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5 The Substitution of Labor, Skill, and Capital: Its Implications for Trade and Employment

Vittorio Corbo and Patricio Meller

5.1 Introduction

One of the important questions that arise when we consider the implications of alternative trade strategies for employment is the relation of the skill composition of the labor force to the determinants of comparative advantage. Leontief originally conjectured that it was the skills of the American labor force that gave the United States its relatively high labor (in efficiency units) to capital endowment. Since that time, the importance of skills as an explanatory variable in trade flows has repeatedly been found (e.g., Keesing 1966 and Baldwin 1971).

Despite these empirical findings, questions remain as to the appropriate way to model human capital. Trade theory has long been centered upon a two-factor model of the factor proportions explanation of trade. Trade theorists have tended to maintain this framework by attempting to aggregate two of the three factors of production, generally human and physical capital (Kenen 1965). In this regard, questions arise about the appropriate aggregation: Is human capital a close or perfect substitute for physical capital, or is human capital appropriately regarded as labor-augmenting, increasing a country's endowment of efficiency units of labor?

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In this chapter we attempt to investigate this question by applying modern production-function estimation to Chilean data for forty-four manufacturing four-digit industries. Whereas, traditionally, econometricians estimated production functions after aggregating unskilled labor and human capital to form one labor factor (Hildebrand and Liu 1965; Griliches and Ringstad 1971), the modern approach is to test for the appropriate aggregation. Aggregation is studied as a problem of forming a "jelly" of factors. The aggregator function need not be linear in the variables. Testing has usually been done within the context of a maintained hypothesis about the form of the production function.

The translog production function has been the most widely used hypothesis with respect to the technology. For this case, Berndt and Christensen (1973*a*) have shown that, except in cases of fixed proportions or perfect substitution, one consistent aggregate of different productive inputs exists if and only if "some" elasticities of substitution between pairs of factors are equal. For example, in the case of the three factors, unskilled labor (L), skill or human capital (S), and physical capital (K), combining unskilled labor and skill into one aggregate—labor—is valid if $\sigma_{LK} = \sigma_{SK}$. On the other hand, combining human and physical capital is appropriate if $\sigma_{SL} = \sigma_{KL}$. There already exists a considerable empirical literature oriented toward examining which are the consistent aggregates of the different productive inputs (Berndt and Christensen 1973*b*, 1974, Humphrey and Moroney 1975; Stern 1976; Corbo and Meller 1979*a*). This is the approach followed in this paper.

In addition to the question of appropriate aggregation, it is also important to ascertain the degree of complementarity or substitutability between different pairs of factors, and to determine whether there exists some difference in the substitutability between pairs of inputs among tradable manufacturing sectors (i.e., manufacturing industries that produce exportables or import-competing goods).[1] For instance, is there greater complementarity between physical capital and skill for the exportable manufacturing industries than for the import-competing ones? For classification of industries according to their trade category, we have used the same criteria and information used in our previous study, Corbo and Meller (1981).

In section 5.2 we describe the properties and characteristics of the translogarithmic production function; we also discuss the notions of separability and aggregation and explain the logic and sequence of tests on the translogarithmic function to be able to verify the different hypotheses of input aggregation. In section 5.3 we present the information related to the data and the econometric and statistical results of the different tests. In section 5.4 we present the conclusions based on the empirical results.

5.2 Translog Production Function Characteristics

The properties of the translogarithmic production function are briefly the following (see Berndt and Christensen 1973*a*):

1. A general translog is not a homothetic function; therefore the level of production affects the technological characteristics.

2. A priori assumptions are not required in relation to the elasticities of output with respect to factor input. Therefore the monotonicity property of estimated functions has to be verified.

3. A priori assumptions are not required in relation to the convexity of the isoquants. That is, the elasticities of substitution between factors are not restricted a priori to be nonnegative, so that the convexity condition has to be checked.

4. Given the nonhomotheticity property, the monotonicity and convexity conditions have to be checked at each point of the isoquant map to be able to have a well-behaved production function. In other words, the elasticities of output with respect to factor inputs and the elasticities of substitution between factors are not necessarily constant and may vary along each isoquant. Moreover, they depend on the production level.

5. The Cobb-Douglas is a special case of the translog function.

6. The translog function is linear in the parameters, so that it is possible to use linear regression techniques for estimation.

7. Finally, the most important property for this study is that the translog does not impose a priori assumptions related to the separability between the inputs; separability between the inputs can be tested. This property permits determination of whether the conditions for a consistent aggregate of the different pairs of productive factors are met.

The translog function with symmetry imposed ($\gamma_{sk} = \gamma_{ks}$) can be written as:

$$
\begin{aligned}
(1) \qquad \ln Y_{ij} = {} & \alpha_0^i + \alpha_1^i \ln L_{ij} + \alpha_2^i \ln S_{ij} + \alpha_3^i \ln K_{ij} \\
& + \tfrac{1}{2}\gamma_{11}^i (\ln L_{ij})^2 + \gamma_{12}^i (\ln L_{ij})(\ln S_{ij}) \\
& + \gamma_{13}^i (\ln L_{ij})(\ln K_{ij}) + \tfrac{1}{2}\gamma_{22}^i (\ln S_{ij})^2 \\
& + \gamma_{23}^i (\ln S_{ij})(\ln K_{ij}) + \tfrac{1}{2}\gamma_{33}^i (\ln K_{ij})^2,
\end{aligned}
$$

where γ is value added, L is labor, S is skill, K is capital, i is an index of a four-digit ISIC industry, and j is an index of a firm within the ith industry.

The hypothesis of constant returns to scale can be tested directly from (1). Constant returns to scale implies a set of restrictions on the parameters of the function (see Berndt and Christensen 1973*b*, p. 84). A production function is considered well-behaved if it has positive marginal products for each input (i.e., positive monotonocity) and if it is quasi-concave.

