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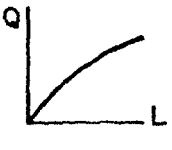

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I. Introduction

The energy price shocks of the 1970's drastically altered the relative price relationships between basic factor inputs, thereby inducing significant structural changes in most countries and regions. Not only were the own-price and cross-price elasticities of these basic inputs --labor, capital and energy-- greatly affected but so were their respective elasticities of substitution. A priori it would be expected that nowhere would these relationships have been more influenced and changed than in those countries/regions which were large pretroleum-derived energy importers.

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A B S T R A C T

The energy shocks of the 1970's that altered the relative price relationships between factor inputs and induced structural changes are analyzed with the use of a translogarithmic cost function that incorporates the inputs capital, labor, and energy. The developmental implications of these structural changes on a small, open, and energy/capital importing region are emphasized, taking the case of Puerto Rico as an example. In terms of the partial elasticities of substitution, the capital-labor relationship moved from highly substitutable in the pre-1973 period to weakly complementary thereafter. The energy-labor association was transformed from high to low substitutability, and that of energy-capital from highly complementary to substitute.

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It is the purpose of this article to analyze the nature of these changing price cum structural relationships during a period which both precedes and straddles the 1970s. The analysis will be carried out especially with a view toward the implications of such changes on the economic development of relatively small, petroleum and capital importing countries/regions. A KLE (capital, labor, energy) translogarithmic cost function is utilized to measure these economy-wide effects using data pertinent to the example of Puerto Rico. While it will be argued that, in economic terms, Puerto Rico can be taken as simply a region of the United States economy, the existence of an independent and separable data base permits the ensuing analysis. Coverage extends over the years 1956-1982, with period subdivisions pertaining to the intervals 1956-1972 and 1973-1982.

There has been a great deal of previous work carried out along these general lines of energy input substitution. The seminal work was done by Berndt and Wood, Griffin and Gregory, Fuss, Halvorsen and Ford, and Pindyck.[1/] Later efforts include those of Field and Grebenstein, Harper and Field, and Garofalo and Malhotra.[2/] Almost invariably these (and other) studies have been restricted to the manufacturing sectors in industrialized nations. As such, they certainly have developmental implications for future economic growth in the already developed world. However, their results and implications may not be transferable to either the manufacturing sector and/or the overall economies of the less developed regions. Moreover, they have produced contradictory empirical results with respect to, for example, the substitutability or complementarity of capital and energy. Such results appear to be a function of different model specifications, the proxy definitions of the variables, and the use of time-series or cross-section analyses.

The model which is subsequently presented addresses itself to several of the above-mentioned issues. It applies to an open developing economy in its entirety, thereby moving away from a developed economy and manufacturing focus.[3/] It emphasizes the implications for economic development of the empirical results, and it permits comparisons of the pre-and post-energy price rise periods. Moreover, it employs a time-series methodology, which appears to be conceptually superior to a cross-section one in view of the economic development implications it proposes to analyze. After all, economic development occurs across time in any given country, so that inferences taken from multi-country cross-section samples do not seem relevant to the task at hand.

II. An Initial View of Structural Change in Puerto Rico: 1956-1982

The Puerto Rican economic development model can be taken as a case of regional development within the larger economy of the United States. There exist no barriers (other than geographical) to the free flow of labor, capital, entrepreneurial talent, and materials between the island and the U.S. mainland. The same monetary system is extant, and the U.S. tariff structure governs Puerto Rico's external trade.

Since the late 1940s the Puerto Rican economic model has been based on the use of manufacturing tax incentives to draw external capital and technology to this capital-and natural resource-poor island. The economic development strategy implemented was implicitly based upon relatively low input prices: labor prices were initially low due to an abundance of this factor, real capital costs were low due to the existence of generous tax incentives, and energy prices remained low until 1973 due to world supply phenomena. This latter element is particularly important, for close to 100 percent of the energy produced on the island is derived from petroleum imports.

