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4 Country and Sectoral Variations in Manufacturing Elasticities of Substitution between Capital and Labor

Jere R. Behrman

4.1 Introduction

Foreign trade and domestic policy regimes often alter relative primary factor prices. Subsidized credit, differential import taxes that favor capital goods imports, and minimum wages are a few examples. The effect of these policies on the demand for labor and for other primary factors depends critically on the degree of technical substitution among production inputs. A hypothesis frequently maintained (though not always explicitly stated) is that elasticities of substitution between capital and labor are zero. The purpose of this chapter is to test to what extent this and some related hypotheses about the underlying production relations are consistent with empirical realities.

I focus upon estimates of elasticities of substitution between capital and labor for a 1967–73 cross section of seventy countries with up to twenty-seven two-digit manufacturing sectors for each country. The reasons the elasticities of substitution are of interest are well known. (1) As is mentioned above, these elasticities relate to the degree of flexibility in responding to changing domestic and international contexts, whether such changes are due to conscious policies or to other shocks to the system.[1] (2) They also relate to the distribution of income between capital and labor and to changes in this distribution over time, given labor supply and other critical developments, if there are pressures for real payments to such factors to be approximately proportional to their marginal prod-

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ucts. (3) Their relative magnitudes across sectors enter critically into the determination under neoclassical assumptions of the effects of varying primary factor endowments on the patterns of trade and of relative factor prices. (4) They affect the stability or instability of certain growth paths implied by some aggregate formal models, such as the Harrod-Domar case. (5) In market economies they play a crucial role in determining the extent to which unemployment can occur owing to inappropriate relative factor prices, with one extreme being the well-known Eckaus (1955) case of large unemployment in some developing countries owing to no such substitution possibilities and an incompatible factor mix for given technologies. (6) The appropriateness of many linear planning models, finally, depends on the accuracy of the assumption that such elasticities are close to zero, though this is in part a question of aggregation, since most such models allow substitution among activities, though not within them (see Blitzer, Clark, and Taylor 1975 for a recent review of these models).

Of course there are previous cross-country estimates of these elasticities of substitution that relate to developing countries, as well as a growing number of cross-sectoral and time-series estimates for individual developing countries. Among the former the best known is the study by Arrow, Chenery, Minhas, and Solow (1961), cited hereafter as ACMS. White (1978) reviews many of the latter. He notes that the estimates tend to be concentrated between 0.5 and 1.2, but that they are not as robust as might be desirable to changes in data sets and that a number of them are outside the range indicated above.

As is discussed below, the estimates presented in this paper are subject to many of the same limitations as are previous estimates. Nevertheless, I judge that they make a contribution to our understanding of the underlying substitution possibilities for a number of reasons. (1) The data used pertain to roughly the same period as do the data for most of the other studies in the alternative trade strategies and employment project. Thus they provide a better base for evaluating assumptions about elasticities of substitution in the project than do estimates from much earlier time periods if, as seems plausible, the tremendous changes that have occurred in the past two decades have altered the underlying parameters of production relations. I use data from 1967 to 1973, while those used by ACMS, for example, are from 1950 to 1955. (2) The data used permit the inclusion of many more countries with a richer diversity of experience than has been possible in most, if not all, earlier studies. There are more than three times as many countries in my sample, for example, as in that of ACMS. (3) Using as one observation the average value over several years for a particular sector in a specific country may lessen possible biases due to short-run fluctuations. (4) For the same reason, the maintained hypothesis in the ACMS form (which I also use) regarding the pressures for competitive-like behavior is more palatable. (5) By combining countries and sectors I am able to explore to what extent country-specific or sector-specific characteristics account for the diversity of estimates on which White (1978) and others have commented. (6) Furthermore, I can explore interesting questions regarding the relation of the patterns across countries, either because of specification error or because of differential economic environments, to such characteristics as the level and rate of development, the quality of the labor force, the degree of openness to international trade, the extent of domestic inflation, and the degree of foreign-sector disequilibrium.

4.2 ACMS Model and Assumptions

The most widespread approach for estimating elasticities of substitution between capital and labor is that of ACMS. Because of limitations on the availability of data that are discussed in section 4.4 below, I use the ACMS approach in this paper instead of some more general formulation (e.g., translog production functions).

Assume that there is a well-defined relationship between real value added per unit time (V) and the services per unit time of homogeneous labor (L) and of homogeneous capital (K) that are combined efficiently to produce V. Assume that this relationship has a constant elasticity of substitution (CES, $\sigma = 1/(1+\rho)$) and a constant elasticity of scale (μ). Assume that production behavior approximates profit maximization (or cost minimization) under perfect competition with a given real wage (W). Then relation (1) is the CES production function and relations (2) and (3) are alternative forms of the ACMS relation as derived from the marginal productivity condition in the labor market:[2]

(1) $$V = B[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-\mu/\rho}$$

(2) $$\ln(V/L) = a + \sigma \ln W + b \ln V,$$

where $$a = -\sigma \ln(\mu(1-\delta)B^{-\rho/\mu})$$

$$b = -(1-\sigma)(1-\mu)/\mu.$$

(3) $$\ln(V/L) = c + d \ln W + g \ln L,$$

where $$c = -\mu/(\mu+\rho)\ln(\mu(1-\delta)B^{-\rho/\mu})$$

$$d = \mu/(\mu+\rho)$$

$$g = -(1-d)(1-\mu).$$

Note that relations (2) and (3) both identically collapse to relation (4) if there are constant returns to scale ($\mu = 1$):

$$(4) \qquad \ln(V/L) = a + \sigma \ln W.$$

If there is an additive, independent disturbance term with a zero mean and constant own variance, ordinary least squares (OLS) estimation procedures are appropriate for these relations.

In section 4.4 below I present estimates of a number of variants of the ACMS forms, including ones that allow the parameters to vary systematically across sectors or across countries. One rationale for such varying parameters is casual observation, supported by empirical studies, that productivities and elasticities of substitution indeed do vary at least across sectors. Another reason is possible omitted variables, a topic discussed in section 4.3.

The advantages of estimating elasticities of substitution between capital and labor from the ACMS forms are several. The relations are simple. The data requirements are limited to widely available series (V, L, W). They do not include capital services (K), or the rate of return on capital, both of which are much more rarely available. The elasticity of substitution (σ) enters as a first-order parameter rather than as a second-order parameter as in the original production function of relation (1). Therefore there is more chance of estimating it with some precision from the ACMS form. Finally, conditions often are such that simultaneous bias is not a problem, in contrast to those that are relevant in the direct estimation of the CES function in relation (1).

The disadvantage of the ACMS approach compared with direct estimation of the CES production function is the reliance on the assumption regarding approximate profit maximization under perfect competition. It also shares with the direct estimation of the CES production function a number of other possibly strong assumptions: only capital and labor services enter into the production of real value added, capital and labor are homogeneous, the elasticity of substitution between capital and labor is constant, and capital and labor services are proportional, respectively, to capital and labor stocks. The assumption above about the additive independent disturbance term in the ACMS form in order to use OLS estimates also may be strong, as is discussed in the next section.

4.3 Bias in the Estimation of the ACMS Model

The disturbance term in the ACMS relation may reflect random errors in the variables, omitted variables, and/or specification errors regarding the form of the production function or the existence of behavior approximating profit maximization under perfect competition.[3] Many plausible reasons for including the disturbance term imply that it is not distributed independently of the right-side variables in the ACMS relation. As a result, OLS estimates of the parameters of the ACMS form probably often are biased. I briefly consider three important types of bias in this section.

4.3.1 Random Errors in the Variables

Random errors in the variables may be present for such reasons as random errors in reporting or recording, random fluctuations in capacity utilization and hours of work of employees, cyclical fluctuations in the quality of labor and capital, or random fluctuations in the prices used for deflating reported value added and wage series. The last source is particularly likely for cross-country data that must be translated into a common currency using exchange rates that may fluctuate around equilibrium values.

