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Adjustment in General Equilibrium: Some Industrial Evidence

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Abstract

The link between output changes and factor-mix adjustments in general equilibrium is examined for each of nine industries using pooled data from 12 developed countries over the years 1970–85. Specifications of the Stolper-Samuelson theorem and the specific-factors model of production are built on the assumptions and structure of theory with each industry isolated in turn. In their simplest version with only capital and labor input, these competitive general-equilibrium models explain a good deal of the observed variations in industrial factor mixes. The specific-factors model performs better.

1. Introduction

The theory of production and trade is built in large part on the competitive paradigm contained in general-equilibrium models of production. The Stolper-Samuelson theorem (1941) of the Heckscher-Ohlin model captures the link between an industry's price and the return to its intensively used factor of production, illustrated in Edgeworth box and Lerner-Pearce diagrams. The specific-factors model assumes every industry is characterized by productive capital used only in that industry, creating a direct link between the price of an output and its specific factor.

This paper provides some empirical evidence for the Stolper-Samuelson theorem and specific-factors model. Model specifications are estimated using data for each of nine manufacturing industries across 12 OECD countries from 1970–85. In the Stolper-Samuelson specification, a rising price in an industry causes the capital-labor ratios to adjust according to factor intensity. In the specific-factors model, a higher price in an industry is expected to increase labor input.

There are data available for many industries, suggesting a model with many goods. When the prices of goods are exogenously given at world levels, however, a production model with two factors shared by each industry is overdetermined. Introducing demand allows a tractable model, but relaxes the intensity links. The present paper isolates each industry and aggregates the others into a single sector, developing a series of two-sector models to coincide with the Stolper-Samuelson theorem.

Leamer (1994a) argues that an idea needs an issue, a theory, and evidence to survive. The Stolper-Samuelson theorem meets the first two conditions, but lacks much of the third. The theorem was originally presented and applied largely in the context of

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international trade theory. The general-equilibrium model can, however, describe a totally closed economy experiencing demand-driven price changes. If the demand for a good rises, its price increases and the Stolper-Samuelson theorem predicts relative factor-price adjustment. This link between prices of goods and prices of factors through the production structure, holding technology constant, is the heart of the Stolper-Samuelson theorem. When the price of a good changes, outputs adjust as productive factors shift between industries. The present paper adopts this general perspective without a direct link to trade or trade policy.

The appeal of the Stolper-Samuelson theorem stems from its clear identification of winners and losers. Economists concerned with income redistribution due to trade policy often invoke the theorem. Tariffs are generally thought to favor relatively scarce factors of production and harm relatively abundant factors. Whether and how this intuition applies to an economy composed of many industries remains an intriguing puzzle. This paper provides one approach to interpreting and applying the theorem.

2. The Isolated-Industry Model and the Specific-Factors Model

With many factors and goods, there are unambiguous factor-intensity rankings only under very restrictive conditions, as developed by Chang (1979) and Ethier (1984). Output in industry j is a function of capital and labor inputs, $x_j = x_j(K_j, L_j)$. Assume homothetic neoclassical production functions. With competitive pricing, cost equals price. Unit-value isoquants represent the amount of good j worth one unit of *numéraire*, namely one US dollar. The isolated-industry model simplifies the economy to only two sectors, leading to unambiguous predictions depending on industrial factor intensity. Other manufacturing output is aggregated into x_0.

The isolated industry j is labor intensive if $(K/L)_j < (K/L)_0$. Let the price p_j of this labor-intensive good rise, holding constant the price of the other good and total endowments of capital and labor available in manufacturing. The expanding industry hires more labor per unit of capital than in the contracting sector, relative wages rise, and both industries become more capital intensive. Output of the labor-intensive good increases while output in the other sector drops. Symmetrically, higher price for a capital-intensive good would result in lower relative wages and capital-labor ratios. This dependence on factor intensity captures the essence of the Stolper-Samuelson theorem.

Suppose capital is a specific factor, as in Jones (1971), Samuelson (1971), and Neary (1978). Some of the capital equipment used in these industries cannot easily be converted for use in other industries. Except for some technical workers, the majority of labor in most groups (janitors and economists, for instance) can work in different industries. There are nine industries in the present specific-factors model, each with its own specific capital input. Labor is the common factor, being mobile between industries. Labor and each industry's capital are fully employed and a unique labor input is determined in every industry. A higher price in industry j would shift the unit-value isoquant toward the origin. The supporting isocost line in industry j becomes steeper, as the return to capital rises proportionately more than the wage. Labor enters the sector and output increases, with specific capital fixed.

3. Previous Empirical Studies

Empirical studies of the Stolper-Samuelson theorem are relatively rare, perhaps because the real world does not appear to conform to assumptions of the theory. It is known that there are more than two separable inputs in these production processes. Branson and Monoyios (1977) argue that skilled labor is an important input in observed trade. Clark, Hofler, and Thompson (1988) show that there are at least nine separable skill types of labor in a cross-section study of US manufacturing. Leamer (1984) successfully specifies a model with different types of labor, capital, and resource inputs.