The translog function is strictly quasi-concave (strictly convex isoquants) if the bordered Hessian matrix is negative definite. In the case of three inputs, this requires the bordered principal minors of the Hessian matrix to be positive and negative respectively. The translog function does not satisfy these restrictions globally. Still, if we can find wide enough regions in input space (including the observed output and input levels) where these restrictions are satisfied, then the translog function is considered well behaved. To do this, monotonicity and quasi-concavity of the estimated translog function must be checked at every data point in the sample.

Now let us examine the concepts of aggregation and separability of inputs. To this effect, we follow closely Green (1964) and Berndt and Christensen (1973*a*).

Intuitively, one would think that aggregating two production inputs would require perfect substitutability between them in the production process. But it is very rare to find two productive factors having perfect substitution between them. In economic theory, aggregation has a less restrictive meaning.

We say that aggregation is consistent when using more detailed information than contained in the aggregate results in no difference in the analysis of the problem. The conditions for aggregating two inputs, X_1, and X_2, and obtaining a consistent aggregate input X, require forming an index of consistent quantity Q for the aggregate of the inputs X_1 and X_2, such that when multiplying by an aggregate price index P, of components P_1 and P_2 associated with X_1 and X_2, it should give us the total cost of the inputs (Green 1964).[2] This concept of consistent aggregation is closely related to the concept of functional separability developed by Leontief.

It is said that two variables X_1 and X_2 are functionally separable from a third variable Z if and only if $F(X_1, X_2, Z) = G(H[X_1, X_2], Z)$. The mathematical condition for the variables X_1 and X_2 to be functionally separable from Z is that:

$$\frac{\partial}{\partial Z}\left(\frac{\partial F/\partial X_1}{\partial F/\partial X_2}\right) = 0.$$

Assuming that X_1, X_2, and Z are inputs in a productive process, the condition of functional separability implies that the marginal rate of technical substitution between the inputs X_1 and X_2 is independent of the third input Z. In other words, if we keep the inputs X_1 and X_2 constant and increase the input Z, the increase in Z would affect in equal proportion the marginal productivities of X_1 and X_2; the effect of Z is similar to that of the neutral technical progress described by Hicks (Humphrey and Moroney 1975).

That two variables (X_1 and X_2) are functionally separable from a third one (Z) implies that those two variables (X_1 and X_2) can be aggregated; in other words, it is possible to find an index of consistent quantity and an aggregated price index that would permit a consistent aggregation (see Green 1964).

Berndt and Christensen (1973*a*) have shown that, in general, conditions of functional separability of two variables are equivalent to certain equality conditions between the elasticities of substitution between factor inputs. In other words, that the inputs X_1 and X_2 are functionally separable from the input Z implies (as a necessary and sufficient condition) that $\sigma_{1Z} = \sigma_{2Z}$ (the elasticity of substitution between X_1 and Z is equal to the elasticity of substitution between X_2 and Z).

Therefore, in the case of a productive process with three inputs, the problem of aggregation of two inputs can be transformed into the problem of examining the equality of the elasticities of substitution between those two inputs with respect to the third factor.

Introducing the condition of equality of the elasticities of substitution between inputs implies certain restrictions on the parameters of the function; these restrictions can be tested econometrically. In the case of the translog function of equation (1), three types of pairwise weak separability may exist: the weak separability of L and S from K, L and K from S, and S and K from L. Furthermore, for the translog function, these separability conditions are fulfilled globally if and only if some specific set of restrictions on the parameters of the function is fulfilled.[3] Global separability imposes more restrictive conditions on the parameters of the translog function; that is, it requires all $\gamma_{ij} = 0$ for $i \neq j$.[4]

5.3 Data and Statistical Results

5.3.1 Data

For our data, the basic unit of information is the establishment as defined in the 1967 Chilean census of manufactures. There are 11,468 establishments, grouped into eighty-five industries according to the four-digit International Standard Industrial Classification (ISIC). From these eighty-five industries we selected a subset of forty-four that allow at least ten degrees of freedom for the estimation of equation (1). Within each industry we selected a subset of establishments that satisfied each of the following restrictions.

1. Number of days worked by the establishment ≥ 50
2. Wage bill of blue-collar workers > 0
3. Book value of machinery > 0
4. Gross value added > 0
5. Nonwage gross value added >0
6. Number of persons employed ≥ 10
7. Number of white-collar workers > 0

8. Number of blue-collar workers > 0
9. (Book value of machinery/gross value added)$_{ij}$ >1/10 (Book value of machinery/gross value added)$_i$

All these restrictions are self-explanatory with perhaps the exception of restriction 9. That was used to eliminate establishments that satisfied restriction 3 but had a very small value for the book value of machinery. When the ratio of book value to value added for a particular establishment was less than one-tenth that of the remainder of the industry, the firm was eliminated from the sample.

The definitions of the variables used in our estimate are as follows:

L = Average annual number of man-days. It is measured as the sum of production workers, blue-collar workers in auxiliary activities, white-collar workers, and entrepreneurs times the number of days worked by the establishment.[5] The units of L are defined in such a way that for a given industry i, the mean of L equals one.

S = Skill-days units, average annual number of equivalent blue-collar-days minus L.[6] The equivalent number of blue-collar-days is measured as the ratio of the total wage payments, plus an imputation for entrepreneurs, to the minimum wage rate of the whole industrial sector.[7] The units of S are defined in such a way that for a given industry i, the mean of S equals one.

K = Book value of machinery at 1967 prices less accumulated depreciation.[8] The units of K are defined in such a way that for a given industry i, the mean of K equals one.

Y = Gross value added at 1967 prices.[9] The units of Y are defined in such a way that for a given industry i, the mean of Y equals one.

