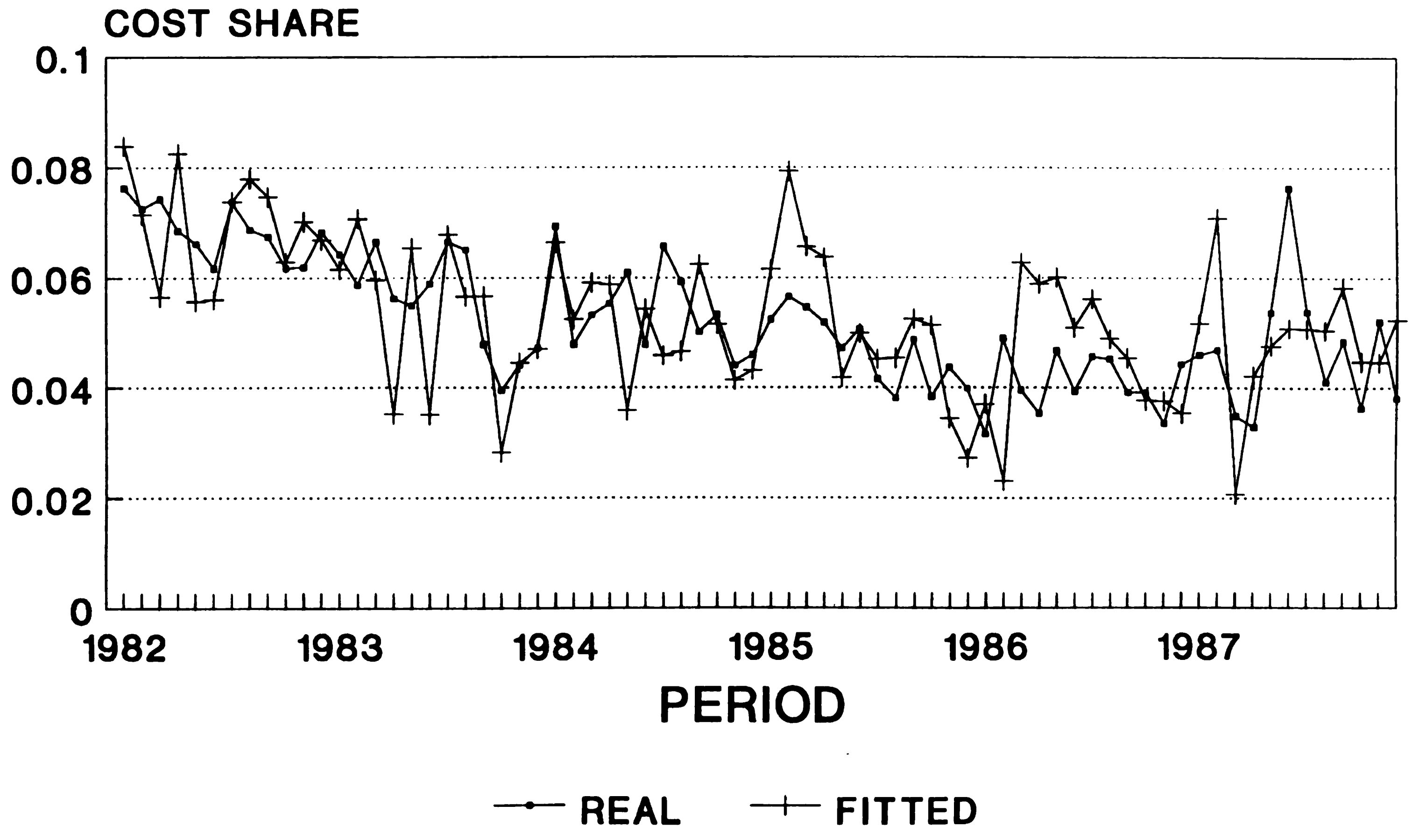


FIGURE 16: IKPC
FOSSIL FUELS - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

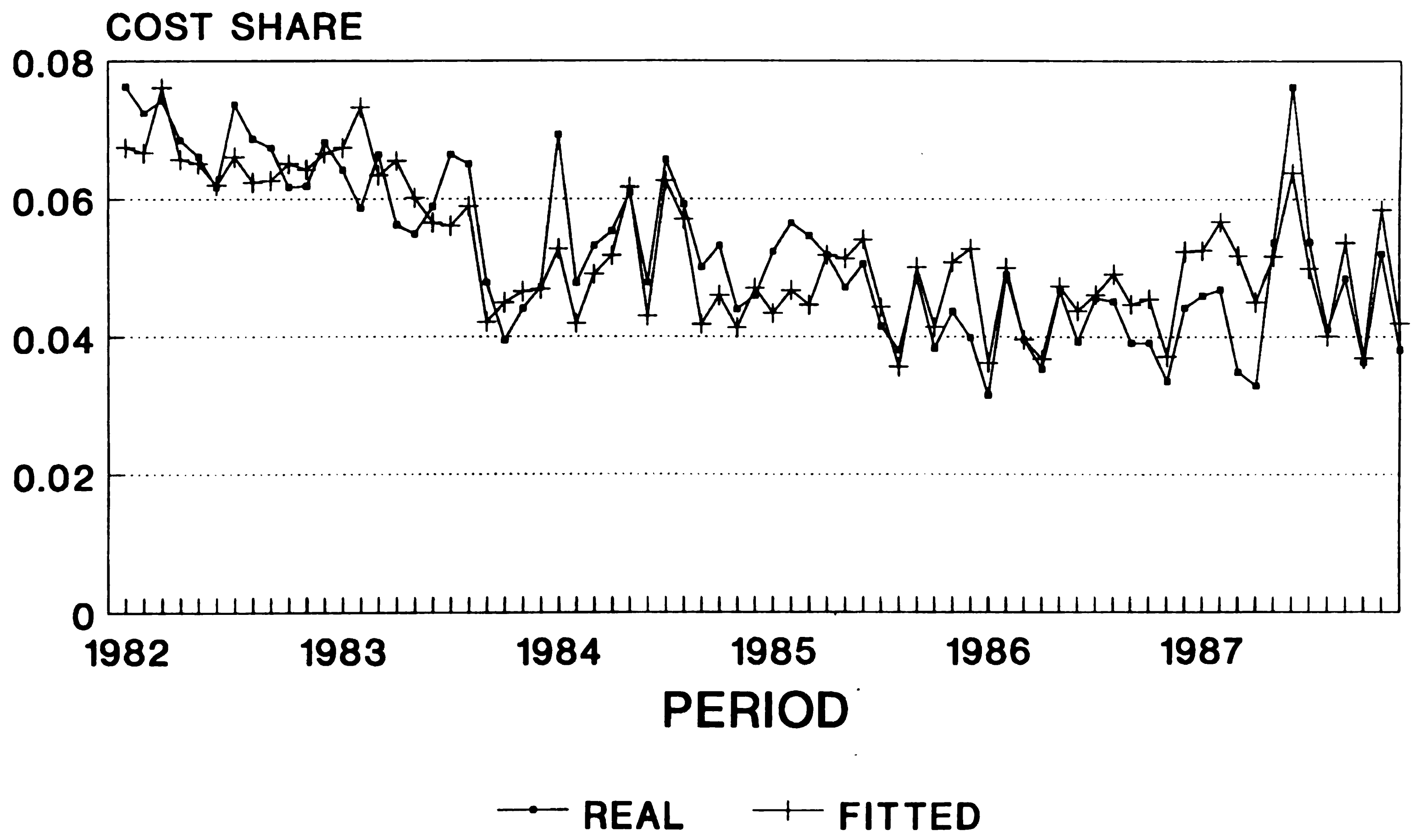


FIGURE 16: IKPC
FOSSIL FUELS - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