During the 1950s and 1960s the above combination of factors led to high rates of economic growth. As may be observed from Table 1, real per capita GNP rose at a rate of five percent between 1956 and 1972. During this same period capital and technology imports that implicitly incorporated a high (and inexpensive) energy-use content were brought in, with most coming in unchanged from the U.S. The most significant manifestation of this began in the 1960s with the promotion of petroleum refineries and the development of a petrochemical complex.

Under such circumstances, it would be expected that capital and labor would become increasingly substitutable due to the high capitalization of the economy, especially after the mid-1960s. Moreover, one would also postulate that capital and energy would be strongly complementary productive factors (prior to 1973) due to the relatively low prices of both inputs. In fact, the relatively low and falling real oil prices of the pre-1973 era induced large per capita energy consumption gains while leading to increased energy intensity of production, a rising use of capital, and capital-deepening. These effects in combination generated labor productivity gains on the order of 4 to 5 percent. From this latter relationship it would additionally be hypothesized that labor and energy should be slightly substitutable. One would further expect relatively high own-price elasticities for energy.

Of course, the post-1972 world was drastically altered due to the two oil price shocks of the 1970s, and nowhere would it be expected to change more than in a highly capitalized and energy-dependent region. It is precisely the purpose of the paper to explore the nature of such changes in terms of the substitutability/complementarity relationships between labor, capital, and energy.

Table 1 offers a preliminary glance at some of the changing structural elements in the Puerto Rican economy by comparing growth rates and percentages prior to and following the first oil price shoch of 1973. As is readily

TABLE 1

SELECTED STRUCTURAL CHANGES: PUERTO RICO, 1956-1982

Line	Variable	1956	1972	1982	Annual Growth Rates 1956-1972	Annual Growth Rates 1972-1982
1	Real Gross National Product (GNP)[a]	1186	3231	3978	6.5	2.1
2	Real Per Capita GNP (1954 dollars)	527	1145	1222	5.0	0.7
3	Real Gross Domestic Product (GDP)[a]	1134	3511	4550	7.3	2.6
4	GNP as % of GDP (current prices)	104.4	91.0	76.9	-	-
5	Real Gross Fixed Domestic Investment (GDI)[a]	205	973	440	10.2	-7.6
6	Real Per Capita GDI (1954 dollars)	91	345	135	8.7	-9.0
7	GDI as % of GNP (current prices)	18.1	30.5	14.1	-	-
8	Public Sector Share of GDI (current prices)	29.9	35.7	46.1	-	-
9	Percent GDP from Manufacturing (current prices)	22.3	25.2	36.7	-	-
10	Total Employment (thousands)	558	738	719	1.8	-0.3
11	Labor Productivity[b]	2125	4378	5533	4.6	2.4
12	Unemployment Rate	13.2	12.0	21.8	-	-
13	Participation Rate	48.3	45.1	41.9	-	-
14	Percent Employment in Manufacturing	12.5	19.2	18.6	-	-
15	Transfers as % of Personal Income	13.7	16.4	31.1	-	-
16	Real Price Fuel Oil (per barrel)[c]	2.27	1.86	9.07	-1.2	17.2
17	Imports, Barrels Petroleum (millions)	10.2	53.4	51.1	10.9	-0.4
18	Electric Energy Consumption (millions KwH)	931	8895	10,236	15.1	1.4
19	Per Capita Energy Consumption (KwH)	414	3152	3145	13.5	-
20	Electric Energy Consumption Per $1000 Real GNP (KwH)	785	2753	2573	8.2	-0.7
21	Merchandise Imports as % GDP	55.1	49.0	51.7	-	-

[a] Millions of 1954 dollars.

[b] Line 1 divided by line 10.

[c] Deflated by the implicit price deflator for personal consumption expenditures (1954 = 100).

