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FACTOR SUBSTITUTION IN PRODUCTION IN INDUSTRIALIZED AND LESS DEVELOPED COUNTRIES

by

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ABSTRACT

The paper develops and estimates a simple transcendental logarithmic model of production for three developing countries. The hypothesis of separability of imported inputs from the primary factors is tested and rejected, and estimates of the substitution elasticities are calculated. The results, combined with those from the related literature, show that the factor substitution patterns are systematically different in developed and developing countries. This difference has important implications for the way these economies and, in particular, their labor markets respond to external shocks.

FACTOR SUBSTITUTION IN PRODUCTION IN INDUSTRIALIZED AND LESS DEVELOPED COUNTRIES

Introduction

Casual evidence suggests that the input bundles and the techniques used in production differ significantly between industrialized and less developed countries (LDCs). In LDCs, for example, the techniques used are generally more labor intensive and a higher proportion of the intermediate and capital goods used in production is imported. Relatively little, however, has been done to study these differences in depth. The purpose of this paper is to contribute to this investigation, concentrating on one specific question: are there any systematic differences in the pattern of factor substitution, and if yes, what are their policy implications?

We study substitution patterns by comparing empirical estimations of transcendental logarithmic (translog) production models for different countries. There are two reasons for this choice. The first is that the translog model is the most flexible framework for estimating technological relationships because it imposes the least stringent assumptions on the data. Unlike the Cobb-Douglas and the CES forms, it allows for testing of the symmetry and input separability hypotheses. It also gives yearly (in the case of annual data) unrestricted estimates of the elasticities of substitution, which reveal changing patterns over time. The second reason is that there already exists a body of research using translog forms with structure similar to ours. This means that the results are easily comparable and some generalizations can be made.

We estimate translog cost functions for three LDCs: Pakistan, Tunisia and Colombia. In the case of Colombia we distinguish between estimations based on a sample that includes the whole economy and on one that excludes agriculture. We compare our results with work done on South Korea (Mohabbat and Dalal, 1983), India (Mohabbat, Dalal et al., 1984), Brazil (Demekas and Varangis, 1986), for LDCs, and the U.S.A. (Burgess, 1974), Canada (Kohli, 1978) and a group of ten other industrialized countries (Pindyck, 1979).

Our paper is organized as follows. In the next section we present the model and the data used in our estimations. Then we present our empirical results alongside with the existing literature. Finally we discuss the conclusions and the limitations of the study.

The Model

The production technology can be described as a transformation function $T(y; x) = 0$, where y and x are vectors of outputs and inputs, respectvely. If $T(y; x)$ is well defined and continous for all non-negative x and y and satisfies the usual convexity requirements, then there exists a unique cost function defined as $C(y, w) = \{\min wx, \text{ subject to: } x \in V(y)\}$, where w are the input prices and $V(y)$ the input requirement set. Assuming that the technology is separable with respect to a partitioning between inputs and outputs, the cost function can be written as: $C(y, w) = H(y)Z(w)$.

For estimation purposes in this paper we make the input-output separability assumption. This means that the composition of output does not affect the optimal input bundle and we can, therefore, use a single aggregate output specification.

Input-output separability should ideally be tested as a hypothesis rather than imposed as an assumption. Its importance, however, for the questions this paper is asking is likely to be minimal. Furthermore, although other researchers have used multiple output specifications and tested for input-output separability, the hypothesis was accepted in two out of the five countries mentioned earlier[1].

The inputs in the production process are labor (L), capital (K) and imports (M). This specification of inputs is the same as the one used in all other literature we refer to and, therefore, the results are directly comparable. We assume that factors are employed up to the point where their price equals their marginal product and, furthermore, that there are no lags in the attainment of the minimum cost factor combinations; in other words, the firms are always on their demand curves. For any arbitrary cost function satisfying these assumptions, the translog functional form in (1) below is a second order approximation (Christensen, Jorgenson & Lau, 1973):

$$\ln C = \alpha_o + \alpha_a \ln Q + (1/2)\alpha_{aa}(\ln Q)^2 + \Sigma\beta_i \ln W_i + \\ + (1/2)\Sigma\Sigma\gamma_{ij}\ln W_i \ln W_j + \Sigma\delta_i \ln W_i \ln Q \qquad (1)$$

where Q is output, W_i and W_j are input prices and i, j = L, K, M.