The simple errors-in-variables model is well known. Consider the true ACMS relation (4) with all variables measured from their means so that the constant can be suppressed, with $y = \ln(V/L)$ and $x = \ln W$ being the true variables, and with an additive disturbance term (e):

$$y = \sigma x + e. \tag{5}$$

Assume, however, that instead of observing y and x, we measure $Y = y + v$ and $X = x + u$, where v and u are random measurement errors with zero means, constant own variances (var v and var u, respectively), and zero correlations with each other and with the rest of the system. Let $w = e + v - \sigma u$. Then relation (5) can be rewritten in terms of observed variables as:

$$Y = \sigma X + w. \tag{6}$$

The OLS estimate of σ from relation (6), however, is inconsistent because w and X are correlated so that σ is underestimated:

$$\text{plim } \hat{\sigma} = \frac{\sigma}{1 + \text{var } u/\text{var } x} \tag{7}$$

The extent to which the elasticity of substitution is biased toward zero clearly depends on var u/var x. If one knows this ratio a priori, one can adjust for such measurement error.

For the present study there is no a priori information about the degree of random errors in the right-side variable(s).[4] However, for the simplest ACMS form in relation (4) the extent of the measurement error can be explored by reversing the regression (i.e., letting $\ln(V/L)$ be the right-side variable). Ceteris paribus this gives an upper bound estimate for the elasticity of substitution. Thus I can see how narrow or broad a range of estimates is implied by the two OLS estimates.

More generally I attempt to lessen the impact of errors in the annual values of variables by using as much as is possible average values over several years as one observation. To the extent that the sources of such errors are additive random measurement error or random cyclical domestic or foreign-sector fluctuations, this procedure should reduce the importance of random errors in the variables.[5]

Finally, one source of possible random error is the use of different definitions across countries. For example, in the data set for this study, value added is given in factor values for twenty-nine countries, producer values for twenty-six countries, and nonspecified terms for fifteen countries. In forms in which value added is used to define the left-side variable (e.g., relation 4) this does not bias the coefficient estimates (e.g., $\hat{\sigma}$) since var y does not enter into relation (7). In forms in which value added is used as a right-side variable (e.g., the reversed form of relation 4 or relation 2), if such changes in definition are random across countries they cause an error in the variables bias in the coefficient estimate(s). To attempt to lessen such a bias, I include additive dummy variables that are nonzero, respectively, if value added is given in producer values or in nonspecified terms.

4.3.2 Omitted Variables

Probably most important among omitted variables are possible systematic variations in the quality of labor or in product prices. Consider once again the simplest form of the ACMS relation with an additive disturbance term (e) and all variables measured from their means so that the constant can be surpressed. Let P be the appropriate sectoral price deflator, P^* a common deflator that is used across sectors instead of P, and Q a measure of the quality of labor that enters in multiplicatively with the quantity of labor (L) to obtain the total effective labor force. Then the true relation is:

$$\ln(V/(LQ)) = \sigma \ln(W/Q) + e. \tag{8}$$

However, the estimated relation is:

$$\ln(VP/(LP^*)) = \sigma \ln(WP/P^*) + e'. \tag{9}$$

Therefore,

$$e' = (1-\sigma)(\ln Q + \ln(P/P^*)) + e. \tag{10}$$

OLS estimation of relation (9) without including the first right-side term in relation (10) leads to an estimate of σ that is biased toward unity if $\ln(W/P^*)$ is positively correlated with $\ln Q + \ln(P/P^*)$.

$$p\lim \hat{\sigma} = \sigma + (1-\sigma)\left[r_{\ln(W/P^*),\,\ln Q} + r_{\ln(W/P^*),\,\ln(P/P^*)}\right], \tag{11}$$

where the rs refer to the respective regression coefficients in the "auxiliary" regressions of the respective excluded variables on the included variable.

A priori it seems quite probable that in the sample used for this study both of the terms in the right-side bracket of relation (11) are positive.

Both across sectors within countries and across countries there seems to be a direct positive association between real wages and the quality of the labor force. Moreover, sectors within a country with some oligopoly power owing to international trade barriers are likely to have relatively high real wages and relatively high ratios of P/P^*.

In the estimates below I attempt to control for these factors by three means. First, additive sectoral dummy variables are included. They should have significantly nonzero coefficient estimates if there are systematic correlations of high-quality, high-wage labor in certain manufacturing sectors across countries or if there are systematic patterns in differential sectoral protection and associated high sectoral wages across countries. I also include the number of establishments in each sector/country cell as a limited proxy for the degree of domestic oligopolistic power.[6]

Second, important country characteristics are represented by including direct proxy variables that may be related to systematic patterns across countries in the quality of labor and in P/P^*. These variables are discussed in the next section.

Third, the ACMS correction factor for finding the true elasticity of substitution from the estimated value given missing quality of labor data is used. On the basis of a constant elasticity (η) relation between the overall efficiency parameter (B in relation 1) and the real wage, ACMS derive the following:

$$\sigma = \frac{\hat{\sigma} - \eta}{1 - \eta}. \tag{12}$$

If $\eta < \hat{\sigma} < 1$, relation (12) states that the estimated elasticity of substitution between capital and labor is biased toward 1 because of the association among wages, the overall efficiency parameter, and the quality of labor. ACMS very roughly estimate η to be 0.3.

Before concluding this discussion of my strategy for dealing with possible omitted variables, I note that within this framework it is not possible to distinguish between the situation in which the sectoral and country dummy variables and proxies are controlling for missing variables (such as labor quality) and the one in which they are representing the determinants of different levels of neutral technology or overall productivity (i.e., B in relation 1 that enters into the constants in the ACMS forms). Therefore the results must be interpreted with care.

4.3.3 Simultaneous-Equations Bias

If the real wage is endogenous, even the simplest ACMS form in relation (4) is subject to simultaneous-equations bias. As a result, the elasticity of substitution between capital and labor is underestimated.

If there is such a bias, to deal really adequately with it would require the estimation of a complete multiequation system with some consistent procedure. But the data base for this study is not sufficiently comprehensive for such an approach.

A second best approach that is adopted is to follow the recommendation of Maddala and Kadane (1966) to "reverse" the ACMS relation by estimating the real wage as the dependent variable and the real value added per laborer as the right-side variable. This recommendation is based on their findings in a Monte Carlo study that the estimate of the elasticity of substitution between capital and labor is much more robust under simultaneous-equations problems if estimated in this reversed form than if estimated in the original ACMS form. Note that this procedure also is discussed above in regard to errors in the variables. If the two estimates of the elasticity of substitution differ significantly between the ACMS and the reversed form, with the data set for this study I see no way of identifying the extent to which such a result reflects measurement error versus simultaneous-equations bias. However, the case for real wages being endogenous is not particularly strong. On a priori grounds treating simultaneous-equations bias as a second-order consideration seems satisfactory.

4.4 Data

The basic source for data for this study is a tape, much of which is reproduced in the United Nations (1976). It includes usable data on value added, wages and salaries, the number of employees, and the number of establishments for up to twenty-seven ISIC three-digit manufacturing sectors for seventy countries for up to seven years (1967–73). Table 4.1 indicates the included manufacturing sectors. Table 4.2 gives the countries. By the World Bank (1978) classification, these countries include twelve in the low-income group (1976 GNP per capita under U.S. $250), thirty-five in the middle-income group (developing countries with 1976 GNP per capita over U.S. $250), eighteen industrialized countries, two capital-surplus oil exporters, and three centrally planned economies.

Before these data can be used to estimate the ACMS relations, the value added and wage and salary series must be converted into common real terms. This conversion was made by using official exchange rates to convert to current United States dollars and then deflating by the United States deflator to obtain real values.