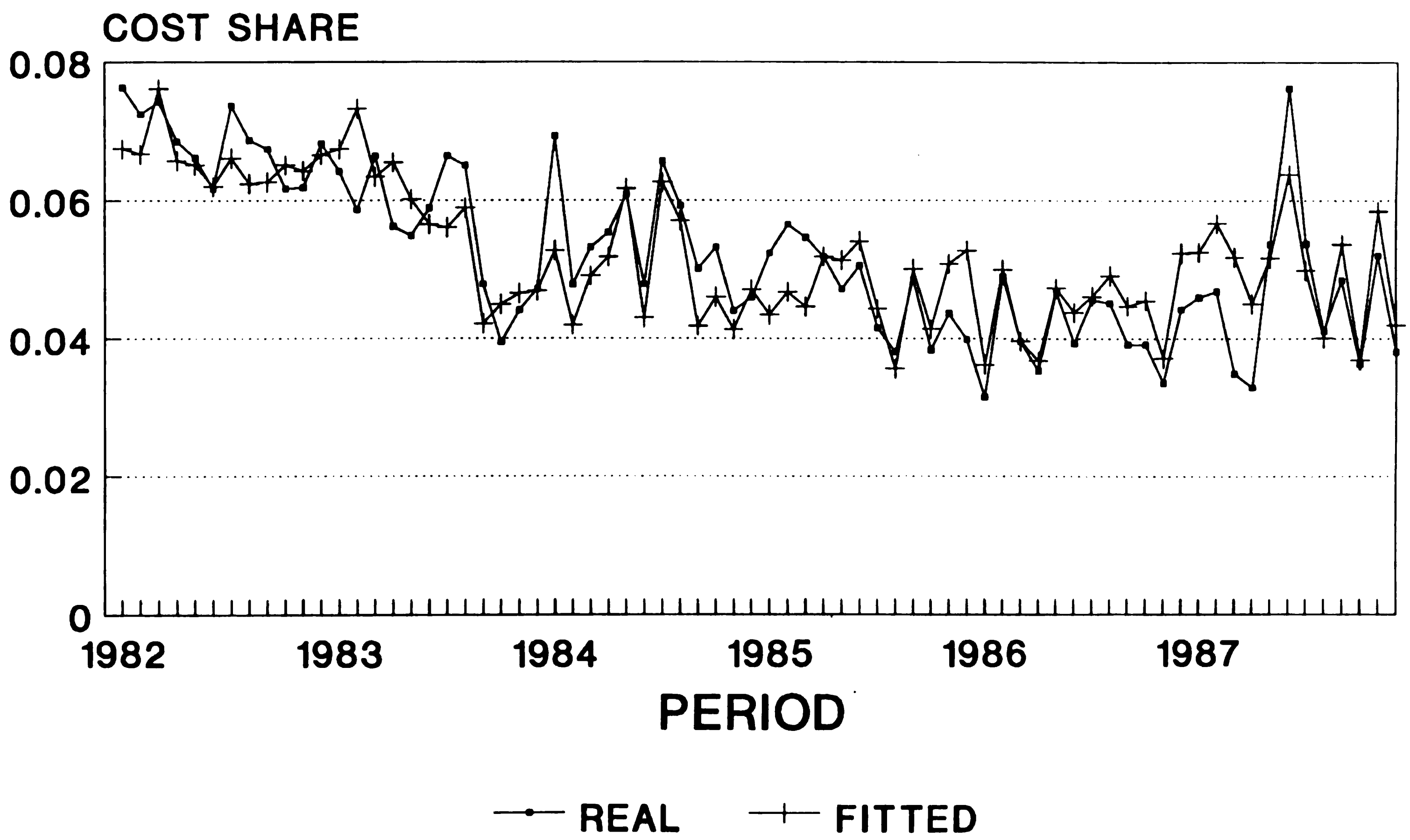


FIGURE 18: IKPC

HYDROELECTRICITY - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

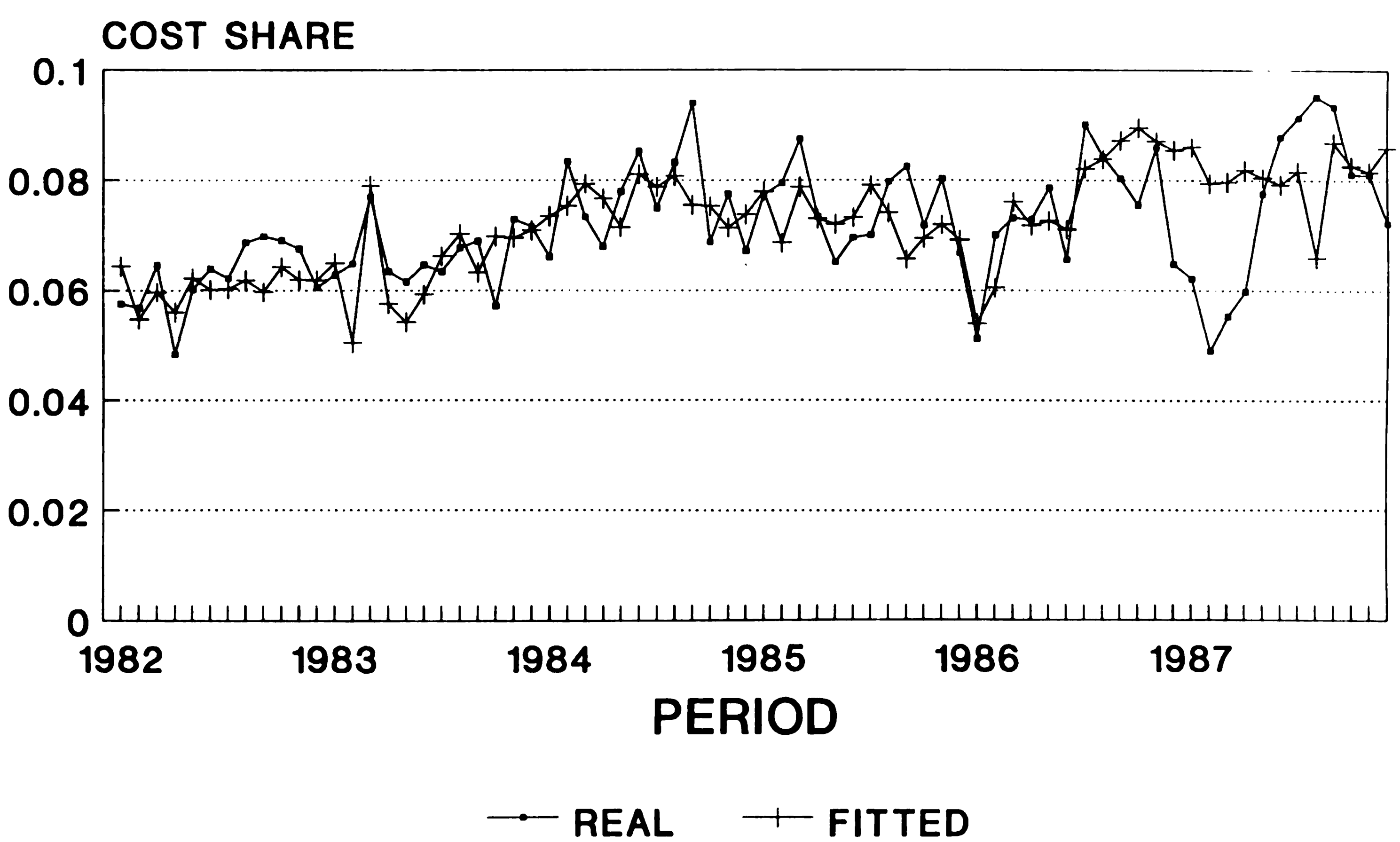


FIGURE 19: IKPC

CAPITAL - FITTED EQUATION
COST FUNCTION - 6 INPUTS

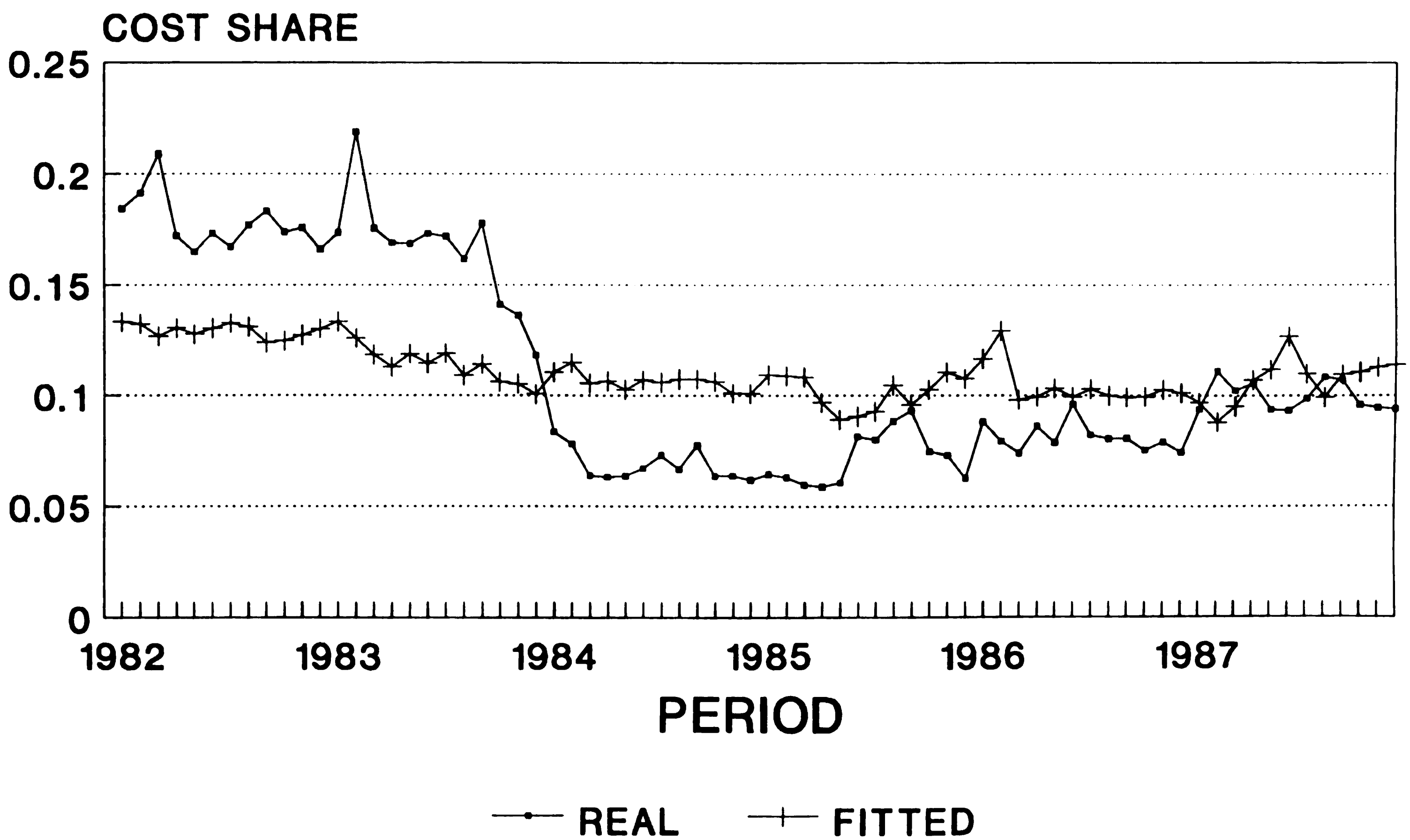


FIGURE 20: IKPC