5.3.2 Statistical Results

In all our estimates, the ordinary least squares (OLSQ) estimating procedure was used. A difficulty with the use of OLSQ is that the regressors (the factor quantities) are firms' decision variables as much as the production level. Failure to take account of this problem introduces contemporaneous correlation between the regressors and the random error of the regression (the simultaneity problem). In such a case, the OLSQ estimates of equation (1) are biased and inconsistent. Consistent estimates could be obtained by using an instrumental variable (IV) estimator; however, in cross-sectional analysis, the usual instruments—lagged values of the explanatory variables—are usually so highly correlated with the variables for which they are serving as instruments that the

OLSQ and IV results are not very different (Griliches 1967, p. 277). In our case, only one cross section was available, and consequently there was no variable that could be used as an instrument. Therefore we have estimated our model using OLSQ, and thus our results may be subject to some simultaneous-equation bias.

It could be argued that more efficient estimates might be obtained by using the set of equations derived from profit maximization in perfectly competitive product and factor markets, assuming further that the translog function is locally concave around the equilibrium. This is the procedure used in almost all estimates of translog functions. As with any other full-information method, we can be confident of obtaining more efficient estimates only so long as the assumptions used to derive the system of equations are true. If they are not, a specification error is introduced that will have unknown consequences for the properties of our estimates. In the case of Chilean manufacturing there is the strong danger of specification error owing to the presence of noncompetitive elements.[10] For this reason, we estimated the production function directly.

The problem of heteroskedasticity is minimized in our estimation procedure because we work with all the variables scaled in such a way that their means are equal to one. In this way, values of the variables are of similar magnitude.

Turning to the results of the direct estimation of the translog function, in table 5.1 we present estimates of the unconstrained translog function for the forty-four industries. These are the industries for which we have ten or more degrees of freedom. As can be seen, the number of firms was very large for some industries, ranging as high as 293 for sector 3117 (bakery products). The R^2s are extremely high for cross-section regressions. The lowest one is 0.649 for sector 3132 (wine industry), and all but five are above 0.8.

The first test performed for the general translog model was for constant returns to scale (CRTS). In only three cases out of forty-four is CRTS rejected at the 1 percent level.[11] These are bakery products (ISIC 3117), wearing apparel except footwear (ISIC 3220), and cement for construction (ISIC 3693).

For the forty-one CRTS sectors, we tested further for a Cobb-Douglas technology. For thirty-five out of the forty-one sectors the Cobb-Douglas technology could not be rejected (see table 5.2). There are six CRTS sectors for which the Cobb-Douglas technology was rejected: spinning, weaving, and finishing textiles (3211); sawmills, planing, and other wood mills (3311); printing, publishing, and allied industries (3420); furniture and fixtures primarily of metal (3812); special industrial machinery (3824); and machinery and equipment not elsewhere classified (3829). For these six sectors we proceeded further to test for pairwise linear and nonlinear separability.

Table 5.1 **Unconstrained Translog Function**

$\ln y = \alpha_0 + \alpha_1 \ln LM + \alpha_2 \ln LS + \alpha_3 \ln K + \frac{1}{2}\gamma_{11} (\ln LM)^2 + \frac{1}{2}\gamma_{22} (\ln LS)^2 + \frac{1}{2}\gamma_{33} (\ln K)^2 + \gamma_{12} (\ln LM)(\ln LS) + \gamma_{13} (\ln LM)(\ln K) + \gamma_{23} (\ln LS)(\ln K)$

ISIC Code	Number of Obser-vations	α_0	α_1	α_2	α_3	γ_{11}	γ_{22}	γ_{33}	γ_{12}	γ_{13}	γ_{23}	R^2	SSR
3111	100	−.0969	.6357	.4484	.1486	.0561	.1278	−.0657	−.1966	.1907	−.0519	.7909	37.011
		(−.951)	(4.369)	(3.713)	(1.683)	(.222)	(1.872)	(−.868)	(−2.002)	(2.173)	(−.745)		
3112	46	.0258	.2066	.3159	.4424	.4330	.1070	.2475	−.2462	−.2865	−.0014	.8753	15.751
		(.160)	(.658)	(1.296)	(2.252)	(.683)	(1.475)	(1.077)	(−.865)	(−1.038)	(−.008)		
3113	32	−.0949	.4555	.3746	.3852	.2912	.0124	.2608	.2610	−.2727	−.0801	.8405	7.884
		(−.470)	(.828)	(1.576)	(1.012)	(.330)	(.141)	(.616)	(.723)	(−.491)	(−.509)		
3114	37	.2072	.2896	.2618	.2779	.1795	.0056	.0117	−.2531	−.0026	.0965	.8795	5.374
		(1.645)	(1.012)	(1.468)	(1.663)	(.669)	(.140)	(.071)	(−1.248)	(−.134)	(.769)		
3115	34	.1007	.5486	.6210	.4300	−.7311	.1258	−.4432	.3926	.1704	.0105	.8386	6.674
		(.656)	(2.159)	(2.401)	(2.253)	(−2.152)	(.316)	(−1.846)	(1.525)	(.826)	(.041)		
3117	293	−.1798	.6429	.3099	.1947	.0176	.0508	−.0157	−.0247	.0105	.0186	.7891	54.246
		(−3.364)	(9.618)	(8.074)	(4.334)	(.133)	(6.298)	(−.419)	(−1.451)	(.184)	(1.763)		
3119	26	.0346	.0499	.3450	.5376	.6473	−.1198	−.0432	−.3063	−.1509	.2314	.9722	2.032
		(.213)	(.224)	(1.856)	(3.126)	(1.070)	(−.361)	(−.370)	(−1.554)	(−.405)	(1.353)		
3121	39	−.9560	.5394	.7454	.0411	−.0076	.1891	−.3394	−.4169	.3795	.1794	.8747	10.589
		(−4.973)	(1.537)	(2.571)	(.187)	(−.007)	(2.273)	(−1.370)	(−.922)	(.913)	(.968)		
3131	25	−.0454	−.2487	.9613	.1758	.7664	.6798	−.1462	−.7801	−.2237	.1166	.8530	5.737
		(−.159)	(−.663)	(3.760)	(.830)	(.724)	(2.222)	(−.588)	(−1.638)	(−.786)	(.480)		
3132	70	−.2464	.9611	−.0270	.1246	.4401	−.0116	−.2697	.0522	.0826	−.0298	.6490	26.827
		(−1.676)	(5.338)	(−.255)	(.809)	(1.570)	(−.495)	(−1.277)	(1.194)	(.441)	(−.640)		