As I have mentioned several times, another preliminary step was to average the data over all available years in the period 1967–73. One reason for this averaging is that for various countries data are incomplete in some years. A more basic reason is to lessen the problems of errors in the variables that are discussed above in section 4.3 and thereby obtain better estimates of the fundamental underlying parameters. Such averaging reduces downward biases due to additive random or cyclical fluctuations in reporting and recording the data; in intensity of use and quality of capital and labor (i.e., shutting down old equipment or laying off less productive workers in periods of lessened demand); and in prices, wages, and exchange rates. A third reason for such averaging is that it allows one to work out adjustment processes of a physical sort and in regard to price expectations. A final reason is that the maintained hypothesis of approximate profit maximization under perfect competition is more palatable over longer periods because, in comparison with annual units of observation, there is more time for information to become widespread and for substitutes to develop or be imported.

In addition to the basic data, sectoral dummy variables and proxies for country characteristics are used to attempt to control for missing variables (see section 4.3) and to explore hypotheses regarding systematic variations in the parameters of the underlying production relations. The country characteristics include: real GDP per capita and life expectancy at birth to represent the level of development and the quality of labor; exports plus imports relative to GNP to represent the degree of openness to the foreign sector; the rate of inflation to represent internal price stability; the ratio of the black market to the official exchange rate to represent disequilibrium in the foreign sector;[7] wages as a proportion of national income to represent the factoral distribution of income; and the rate of growth in per capita real product to represent dynamism (see the Appendix for data sources). This set of variables includes only a limited number of imperfect measures of possible relevant country characteristics. Nevertheless, the results obtained by using them should be suggestive regarding omitted variable biases or the degree of homogeneity of parameters of the production relations.

For some of these country variables, as well as for the number of establishments in each sector, data are not available for all observations. Under the assumption that such missing values are random,[8] the Monte Carlo studies of Hester (1976) and of Behrman, Flesher, and Wolfe (1979) suggest that the Glasser (1964) method of moments is relatively robust. In this method each bivariate moment is calculated on the base of all overlapping observations on the relevant two variables. This method is used here.

Of course there are several important limitations of the data set. Most of these are shared with many data sets that are used for estimating parameters of production relations. First, the basic data are sector averages, not observations for individual plants or firms. I am assuming that the relations that are estimated on the basis of these average data also hold on a more micro level. However, they presumably incorporate not only technical substitution in the purest production function sense, but also changes in composition of production and processes within the three-digit sectors.[9] As such they probably incorporate other dimensions

Table 4.1 **ISIC Industrial Sectors Included in Study and Estimated Sectoral Effects**

ISIC Number	Industrial Sector	Number of Countries	Estimates of Coefficients of Additive Sectoral Dummy Variables from Regression: 3–4	3–6	3–7	3–14	Estimated Sectoral Increments to σ from Regression 6-1
312	Food products	68	.42[a]	−.11	.28[a]	.15	.05[a]
313	Beverages	67	.81[a]	.52[a]	.83[a]	.63[a]	.11[a]
314	Tobacco	62	1.08[a]	.96[a]	.97[a]	1.06[a]	.14[a]
321	Textiles	70	.18[b]	−.23[a]	−.04	−.01	.02[b]
322	Wearing apparel	68	.10	−.34[a]	−.21[a]	−.08	.01
323	Leather and products	64	.12	−.09[a]	−.20[a]	.09	.01
324	Footwear	61	.04	−.22[a]	−.18[b]	−.07	.00
331	Wood products	68	.17[b]	−.24[a]	−.11	.01	.02
332	Furniture and fixtures	64	.04	−.35[a]	−.10	−.16[b]	.00
341	Paper and products	66	.36[a]	.09	.22[a]	.27[a]	.05[a]
342	Printing and publishing	65	.04	−.33[a]	.11	−.18[b]	.01
351	Industrial chemicals	69	.57[a]	.33[a]	.61[a]	.42[a]	.08[a]
352	Other chemical products	57	.60[a]	.27[a]	.66[a]	.40[a]	.08[a]

353	Petroleum refineries	59	1.00[a]	1.07[a]	1.29[a]	.95[a]	.13[a]
354	Petroleum, coal products	53	.35[a]	.48[a]	.29[a]	.43[a]	.03[a]
355	Rubber products	64	.40[a]	.15[b]	.31[a]	.28[a]	.05[a]
356	Plastic products, n.e.c.	56	.33[a]	.09	.09	.28[a]	.04[a]
361	Pottery, china, etc.	66	.07	−.02	.05	.04	.01
362	Glass and products	58	.12	−.01	.06	.05	.02
369	Nonmetal products, n.e.c.	62	.35[a]	−.04	.20[a]	.18[b]	.05[a]
371	Iron and steel	68	.33[a]	.25[a]	.32[a]	.28[a]	.03[a]
372	Nonferrous metals	61	.23[a]	.29[a]	.33[a]	.24[a]	.03[a]
381	Metal products	65	.23[a]	−.19[a]	.21[a]	−.00	.03[a]
382	Machinery, n.e.c.	65	.06	−.24[a]	.06	−.11	.00
383	Electrical machinery	67	.24[a]	−.06	.24[a]	.06	.03[a]
384	Transport equipment	67	.08	−.24[a]	.06	−.11	.01
385	Professional goods	64					

NOTE: The data source is given in Section 4.4. Data are not available for all countries for all sectors because some countries report no production in some sectors. The regressions refered to in the last five column heads are given below in tables 4.3 and 4.6.

[a]Significantly nonzero at 5 percent level.

[b]Significantly nonzero at 10 percent level.

of the adjustment process that are of interest in regard to the question of the degree of macro response to trade regimes and development policies additional to pure technical substitution. Second, the diversity of included countries makes suspect the assumption that the sectors and variables are homogeneous. As I noted in the previous section, this can

Table 4.2 Countries Included in Study Classified into World Bank Categories

Low-income countries	*Middle-income countries* (cont.)
1. Ethiopia	38. Iraq
2. Bangladesh	39. Cyprus
3. Somalia	40. Barbados
4. Zaire	41. Yugoslavia
5. India	42. Portugal
6. Mozambique	43. Malta
7. Pakistan	44. Greece
8. Tanzania	45. Singapore
9. Madagascar	46. Spain
10. Indonesia	47. Israel
11. Kenya	*Industralized countries*
12. Uganda	48. South Africa
Middle-income countries	49. Ireland
13. Egypt	50. Italy
14. Mauritania	51. United Kingdom
15. Nigeria	52. New Zealand
16. Bolivia	53. Japan
17. Philippines	54. Austria
18. Zambia	55. Finland
19. Papua New Guinea	56. Australia
20. Rhodesia	57. Netherlands
21. Ghana	58. Luxembourg
22. Jordan	59. Belgium
23. Colombia	60. Federal Republic of Germany
24. Guatemala	61. Norway
25. Ecuador	62. Denmark
26. Republic of Korea	63. Canada
27. Dominican Republic	64. United States
28. Peru	65. Sweden
29. Tunisia	*Capital surplus oil exporters*
30. Malaysia	66. Libya
31. Turkey	67. Kuwait
32. Chile	*Centrally planned economies*
33. Jamaica	68. Hungary
34. Mexico	69. Poland
35. Brazil	70. Czechoslovakia
36. Fiji	
37. Panama	

Note: Based on World Bank (1978). Within categories countries are ranked in ascending order of 1976 GNP per capita.

lead to errors in the variables and to omitted-variable biases. I attempt to control for heterogeneity by using the sectoral and country dummy variables and characteristics discussed above, but undoubtedly such controls are imperfect. Third, the basic data set does not include some variables that would be useful. Examples include capital stocks, rates of return on capital, measures of the quality of labor, and better concentration indexes. Therefore I am limited in the range of hypotheses that can be explored in regard to functional forms, market behavior, and missing variables. Fourth, the data are cross sectional, but for many purposes elasticities of substitution between capital and labor are of interest for questions regarding what happens with changes over time. For my results to have relevance for such issues, I must assume that differences across countries are related to dynamic changes over time in one country.