SOURCES: Puerto Rico Planning Board, Income and Product, various years; Puerto Rico Department of Labor, work sheets, various years; Puerto Rico Electric Energy Authority, work sheets.

appreciated, before 1973 real per capita gross product and real gross investment grew at high rates; these rates were decidedly lower (or negative) afterwards. The gap between gross national product (GNP) and gross domestic product (GDP) widened substantially after 1973 as a consequence of the overdependence on external capital imports and the lack of internal growth and investment opportunities. Both total investment and total employment came to rely increasingly on public sector spending, and labor markets weakened considerably. The unemployment rate soared from the 10-12 percent level of the 1950s and 1960s to a 15-25 percent range after the mid-1970s, and the overall and age-specific participation rates dropped significantly. Public transfer payments (from both the United States and Puerto Rican governments) rose rapidly in proportional and absolute terms during the 1970s.

Although the percentage of gross output generated in manufacturing rose steadily both prior to and subsequent to 1973, factory employment reached a ceiling at around 150,000 (approximately one-fifth of total employment). After October of 1973 it obviously became more expensive to use energy in the factories and in the rest of the economy. Petroleum imports and electric energy consumption, both of which had increased in the pre-1973 period at high rates, essentially stabilized thereafter; clearly, energy price rises generated strong income and price effects (conservation efforts included in the latter). If the price effects outweighed the income effects, this would lead to a decline in the own-price short-run elasticity of oil.

III. The Translog Model

As do previous studies of this nature which have used the translog approach, we assume that the Puerto Rican economy exhibits a twice-differentiable production function that is monotonic, quasi-concave, and embodies constant returns to scale and Hicks-neutral technical change. The corresponding cost

function becomes one that is doubly differentiable, and can be represented by:

$$(1) \quad C = C\ (Y,\ P_K,\ P_L,\ P_E,\ P_M)$$

where Y is gross output and P_K, P_L, P_E, and P_M represent the input prices of capital, labor, energy, and raw materials respectively. The elasticities of substitution between inputs can be directly determined from function (1).

By postulating that the cost function is weakly separable from raw materials[4/], we restate (1) as :

$$(2) \quad C = C\ [\bar{Y},\ \phi\ (P_K,\ P_L,\ P_E),\ P_M]$$

Therefore ϕ will be estimated as if it were independent of P_M. The translog cost function of the homothetic KLE aggregate takes the following form :

$$(3) \quad \ln\phi = \ln\alpha_0 + \sum_i \alpha_i \ln P_i + 1/2 \sum_i \sum_j \beta_{ij} \ln P_i \ln P_j$$

$i,j = K,\ L,\ E$ and α and β refer to parameters.

Differentiating (3) logarithmically and applying Shephard's Lemma generates three linear equations in which the proportion of the total cost represented by each factor input is a function of the prices of the three factors. These prices are taken as exogenous to the system, thereby imposing certain parameter restrictions. Adding a stochastic error term to each equation we arrive at:

$$(4a) \quad S_K = \alpha_K + \beta_{KK}\ln P_K + \beta_{KL}\ln P_L - (\beta_{KK} + \beta_{KL})\ln P_E + u_K$$

$$(4b) \quad S_L = \alpha_L + \beta_{KL}\ln P_K + \beta_{LL}\ln P_L - (\beta_{KL} + \beta_{LL})\ln P_E + u_L$$

$$(4c) \quad S_E = \alpha_E + \beta_{KE}\ln P_K + \beta_{EL}\ln P_L - (\beta_{KE} + \beta_{EE})\ln P_E + u_E$$

By utilizing the Iterative Zellner Efficient Procedure (IZEF) one of these equations can be eliminated for estimation purposes, thereby deriving efficient estimators in the remaining two equations. These IZEF estimators are equivalent to maximum likelihood estimators. We can rewrite the prices

as logarithms of price ratios. Thus, the final form of the equations that are estimated in this study becomes :

$$(5a) \quad S_E = \alpha_E + \beta_{EE}\ln(P_E/P_K) + \beta_{EL}\ln(P_L/P_K) + u_E$$

$$(5b) \quad S_L = \alpha_L + \beta_{EL}\ln(P_E/P_K) + \beta_{LL}\ln(P_L/P_K) + u_L$$