3211	232	.0852	.5868	.3312	.0491	−.0984	.0399	−.1285	−.0028	.1065	−.0088	.8872	48.005
		(1.417)	(6.987)	(5.526)	(.840)	(−.828)	(2.569)	(−2.798)	(−.064)	(1.889)	(−.238)		
3212	22	.2000	.6872	−.0094	.2559	.2532	−.8880	−.1742	.6950	−.4157	.2281	.9154	1.321
		(1.631)	(3.083)	(−.048)	(1.568)	(.386)	(−2.042)	(−.395)	(1.479)	(−.690)	(.989)		
3213	145	−.1369	.7275	.2034	.1910	−.0781	.0062	.0496	.0960	−.0530	−.0354	.8996	23.278
		(−2.127)	(5.568)	(2.395)	(2.476)	(−.281)	(.384)	(.669)	(.954)	(−.459)	(−.591)		
3220	239	−.1254	.7577	.2678	.1562	−.1419	.0278	.0704	.6999	−.0665	−.0434	.8643	48.143
		(−2.439)	(8.059)	(4.491)	(2.614)	(−.791)	(2.004)	(.979)	(1.421)	(−.774)	(−1.046)		
3231	57	−.0689	.9764	.1041	.0799	−.6704	−.1552	−.0126	.2915	.2156	−.1183	.8507	12.469
		(−.554)	(3.610)	(.473)	(.614)	(−.897)	(−.753)	(−.081)	(1.314)	(.719)	(−.663)		
3233	30	.0992	.0859	.5592	.4361	.3751	.1526	.3786	−.2934	−.4114	.0132	.8408	3.907
		(.606)	(.224)	(2.900)	(2.120)	(.300)	(.852)	(1.696)	(−.626)	(−.913)	(.098)		
3240	138	−.1239	.3517	.3896	.3604	.0924	.0118	.1992	.0613	−.2323	.0054	.9195	21.566
		(−1.915)	(3.046)	(4.768)	(5.326)	(.376)	(.211)	(2.504)	(.633)	(−2.202)	(.097)		
3311	252	.1255	.4704	.3197	.1448	.0542	.0542	−0.9920	−.0496	.0202	.0059	.7956	65.886
		(2.260)	(7.824)	(7.410)	(3.311)	(.723)	(5.804)	(−2.479)	(−2.235)	(.441)	(.419)		
3312	27	−.0376	.2378	.1928	.3681	−.5919	.0202	.2552	−.1667	.0750	.0069	.8176	2.478
		(−.241)	(.991)	(1.949)	(3.626)	(−.906)	(.708)	(1.642)	(−1.778)	(.275)	(.165)		
3320	132	−.0998	.5238	.2539	.2824	−.0079	.0307	.0278	−.0337	−.0175	.0358	.8194	26.851
		(−1.279)	(4.813)	(3.698)	(3.657)	(−.029)	(1.938)	(.338)	(−.471)	(−.146)	(.873)		
3411	19	.0101	.4048	.2956	.2517	−2.2174	1.9648	.3246	.2409	.8514	−1.2373	.9868	1.011
		(.048)	(.575)	(.410)	(1.512)	(−1.041)	(1.503)	(1.587)	(.311)	(1.326)	(−1.609)		
3420	149	.0632	.1452	.6026	.2452	.2193	.0794	−.0173	−.1518	−.0570	.0546	.9091	23.040
		(1.057)	(1.738)	(8.825)	(4.411)	(1.594)	(6.449)	(−.385)	(−2.014)	(−.868)	(2.884)		
3511	32	.1717	.5276	.7685	−.4997	1.2334	−.2198	−.6203	−.5226	.1866	.2736	.7520	10.512
		(.522)	(1.417)	(1.834)	(−1.732)	(1.462)	(−.554)	(−2.758)	(−1.238)	(.651)	(1.046)		

Table 5.1 (continued)