CAPITAL - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

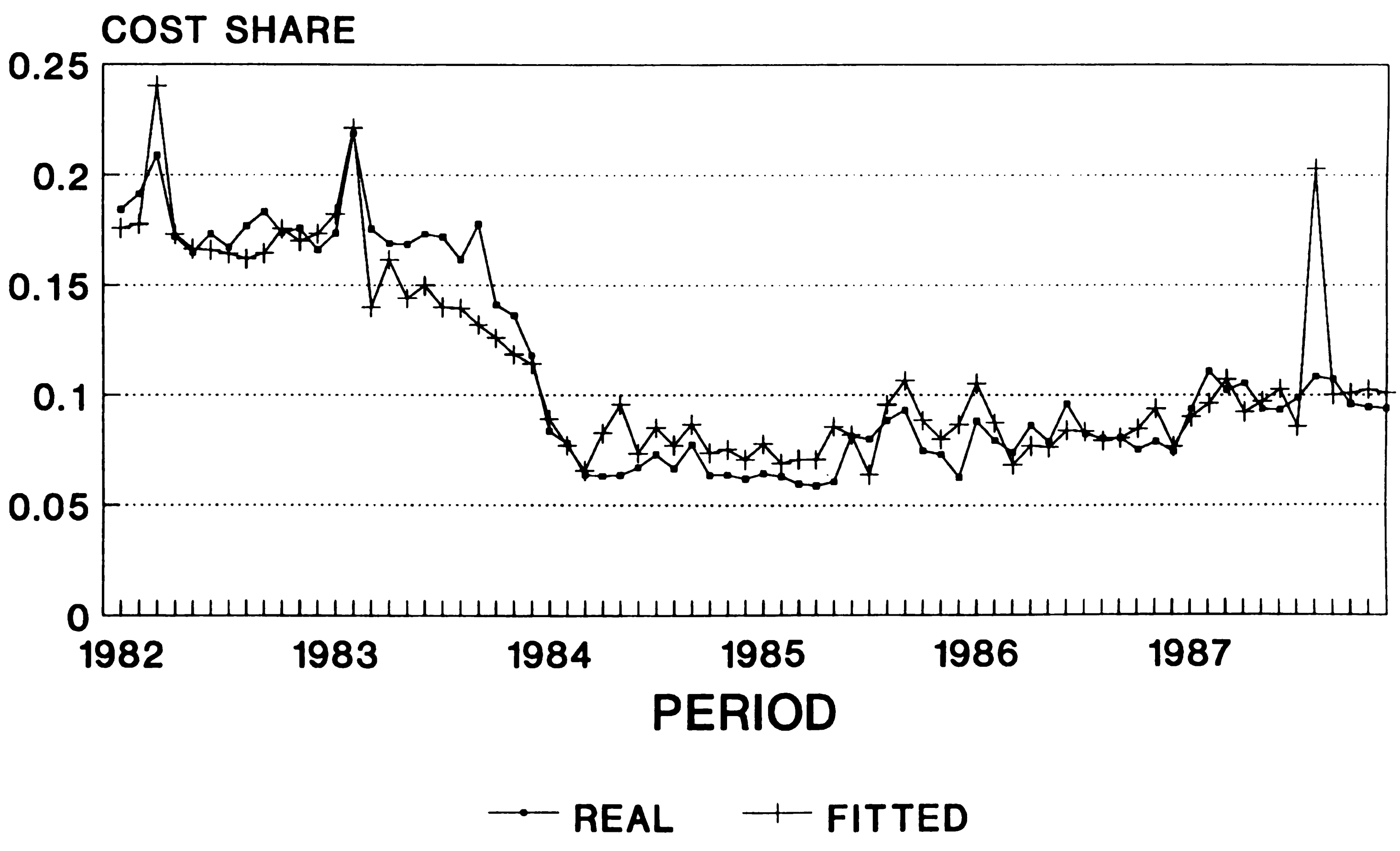


FIGURE 21: PCC

BIOMASS - FITTED EQUATION
COST FUNCTION - 6 INPUTS

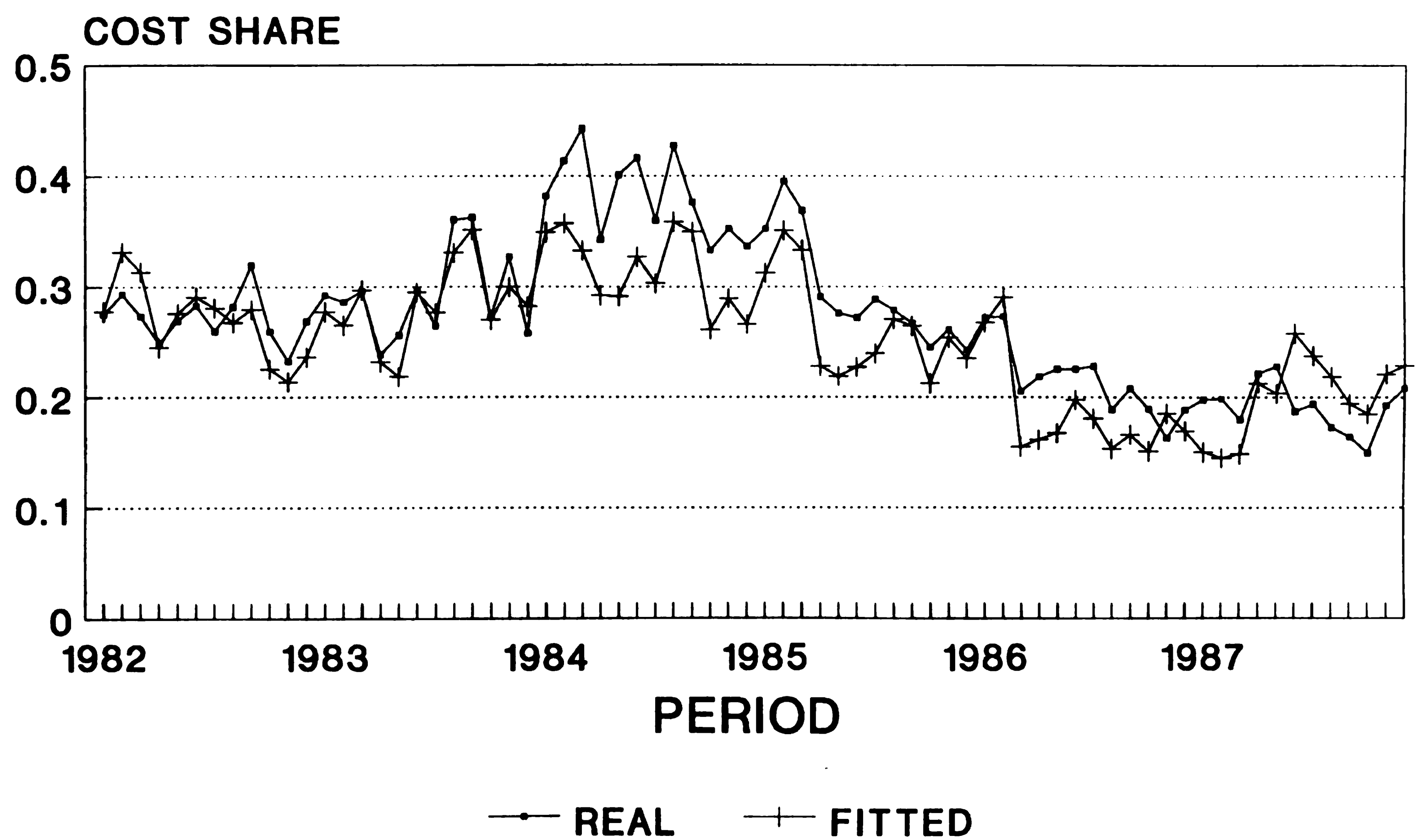


FIGURE 22: PCC
BIOMASS - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

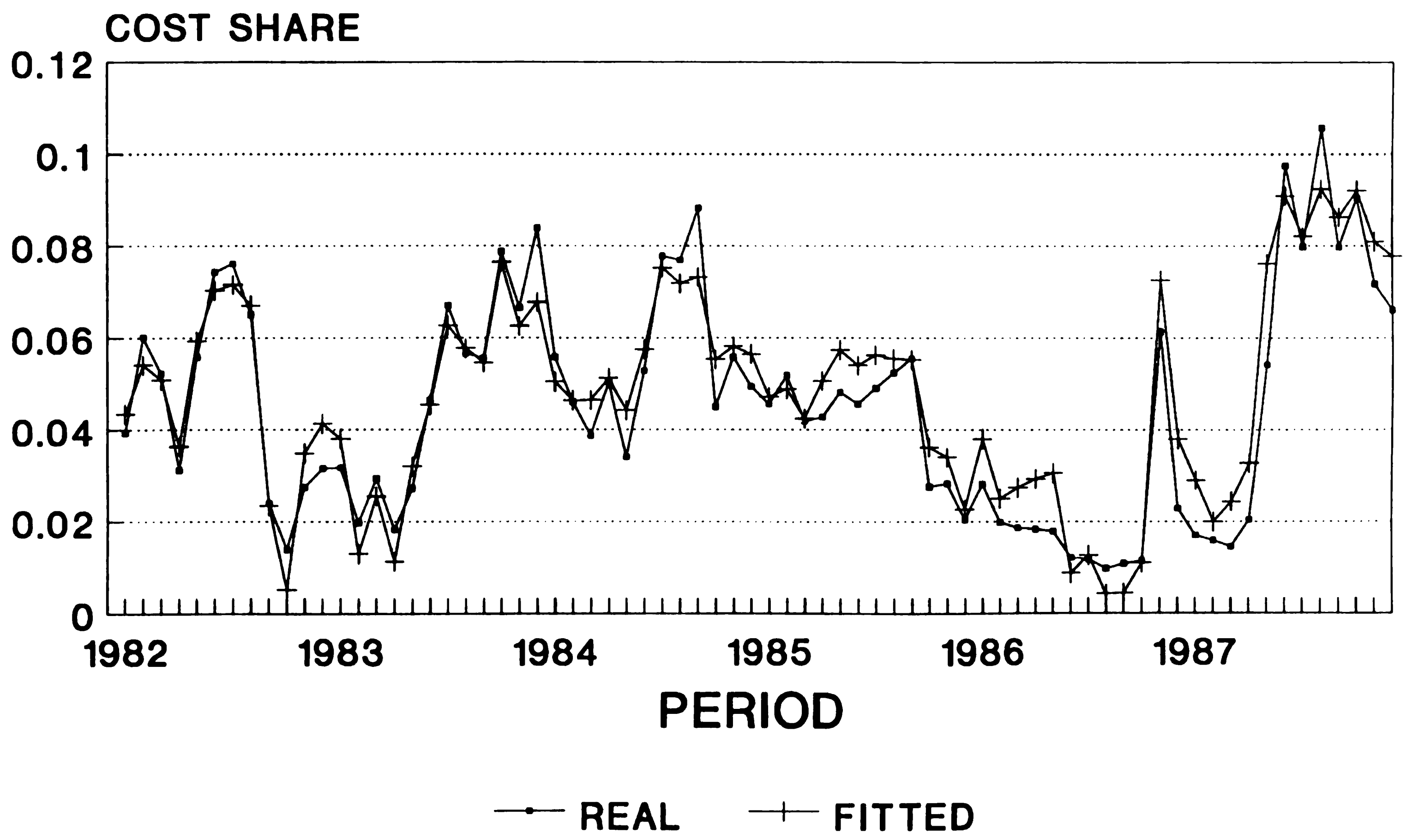