This specification is consistent with Hicks-neutral technical progress up to an additive term with a unitary coefficient (Berndt & Christensen, 1973b). By logarithmically differentiating (1) we derive the following factor share equations:

$$S_i = \frac{\ln C}{\ln W_i} = \beta_i + \Sigma\gamma_{ij}\ln W_j + \delta_i \ln Q \ , \qquad (2)$$

We want our cost function to be well-behaved, namely monotonic, concave and linearly homogenous to factor prices, and the technology to display constant returns to scale. These assumptions, which are henceforth treated as maintained hypotheses, imply the following parametric restrictions:

$$\sum_i \beta_i = 1 \tag{3.a}$$

$$\sum_i \gamma_{ij} = \sum \gamma_{ji} = 0 \tag{3.b}$$

$$\delta_i = 0, \quad \forall \ i \tag{3.c}$$

The three share equations add up to one by construction. For estimation purposes we can, therefore, drop one and estimate the remaining two independently and then retrieve the coefficients of the third. We drop the S_k equation and the reduced form model, after incorporating (3.a -3.c) becomes:

$$S_L = \beta_L + \gamma_{LL} \ln W_L + \gamma_{LK} \ln W_K + \gamma_{LM} \ln W_M \tag{4.a}$$

$$S_M = \beta_M + \gamma_{ML} \ln W_L + \gamma_{MK} \ln W_K + \gamma_{MM} \ln W_M \tag{4.b}$$

To estimate the reduced form we choose to use an iterative Seemingly Unrelated Regressions technique for two reasons. First, because the cross-equation restrictions (3) mean that the errors of the equations are not independent; the Zellner technique of Seemingly Unrelated Regressions is, therefore, required (Zellner, 1962). Second, the choice of the share equation to be dropped would ordinarily affect the estimates, unless Maximun Likelihood Estmation (MLE) rather than Ordinary Least Squares is used. Iteration of the Zellner technique, however, has been proved (Kmenta & Gilbert, 1968) to yield

estimates that are asymptotically equivalent to the MLE estimates. Thus, our calculations use all the available information and do not depend on which share equation is dropped.

In order for our cost function to be consistent with cost minimization the symmetry properties must hold i.e. the cross partial derivatives with respect to the input prices must be symmetric (Berndt & Christensen, 1973b). In the context of our reduced form (4) this implies $\gamma_{ij} = \gamma_{ji}$, $\forall$ i, j. We estimate the model with and without the symmetry restriction and we test for the validity of the hypothesis.

The estimates of the translog function permit a straightforward calculation of the Allen-Uzawa Partial Elasticities of Substitution (AES) between factors, as well as the own-price elasticities of the compensated factor demands (see Uzawa, 1962; Berndt & Christensen, 1973a). In general the AES is defined as follows:

$$\sigma_{ij} = \frac{CC_{ij}}{C_i C_j} \tag{5}$$

where $C_i = \frac{\partial C}{\partial W_i}$, $C_j = \frac{\partial C}{\partial W_j}$, $C_{ij} = \frac{\partial^2 C}{\partial W_i \partial W_j}$, i, j = K, L, M.

In terms of the parameters of the model (5) can be rewritten more simply:

$$\sigma_{ij} = 1 + \frac{\gamma_{ij}}{U_i U_j} \tag{5.b}$$

where $U_{i,j}$ are the fitted factor shares.

The own-price elasticities of the compensated factor demands η_i can also be simply expressed:

$$\eta_j = \frac{\gamma_{jj} + U_j^2 - U_j}{U_j} \qquad (6)$$

where η_j is the elasticity of the compensated demand for the j factor with respect to its own price.

The AES also offer a simple way to test the hypothesis of input separability. The question of separability of imports from the primary factors, in particular, is a recurring theme in the translog literature. If imports are separable from labor and capital, then $\sigma_{ML} = \sigma_{MK}$. This holds if either:

$$\gamma_{ML} = \gamma_{MK} = 0 \text{ , so that } \sigma_{ML} = \sigma_{MK} = 1,$$

(linear separability), or:

$$\gamma_{ML}U_MU_K = \gamma_{MK}U_MU_L \text{ , so that } \sigma_{ML} = \sigma_{MK} = \neq 1.$$

(non linear separability).