The Allen-Uzawa elasticities of substitution between factors are then estimated as:

$$(6a) \quad \sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j} \qquad i,j = K, L, E \qquad i \neq j$$

$$(6b) \quad \sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2} \qquad i = K, L, E$$

Finally, the price elasticities of demand (E_{ij}) for factor inputs are estimated from :

$$(7) \quad E_{ij} = S_j \sigma_{ij} \qquad i, j = K, L, E$$

IV. The Results and Their Developmental Policy Implications

A. Elasticities of Substitution

The partial elasticity estimates of input substitution are found in Table 2. They cover both the entire 1956-1982 interval and are further divided into two subperiods (1956-1972 and 1973-1982) which predate and follow the oil price shocks. A positive sign fronting the coefficients denotes that the two inputs emerged as substitutes from the estimation process, whereas a negative sign implies complementarity.

1. Capital-Labor

Over the entire 1956-1982 time span and in the 1956-1972 subperiod capital and labor emerge as substitutes, whereas in the 1973-1982 subperiod this substitutability disappears and shades into generally weak complementarity.

TABLE 2

IZEF ESTIMATED ALLEN-UZAWA PARTIAL ELASTICITIES OF SUBSTITUTION[a] VIA TRANSLOG COST FUNCTION FOR THE PUERTO RICAN ECONOMY: 1956-1986

	Capital-Labor			Energy-Labor			Energy-Capital		
Year	1956-1982	1956-1972	1973-1982	1956-1982	1956-1972	1973-1982	1956-1982	1956-1972	1973-1982
1956	0.359	0.776	-	-0.234	1.165	-	-1.119	-2.722	-
1957	0.390	0.787	-	-0.079	1.144	-	-0.708	-2.000	-
1958	0.343	0.771	-	-0.296	1.173	-	-1.309	-3.057	-
1959	0.407	0.793	-	-0.253	1.168	-	-0.930	-2.390	-
1960	0.423	0.799	-	-0.408	1.188	-	-1.086	-2.664	-
1961	0.381	0.784	-	-0.355	1.181	-	-1.242	-2.938	-
1962	0.357	0.776	-	-0.332	1.178	-	-1.317	-3.069	-
1963	0.342	0.771	-	-0.508	1.202	-	-1.731	-3.797	-
1964	0.336	0.769	-	-0.536	1.206	-	-1.820	-3.954	-
1965	0.335	0.768	-	-0.493	1.200	-	-1.740	-3.814	-
1966	0.422	0.798	-	-0.510	1.202	-	-1.279	-3.003	-
1967	0.418	0.797	-	-0.624	1.217	-	-1.485	-3.364	-
1968	0.452	0.809	-	-0.704	1.228	-	-1.396	-3.208	-
1969	0.521	0.833	-	-0.968	1.263	-	-1.266	-2.981	-
1970	0.507	0.828	-	-0.842	1.246	-	-1.210	-2.881	-
1971	0.360	0.777	-	-0.262	1.169	-	-1.172	-2.815	-
1972	0.302	0.757	-	-0.008	1.135	-	-0.910	-2.355	-
1973	0.467		0.008	-0.252		-1.808	-0.646		2.673
1974	0.507	-	0.082	0.422	-	-0.297	0.420	-	1.590
1975	0.341	-	-0.226	0.593	-	0.088	0.411	-	1.599
1976	0.263	-	-0.372	0.626	-	0.161	0.378	-	1.632
1977	0.238	-	-0.419	0.631	-	0.173	0.361	-	1.650
1978	0.357	-	-0.197	0.606	-	0.117	0.458	-	1.551
1979	0.461	-	-0.003	0.577	-	0.051	0.552	-	1.455
1980	0.441	-	-0.041	0.675	-	0.272	0.690	-	1.315
1981	0.480	-	-0.032	0.669	-	0.257	0.727	-	1.277
1982	0.416	-	-0.086	0.673	-	0.267	0.657	-	1.348

[a] A positive sign denotes substitute inputs, whereas a negative sign denotes complementary inputs.