Magee (1980) makes the first attempt at empirical investigation of the Stolper-Samuelson theorem, pointing out that the theorem predicts labor and capital would lobby on opposite sides of trade policies. Testimony of groups representing labor and capital before the US Congress on the Trade Reform Act of 1973 shows that lobbying activity occurred along industry lines rather than factor lines. Magee points out, however, that lobbying is more concerned with the short run, while the Stolper-Samuelson theorem is a long-run proposition. Magee's interpretation is in accord with the point of Leamer (1994a) that trade theories should not be "tested" in order to be accepted or rejected. Leamer argues that tests should simply suggest conditions under which a theory is applicable and capable of making predictions.

Leamer (1984) points out that direct econometric estimation of Stolper-Samuelson effects is difficult because of the high degree of collinearity between prices of goods and prices of factors. Detailed and reliable data on factor prices, especially capital, are not available. Moreover, a change in technology or other exogenous supply shocks would alter the relation between prices of goods and factor prices. Leamer appeals to Samuelson's reciprocity relation between the Stolper-Samuelson and Rybczynski theorems in order to estimate Stolper-Samuelson effects, focusing on the effects of tariffs on factor prices. The model is not judged by the estimates but is used as the framework for estimation. Leamer (1994b) applies the same procedure to estimate the wage effects of free trade between the US and Mexico.

Gaston and Trefler (1994) directly estimate the effect of tariffs on US manufacturing wages, which they find to be negative. They believe less efficient resource allocation under protection may be the cause. Workers may also receive economic rent from tariffs by avoiding the cost of searching for new jobs.

Krugman and Lawrence (1994) examine the factor-price equalization theorem based on the logic of the Stolper-Samuelson adjustment process. If factor prices across countries are to become equal through trade, they would generally have to move in the direction predicted by the Stolper-Samuelson theorem. Increased international trade is expected to raise the price of a country's abundant factors and reduce the price of its scarce factors. Such a change would lead all industries to substitute scarce factors for abundant factors as trade increases. In the US, relatively scarce unskilled workers should be substituted for abundant skilled workers. Krugman and Lawrence find that this prediction does not hold between 1979 and 1989, a period when international trade increased. Thompson (1985) points out, however, that models of production with as few as three factors do not have such straightforward predictions.

Lawrence and Slaughter (1993) set out to determine whether international trade has caused the slow growth in real hourly compensation and the increase in income disparity in the US since 1973, using the Stolper-Samuelson theorem as a conceptual framework. Their empirical analysis suggests that increased trade and the Stolper-Samuelson process had little influence on relative wages in the US during the 1980s.

Bhagwati and Dehejia (1993) critically evaluate several recent empirical works, mostly by labor economists, which rely on the Stolper-Samuelson mechanism to determine the impact of international trade on US wages. They find major theoretical pitfalls in these works, and contend that the Stolper-Samuelson theorem is not an adequate guide to reality.

In summary, there is little consensus in the empirical literature. The present paper's contribution lies in specifying empirical models built directly on the theory, controlling for exogenous variables.

4. Industrial Factor-Intensity Rankings

The *International Sectoral Databank* (OECD, 1989) provides data for nine manufacturing industries in 12 developed countries. Two advantages of this data set are consistency across countries and the inclusion of capital input. The data cover the years 1970–85, and are expressed in 1980 US dollars.

The first step in implementing the Stolper-Samuelson theorem is to rank industries in each country by factor intensity. The average ratio of capital to labor over the entire time period is calculated. Table 1 presents the rankings by capital-labor ratios. For each industry, the first number shows its ranking, with 1 as the most labor intensive. The number following in parentheses is the capital-labor ratio in thousands of dollars of capital per worker. Industries are compared with the capital-labor ratio in total manufacturing, which appears in parentheses along the last row. Each industry is calssified as either L (labor intensive) or K (capital intensive) relative to aggregate manufacturing in each country.

There is a fairly consistent factor-intensity ranking of industries. In every country, textiles (TX), other manufactures (OM), wood (WD), and machinery and equipment (ME) are labor-intensive industries. Chemicals (CH) and nonmetallic minerals (NM) are capital intensive in every country. Basic metals (BM) and food (FD) are also classified as capital-intensive industries, because BM is labor intensive only in the Netherlands and FD only in Canada and Japan. Paper (PA) is a borderline industry, capital intensive in half the countries. Comparing the distance between the capital-labor ratios and the average in manufacturing, countries with capital-intensive paper industries lie farther from the average. Thus, PA is classified as capital intensive.

Industries can also be consistently compared across countries. For instance, aggregate manufacturing (MF) is the most capital intensive in the Netherlands and Sweden, and the most labor intensive in the UK and Japan. Textiles (TX) is the most labor intensive in the US, and chemicals (CH) the most capital intensive in the Netherlands. The variation in the capital-labor ratio across countries is largest in paper (PA) and basic metals (BM).