In this paper we test for linear separability between imports and primary domestic factors.

For our estimations we use annual data from Pakistan, Tunisia and Colombia from 1970 to 1981. In the case of Colombia we report separately the results for the whole economy from those that pertain only to the non-agricultural sectors. Total costs is calculated as GDP in domestic prices plus the current value of imports in domestic currency; the data comes from the World Bank World Tables. Employment, population and wage series come from the ILO Yearbook of Labor Statistics. The price index of imports is

calculated from value of imports series in current and constant domestic prices; the data comes from the World Bank Tables. Finally, the price of capital services is calculated using the formula suggested by Christensen & Jorgenson (1969):

$$W_K(t) = r(t)q(t-1) + dq(t) - g(t) \qquad (7)$$

where: r(t) is the Treasury Bill rate, or some other official interest rate from the IMF International Financial Statistics: q(t) is the deflator of gross capital formation, calculated from World Bank World Tables series: d is the depreciation rate, set at 8%; and g(t) represents the capital gains and is defined as q(t) - q(t-1).

Empirical Results

The parameter estimated for the four samples are presented in Table 1, together with the F-tests for the symmetry and linear separability of imports hypotheses. In all four samples (Pakistan, Tunisia, Colombia and Colombia non-agricultural sectors) the symmetry hypothesis is accepted at the 5% significance level (1% for Tunisia). The import separability hypothesis is tested alone and in conjunction with symmetry and rejected in both forms in all four samples. This result provides an a posteriori justification for using a three-input translog functional form. It is also worth noting that import separability was rejected in all the other country-studies we are referring to. The parameter estimates in table 1 reflect, therefore, only the symmetry restrictions.

Table 2 shows the estimates of the partial elasticities of substitution (AES). The translog form offers one elasticity estimate for every year. For

expository purposes we report the estimates for three selected years only, so that both the orders of magnitude and the changes over time become apparent.

In Pakistan and Tunisia σ_{LM} is negative for the first few years, indicating a complementary relation between labor and imported inputs. In all four samples σ_{LM} is very small and increases in size over time. The AES between labor and capital, on the other hand, is everywhere positive and high, showing that capital and imports are very close substitutes. Over time, with the exception of the last few years in Pakistan, σ_{MK} is either stable or falling. Finally, capital and labor appear to be close substitutes as well, except in the case of Tunisia. This result flies in the face of often heard reservations about the ease of primary factor substitution in developing countries.

Exactly the same pattern of factor substitution is documented in the research done on other LDCs. Table 3 summarizes and compares the results of our and other papers, presenting the country, the source, the structure of the model used and the ranking of the AES. The AES between labor and imports is the lowest in all LDCs and is negative in India and Brazil. Capital and imports, on the other hand, are strong substitutes - σ_{KM} is the highest AES in all LDCs except Colombia. In industrialized countries the opposite is true. Labor and imports are strong substitutes, whereas capital and imports are complements (σ_{KM} is negative in both the USA and Canada).

Table 3 also presents and compares the estimates of the own-price elasticity of the demand for labor. Our estimates have the expected negative sign for all the years. Here we present just the ranges within which our - and other researchers' - estimates lie. It appears that the compensated demand for labor is everywhere inelastic. In some cases, esp. India and

Pakistan, η_L is very close to zero. The highest estimate comes from Brazil, but even there it is well below unity for most of the years the authors report. No marked difference between estimates for industrialized countries and LDCs appears to exist.

Pindyck (1979) estimates translog cost functions for ten industrialized countries (including the USA., and Canada) and surveys a body of related translog literature. That family of models differs from ours in that it focuses on the pattern of substitution between capital, labor and energy, rather than primary and imported inputs. To the extent that the energy input is imported, however, their results can be compared to ours. It turns out that in eight out of the ten countries (Japan, france, Italy, the Netherlands, Norway, Sweden, West Germany and the UK) the ranking of AES is the same as the one we report for industrialized countries in Table 3. The AES between labor and energy is the highest, followed by the AES between labor and capital and that between capital and energy: $\sigma_{LE} > \sigma_{LK} > \sigma_{KE}$.