These disadvantages are significant. But the advantages are also substantial, and in my judgment they are more than sufficient to warrant the empirical explorations of this study. By combining across sectors and across countries it is possible to have a large number of observations (1,723) to estimate the parameters of interest, as well as sectoral or country-specific deviations from them.[10] The range of country experiences includes a number of developing countries for which the results are of particular interest for the project on alternative trade strategies and employment. The range of countries also makes more probable the identification of parameters in the underlying production relations because of great variations in fixed capital stocks and in relative prices. The sector and country dummy variables and characteristics permit some, albeit imperfect, control for missing variables. Finally, the possibility of using average data over several years may lessen considerably the errors-in-variables problems discussed above, it allows the estimation of longer-run, more fundamental underlying parameters, and it makes the maintained hypothesis of approximate profit maximization under perfect competition more palatable.

4.5 Estimates of the Variants of the ACMS Relation from a Cross-Sector, Cross-Country Sample

Based on the considerations discussed in sections 4.2 and 4.3 and the data described in section 4.4, I have estimated a number of variants of the ACMS relation. Table 4.3 summarizes some of the more interesting estimates of the basic model and extensions thereof that involve additive terms. Table 4.4 gives some of the more interesting estimates of the "reversed" model with $\ln W$ instead of $\ln(V/L)$ as the dependent variable. Table 4.5 gives a grouping of the industrial sectors on the basis of the estimates. Table 4.6 includes some estimates of the basic model with multiplicative terms. The convention is adopted of referring to the var-

Table 4.3 Estimates of ACMS Relation with ln (*V*/*L*) as Dependent Variable and with Additive Sectoral and Country Variables

							ln of Country Characteristics							
Regression Number	Constant	ln *W*	ln *V*	ln *L*	Sector Dummies[a]	ln Number of Establishments	GDP per Capita	Life Expectancy	Trade/GNP	Inflation[b]	Black Market/Official Exchange Rate	Wages/National Income	Growth in Product per Capita[b]	$\bar{R}^2$/SE
3-1	1.22	.94												.66
	(9.9)	(57.7)												.65
3-2	2.09	.79	.092											.73
	(17.5)	(48.0)	(20.0)											.59
3-3	1.43	.91		.056										.68
	(11.8)	(55.6)		(10.3)										.63
3-4	1.20	.91			Yes									.72
	(8.8)	(59.4)			Table 4.1									.59
3-5	1.23	.91				.055								.69
	(10.3)	(57.1)				(12.1)								.63
3-6	1.59	.83			Yes	.092								.78
	(12.8)	(58.4)			Table 4.1	(19.8)								.54
3-7	1.10	.35			Yes		.63							.78
	(9.2)	(12.0)			Table 4.1		(21.9)							.53
3-8	−.030	.87			Yes			.36						.72
	(0.1)	(51.1)						(4.2)						.59

3-9	1.05	.91	Yes				−.18					.73
	(7.7)	(60.4)					(7.1)					.59
3-10	1.22	.90	Yes					.16[c]				.72
	(9.0)	(59.4)						(4.7)				.59
3-11	1.14	.91	Yes						.12			.72
	(8.2)	(59.4)							(3.0)			.59
3-12	1.23	.87	Yes							.041		.72
	(9.0)	(67.4)								(3.8)		.60
3-13	1.14	.89	Yes								.045	.73
	(8.5)	(58.7)									(6.8)	.59
3-14	−2.56	1.00	Yes	.044	−.24	1.18	−.10	.00[c]			−.081	.73
	(9.8)	(68.7)	Table 4.1	(9.9)	(17.8)	(20.0)	(3.6)	(0.2)			(25.6)	.58
3-15	1.78	.84	Yes	.089		−.10	−.51[c]	.10[c]	.18		.040	.78
	(5.2)	(54.6)		(16.9)		(1.2)	(0.2)	(2.8)	(4.3)		(6.0)	.53
3-16	2.04	.84	Yes	.089		−.14	.87[c]	.18[c]		−.68[c]	.032	.78
	(6.4)	(57.0)		(16.8)		(1.7)	(0.3)	(5.9)		(0.9)	(5.3)	.53

Note: All regressions are ordinary least squares using Glasser's (1964) method of moments for any missing observations. The data are described in section 4.4 and the Appendix. $\bar{R}^2$ is the coefficient of determination corrected for degrees of freedom. SE is the standard error of the estimate. Absolute values of t statistics are given beneath point estimates. The sample includes 1,723 observations from the twenty-seven industrial sectors in Table 4.1 and the seventy countries in table 4.2. Dummy variables for definitional changes for value added were included in all estimates and have significantly nonnegative coefficient estimates that are not reported in this table.

[a]"Yes" implies that twenty-six sectoral dummy variables were included. "Table 4.1" implies that the coefficient estimates are given in table 4.1.

[b]Not in ln form.

[c]Multiplied by 10^{-2}.

Table 4.4 Estimates of "Reversed" ACMS Relation with ln$W$ as Dependent Variable

					ln of Country Characteristics							
Regression Number	Constant	ln (V/L)	Sector Dummies[a]	ln Number of Establishments	GDP per Capita	Life Expectancy	Trade/GDP	Inflation[b]	Black Market/Official Exchange Rate	Wages/National Income	Growth in Product per Capita	$\bar{R}^2$/SE
4-1	1.69	.70										.67
	(16.7)	(57.7)										.56
4-2	−1.61	.74	Yes	−.048	.024	.78	.28[c]	−.087[c]			−.020	.73
	(7.1)	(68.7)		(10.1)	(2.3)	(14.5)	(0.1)	(3.0)			(6.2)	.50
4-3	−1.74	.76	Yes	−.054		.83	.34[c]	−.021[c]	−.20		−.038	.73
	(5.4)	(5.46)		(10.2)		(10.3)	(0.1)	(0.6)	(4.9)		(6.0)	.51
4-4	−2.81	.79	Yes	−.059		1.12	.020	−.10[c]		−.053	−.048	.73
	(9.2)	(57.0)		(11.0)		(14.9)	(0.8)	(3.1)		(6.8)	(8.2)	.51

NOTE: See note to table 4.3.

[a]"Yes" means that twenty-six sectoral dummy variables were included, but their coefficient estimates are not reported here.

[b]Not in ln form.

[c]Multiplied by 10^{-2}.

ious estimates by the table number and the row number (i.e., regression 3-1 refers to the first regression in table 4.3).

4.5.1 Basic ACMS Model

Regressions 3-1 and 4-1 are estimates of the basic ACMS model and its reversed form under the maintained hypothesis of constant returns to scale in relation (4). Both are consistent with about two-thirds of the variance in the respective dependent variables. The former gives an estimated elasticity of substitution of 0.94, the latter implies 1.43. Under the assumption of random error in the variables, the former is biased downward and the latter is biased upward. If the wage rate is simultaneously determined, the Maddala and Kadane (1966) Monte Carlo experiments imply that the latter is less likely to be contaminated by simultaneous-equations bias. Thus these estimates suggest an elasticity of substitution between capital and labor of about the Cobb-Douglas value of 1 or perhaps somewhat higher.

Because I do not think there is a simultaneous-equations problem, I do not focus below on the reversed estimates. To keep the presentation manageable, in fact, I emphasize the estimates from the direct ACMS form with only occasional reference to the reversed form. The reader should keep in mind, however, that if there is random measurement error in the real wage series (the effect of which is not offset by any other measurement error in right-side variables), then the estimate of the elasticity of substitution from the direct ACMS form is biased downward.