FIGURE 22: PCC
BIOMASS - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

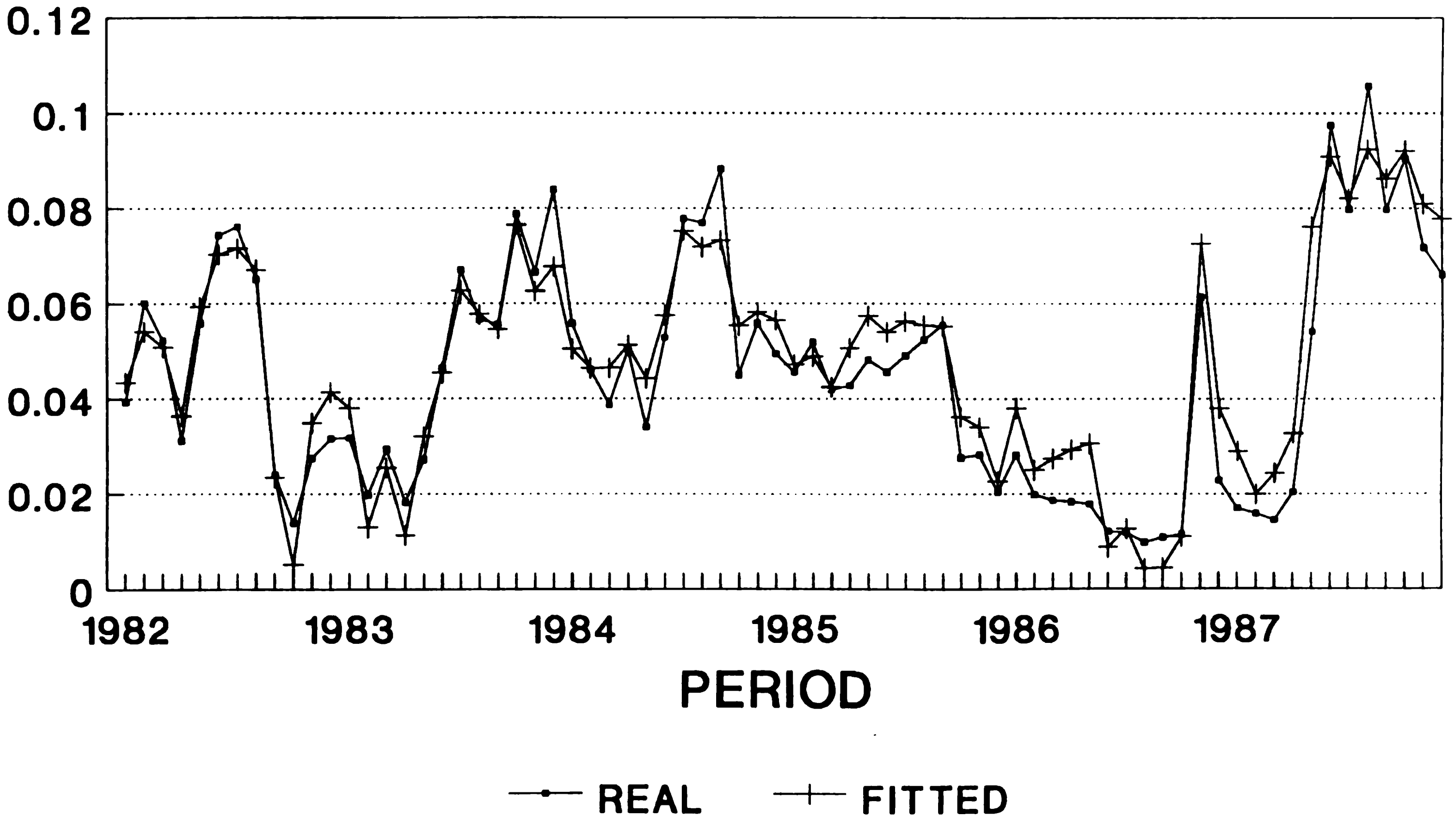


FIGURE 23: PCC

FOSSIL FUELS - FITTED EQUATION
COST FUNCTION - 6 INPUTS

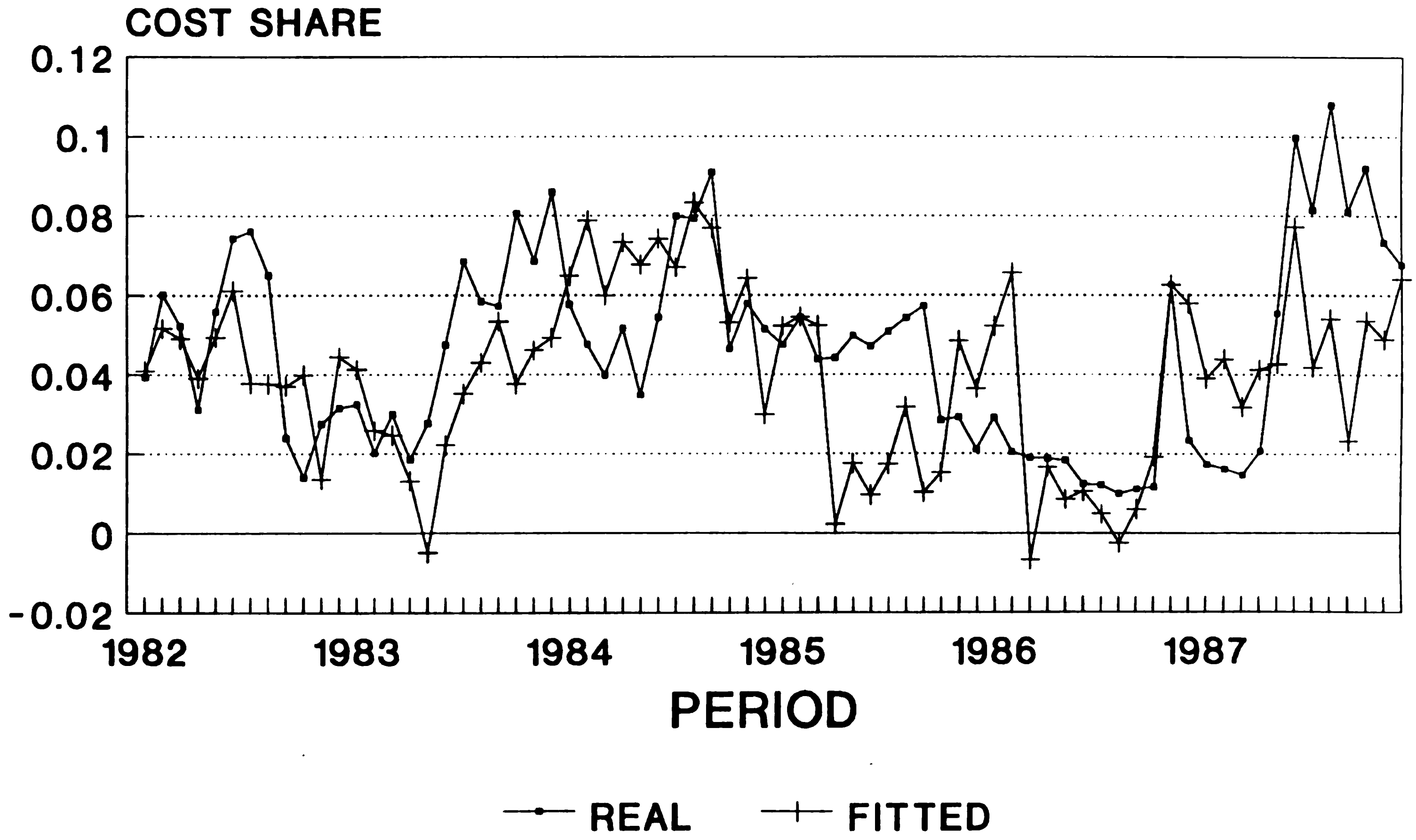


FIGURE 25: PCC
HYDROELECTRICITY - FITTED EQUATION
COST FUNCTION - 6 INPUTS