ISIC Code	Number of Observations	α_0	α_1	α_2	α_3	γ_{11}	γ_{22}	γ_{33}	γ_{12}	γ_{13}	γ_{23}	R^2	SSR
3521	25	−.1717	.6832	−.0326	.5779	1.9223	.2698	.6510	−.7128	−.0654	−.5540	.9259	2.362
		(−.870)	(1.527)	(−.075)	(2.471)	(1.153)	(.603)	(.690)	(−1.001)	(−.063)	(−1.417)		
3522	45	.1518	.3642	.2531	.2847	−.0685	−.4998	−.3249	.1172	−.1271	.3850	.9267	5.148
		(1.753)	(1.668)	(1.330)	(2.065)	(−.081)	(−2.123)	(−1.776)	(.359)	(−.357)	(1.295)		
3523	52	.0928	.6236	.3625	.2749	−.4711	.3221	.1360	−.0827	.1991	−.2571	.9054	11.740
		(.620)	(1.503)	(1.251)	(1.581)	(−.422)	(1.164)	(.939)	(−.174)	(.644)	(−1.687)		
3529	37	.0857	.0978	.4629	.3359	.0322	−.0171	−.3226	−.2956	.1499	.2963	.8459	8.774
		(.425)	(.464)	(1.254)	(1.058)	(.076)	(−.074)	(−1.614)	(−1.020)	(.653)	(1.151)		
3559	24	.4050	.2203	.5989	.2153	−.1486	−.1439	−.1302	−.1194	−.0417	.2631	.9441	2.296
		(1.832)	(.393)	(1.646)	(.839)	(−.278)	(−.494)	(−.3021)	(−.383)	(−.109)	(.935)		
3560	77	−.0313	.2301	.5860	.2402	−.0234	.0910	−.2111	−.2297	.1478	.1633	.8565	16.666
		(−.315)	(1.816)	(5.642)	(2.751)	(−.073)	(2.414)	(−2.008)	(−1.606)	(.994)	(1.512)		
3620	32	−.0412	.0190	.6888	.1808	−.0205	−.3357	−.0137	.2631	−.3814	.3024	.9480	3.830
		(−.316)	(.095)	(2.923)	(1.175)	(−.055)	(−.711)	(−.101)	(.730)	(−2.183)	(1.488)		
3693	39	.0102	.3179	.4565	.1966	.5817	.0551	.0497	.0421	−.4759	.1008	.9178	3.818
		(.090)	(1.685)	(4.293)	(2.544)	(1.950)	(2.683)	(.529)	(.864)	(−3.270)	(1.473)		
3710	42	.0324	.1465	.5536	.1791	.2204	.1878	−.0360	−.1708	−.0265	−.0274	.8996	9.126
		(.208)	(.731)	(2.749)	(1.365)	(.651)	(.523)	(−.278)	(−.625)	(−.136)	(−.150)		
3811	26	−.0991	.4356	.5703	.0732	.6465	.1235	−.1083	−.3929	−.0828	.1734	.8977	4.266
		(−.473)	(1.105)	(1.550)	(.264)	(.592)	(.237)	(−.313)	(−.667)	(−.278)	(.394)		

3812	47	−.0973	.3576	.5318	.2389	1.1467	.1032	.0701	−.5705	−.1552	.1122	.9161	6.134
		(−.821)	(1.625)	(3.260)	(2.023)	(1.555)	(.882)	(.686)	(−3.262)	(−.627)	(1.127)		
3813	76	.0350	.5016	.3285	.3630	−.1609	.0513	.1348	−.0454	−.0547	−.0362	.8736	15.811
		(.292)	(3.659)	(2.870)	(4.166)	(−.615)	(2.264)	(1.764)	(−.419)	(−.586)	(−.538)		
3814	56	.0826	.1063	.4646	.3759	.1110	.0682	.0627	−.0075	0.0833	−.0203	.9193	8.170
		(.837)	(.708)	(3.380)	(3.852)	(.425)	(1.958)	(.682)	(−.061)	(−.939)	(−.274)		
3815	31	−.0128	.3888	.5902	.2002	−.3193	.3796	−.0794	−.2783	.1244	.0341	.8803	5.349
		(−.077)	(1.514)	(2.120)	(1.087)	(−.534)	(1.267)	(−.250)	(−.607)	(.386)	(.101)		
3819	86	−.0438	.7057	.2339	.2117	−.1524	.0303	.0260	.0070	.0058	−.0089	.8588	13.567
		(−.496)	(4.656)	(2.833)	(2.761)	(−.383)	(1.895)	(.376)	(.094)	(.039)	(−.216)		
3822	30	.0197	.3572	.5764	.1800	−.0211	.0782	.0307	.0193	.0204	−.0202	.8929	3.138
		(.153)	(2.215)	(4.798)	(2.002)	(−.038)	(2.467)	(.327)	(.072)	(.166)	(−.215)		
3824	19	−.1429	.0569	1.1619	−.0668	.1693	.2367	−.1289	−.1927	−.3874	.3237	.8677	1.495
		(−.782)	(.235)	(2.894)	(−.256)	(.252)	(2.981)	(−.405)	(−.418)	(−.873)	(.949)		
3829	89	−.1209	.2540	.5760	.1858	−.0485	.0668	−.0329	.0132	−.0121	.0059	.9006	18.840
		(−1.374)	(1.777)	(5.256)	(2.178)	(−.282)	(2.999)	(−.407)	(.235)	(−.132)	(.259)		
3839	19	.0799	−.1985	.7805	.2709	.6094	.6439	−.0230	−.8114	−.1075	.1080	.0950	2.049
		(.349)	(−.544)	(1.612)	(1.198)	(.746)	(1.008)	(−.144)	(−1.056)	(−.524)	(.463)		
3841	19	.2533	.5058	.4955	.0232	.3142	.7743	.6745	−.4132	.2226	−.6364	.9920	.310
		(−1.334)	(1.324)	(1.279)	(.191)	(.433)	(2.340)	(5.962)	(−.935)	(1.319)	(−3.752)		
3843	73	−.3994	.4041	.4784	.3894	−.8777	−.1405	.1105	.4210	.0411	−.0061	.8536	20.364
		(−3.514)	(2.069)	(2.704)	(2.735)	(−1.928)	(−.897)	(.660)	(1.491)	(.273)	(−.069)		

Table 5.2 **Cobb-Douglas with CRTS**

$\ln y = \alpha_0 + \alpha_1 \ln LM + \alpha_2 \ln LS + \alpha_3 \ln K$: subject to $\alpha_1 + \alpha_2 + \alpha_3 = 1.0$