In Italy and Japan the order of the last two AESs is reversed, but the differences are not statistically significant. In Canada and the U.s.A., the ranking is different, with σ_{KE} having the highest and σ_{LE} the lowest values. These two countries, however, are less dependent on imports for their energy needs and the model estimates there are bound to be different from ours.

Summary and Conclusions

We constructed and estimated a simple translog cost function in four different data sets from developing countries. Our results, together with those of other comparable research, point out a few interesting stylized

facts.

First, the substitution of primary factors does not seem to be problematic in LDCs. Switching and fine-tuning of techniques of production to compensate for relative factor price movements appears, therefore, to be no less feasible than in industrialized countries.

Second, there is a marked difference between industrialized countries and LDCs in the pattern of substitution between imports and primary factors. In industrialized countries imports are close substitutes to labor and complements to capital. In LDCs the opposite is true: imports are close substitutes to capital and very weak substitutes or complements to labor. This difference is statistically significant and systematic.

This difference is most likely due to the nature of imports in two groups of countries. In LDCs most imports consist of capital goods and are, therefore, very close substitutes to domestic capital. In industrialized countries most imports are labor intensive intermediate goods or raw materials, used as complements to domestic capital in production.

To the extent that technological advancement for LDCs means moving closer to industrialized countries norms, the change of the AES over time in our sample conforms to what one would expect. LDC imports become closer substitutes to labor, although their relationship with capital does not change. Moreover, the estimates from Colombia show that the sample excluding agriculture is closer to the industrialized country norm than the whole economy. This is the expected result, of course, given that agriculture uses less modern technology.

The most interesting policy implications of this dissimilarity between industrialized countries and LDCs have to do with the way different countries

respond to external shocks. The same external shock, e.g. an rise in the price of imported inputs, will create a different set of conditions for the economy as a whole and, in particular, for the labor market, depending on the technological characteristics of production. In industrialized countries an import price hike will, through the strong substitution effect, tend to increase the demand for labor considerably. In LDCs, on the contrary, the same shock will tend to increase the demand for labor by very little, or even decrease it. Labor market adjustment to the post-schock conditions is, therefore, easier for industrialized economies than for LDCs, because of the technological differences in production.

The same argument serves to illustrate the differences in the macroeconomic and distributional characteristics of the same policy measures. Protection, for example, which increases the domestic price of imports the producers face, is more beneficial for labor in industrialized countries than in LDCs. In the former protection will have a strong positive effect on the demand for labor, whereas in the latter the effect will be weak or negative. Domestic tax policies that result in increasing the cost of capital services, on the other hand, will tend to redistribute income in favor of labor in LDCs, but at the same time, increase significantly the demand for imports and the pressure on the trade account. Similar policies in industrialized countries will tend to improve the trade account.

The above conclusions about the different effects of relative factor price movements in industrialized countries and LDCs depend on the size of the income effect. The AES estimates measure only the compensated elasticities. We implicitly assume that the size of the income effects of a relative factor price change is approximately the same in both groups of countries, so that we

can compare its pure substitution effects on factor demands ceteris paribus. Even then, however, the size of the total effect is unclear. This is why we restrict ourselves in discussing the relative, rather than the absolute effects of factor price movements.

For the same reason, finally, one should be careful in interpreting the estimates of the own-price factor demand elasticities. Their small size indicates a rather inelastic labor demand. Wage cuts, however, may prove effective in increasing employment if the income effect is strong enough.

Table 1

ESTIMATES AND F-TESTS OF THE TRANSLOG MODEL

	Pakistan	Colombia (total economy)	Colombia (non-agricultural sectors	Tunisia
β_L	0.289905 (0.298006)	0.122656 (0.023201)	0.090158 (0.022419)	0.885074 (0.120887)
γ_{LL}	0.100116 (0.045018)	0.045708 (0.012967)	0.038234 (0.013421)	0.044682 (0.043041)
γ_{LM}	-0.068237 (0.034617)	-0.023797 (0.013303)	-0.014212 (0.013770)	-0.111298 (0.046689)
γ_{LK}	0.031878 (0.028451)	0.021910 (0.002142)	0.024022 (0.001961)	-0.066651 (0.009959)
β_M	0.059865 (0.095882)	0.049984 (0.026429)	0.061432 (0.025809)	-0.551843 (0.096600)
γ_{ML}	-0.068237 (0.034617)	-0.023797 (0.013303)	-0.014212 (0.013770)	-0.111298 (0.046689)
γ_{MM}	0.093169 (0.032108)	0.029093 (0.013767)	0.019222 (0.014251)	0.239828 (0.051767)
γ_{MK}	0.024931 (0.006328)	0.005295 (0.002520)	0.005010 (0.002369)	0.128530 (0.008102)
$F(3,16)^1$	2.176	3.412	2.259	5.069
$F(2,16)^2$	6.356	7.499	12.880	11.195
$F(5,16)^3$	32.701	6.935	4.310	114.173