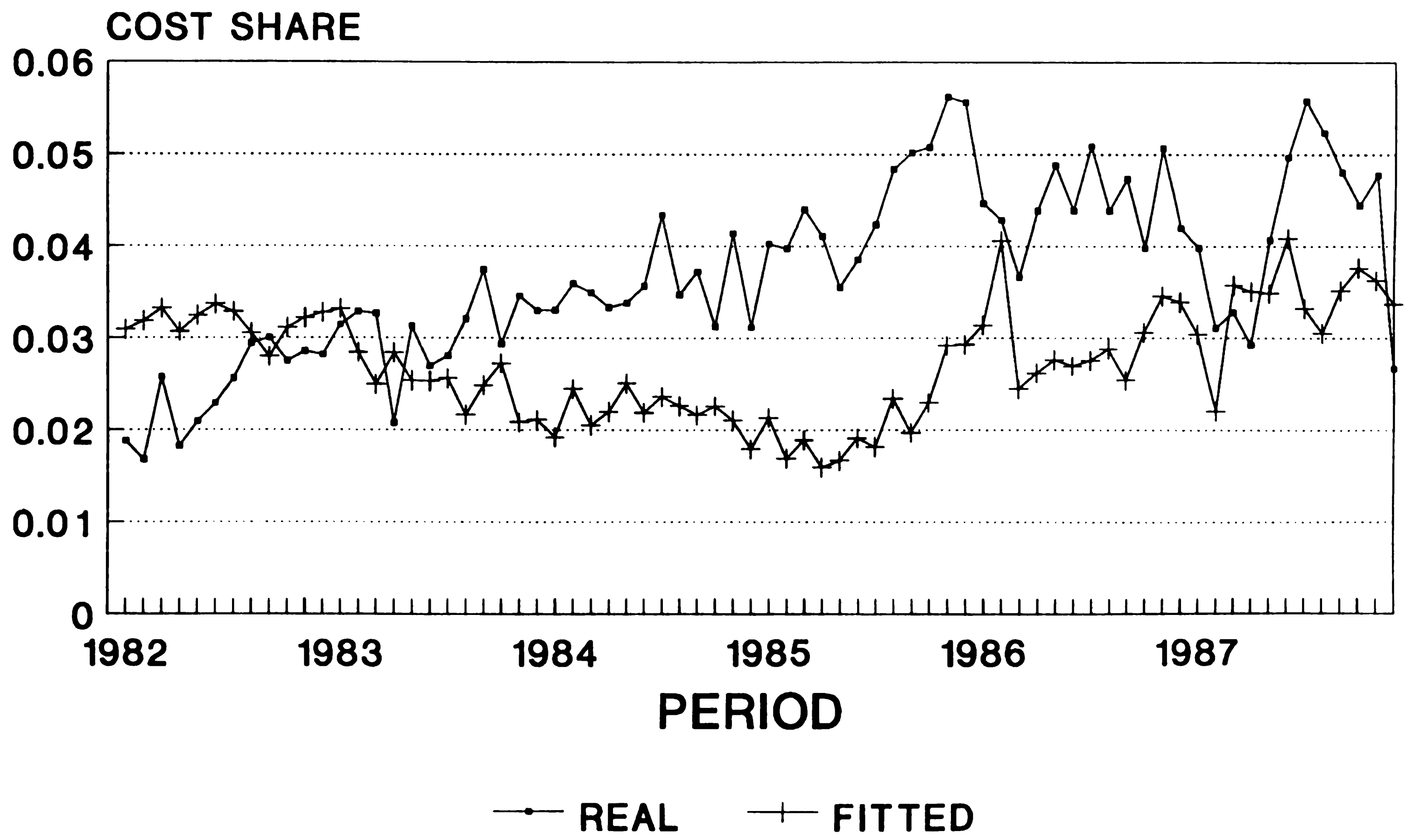


FIGURE 25: PCC
HYDROELECTRICITY - FITTED EQUATION
COST FUNCTION - 6 INPUTS

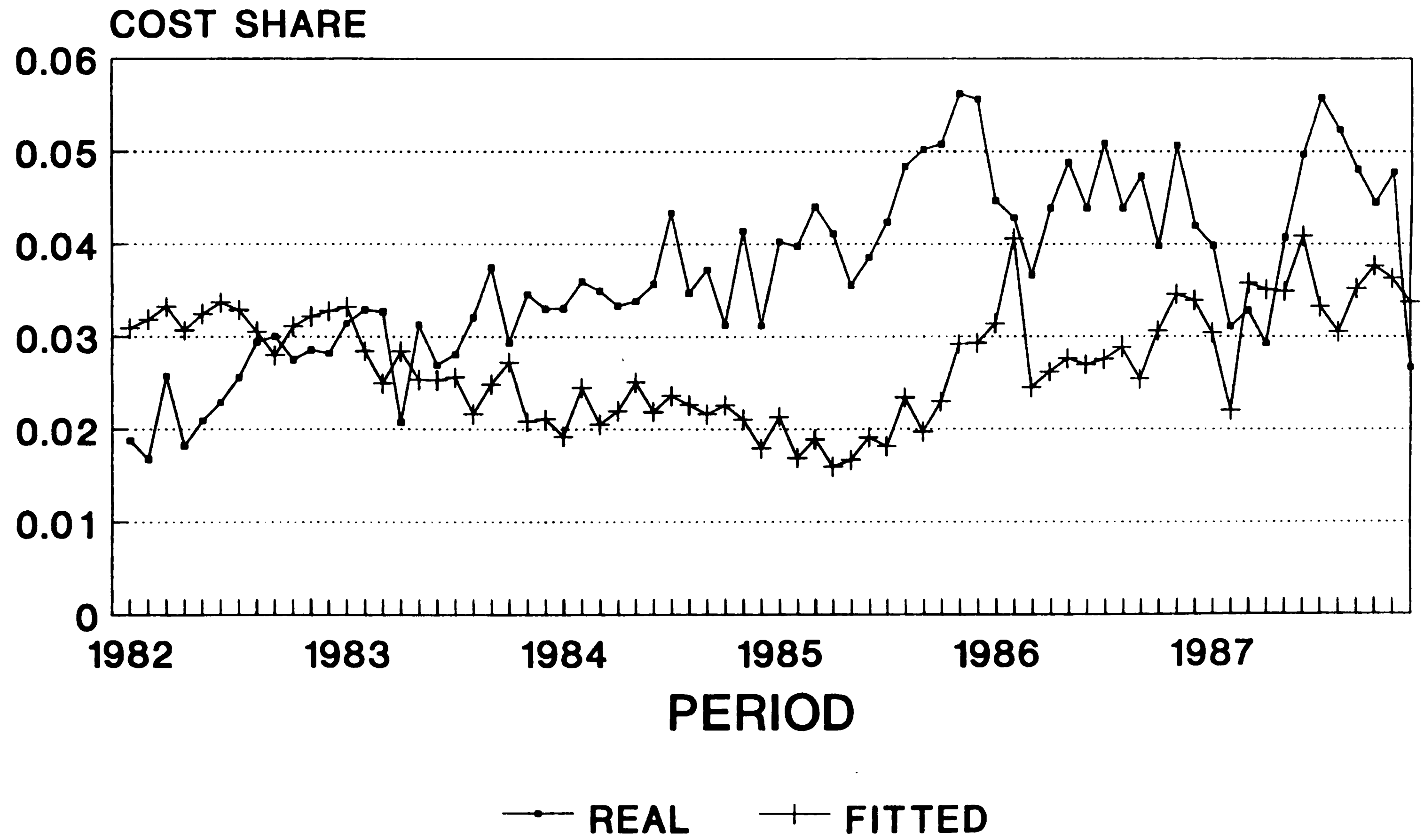


FIGURE 26: PCC
HYDROELECTRICITY - FITTED EQUATION
PRODUCTION FUNCTION - 6 INPUTS

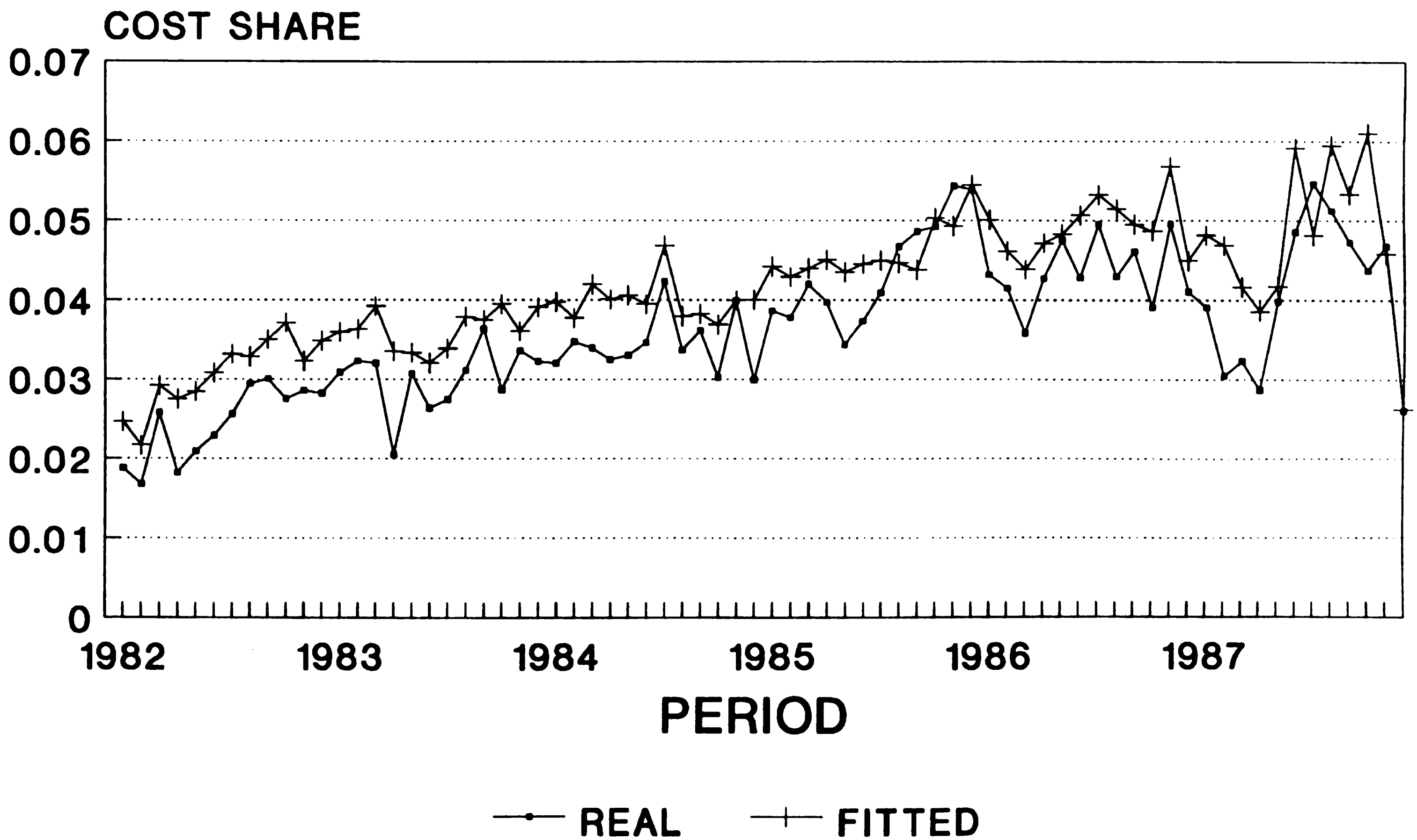


FIGURE 27: PCC

CAPITAL - FITTED EQUATION