ISIC Code	Number of Observations	α_0	α_1	α_2	α_3	R^2	SSR	F
3111	100	−.168	.396	.357	.247	.758	42.766	1.491
		(−2.126)	(5.577)	(5.666)	(4.333)			
3112	46	−.163	.506	.118	.377	.828	21.733	2.040
		(−1.347)	(4.865)	(2.000)	(3.307)			
3113	32	.072	.429	.237	.334	.820	8.886	.295
		(.507)	(3.516)	(4.740)	(3.408)			
3114	37	.335	.648	.094	.258	.808	8.550	2.598
		(2.681)	(8.307)	(2.350)	(3.440)			
3115	34	.033	.556	.316	.128	.670	13.624	4.111
		(.251)	(4.672)	(1.745)	(.969)			
3119	26	.015	.213	.372	.416	.958	3.082	1.490
		(.151)	(2.505)	(4.428)	(6.933)			
3121	39	−.912	.389	.261	.351	.817	15.490	2.178
		(−6.561)	(3.087)	(3.222)	(3.375)			
3131	25	.003	.263	.463	.274	.705	11.496	4.740
		(.018)	(1.574)	(2.967)	(1.764)			
3132	70	−.111	.692	.018	.289	.591	31.249	.307
		(−1.219)	(6.989)	(.666)	(3.010)			
3211	232	.096	.584	.208	.207	.874	53.764	8.102*
		(2.181)	(16.680)	(8.320)	(6.088)			
3212	22	.045	.438	.163	.399	.847	2.384	2.583
		(.542)	(4.132)	(1.273)	(3.764)			

3213	145	−.177 (−3.933)	.578 (11.115)	.172 (5.058)	.250 (5.681)	.890	25.509	.503
3231	57	−.127 (−1.628)	.527 (5.377)	.365 (3.842)	.109 (1.379)	.835	13.799	.716
3233	30	.076 (.783)	.329 (2.350)	.450 (4.639)	.221 (2.511)	.797	4.976	1.240
3240	138	−.122 (−2.541)	.397 (8.446)	.338 (8.243)	.264 (6.285)	.908	24.680	3.646
3311	252	.116 (2.829)	.646 (18.450)	.088 (5.866)	.266 (7.600)	.751	80.192	15.267*
3312	27	.172 (1.653)	.710 (8.160)	.083 (3.458)	.208 (2.337)	.638	4.922	3.855
3320	132	−.111 (−2.055)	.672 (14.933)	.073 (3.041)	.255 (5.666)	.800	29.685	3.640
3411	19	.105 (1.019)	.406 (3.123)	.333 (1.947)	.262 (4.158)	.979	1.629	.712
3420	149	.073 (1.520)	.411 (10.024)	.233 (9.708)	.357 (9.394)	.870	32.850	19.710*
3511	32	.083 (.439)	.352 (2.378)	.547 (3.022)	.101 (.782)	.574	18.059	3.131
3521	25	−.148 (−1.510)	.221 (.884)	.291 (1.841)	.487 (2.459)	.851	4.757	1.268
3522	45	.044 (.666)	.210 (2.121)	.369 (3.690)	.421 (5.134)	.905	6.645	2.841
3523	52	.011 (.098)	.146 (1.315)	.562 (4.973)	.292 (3.792)	.883	14.498	.407

Table 5.2 (continued)

ISIC Code	Number of Observations	α_0	α_1	α_2	α_3	R^2	SSR	F
3529	37	.123 (1.230)	.386 (3.446)	.322 (2.576)	.292 (2.862)	.815	10,538	.875
3559	24	.022 (.266)	.554 (3.668)	.481 (4.219)	−.035 (−.284)	.919	3.322	.572
3560	77	−.083 (−1.238)	.417 (5.712)	.289 (5.160)	.295 (4.538)	.827	20.101	3.905
3620	32	.048 (.475)	.506 (4.147)	.231 (1.560)	.262 (2.977)	.914	6.355	2.311
3710	42	.062 (.738)	.219 (2.281)	.464 (4.000)	.317 (4.594)	.892	9.787	.174
3811	26	−.123 (−1.149)	.608 (5.477)	.264 (1.639)	.128 (1.040)	.873	5.064	.966
3812	47	−.190 (−2.043)	.498 (6.225)	.390 (5.416)	.112 (1.349)	.849	11.050	6.851*
3813	76	−.137 (−1.851)	.489 (8.890)	.200 (4.444)	.311 (5.759)	.833	20.837	2.790

3814	56	.086 (1.303)	.418 (8.360)	.140 (3.888)	.441 (8.480)	.898	10.292	3.563
3815	31	−.063 (−.583)	.434 (3.312)	.194 (1.437)	.372 (2.676)	.843	7.016	.825
3819	86	−.098 (−1.606)	.657 (14.600)	.109 (4.360)	.235 (5.875)	.842	15.140	1.689
3822	30	.023 (.244)	.561 (7.480)	.230 (5.111)	.209 (3.370)	.821	5.235	4.842
3824	19	.011 (.082)	.544 (4.000)	.036 (.642)	.419 (3.103)	.560	4.972	8.027*
3829	89	−.139 (−2.074)	.574 (10.830)	.131 (4.517)	.296 (5.285)	.874	23.965	5.909*
3839	19	.102 (.980)	.072 (.452)	.612 (3.517)	.316 (4.051)	.856	2.803	.820
3841	19	.007 (.058)	.446 (3.185)	.375 (2.884)	.179 (2.486)	.956	1.707	4.493
3843	73	−.455 (−5.617)	.292 (2.891)	.507 (5.761)	.202 (2.589)	.819	25.237	.775

NOTE: An asterisk denotes that the hypothesis that the Cobb-Douglas specification is correct can be rejected (see text).

For linear restrictions, the existence of a linear logarithmic index for L and K was rejected in all six cases. We cannot reject the existence of a linear logarithmic aggregator for L and S in industries 3311, 3812, 3824, and 3829. For S and K, the existence of a linear logarithmic aggregator is rejected for all sectors except 3824.[12]

Finally, for the three sectors for which the CRTS hypothesis was rejected, we tested for complete global separability. In all three cases we found that a linear logarithmic aggregator can be built for labor (L) and skill (S), but for only one out of these three sectors is a linear aggregator of S and K possible.