If there is random measurement error in the $\ln(V/L)$ series, it does not bias the estimate of the elasticity of substitution from the direct ACMS form (see relation 7 above). However, it biases downward the estimate of the inverse of this elasticity in the reversed form. As is discussed in section 4.3 above, one possible source of such random error is the alternative definitions that are used across countries for value added. The dummy variables that are mentioned in section 4.3 to represent these changes indeed do have significantly nonzero coefficients when they are included in the regressions. However, whether they are included or not does not alter the estimate of the elasticity of substitution from the reversed ACMS form by as much as 1 percent. Therefore these estimates do not indicate that this source of random measurement error is very important.

4.5.2 Returns to Scale

If the returns to scale are not constant (i.e., if $\mu \neq 1$), the basic direct ACMS form can be written as in relations (2) and (3). Regressions 3-2 and 3-3 are estimates of these relations. In both cases the additional variables have coefficient estimates that are significantly nonzero at standard significance levels, and the extent of overall consistency with the variation in the dependent variable increases slightly. In both cases the estimate of the elasticity of substitution drops somewhat—to 0.79 and 0.86, respectively. Thus the additional variables ($\ln V$ and $\ln L$, respectively) seem to be representing some systematic variable(s) whose exclusion leads to a small upward bias ceteris paribus in the estimated elasticity of substitution from the simplest ACMS form.

However, the magnitude of the estimates suggests that the additional variables are not representing returns to scale alone. They imply values of μ of 1.80 and 1.58, respectively! Such high returns to scale are not credible.

Although I am comfortable with the assumption that there is not a significant simultaneity problem in estimating the ACMS relation with $\mu = 1$ as a maintained hypothesis, if $\mu \neq 1$ so that $\ln V$ or $\ln L$ enter in as right-side variables, simultaneity may be a problem. In addition to the ACMS relation, there is the production function in relation (1) that determines simultaneously $\ln V$ and $\ln L$. Could such simultaneity bias be the explanation for the very high estimates of μ? No. Griliches and Ringstad (1971) demonstrate that the simultaneity bias in this system leads to a downward bias in the estimate of μ, not an upward one.[11]

Another possibility is that the $\ln V$ and $\ln L$ are representing sectoral or country characteristics that have a significant role in an extended ACMS model because of omitted variables or because the coefficients vary systematically across countries or sectors or both. The estimates are consistent with such a hypothesis in that the implied values of μ change dramatically depending on what sector and country variables are included. Apparently there is considerable multicollinearity between $\ln L$ and $\ln V$ and various linear combinations of the sector and country variables. The implied μs range from -2.38 to 1.80, with almost no a priori plausible values.[12]

Therefore I have adopted the maintained hypothesis that the returns to scale are constant for the remaining estimates. To the extent that there really are returns to scale, the maintained hypothesis of constant returns to scale may bias somewhat the coefficient estimates for correlated sector and country variables. The impact of including or not including $\ln V$ and $\ln L$ on the estimates of the elasticity of substitution, however, is never larger than 0.05 once sectoral dummy variables and some country characteristics are included. Thus maintaining the hypothesis of constant returns to scale apparently does not substantially alter any conclusions about the magnitude of the elasticity of substitution between capital and labor.

4.5.3 Additive Sectoral Characteristics

In section 4.4 the possibility is discussed that there may be systematic sectoral differences in the quality of labor or in the ratio of the true to the common price deflator that is used. The right-side term in relation (11) gives the bias that may result from such sectoral differences. A priori it seems that the bias probably is toward a value of 1 for the estimate of the elasticity of substitution.

I explore the possibility of controlling for these, or other, systematic additive sectoral differences by including sectoral additive dummy variables. Regressions 3-4 and the associated column in table 4.1 are the result of adding these dummy variables to the basic ACMS relation with constant returns to scale. The estimated elasticity of substitution drops from 0.94 to 0.91, which suggests that the effect of such sectoral patterns on the elasticity of substitution, if any, is small.

Of course the significantly nonzero sectoral dummy variable coefficient estimates in fact may not be representing systematic sectoral differences that could bias the estimates of the elasticity of substitution. Instead they may be representing sectoral differences in the parameters that make up the constant term. Assume, for example, that all parameters of the production relation are identical across sectors except for the multiplicative neutral technology term, B in relation (1). Then the solution of the definition of the constant term in relation (2) (still with $\mu = 1$) gives the following ratio of neutral technology terms for the ith and jth sectors:

$$\frac{B_i}{B_j} = e^{(a_i - a_j)/\rho\sigma}. \tag{13}$$

On the basis of these assumptions and the estimates in regression 3-4, to provide a specific illustration, B_{351}/B_{354} equals 11.5. Under these assumptions, thus, the estimated coefficient of the sectoral dummy variables may be representing rather large differences in the sectoral neutral technology parameters. With the present data set, unfortunately, I see no way to identify the extent to which these significantly nonzero coefficient estimates of the sectoral dummy variables are due to an omitted variable problem or to systematic sectoral differences in the components of the constant term.

I also explore the possibility of controlling for sectoral differences by including the number of establishments per sector. This variable might be related to the degree of domestic oligopoly power. The fewer the number, ceteris paribus, the greater such power and the more there is a bias in using a common deflator across sectors—but also the greater may be the multiplicative neutral technology parameter (albeit for price, not technological, reasons). On the other hand, the larger the number of firms, the greater is the competitive pressure to operate efficiently with current-practice technology and thus to have a higher multiplicative neutral technology factor. Thus the sign of this variable is not obvious a priori. However, the rationale for its use does suggest that it might interact with the degree of openness of the economy, since foreign competition substitutes for domestic competition in open economies.

Regression 3.5 includes the ln of the number of establishments in the basic ACMS relation. Its inclusion by itself causes the estimate of the elasticity of substitution to drop from 0.94 to 0.91, which is not a substantial amount. The identification problem remains: the number of firms in each sector may be representing omitted variables (e.g., differential sectoral prices) or it may be due to the dependence of some components in the constant term on the number of firms in the industry. To the extent that the latter possibility is the true one and only B varies across sectors, the positive sign may imply that more establishments lead to higher neutral technology terms through greater pressure for efficiency and adoption of best-practice technology. Alternatively, if δ varies across sectors the positive sign may suggest that more firms lead to larger capital shares, ceteris paribus.

A comparison of regressions 3-15 and 3-16 reveals no evidence to support the conjecture of a significant interaction between the number of establishments and variables pertaining to the openness or degree of disequilibrium in the foreign sector. However, consideration of regressions 3-5, 3-6, 3-7, and 3-14 suggests that there is some interaction among this variable, the sectoral dummy variables, and the ln of real per capita income. Despite such interactions, tables 4.3 and 4.4 suggest that an estimate of a positive coefficient for the number of establishments in the direct ACMS form (and therefore negative in the reversed form) is quite robust.

The association between the ln of the number of establishments and the sectoral dummy variables is not surprising. It may reflect similarities across countries in patterns of sectoral demands and domestic production and in choices of technology. When both the number of establishments and the sectoral dummy variables are included, the estimated elasticity of substitution drops to 0.83, the coefficient estimate of the ln of the number of establishments almost doubles, and some of the coefficient estimates for the dummy variables change significantly (regression 3-6).

The association between the ln of the number of establishments and the ln of per capita GDP also is not surprising. Higher per capita income countries tend to have a greater B, more total economic activity, and more establishments in the industrial sectors.

The implications of these associations for the pattern of sectoral dummy variable coefficient estimates are clear in tables 4.1 and 4.5. No matter what other variables are included in the regressions, four patterns emerge: one if neither the number of establishments nor the per capita GDP is included (e.g., regression 3-4), one if only the number of establishments is included (e.g., regression 3-6), one if only per capita GDP is included (e.g., regression 3-7), and one if both are included (e.g., regression 3-14). For some sectors the coefficient estimates do not vary much across these four possibilities. For others interaction is much more important, so the estimates differ much more across these possibilities.