COST FUNCTION - 6 INPUTS

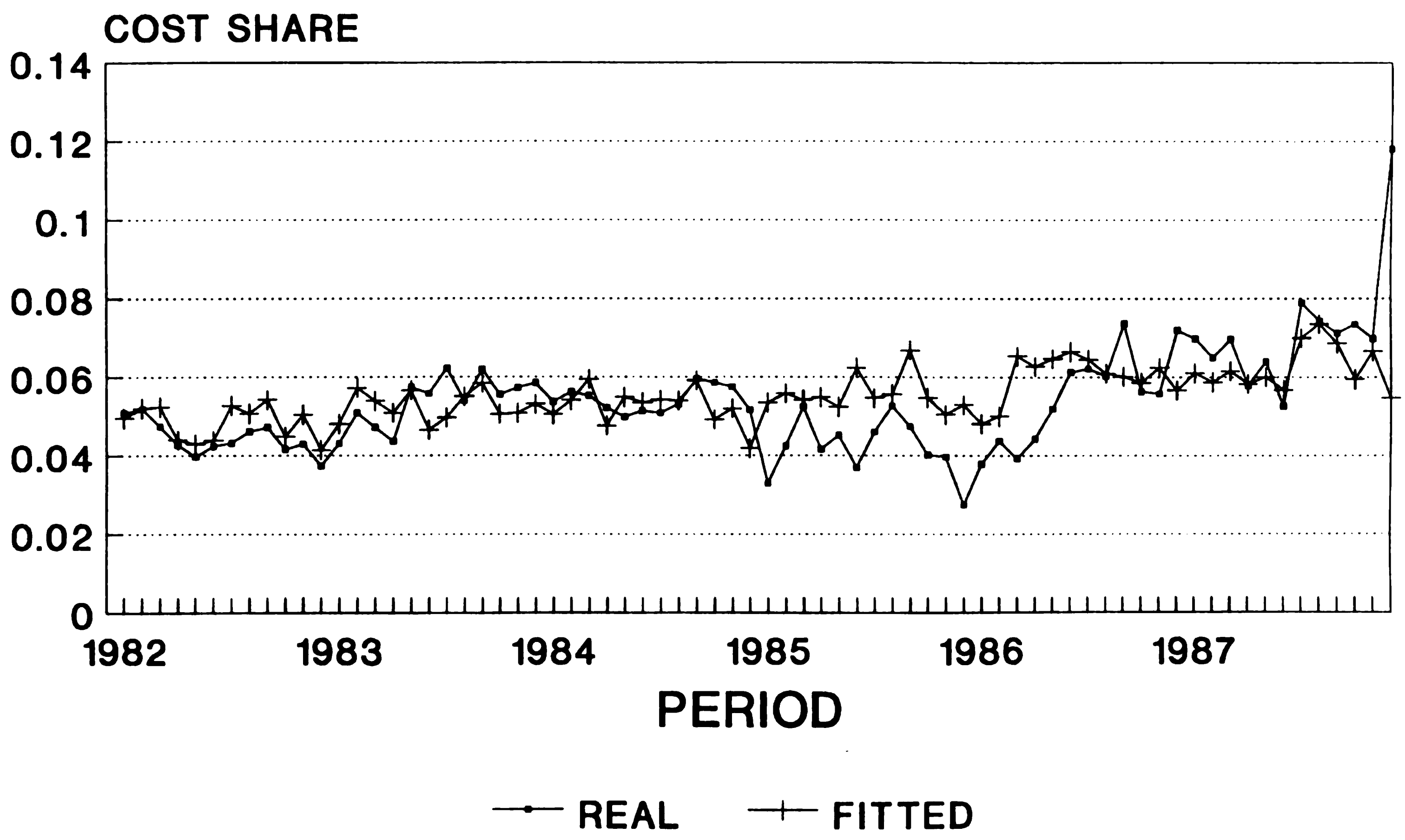


FIGURE 28: PCC

BIOMASS - FITTED EQUATION
PRODUCTION FUNCTION -6 INPUTS

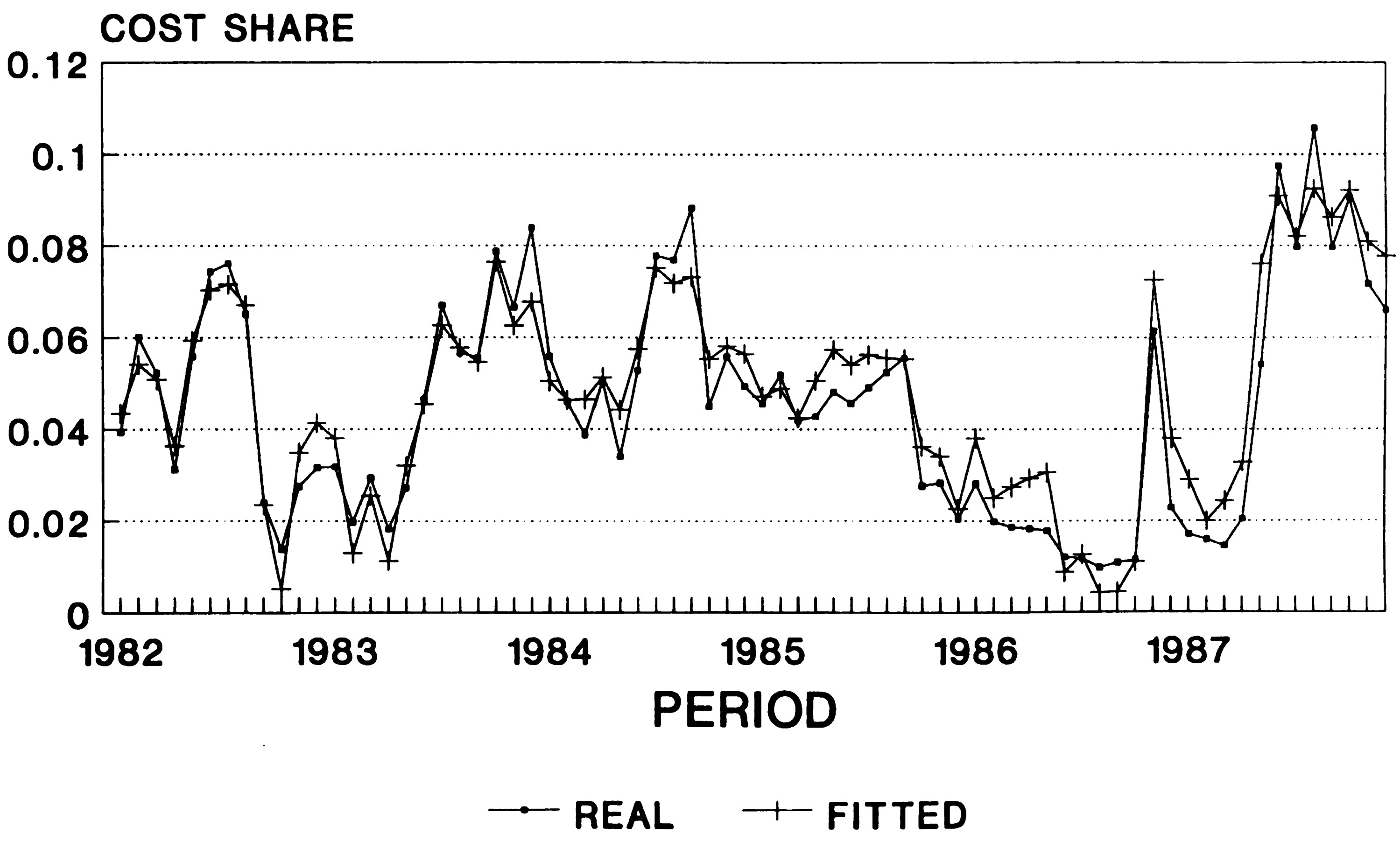


FIGURE 29: RIOCELL
BIOMASS - FITTED EQUATION
COST FUNCTION - 5 INPUTS

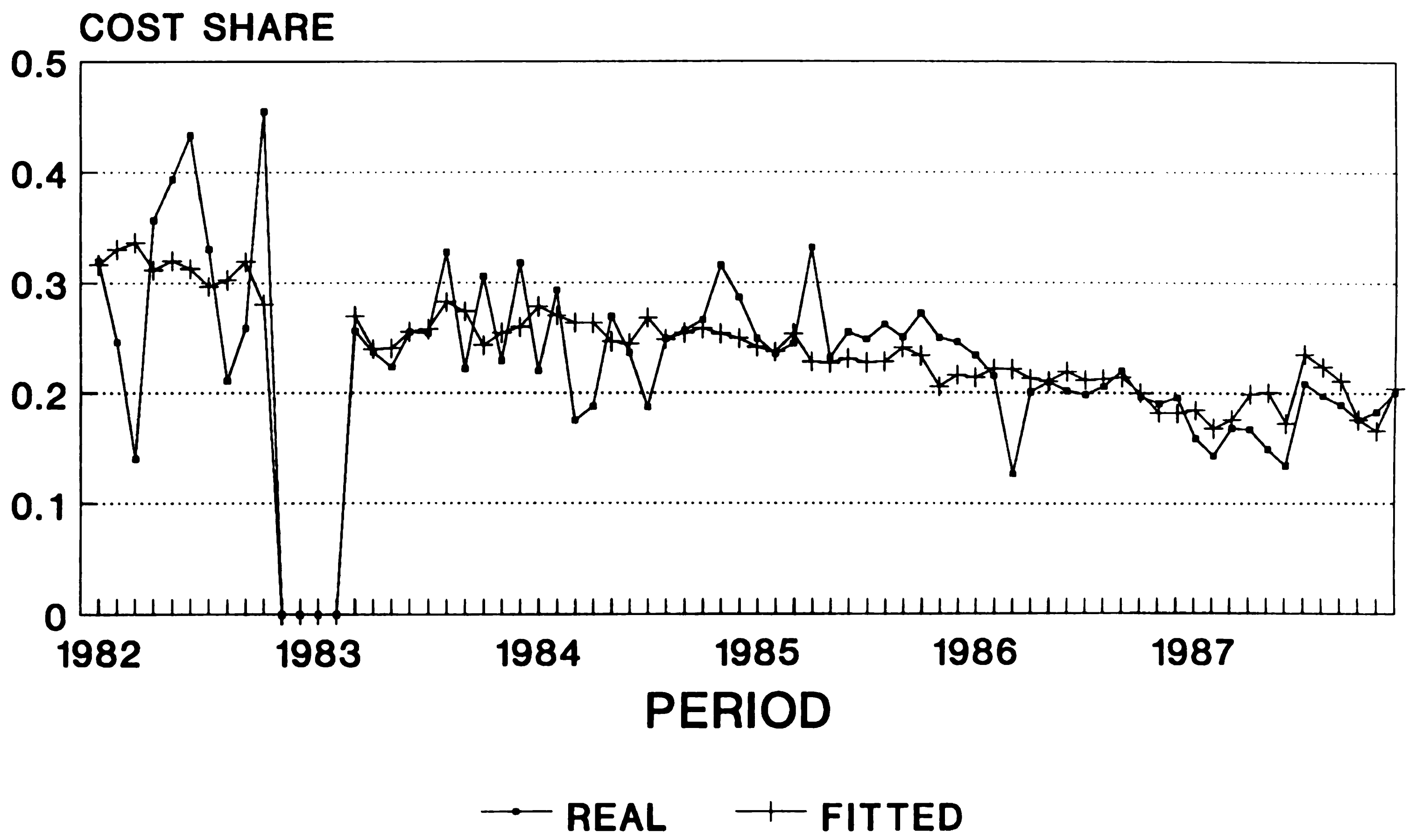


FIGURE 30: RIOCELL