In other words, taking the 1956-1982 period as a whole no noticeable change occurs in the substitute relationship between labor and capital, while the methodology of period division does bring out definite structural changes in the relationship. These changes are clearly centered around 1973.

The relatively high values attached to the capital-labor substitutability association over most of the observed years is not at all unexpected given the high rates of economic growth experienced by Puerto Rico in the 1950s and 1960s. However, as real wages steadily rose during this time, labor became less competitive as a productive factor vis-à-vis other areas of the world, mainly in the more labor-intensive sectors. This led to the importation of increasingly capital-intensive and high value-added production processes, especially in the key manufacturing sector.

The consequences of such a development strategy can be seen from the following definition of the elasticity of substitution :

$$\sigma = \frac{d(K/L)}{d(w/r)} \cdot \frac{w/r}{K/L}$$

where K = capital, L = labor, w = real wage rate, and r = cost of capital. The expression w/r, or the wage/rental ratio, is the key element. Clearly, an increasing real wage and/or a decreasing capital cost raise the ratio. In the Puerto Rican case both effects were present prior to 1973, with capital costs being drastically lowered by the existence of 100% tax exemptions (prior to 1978). Thus, the increasing wage/rental ratio led to a rising capital-labor ratio. This phenomenon, in conjunction with relatively high capital-labor elasticities of substitution, would appear to lend empirical support to the (employment) elasticity-optimist school of thought, given that for the 1956-1972 subperiod the island's capital-labor elasticities of substitution fluctuated in a range between 0.757 and 0.833. As seen in Table 1, total employment did increase at an annual rate of 1.8% between 1956 and 1972.

However, this situation changed drastically after 1972, as the 1973-1982 subperiod capital-labor elasticities of substitution fell off markedly and then turned negative, lending credence to the (employment) elasticity-pessimist argument. Far higher energy prices generated a strong substitutability relationship between energy and capital, and this in turn influenced the capital-labor association. In fact, Puerto Rico's capital/labor ratio had trended upward since the late 1950s, and after the mid-1960s was more than twice as high as that in the United States, indicating a relatively greater capital-intensity of production in the former.[5/] This capital deepening effect can also be observed in terms of the capital/GDP ratio, which also trended upward in the three decades following the 1940s. Thus, labor-saving capital accumulation created a mismatch between (low-skilled) labor supply and the production processes, leading to unemployment rises. Emigration to the U.S. mainland became increasingly important as an escape valve for labor market pressures.

Such capital deepening and capital-labor substitutability changes have distinct implications for the island's labor markets and job creation efforts. It is no coincidence that these capital stock trends have been accompanied by higher unemployment rate plateaus, lower participation rates (despite strong net migrations), and essentially insignificant job growth in the private sector. Between 1970 and 1986 total employment grew by a relatively low 13 percent, while private sector employment rose by a little over 3 percent; at the same time GDP jumped by 74 percent and the gap between GNP and GDP substantially widened. In 1970 GNP was 93.1 percent of GDP; by 1986 this fraction had fallen to 74.8 percent.

2. Energy-Labor

With respect to energy-labor elasticities, over the whole period energy and labor emerge as complementary inputs through 1973 and strong substitutes

thereafter. This post-1973 substitutability is reinforced by the 1973-1982 coefficients, but the 1956-1972 coefficients completely contradict these findings. There are rational explanations for both cases, but the paradox found during the years 1956 through 1972 is not easily explained away.