Table 4.5 **Grouping of ISIC Industrial Sectors by Signs of Significantly Nonzero Additive Dummy Variable Coefficient Estimates in Table 4.1**

1. *Not significantly nonzero*
   361 Pottery, china, etc.
   362 Glass and products
   385 Professional goods
2. *Significantly positive*
   314 Tobacco
   353 Petroleum refineries
   313 Beverages
   352 Other chemical products
   351 Industrial chemicals
   371 Iron and steel
   354 Petroleum, coal products
   355 Rubber products
   372 Nonferrous metals
3. *Significantly less than group 1 if control for number of establishments, otherwise not*
   321 Textiles
   322 Wearing apparel
   323 Leather and products
   324 Footwear
   331 Wood products
   332 Furniture and fixtures
   342 Printing and publishing
   382 Machinery, n.e.c.
   384 Transport equipment
4. *Significantly greater than group 1 if no control for number of establishments, otherwise not*
   312 Food products
   341 Paper and products
   356 Plastic products, n.e.c.
   383 Electrical machinery
5. *Significantly greater than group 1 if no control for number of establishments, but significantly less if control*
   381 Metal products

Table 4.5 groups the twenty-seven ISIC industrial sectors according to the estimates obtained in these four possibilities. The first group is the reference group. The three included sectors remain the same under all four specifications.

The second group has significantly positive estimates that are robust under alternative specifications. The sectors are roughly in descending order of these estimates. In some cases the sectors seem to be high-technology and capital-intensive (e.g., petroleum refineries, industrial and other chemicals), which may imply relatively high values of the multiplicative neutral technology factor. In other cases, such as for tobacco and beverages, the high values may reflect the relatively great protection often granted by foreign trade regimes.

The third group has significantly negative estimates if the ln of the number of establishments is included (though not always if also the ln of GDP per capita is added), but nonsignificant ones otherwise. It seems to be composed of relatively low-technology, labor-intensive industries.

The fourth group is not significantly different from the reference group if the ln of the number of establishments is included, but otherwise it has significantly positive estimates. It seems to be composed of industries that are intermediate between groups 2 and 3 in technology and capital intensity.

The fifth group is composed of only one sector—metal products—and combines the significantly nonzero features of groups 3 and 4.

4.5.4 Additive Country Variables

I include additive country variables in the ACMS form for reasons similar to the reasons I include additive sectoral dummies: (1) They may lessen the bias due to omitted variables (section 4.3). (2) The production parameters in the constant term may vary systematically across countries. As with the sectoral variables, I generally am unable to identify the relative importance of these two reasons in explaining the significance of these variables.

Regressions 3-7 through 3-13 each include one of the seven country characteristics discussed in section 4.4 in addition to the sectoral dummy variables in the direct ACMS form. Regressions 3-14 through 3-16 include groups of four country variables in addition to the ln of the number of establishments and the sectoral dummy variables in the direct ACMS form. Only four country variables are included in each regression because of high multicollinearity among some combinations of these variables. Regressions 4-2 through 4-3 are identical to regressions 3-14 through 3-16 except that the reversed ACMS form is used. The coefficients of the country variables in the reversed form are the coefficients in the direct form multiplied by $-1/\sigma$.

I now consider the country variables seriatim as they are discussed in section 4.4 and as their coefficient estimates are presented in tables 4.3 and 4.4.

1. *Real GDP per capita and life expectancy at birth* are included to represent the level of development and the quality of labor. Included alone without any other country variables, both have positive significantly nonzero coefficients, and both are associated with lower estimates of the elasticity of substitution. Their addition causes a drop of the estimate of that elasticity from 0.91 in regression 3-4 to 0.35 in regression 3-7 and to 0.87 in regression 3-8. Prima facie these declines might suggest that the failure to correct for labor quality in other regressions causes a significant and perhaps substantial bias toward one in the estimated value of the elasticity of substitution between capital and labor.

If, alternatively, the significant coefficient estimates for these variables represents entirely differential multiplicative neutral technology terms (i.e., *B*s in relation 1) across countries, then their impact is substantial. Under assumptions analogous to those that are discussed above in regard to relation (13), but with the subscripts referring to the *i*th and *j*th countries now, a difference of one standard deviation in GDP per capita across countries and the estimates in regression 3-7 imply B_i/B_j equals 3.2, and a difference of one standard deviation in life expectancy at birth across countries and the estimates in regression 3-8 imply B_i/B_j equals 1.7.

However, I am wary of placing too much weight on these estimates because they are not very robust and because these variables, particularly the GDP per capita, cause some perplexing patterns in other coefficients. For example, if both of these variables (and no other country variables) are included, ln GDP per capita has a coefficient estimate of -16.1, ln life expectancy at birth has a coefficient estimate of 43.4, and the estimate of the elasticity of substitution is 11.2! If both are included with other country variables, as in regression 3-14, the coefficient estimates become more moderate and the estimated elasticity of substitution is 1.00.

Other examples could be given but would serve little purpose. The basic point is that the coefficient estimates of these two variables do not seem very robust, and the impact of including the ln real GDP per capita variable in particular on the estimate of the elasticity of substitution often is substantial, though under changes in other specifications this elasticity estimate is quite robust. Because of the lack of robustness that is associated with the ln GDP per capita and ln life expectancy at birth variables, no very confident positive conclusions can be reached concerning their possible importance.

As an alternative to using country variables to attempt to control for cross-country labor quality differentials, the ACMS adjustment in relation (12) is mentioned above. For an estimated elasticity of substitution of 0.91 (the modal value in table 4.3), this adjustment gives a corrected value of 0.87.

2. *Exports plus imports relative to GNP* is included to represent the degree of openness to the foreign sector. When this is the only country variable included it has a significantly negative coefficient but does not affect the estimate of the elasticity of substitution (regression 3-9). Given these estimates and assumptions analogous to those made in regard to relation (13) above, a difference of one standard deviation across countries in this variable implies B_i/B_j equals 0.32. Prima facie one possible interpretation is that this variable is serving as an inverse proxy for the state of development. Ceteris paribus, the higher the level of development, the greater the multiplicative technology term (i.e., *B*) and the less the dependence on international trade.

However, the other regressions do not seem to support such an interpretation. When this variable is included with the measures of the level of development, as in regression 3-14, it continues to have a significantly negative coefficient estimate (albeit of smaller absolute magnitude). With many other specifications (e.g., regressions 3-15, 3-16, 4-2, 4-3, 4-4), it does not have a significantly nonzero coefficient. Therefore these regressions do not give much support for a strong role for the openness of the economy to foreign trade as measured by this ratio.

3. *The rate of inflation* is included to represent internal price stability. When it is the only country variable included, it has a significantly positive coefficient estimate, but it does not seem to alter substantially the estimate of the elasticity of substitution (regression 3-9). Given these estimates and assumptions analogous to those underlying relation (13) above, once again, a difference of one standard deviation in the rate of inflation across countries implies B_i/B_j equals 1.97. When other country variables are added to the specification, the sign (if not the magnitude) of the coefficient estimate for this variable remains fairly robust, though not always significantly nonzero.

A priori this variable is included for two reasons. (1) Inflation might have some effect on the estimated elasticity of substitution by representing systematic variation across countries in P/P^* in relation (11). A comparison of regressions 3-4 and 3-9 does not support this alternative. (2) Internal price disequilibrium might lower internal production efficiency and thus B. However, the significantly positive coefficient is consistent with the opposite interpretation.[13]

4. *The ratio of the black market to the official exchange rate* is included to represent foreign sector disequilibrium. The coefficient estimates for this variable are positive in the ACMS form and negative in the reversed form. The point estimates in regression 3-11 and relation (13) imply that a difference of one standard deviation in this ratio across countries gives B_i/B_j equal to 1.66.