BIOMASS - FITTED EQUATION

PRODUCTION FUNCTION - 5 INPUTS

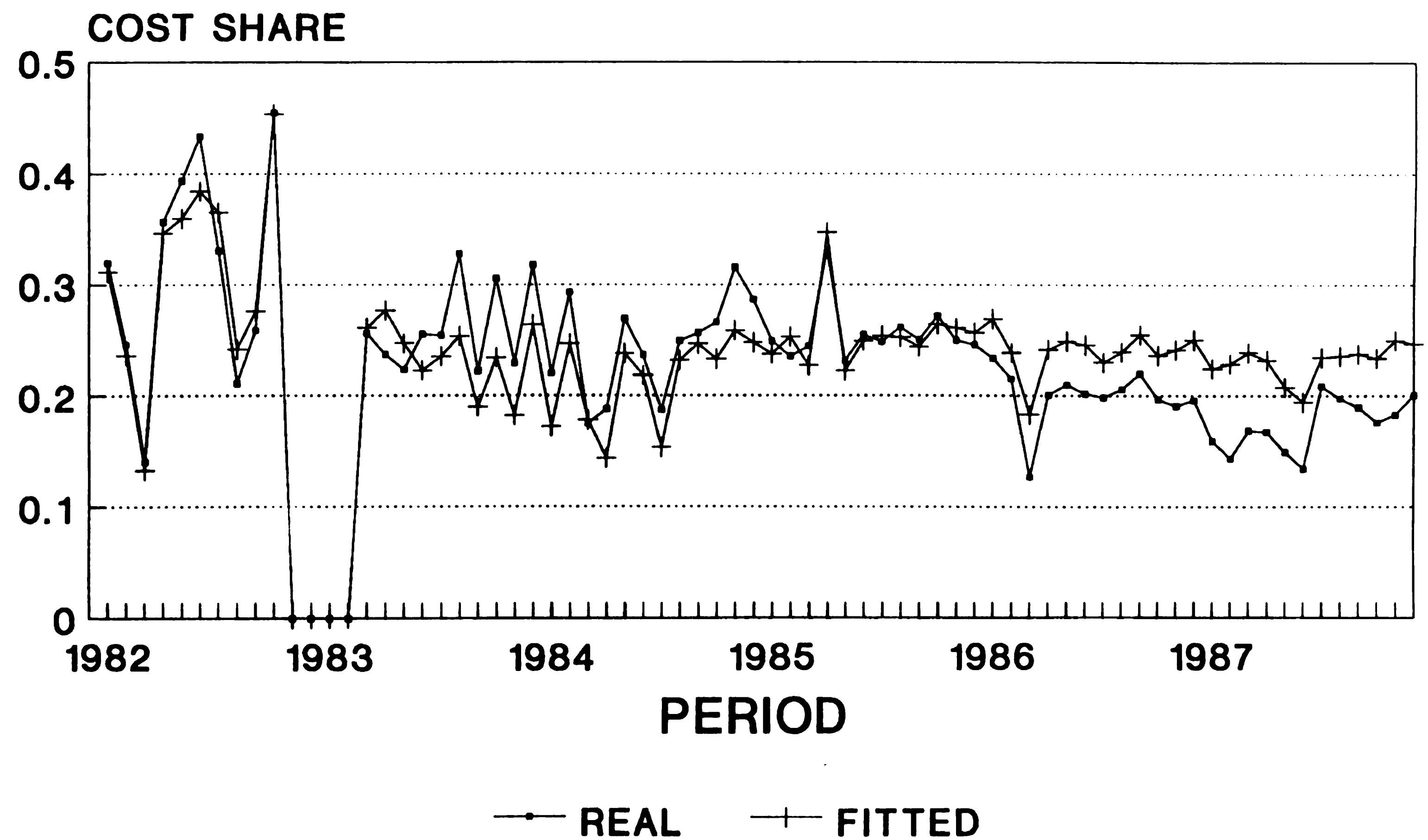


FIGURE 31: RIOCELL

FOSSIL FUELS - FITTED EQUATION
COST FUNCTION - 5 INPUTS

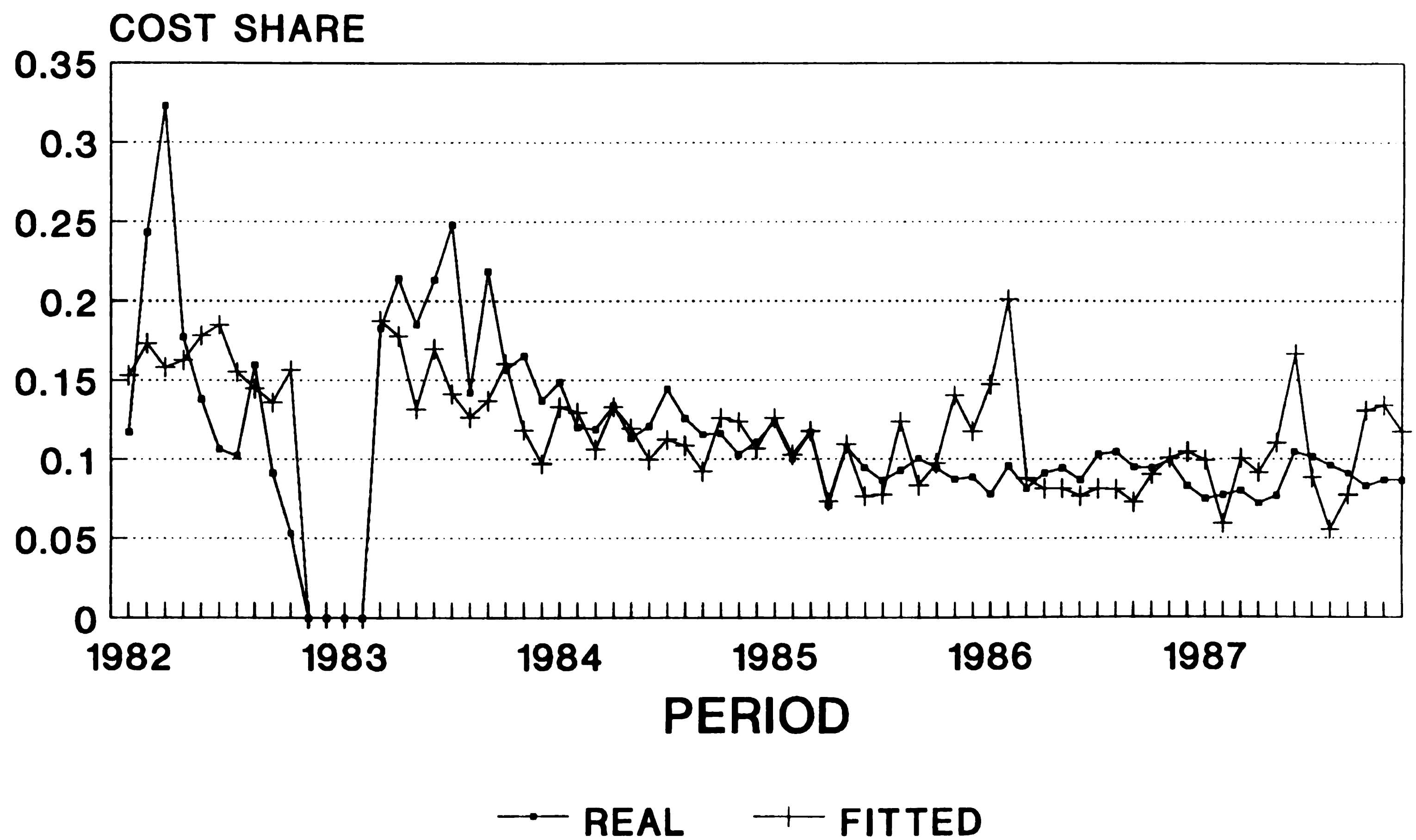


FIGURE 32: RIOCELL

FOSSIL FUELS - FITTED EQUATION
PRODUCTION FUNCTION - 5 INPUTS