The complementary relationship between energy and labor prior to 1974 may simply be the result of the high rates of economic growth experienced during that time. Energy was cheap (until 1973), and as a consequence its use in conjunction with manpower was way above optimal levels. Admittedly, this is a rather weak rationale. The substitute relationship which emerges when the 1956-1972 span is taken alone and which also emerges in the post-1973 interval is more logical. This link is most likely derived from the relatively high substitutability found in the capital-labor association (discounting the weak complementarity displayed between capital and labor between 1973 and 1982). The importation of capital, technology, and capital-intensive production processes that are geared toward the needs and produc - tion/consumption structures of developed economies (where labor is relatively scarce) would certainly stimulate this substitution effect. That the elasticity coefficients are far stronger in the 1956-1972 subperiod than in the latter subperiod does appear to indicate that the demand for high energy-using production techniques was diminished in response to the post-1972 energy price rises. This suggests that factor price changes did have a significant impact on the choice of production techniques, and that the adjustment processes occurred with a good deal of velocity. For example, new technology-intensive processes (e.g., electronics) were stimulated since they involve relatively lower energy-consuming use. Moreover, these same processes are less sensitive to energy price changes and minimum wage hikes.

3. Energy-Capital

The empirical evidence regarding the energy-capital relationship over time is unequivocal as between the entire period and the two subperiods. The

pre-energy price shock era found that capital and energy were complements, while this association was completely turned around into one of substitutability after 1973.

That energy-capital complementarity was the rule prior to 1973 in Puerto Rico is anticipated. It appears that there did occur a quite inflexible transfer of technology between the rest of the world (over-whelmingly the United States) and the island. Moreover, in the era of cheap energy there was no perceived need to undertake the adoption of energy-saving techniques and assorted energy-conservation measures. The abrupt switch from complementarity to substitutability that took place in 1973-1974 is, of course, no coincidence in the face of the quadrupling of crude petroleum prices; Puerto Rican fuel oil prices jumped from $3.28 per barrel in early 1973 to $11.00 per barrel in 1974. These enhanced substitution possibilities between energy and capital suggest a degree of flexibility that is certainly a prerequisite to future growth.

However, enhanced substitutability between energy and capital seems to have been more influenced by conservation efforts and a decline in high energy-consuming industries (e.g., petrochemicals) rather than by significantly higher investment in capital and energy saving equipment. In a ceteris paribus world these higher energy prices would have increased the demand for capital, thereby leading to more investment. That this capital goods demand spurt did not take place in Puerto Rico means that a host of other factors also influence the demand for new capital goods.

B. Own-Price Elasticities of Demand

The estimated own-price elasticities of demand for each of the three factor inputs considered in this study are presented in Table 3. As in the case of the substitution elasticities, they are displayed for the whole 1956-1982 period and for the two 1956-1972 and 1973-1982 subperiods.

TABLE 3

IZEF ESTIMATED OWN-PRICE ELASTICITIES OF DEMAND VIA TRANSLOG COST FUNCTION FOR THE PUERTO RICAN ECONOMY: 1956-1982

	Energy			Capital			Labor		
Year	1956-1982	1956-1972	1973-1982	1956-1982	1956-1972	1973-1982	1956-1982	1956-1972	1973-1982
1956	0.344	-0.614	-	-0.268	-0.570	-	-0.041	-0.138	-
1957	0.165	-0.659	-	-0.297	-0.580	-	-0.053	-0.151	-
1958	0.418	-0.594	-	-0.253	-0.565	-	-0.037	-0.133	-
1959	0.344	-0.614	-	-0.308	-0.583	-	-0.052	-0.151	-
1960	0.495	-0.575	-	-0.321	-0.587	-	-0.056	-0.155	-
1961	0.468	-0.582	-	-0.284	-0.575	-	-0.042	-0.140	-
1962	0.452	-0.586	-	-0.264	-0.568	-	-0.038	-0.134	-
1963	0.651	-0.534	-	-0.249	-0.563	-	-0.032	-0.127	-
1964	0.686	-0.525	-	-0.243	-0.561	-	-0.030	-0.125	-
1965	0.639	-0.538	-	-0.243	-0.561	-	-0.030	-0.126	-
1966	0.613	-0.544	-	-0.317	-0.586	-	-0.050	-0.149	-
1967	0.737	-0.512	-	-0.313	-0.585	-	-0.048	-0.146	-
1968	0.799	-0.496	-	-0.340	-0.592	-	-0.056	-0.155	-
1969	1.005	-0.441	-	-0.388	-0.602	-	-0.079	-0.181	-
1970	0.891	-0.471	-	-0.380	-0.601	-	-0.074	-0.176	-
1971	0.375	-0.606	-	-0.268	-0.570	-	-0.040	-0.137	-
1972	0.117	-0.671	-	-0.222	-0.553	-	-0.036	-0.133	-
1973	0.310	-	1.006	-0.355	-	-0.088	-0.070	-	0.054
1974	-0.391	-	-0.099	-0.400	-	-0.175	-0.131	-	0.005
1975	-0.508	-	-0.295	-0.300	-	0.013	-0.108	-	0.024
1976	-0.528	-	-0.329	-0.242	-	0.112	-0.100	-	0.030
1977	-0.531	-	-0.334	-0.222	-	0.145	-0.097	-	0.032
1978	-0.521	-	-0.318	-0.314	-	-0.014	-0.116	-	0.017
1979	-0.513	-	-0.303	-0.384	-	-0.143	-0.142	-	-0.003
1980	*-0.583*	-	*-0.433*	*-0.392*	-	-0.158	*-0.179*	-	*-0.031*
1981	-0.585	-	-0.438	-0.413	-	-0.204	-0.198	-	-0.044
1982	-0.578	-	-0.423	-0.375	-	-0.125	-0.166	-	-0.021