A comparison of regressions 3-4 and 3-10 suggests that this ratio is not controlling for a systematic pattern in P/P^* in relation (11) that a priori might seem to cause a bias in the estimated elasticity of substitution. However, the positive sign of the estimate is somewhat puzzling. It does not support the hypothesis that greater foreign sector disequilibrium is associated across countries with lower neutral productivities (i.e., value of B in relation 1). What is important to this study, however, is that the estimate of the elasticity of substitution is quite robust when this variable is included.

5. *The ratio of wages to national income* is included to represent the factoral income distribution. When it is the only country variable included in regression 3-12, it has a significantly positive coefficient that implies (under the necessary assumptions) B_i/B_j equals 1.18 for a differ-

ence of one standard deviation across countries. Its inclusion also results in a drop in the estimated elasticity of substitution from 0.91 to 0.87. Consideration of what happens under specification change in other regressions in tables 4.3 and 4.4 and in ones not reported here, however, leads me to conclude that this variable probably is serving as a proxy for the quality of labor. The drop in the estimated elasticity of substitution (that incidentally is the same as is obtained from the ACMS adjustment for the quality of labor) or the increase in B, or both, reflects the tendency for the wage share to be positively associated across countries with the quality of labor.

6. *The rate of growth of per capita product* is included to represent the relative degree of dynamism across countries. When it is the only country variable included in regression 3-13, its inclusion lowers slightly (probably not significantly) the estimated elasticity of substitution from 0.91 to 0.89. The magnitude of the significantly positive coefficient estimate implies that B_i/B_j equals 2.45 under the assumptions given above for a difference of one standard deviation across countries. Except when this variable is included with indicators of the level of development as in regressions 3-14 and 4-2, the sign and the approximate magnitude of its coefficient estimates are robust under specification changes. There seems to be reasonable support for there being an association between economic growth and the levels of the multiplicative technology terms.

4.5.5 Multiplicative Sectoral and Country Variables

As is discussed above, I explore the effect of including additive country variables to attempt to control for missing variable bias and to see if there is evidence that the parameters of the production relation that enter into the constant term are related to sectoral or country characteristics. Of course the elasticity of substitution itself may be related to sectoral or country characteristics. The results of a limited exploration of such a possibility are now considered. The exploration is limited because of the greater computational difficulties and lesser robustness encountered with the estimates of these multiplicative forms.[14] Table 4.6 includes some relevant estimates.

Regression 6-1 posits that the elasticity of substitution in the direct ACMS relation is a function of sectoral dummy variables only. The estimates imply that the elasticities vary across sectors from 0.86 to 1.00, with the increment above 0.86 given in the last column in table 4.1. The mean value of 0.90 is almost identical to the value estimated in regression 3.4 with additive sectoral dummies. Across sectors there seems to be a definite relation between the estimated additive and multiplicative estimates. All of the group 2 sectors in table 4.2, for example, have estimated significant positive incremental elasticities of substitution—including the five highest values. Thus the additive and the multiplicative sectoral

Table 4.6 Estimates of ACMS Relation with Elasticity of Substitution Dependent on Sectoral and Country Characteristics

					$\ln W \times$ ln of Country Characteristics								
Regression Number	Constant	$\ln W$	$\ln W \times$ Sector Dummies	$\ln W \times$ ln Number of Establishments	GDP per Capita	Life Expectancy	Trade/GDP	Inflation	Black Market/Official Exchange Rate	Wages/National Income	Growth in Product per Capita[b]	Implied Mean σ	$\bar{R}^2$/SE
6-1	1.52	.86	Yes									.90	.72
	(13.1)	(47.7)	Table 4.1										.59
6-2	.93	.70		.44[c]	−.018	.095	−.021	.79[d]			−.49[c]	.98	.67
	(7.5)	(11.5)		(6.2)	(10.3)	(11.7)	(5.3)	(1.6)			(9.9)		.64
6-3	1.40	.90		.64[c]		−.011	−.014	.98[d]	.028		.56[c]	.91	.70
	(10.9)	(13.8)		(9.1)		(0.8)	(3.5)	(1.7)	(4.0)		(5.3)		.62
6-4	1.44	.97		.64[c]		−.029	−.012	2.28[d]		.088	.53[c]	.91	.69
	(11.3)	(15.3)		(9.1)		(2.2)	(3.0)	(4.7)		(0.8)	(5.4)		.62

NOTE: See note to table 4.3.

[a]See note a to table 4.3.

[b]Not in ln form.

[c]Multiplied by 10^{-2}.

[d]Multiplied by 10^{-4}.

dummy variables may be representing partially the same phenomenon. In any case, even if all the variation in the sectoral multiplicative estimates is allocated to sectoral differences in the elasticities of substitution, such variations are not very large.

The remaining regressions in table 4.6 posit elasticities of substitution that depend on the ln of the number of establishments and on different groups of five country variables. The implied mean elasticities of substitution are 0.98, 0.91, and 0.91, respectively. All three of these estimates are close to those in table 4.3. Table 4.7 summarizes the implications for the elasticity of substitution of these estimates and increases of one standard deviation in the included multiplicative variables.

The estimates imply that the number of establishments has a greater effect on the elasticity of substitution than do any of the country variables for variations of the types experienced in the sample. An increase of one standard deviation in the number of establishments in a sector is associated with an increase of 0.03 to 0.04 in the elasticity of substitution (table 4.7). This may reflect that more establishments in a sector increase the pressure for efficient behavior and for exploring substitution possibilities. Alternatively, more establishments may be associated with greater heterogeneity of products and of underlying product technologies. In any case, the estimated effect is not large.

The estimated effect on the elasticity of substitution of variations in the country variables of magnitudes observed in the data set is even smaller. Moreover, interpretation is difficult because of interactions among the linear combinations of the variables similar to those discussed above in regard to the additive country variables. Taken at their face value, however, the estimates imply a few interesting observations.

The level of per capita GNP is negatively associated with the elasticity of substitution, which is consistent with casual observations about there

Table 4.7 **Implied Changes in Elasticity of Substitution Owing to Increases of One Standard Deviation in Sectoral and Country Variables**

		ln of country characteristics						
Regression Number	ln Number of Establishments	GDP per Capita	Life Expectancy	Trade/ GDP	Inflation[a]	Black Market/ Official Exchange Rate	Wages/ National Income	Growth in Product per Capita[a]
6-2	.03	−0.2	.02	−.01	.00			−.01
6-3	.04		−.00	−.01	.00	.01		.01
6-4	.04		−.01	−.01	.01		.00	.01

Note: Coefficient estimates in table 4.6 multiplied by one standard deviation of underlying data series.

[a]Not in ln form.

being fewer substitution possibilities with more advanced technology. The negative coefficient estimates of life expectancy (when GDP per capita is not included) may reflect a similar phenomenon of less substitution when labor is of higher quality and more specialized. The negative coefficient estimates of the degree of openness and the positive one for the foreign sector disequilibrium, finally, may both reflect the lesser heterogeneity of production techniques and of subsectoral products when a country specializes more in its areas of comparative advantage and trades more internationally.

4.6 Conclusion

I have presented new estimates of the elasticity of substitution between capital and labor based on 1,723 observations from twenty-seven three-digit ISIC industrial sectors for seventy countries for the period 1967–73. This is a much more extensive data set with a richer diversity of countries than has heretofore been used. Moreover, by using average data for 1967–73 for each observation I am able to lessen downward biases due to additive recording errors and cyclical fluctuations and make the maintained hypothesis of approximate profit maximization under perfect competition more palatable. Furthermore, I am able to explore the effect of sectoral and country characteristics on the estimated parameters.