It thus appears that, for most cases, there is some slight evidence in support of building an aggregator of labor and skill rather than of skill and capital. Furthermore, in most cases the proper aggregator is a geometric one (linear in the logs) rather than an arithmetic one with equal weights as used in most of the testing of trade theories. If these results can be extended to other countries, we might find that, with a proper aggregation of L and S, a two-factor model with labor (in efficiency units) and capital can be used to study the pattern of trade.

The next task is to evaluate technological differences across tradable sectors. To do this we estimate the elasticities of output with respect to each factor. Table 5.3 provides three rankings of the factor elasticities (labor, skill, and capital) ordered from higher to lower values for the forty-four manufacturing sectors. Of these forty-four sectors, five are manufacturing industries producing exportable goods: canning and preserving of fruits and vegetables (3113);[13] canning, preserving, and processing of fish, crustaceans, and similar foods (3114); wine industries (3132); sawmills, planing, and other wood mills (3311); and manufacture of pulp, paper, and paperboard (3411). Two of the forty-four sectors are industries classified as noncompeting import industries; these are cutlery, hand tools, and general hardware (3811) and special industrial machinery and equipment except metal and woodworking machinery (3824). The remaining thirty-seven manufacturing sectors are classified as import-competing industries.[14]

As we have stated above, it is not possible to reject a CRTS Cobb-Douglas production function as a representation of the technology for most of the industries used in this study; as a consequence, no significant difference has been found between export and import-competing manufacturing in relation to the degree of complementarity or substitution between their productive factors (labor, skill, and physical capital). In fact, in only one case out of five export industries, and in seven cases out of thirty-seven import-competing industries, a CRTS Cobb-Douglas production function was rejected.

To observe the existence of some other technological differences between export and import-competing industries, we have computed the value-added productive factor elasticities. These factor elasticities could be used, specially in the case of a three-input production function, as a sort of measurement of the relative factor intensity of an industry; this is what is done below.

Looking at factor elasticity rankings, we have found the following (see table 5.3): (1) Export-producing sectors are generally clustered above the median value of the labor elasticity. (2) Export-producing sectors are clustered, in general, below the median value of the skill elasticity. (3) Export-producing sectors are clustered around the median value of the capital elasticity. (4) No clear pattern arises for the two sectors classified as noncompeting import industries.

An important dynamic implication of these findings should be stressed. An equal output expansion of tradables will have, in general, a higher employment creation for exportables than for importables; for skill, requirements will be exactly the opposite. For capital, the results are unclear and require the consideration of the specified output mix.

5.4 Conclusions

Perhaps the most striking feature of our findings is the high proportion of cases where estimation of a translog production function indicated that the Cobb-Douglas production form was a satisfactory representation of the technology; if this is valid for most situations, then, it would not be worthwhile the effort to estimate translog production functions (however, this is only known expost). Even more striking, perhaps, is that, in all but three of the forty-four industries for which estimates could be made, the constant returns to scale hypothesis could not be rejected. The remaining three sectors, all import-competing, provided evidence of increasing returns to scale. As a consequence of this type of results, no significant difference has been found between export and import-competing manufacturing industries with respect to the degree of complementarity or substitution between factors of production.

Using the results to investigate some other differences between exportable and import-competing manufacturing industries, the most striking finding is that the output elasticities of exportable industries with respect to labor were generally higher than the median, while those with respect to skills were generally below the median. For capital, no such pattern emerged. It may thus be that differences in the skill composition of the labor force are more important in affecting comparative advantage than are differences in capital/labor endowments.

Finally, for those industries for which the Cobb-Douglas specification could not be rejected, it obviously makes no difference whether skills and unskilled labor are aggregated or whether skills and capital are aggregated. For the industries that were not Cobb-Douglas but had constant

Table 5.3 Ranking of Manufacturing Sectors by Value-Added Elasticities

Numerical Ranking	Labor	Skill	Capital
1	.851 (3117)[a]	.612 (3839)	.487 (3521)
2	.850 (3220)	.562 (3523)	.441 (3814)
3	.846 (3693)	.547 (3511)	.421 (3522)
4	.710 (3312)	.507 (3843)	.419 (3824)
5	.692 (3132)	.464 (3710)	.416 (3119)
6	.672 (3320)	.463 (3131)	.399 (3212)
7	.657 (3819)	.450 (3233)	.377 (3112)
8	.648 (3114)	.390 (3812)	.372 (3815)
9	.646 (3311)	.375 (3941)	.357 (3420)
10	.608 (3811)	.372 (3119)	.351 (3121)
11	.584 (3211)	.369 (3522)	.334 (3113)
12	.578 (3213)	.365 (3231)	.317 (3710)
13	.574 (3829)	.357 (3111)	.316 (3839)
14	.561 (3822)	.338 (3240)	.311 (3813)
15	.556 (3115)	.333 (3411)	.296 (3829)
16	.544 (3824)	.322 (3529)	.295 (3560)
17	.527 (3231)	.316 (3115)	.292 (3529)
18	.506 (3112)	.302 (3559)	.292 (3523)
19	.506 (3620)	.291 (3521)	.289 (3132)
20	.498 (3812)	.289 (3560)	.274 (3131)
21	.489 (3813)	.264 (3811)	.268 (3559)
22	.446 (3941)	.261 (3121)	.266 (3311)
23	.438 (3212)	.237 (3113)	.264 (3240)
24	.430 (3559)	.233 (3420)	.262 (3411)
25	.430 (3815)	.231 (3620)	.262 (3620)
26	.429 (3113)	.230 (3822)	.258 (3114)
27	.418 (3814)	.208 (3211)	.255 (3320)
28	.417 (3560)	.200 (3813)	.250 (3213)
29	.411 (3420)	.194 (3815)	.247 (3111)
30	.406 (3411)	.172 (3213)	.235 (3819)
31	.397 (3240)	.163 (3212)	.232 (3693)
32	.396 (3111)	.140 (3814)	.229 (3117)
33	.389 (3121)	.140 (3220)	.221 (3233)
34	.386 (3529)	.131 (3829)	.209 (3822)
35	.352 (3511)	.124 (3693)	.208 (3312)
36	.329 (3233)	.118 (3112)	.207 (3211)
37	.292 (3843)	.109 (3819)	.202 (3843)
38	.263 (3131)	.094 (3114)	.194 (3220)
39	.221 (3521)	.088 (3311)	.179 (3941)
40	.219 (3710)	.083 (3312)	.128 (3115)
41	.213 (3119)	.073 (3320)	.128 (3811)
42	.210 (3522)	.055 (3117)	.112 (3812)
43	.146 (3523)	.036 (3824)	.109 (3231)
44	.072 (3839)	.018 (3132)	.101 (3511)