Turning initially to the demand price elasticities attached to the energy input, the first thing that arouses curiosity are the positive signs on the price elasticity coefficients for the years 1956 through 1973 in the overall model (1956-1982). Such a result is most likely due to the strength of the income effect far outweighing the price effect during a period of high economic growth rates; during such period the demand for energy became more a function of real income rises than of prices (per barrel fuel oil prices were actually lower in nominal terms in 1971 than in 1956).

The impact of the 1973 oil price shock on the energy price elasticity coefficients is obvious. Demand became decidedly more price inelastic in the post-1973 era. This suggests that rigidities in substitution with other inputs created by the importation of inappropriate production techniques locks an economy into higher expenditures on imported energy requirements. It also means that using the price mechanism to reduce energy consumption will not constitute an optimal reform strategy unless factor substitution possibilities are enhanced. Additionally, these input substitution rigidities combined with demand price inelasticities will have perverse consequences on a country's balance of payments.

The own-price elasticity coefficients attached to capital and labor also divulge strong structural breaks between the pre-and post-1973 periods. As in the case of energy, demand for both these inputs became much more inelastic in the 1973-1982 period. With respect to capital price changes, this also suggests the presence of substitution rigidities. Moreover, it means that public policy efforts to reduce the cost of capital will have less impact on its quantity demanded than prior to 1973. This same basic effect also applies to manpower demand in that (relative) real wage drops will not be as job creating in the post-1973 era as they would have been prior to the first oil price shock. The bottom line is that the post-1973 period finds it more difficult to use pricing policies to attack the twin

and interrelated problems of insufficient demand for both capital and labor. This simply adds another rigidity to the economic policy mix.

V. Summary and Conclusions

The energy price shocks of the 1970s produced severe structural changes in countries and regions around the world, and nowhere were these structural breaks greater than in energy-and capital-importing areas. Moreover, these structural and relative price modifications had distinct implications for economic growth strategies.

As was observed for the case of Puerto Rico, the relationships between factor inputs measured via the use of partial elasticities of substitution were drastically altered. The capital-labor relation moved from highly substitutable to weakly complementary, thereby reducing manpower absorption in a relatively labor abundant region. The energy-labor link was transformed from high to low substitutability, and that of energy-capital from highly complementary to substitute. In terms of the own-price elasticities of demand for each of these factor inputs, each became decidedly more inelastic, thereby injecting greater inflexibility into the use of government-instigated pricing policies that seek to deal with socioeconomic problems.