I carefully consider various sources of biases and attempt to control for them in my estimations. Measurement error may mean the true elasticity is somewhat higher than I estimate; omitted variable bias may mean it is somewhat lower. The estimated values are slightly higher for sectors with more establishments (and therefore more domestic competition?) and for those with more advanced and more capital-intensive technology (group 3 in table 4.5). They are affected even less by country than by sectoral characteristics.

I conclude that under the maintained hypotheses my estimates provide strong support for an elasticity of substitution between capital and labor across industrial sectors and across countries near the Cobb-Douglas value of 1.0. This result is quite robust under the alternative specifications that I consider, with a single caveat about the puzzling role of real per capita GDP. Sectoral and country variations appear to primarily affect not the elasticity of substitution, but the multiplicative neutral technology or overall productivity term (*B* in relation 1).

This elasticity estimate probably incorporates three phenomena: (1) underlying technical substitution possibilities on a more micro level; (2) variations in optimal factor service flows per unit of factor stocks on a more micro level; and (3) changes in product composition in the components of the three-digit sectors. Although I can not decompose my estimates into the contributions of these three phenomena, from the point of view of aggregate trade and more general development policy it is this composite response that is important—and this study suggests that it is substantial.

Such a value for the elasticity of substitution between capital and labor has several important implications. First, it brings into question the frequent specification of planning models and of other analyses that capital/labor coefficients are fixed. This maintained hypothesis seems to overstate the technological rigidities and may lead to inappropriate conclusions.

Second, under neoclassical assumptions regarding factor payments, elasticities of substitution near one imply that the long-run factoral distribution of income between capital and labor is not altered much by differential growth rates of the two factors. If labor grows relatively slowly, the equilibrium wage increases to compensate so that the wage share remains about the same proportion of national income.

Third, the limited variation across three-digit industrial sectors suggests that aggregation to the overall manufacturing level may not be misleading for some analysis.[15] Of course the implications of aggregation generally also depend on other parameters that may or may not be homogeneous across industrial subsectors.

Fourth, and perhaps most important, an elasticity of substitution between capital and labor near the Cobb-Douglas value suggests considerable flexibility in responding to trade and domestic-sector policies that alter the relative costs of capital and labor services. Examples of such policies are legion. Capital subsidies through favorable import and credit treatment and minimum wages are illustrations of frequently used policies that increase the cost of labor relative to that of capital. The estimated value of the elasticity of substitution between capital and labor implies that manufacturing enterprises can respond to such incentives and use relatively more capital and less labor. In many contexts such responses may exacerbate employment problems.

Appendix: Sources of Data for Country Characteristics

Real GDP per capita is for 1970 as estimated from detailed price comparisons and purchasing power calculations by the method given in Kravis, Kenessey, Heston, and Summers (1975) and Kravis, Heston, and Summers (1978). Data are not available for seven countries: Czechoslovakia, Luxembourg, Mauritius, Mozambique, Poland, Rhodesia, and Yugoslavia.

Life expectancy in years at birth in 1970 is from World Bank (1976) and Hansen (1976).

Exports plus imports relative to GNP are calculated from data in World Bank (1976) and United Nations (1975). Data are not available for four countries: Mozambique, Poland, Rhodesia, and Singapore.

The average annual rates of inflation for 1967–73 are calculated from data in International Monetary Fund (1976). Data are not available for three countries: Kuwait, Papua New Guinea, and Uganda.

The average ratios of the black market exchange rate to the official exchange rate for 1967–73 are calculated from data in Pick's (1975, 1976), International Labor Organization (1977), and United Nations (1977). Data are not available for eleven countries: Barbados, Fiji, Guatemala, Jamaica, Luxembourg, Madagascar, Malta, Mauritius, Mozambique, Papua New Guinea, and Somalia.

The average wage shares in national income for 1967–73 are calculated from data in International Labor Organization (1977). Data are missing for twenty-two countries: Bangladesh, Barbados, Brazil, Cyprus, Czechoslovakia, Dominican Republic, Ethiopia, Ghana, Guatemala, Hungary, Indonesia, Mozambique, Nigeria, Pakistan, Philippines, Poland, Rhodesia, Singapore, Sweden, Tunisia, Turkey, and Yugoslavia.

The growth rates of real GNP per capita for 1967–73 are given in World Bank (1975). Data are not available for nine countries: Barbados, Chile, Cyprus, Fiji, Kuwait, Luxembourg, Madagascar, Malta, and Mauritius.

Notes

1. While reasonably large elasticities of substitution between capital and labor promote flexibility, they do not guarantee it. Other constraints, including those of a macro nature, may severely restrict the possibilities of response. For an empirical example, see Behrman (1972*b*, 1977).

2. If a wider class of production functions is allowed, it may not be possible to identify whether the returns from scale are not constant or whether the production function is not homothetic. For example, the Mukerji (1963) production function below leads to the subsequent marginal productivity relation, and the latter is statistically indistinguishable from relation (4):

$$V = \left[B\,\delta K^{-\rho_1} + (1-\delta)L^{-\rho_2}\right]^{-1/\rho_o}$$

$$\ln (V/L) = a' + b'\ln W + c'\ln L,$$

$$\text{where } b' = 1/(1+\rho_o)$$

$$c' = b'\,(\rho_2 - \rho_o).$$

3. In writing this section I have benefited from reading Nerlove (1967) and Griliches and Ringstad (1971), to which the interested reader is referred for more extensive discussions of these issues.

4. If there is more than one right-side variable, but only one has measurement error, its coefficient estimate is unambiguously biased toward zero, but the coefficient estimates of the other variables may be biased in either way (but the bias can be calculated). However, if more than one right-side variable is measured with error, the expressions for correcting for

measurement error become much more complex, and all coefficients may be under- or overestimated. See Levi (1973) and Theil (1961) for further discussion.

5. Behrman (1972*a*), Ferguson (1965), Oi (1962), and Okun (1962) further consider errors in the variables owing to cyclical fluctuations.

6. A more satisfactory measure, such as the market share of the largest three of four firms or the Herfindahl-Hirschman index of concentration, cannot be calculated with the available data.

7. If there are no restrictions on foreign exchange movements, the free or black market exchange rate basically is identical to the official rate, and this ratio is one. If there are restrictions on foreign exchange movements owing to a disequilibrium situation in which the domestic currency is overvalued, the free or black market exchange rate exceeds the official exchange rate, and this ratio exceeds one. For further discussion of this variable, see Behrman (1976, 1977).

8. In principle it would be possible to test the maintained hypothesis that such missing observations are random (e.g., Behrman and Wolfe 1980; Behrman, Wolfe, and Tunali 1980; Heckman 1974; or Maddala 1978), but to do so would be beyond the scope of this study.

9. They also may reflect micro adjustments in the optimal factor service flows per unit of factor stock. See Winston (1974).

10. The total number of observations is less than the product of twenty-seven sectors and seventy countries (i.e., 1,890) because some countries do not produce items in some sectors. Table 4.1 indicates the number of countries for which data for each sector are available.

11. Their derivation is for the Cobb-Douglas case, but my estimates suggest that for my data the Cobb-Douglas assumption of an elasticity of substitution equal to one is approximately satisfied.

12. Such a calculation is meant to merely be suggestive. If in fact all of the other parameters were constant across sectors and all production factors were homogeneous, all factors would be used most productively in the sector with the highest B, which would tend to cause offsetting changes in relative sectoral product prices under most forms of market organization. Because of international trade barriers, in fact, comparisons of Bs across countries (as are presented below) under these assumptions probably are more realistic than are comparisons across sectors.

13. Consideration of regression 3-14 alone might suggest that the rate of inflation is highly associated with the level of development and merely representing it. However regression 4-2 does not seem to support such an interpretation.

14. For the same reasons, I do not present estimates that include both additive and multiplicative sectoral or country variables.

15. Of course the analysis of this study is conditional upon aggregation to the three-digit level being satisfactory.

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