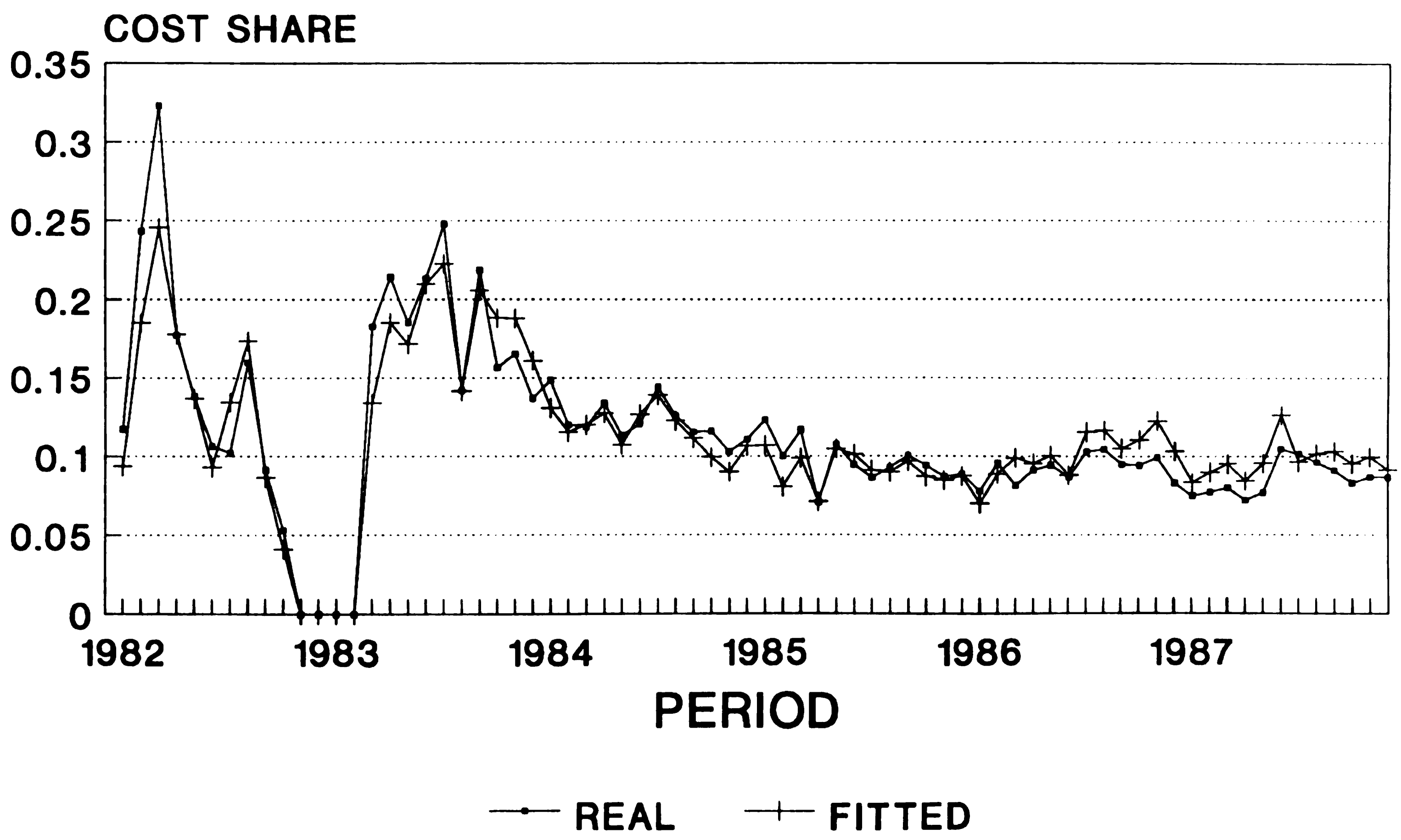


FIGURE 33: RIOCELL
CAPITAL - FITTED EQUATION
COST FUNCTION - 5 INPUTS

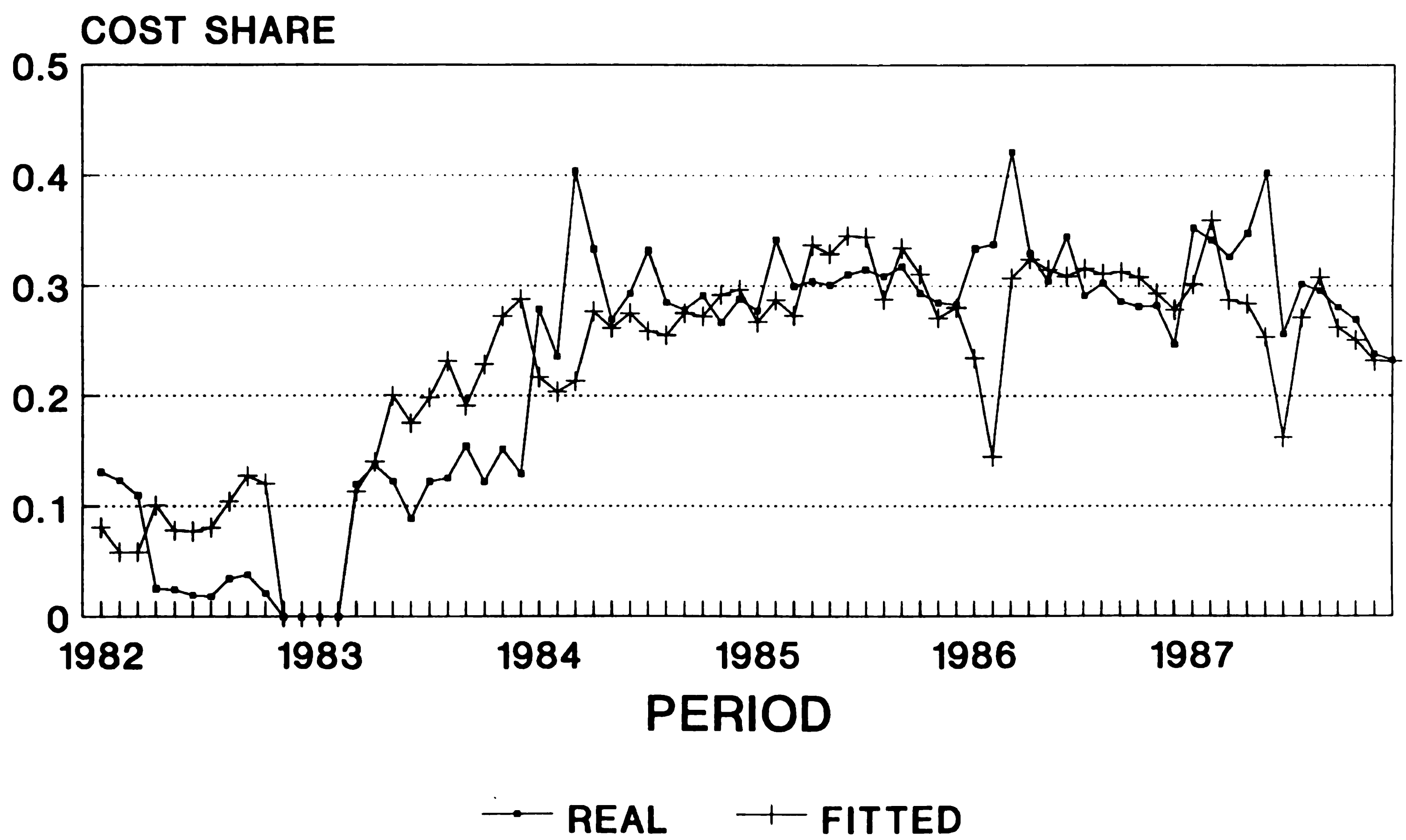
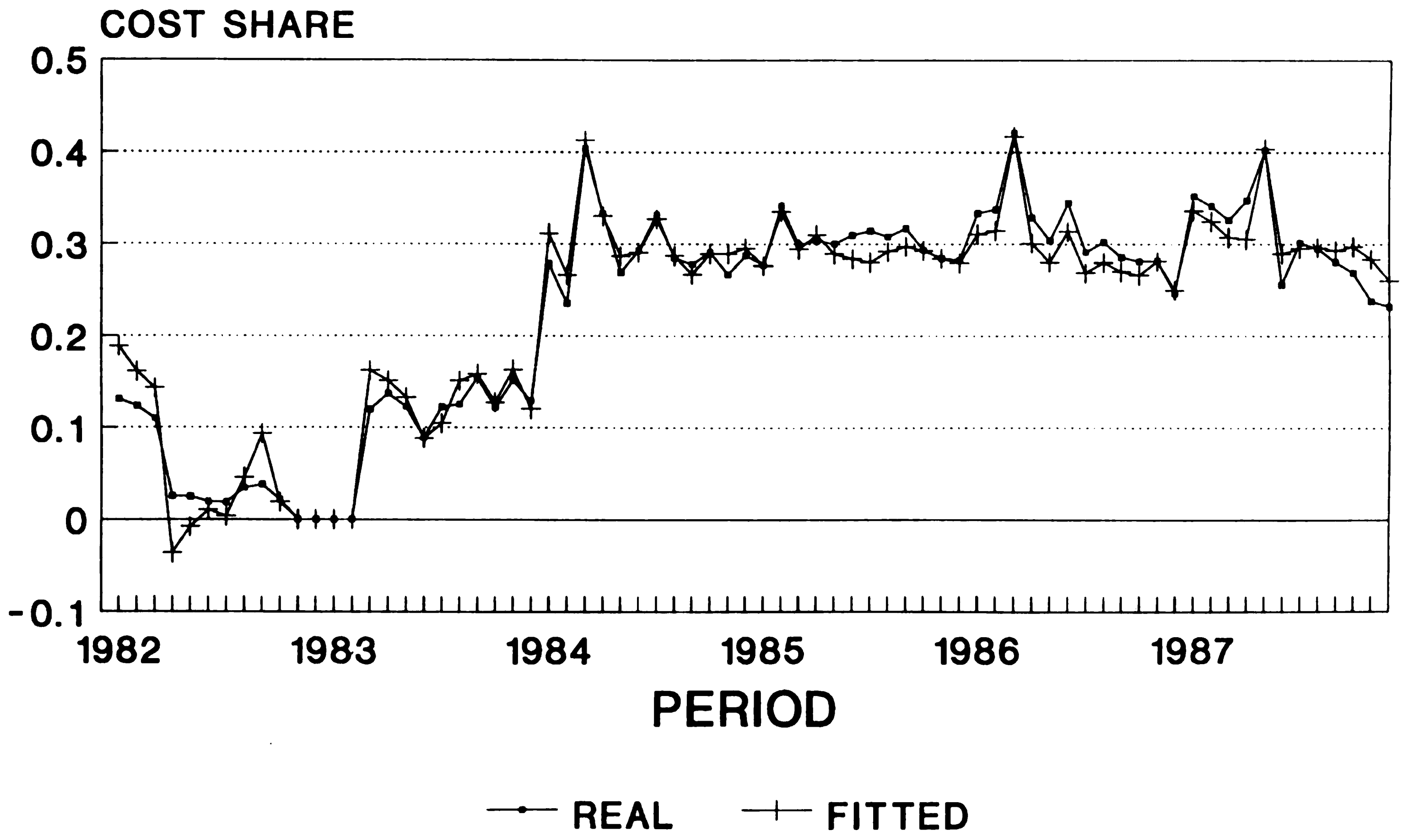


FIGURE 34: RIOCELL
CAPITAL - FITTED EQUATION
PRODUCTION FUNCTION - 5 INPUTS



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