NOTE: For sectors 3211, 3311, 3420, 3812, 3824, and 3829, values obtained in table 5.2 have been used as a local approximation. For sectors 3117, 3220, and 3693, values used correspond to a nonconstant returns to scale Cobb-Douglas function; see Corbo and Meller (1979*b*).

[a]Figures in parentheses correspond to the four-digit ISIC code.

returns to scale, a linear logarithmic aggregator was valid in all cases, but in only one case could a skilled-capital aggregator be defended. These results provide some slight evidence in support of aggregating skilled and unskilled labor into efficiency units.

Notes

1. To our knowledge, Stern (1976) is the only author in the literature who attempted this approach, but data limitations did not allow him to study this question fully.

2. The procedure by which we obtain the number of labor-efficient units to aggregate blue- and white-collar workers is an example of consistent aggregation. The index of consistent quantity Q is $Q = X_1 + (P_2/P_1) X_2$. Using $P = P_1$ as an aggregate price index, the product PQ gives the total wage bill (for blue- and white-collar workers).

3. For details see Berndt and Christensen (1973*a*, p. 102).

4. There is a link between pairwise and global separability; if two sets of weak separability conditions are satisfied, then global separability conditions are automatically satisfied. The hypothesis of constant returns to scale (CRTS) can be tested directly from (1). Constant returns to scale also implies a set of restrictions on the parameters of the function. In the special case of CRTS, the fulfillment of the conditions for global separability implies that the translog function becomes a Cobb-Douglas function. See Berndt and Christensen (1973*a*, p. 84).

5. Preliminary statistical tests and regressions were performed using the number of annual man-hours worked by production workers; however, this variable turned out to be highly unreliable. Therefore the only available variable measurement of a flow was the number of days worked by an establishment during the year of the census of manufactures. The use of this variable implies that in all establishments of the same industry: workers work the same number of hours; absenteeism and part-time workers are equally distributed (part-time workers are negligible in Chilean manufacturing); and the number of shifts worked is the same (most Chilean manufacturing establishments work only one shift).

6. The implicit assumption here is that each worker is composed of two parts: body and skills; see Griliches (1967).

7. The wage rate of entrepreneurs is assumed to be twice the average wage rate of white-collar workers within a given firm. The minimum wage rate of the whole industrial sector is computed as the simple average of the ten lowest wage rates of blue-collar workers observed in the census.

8. The use of book values to measure the capital services factor (besides the traditional limitations of ignoring differences in capacity utilization, accounting procedures, and depreciation rates) in a persistently inflationary economy like Chile's leads to an underestimation of the capital factor of the older establishments, exaggerating their technical efficiency. One of the authors (Meller 1975) earlier used a measure of capital services instead of the value of the stock. The capital service variable was defined as $K = .10K_M + .03\ K_B + .20\ K_V + .10\ (K_M + K_B + K_V + K_I)$, where K_M, K_B, K_V, and K_I are the book values of machinery, buildings, vehicles, and inventory goods. Geometric depreciation rates of .10, .03, and .20 were used for machinery, buildings, and vehicles, and a 10 percent real interest rate was used as the cost of capital. The simple correlation between the capital service measure and the book value of machinery measure was above .95 in sixteen out of the twenty-one industrial sectors considered in that study, with the smallest correlation coefficient being .823. Similar high correlation coefficients were obtained with standard alternative capital measures like electricity consumed by the establishment measured in kilowatt hours and installed capacity of the production machinery measured in horsepower.

9. Even at the four-digit industry level the product homogeneity objection is valid; establishments could be producing goods that are far from being substitutes for each other. Moreover, they produce a great variety of goods and very different proportions of each type, and they also differ considerably in the proportion of value added to the final product. Dividing the four-digit industries according to establishment size should increase the product homogeneity within each industrial group; see Meller (1975). Therefore, at the four-digit ISIC level, the resulting elasticity of substitution would be a sort of measure of the substitution possibilities between productive techniques and the substitution possibilities between different commodities within the same four-digit ISIC industry.

10. For example, we find in the literature statements like: "Industry in Chile is typically monopolistic or oligopolistic" (Harberger 1963, p. 245); "about 17% of all enterprises control 78.2% of total assets in the corporate sector" (Garretón and Cisternas 1970, p. 8); "The level of industrial concentration is rather high—the 52 largest firms of the country (they represent less than 1% of all firms) generate 38% of the value added in the industrial sector" (Lagos 1966, p. 104).

11. This was done by performing a Chow test; for details of the econometric results see Corbo and Meller (1979*b*). Using the CRTS translog for all industries for which the null hypothesis of CRTS was not rejected and a non-CRTS for the other three sectors, we verify whether the estimated functions are well behaved. A table showing the percentage of observations satisfying the monotonicity and quasi-concavity conditions for each one of the forty-four four-digit ISIC industries is available from the authors on request.

12. For details of the test using nonlinear pairwise separability restrictions, see Corbo and Meller (1979*b*).

13. Figures in parentheses correspond to the four-digit ISIC (International Standard Industrial Classification) code.

14. For the trade classification criteria see Corbo and Meller (1981).

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