Notes:
1. Symmetry restriction.
2. Separability of import restrictions.
3. Symmetry and import separability restrictions.

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Table 2

Partial Elasticities of Substitution Estimates, Selected Years

Sample	σ_{ij}	1970	1976	1981
Pakistan	σ_{LM}	-0.669	0.446	0.614
	σ_{LK}	1.171	1.383	2.993
	σ_{MK}	2.384	2.225	3.137
Colombia (total economy)	σ_{LM}	0.053	0.177	0.503
	σ_{LK}	1.143	1.134	1.123
	σ_{MK}	1.074	1.075	1.073
Colombia (non-agricultural sectors)	σ_{LM}	0.396	0.502	0.699
	σ_{LK}	1.164	1.148	1.136
	σ_{MK}	1.068	1.071	1.068
Tunisia	σ_{LM}	-0.153	0.147	0.273
	σ_{LK}	0.564	0.372	0.217
	σ_{MK}	2.978	2.374	2.351

Table 3

Factor Substitution and Labor Demand Elasticity Estimates

Country	Source	Model Structure[1]	Ranking of AES	$(\eta_L)^2$
India	Mohabbat, Dalal et al. (1984)	2 outputs (C, I), 3 inputs (L, K, M)	$\sigma_{Mk} > \sigma_{LK} > \sigma_{LM}$ ($\sigma_{LM} < 0$)	0.143-0.174
S. Korea	Mohabbat & Dalal (1983)	2 outputs (C, I), 3 inputs (L, K, M)	$\sigma_{LK} > \sigma_{MK} > \sigma_{LM}$	0.270-0.340
Brazil	Demekas & Varangis (1986)	3 outputs (C, I, X) 3 inputs (L, K, M)	$\sigma_{MK} > \sigma_{LK} > \sigma_{LM}$ ($\sigma_{LM} < 0$)	0 594-0.845
Pakistan	Own calculations	1 output, 3 inputs (L, K, M)	$\sigma_{MK} > \sigma_{LK} > \sigma_{LM}$	0.071-0.195
Colombia	Own calculations	1 output, 3 inputs (L, K, M)	$\sigma_{LK} > \sigma_{MK} > \sigma_{LM}$	0.524-0.570
Colombia (non-agricultural)	Own calculations	1 output, 3 inputs (L, K, M)	$\sigma_{LK} > \sigma_{MK} > \sigma_{LM}$	0.549-0.606
Tunisia	Own calculations	1 output, 3 inputs (L, K, M)	$\sigma_{MK} > \sigma_{LK} > \sigma_{LM}$	0.429-0.531
U.S.A.	Burgess (1974)	2 outputs (C, I), 3 inputs (L, K, M)	$\sigma_{LM} > \sigma_{LK} > \sigma_{MK}$ ($\sigma_{MK} < 0$)	0.259-0.314
Canada	Kohli (1978)	3 outputs (C, I, X) 3 inputs (L, K, M)	$LM > \sigma_{LK} > \sigma_{MK}$ ($\sigma_{MK} < 0$)	0.319-0.373

Notes:

1. Outputs: C - consumption goods; I - investment goods; X - exports.
   Inputs: L - labor; K - capital; M - imports.

2. η_L is the absolute value of the own-price elasticity of the compensated demand for labor.

Notes

1. Three-output specifications (consumption goods, investment goods and exports) were used by Kohli (1978) for Canada and Demekas & Varangis (1986) for Brazil. Two-output specifications (consumption and investment goods) were used by Burgess (1974) for the USA, Mohabbat & Dala (1983) for S. Korea and Mohabbat, Dalal et al. (1984) for India. In all cases input-output separability was treated as a hypothesis and tested for. In the last two, viz. S. Korea and India, the hypothesis could not be rejected.

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