Reduced sensitivity to factor price changes implies that future oil price shocks (which could involve either price rises or declines) will not generate structural effects as profound as in the pre-1973 era. This, of course, can be either positive or negative, especially in the case of energy costs. However, it does have perhaps serious implications for tax-based economic development strategy, for it implies that lower capital costs created via the tax exemption mechanism will have lesser repercussions on

the quantity demanded of investment. In the case of Puerto Rico, where external capital has historically financed the bulk of investment, this might clearly impact upon the long-run investment ratio.

The analysis suggests that the theory of comparative advantage based upon domestic factor abundancy is not particularly relevant to the Puerto Rican case, especially in the face of close to 100 percent tax exemption and (pre-1973) low energy prices. Given the poor rate of labor absorption, it would appear that tax exemption should be far better tied in to the number of jobs created than it has in the past. The dilemma, of course, is whether or not a region such as Puerto Rico finds itself in a position to be able to pick and choose the type of investment that it receives. In a highly competitive world it probably has little or no scope for such selection.

NOTES

1/ Ernst R. Berndt and David O. Wood, "Technology, Prices, and the Demand for Energy", Review of Economics and Statistics 57 (August 1975): 259-268; James M. Griffin and Paul R. Gregory, "An Intercountry Translog Model of Energy Substitution Responses", American Economic Review 66 (December 1976): 845-857; Melvin A. Fuss, "The Demand for Emergy in Canadian Manufacturing: An Example of the Estimation of Production Structures with Many Inputs", Journal of Econometrics 5 (January 1977): 89-116; Robert Halvorsen and Jay Ford, "Substitution Among Energy, Capital, and Labor Inputs in U.S. Manufacturing", in Robert S. Pindyck (ed.), Advances in the Economics of Energy and Resources: Structure of Energy Markets (Greenwich, Ct.: JAI Press, 1979), 51-75; Robert S. Pindyck, "Interfuel Substitution and the Industrial Demand for Energy: An International Comparison", Review of Economics and Statistics 61 (May 1979): 169-179.

2/ Barry C. Field and Charles Grebenstein, "Capital-Energy Substitution in U.S. Manufacturing", Review of Economics and Statistics 62 (May 1980): 207-212; Carolyn Harper and Barry C. Field, "Energy Substitution in U.S. Manufacturing: A Regional Approach", Southern Economic Journal 50 (October 1983): 385-395; Gaspar A. Garofalo and Devinder M. Malhotra, "Input Substitution in the Manufacturing Sector during the 1970s: A Regional Analysis", Journal of Regional Science 24 (February 1984): 51-63.

3/ A KLE translog model was applied to Puerto Rico's manufacturing sector in José I. Alameda and Arthur J. Mann, "Technology Dependency and Energy Substitutability in a Small, Open, and Petroleum-Importing Developing Economy", Journal of Economic Development 9 (July 1984): 147-166.

4/ Griffin and Gregory used this variant. The lack of reliable data for most materials inputs is the principal restrictive condition.

5/ These trends are well documented in U.S. Department of Commerce, Economic Study of Puerto Rico (Washington: U.S. Government Printing Office, 1979), Vol. I, 92-100.

APPENDIX

DATA CONSTRUCTION AND SOURCES

The data required for the estimation of the KLE translog cost function are the prices and the cost shares of the three inputs. With respect to prices, indexes using the base year 1972 were calculated. The prices themselves are :

capital price	:	prime interest rate;
labor price	:	remuneration by man-hour;
energy price	:	average per barrel price of fuel oil.

The cost shares were calculated using the following expressions :

$$\text{capital share} = \frac{\text{prime interest rate X capital stock}}{\text{total estimated input costs}}$$

$$\text{labor share} = \frac{\text{employee compensation (wages, salaries, suppements)}}{\text{total estimated input costs}}$$

$$\text{energy share} = \frac{\text{average price fuel oil X amount energy consumed}}{\text{total estimated input costs}}$$

SOURCES :

Puerto Rico Planning Board, Income and Product; Puerto Rico Electric Energy Authority, work sheets; U.S. Department of Commerce, Bureau of Economic Analysis, Business Conditions Digest.