5. An Empirical Model of the Stolper-Samuelson Theorem

The empirical model incorporates the assumptions and structure of the underlying theory. Variables which are exogenous in theory are included as independent variables in the regressions. Imperfections in the labor market are controlled by the use of independent variables. The key to specifying a theory is to include the structure of the model which leads to the theoretical outcomes.

In the Stolper-Samuelson theorem, the ratio of wages to rents is the dependent variable, while output prices and factor endowments are independent exogenous variables. Including influences due to imperfections in the labor market, consider the following log linear model:

Table 1. Industrial Factor Intensity, Average for 1970–85[a]

	Rank ($ K/L) K or L intensive[b]											
	Country[c]											
Industry[d]	*BL*	*CN*	*DU*	*DN*	*FR*	*IT*	*JP*	*NL*	*NR*	*SW*	*UK*	*US*
TX	2(34)*L*	1(24)*L*	3(30)*L*	2(26)*L*	1(31)*L*	2(22)*L*	4(29)*L*	4(56)*L*	1(25)*L*	2(33)*L*	2(24)*L*	1(18)*L*
OM	4(55)*L*	2(28)*L*	1(24)*L*	1(19)*L*	3(48)*L*	—	1(13)*L*	1(31)*L*	2(33)*L*	1(7)*L*	1(23)*L*	2(23)*L*
WD	—	4(50)*L*	4(39)*L*	4(39)*L*	—	1(20)*L*	—	—	4(44)*L*	4(50)*L*	—	3(48)*L*
ME	1(31)*L*	3(42)*L*	2(25)*L*	3(30)*L*	2(39)*L*	3(37)*L*	2(27)*L*	3(56)*L*	3(35)*L*	3(50)*L*	3(26)*L*	4(32)*L*
PA	3(51)*L*	6(112)*K*	5(46)*K*	5(41)*L*	4(53)*K*	4(56)*K*	6(109)*K*	2(48)*L*	5(49)*L*	9(115)*K*	4(31)*L*	5(48)*L*
FD	5(68)*K*	5(58)*L*	6(55)*K*	6(55)*K*	8(75)*K*	6(65)*K*	3(29)*L*	6(78)*K*	6(64)*K*	6(78)*K*	5(53)*K*	6(54)*K*
NM	7(75)*K*	9(282)*K*	8(62)*K*	9(85)*K*	6(72)*K*	5(61)*K*	5(50)*K*	7(82)*K*	7(76)*K*	5(72)*K*	6(56)*K*	7(66)*K*
CH	8(104)*K*	7(120)*K*	7(58)*K*	8(80)*K*	7(73)*K*	7(109)*K*	7(140)*K*	8(145)*K*	9(123)*K*	7(106)*K*	8(86)*K*	8(109)*K*
BM	6(70)*K*	8(164)*K*	9(79)*K*	7(74)*K*	5(60)*K*	8(191)*K*	8(145)*K*	5(60)*L*	8(108)*K*	8(116)*K*	7(59)*K*	9(172)*K*
MF	(56)	(60)	(40)	(44)	(51)	(52)	(39)	(68)	(55)	(68)	(39)	(50)

[a] Source: OECD *International Sectoral Databank*, 1989.

[b] 1–9, ranking from the most labor intensive to the most capital intensive industries; (·), thousands of dollars of *K* per *L*; *K* or *L* intensive, capital or labor intensive relative to average in manufacturing (MF) in each country.

[c] BL, Belgium; CN, Canada; DU, Germany; DN, Denmark; FR, France; IT, Italy; JP, Japan; NL, Netherlands; NR, Norway; SW, Sweden; UK, United Kingdom; US, United States.

[d] TX, textiles; OM, other manufactures; WD, wood, wood products; ME, machinery, equipment; PA, paper, printing, publishing; FD, food, beverages, tobacco; NM, nonmetallic minerals; CH, chemicals; BM, basic metals; MF, aggregate manufacturing.

$$\left(w/r\right)_i^t = a_0 + a_1 p_{ji}^{t-k} + a_2 p_{0i}^t + a_3 K_i^t + a_4 L_i^t + a_5 c_i^t + a_6 u_i^t + \varepsilon_i^t, \tag{1}$$

where industries are indexed by $j = 1, \ldots, 9$; countries by $i = 1, \ldots, 12$; and time by $t = 1970, \ldots, 1985$. Variables in equation (1) are expressed in logarithms and defined as:

$(w/r)_i^t$, the wage relative to the return to capital in manufacturing;
p_{ji}^{t-k}, the lagged price of output in isolated industry j;
p_{0i}^t, the aggregate price in the other sector;
K_i^t, the capital endowment;
L_i^t, the labor endowment;
c_i^t, coefficient of variation in wages across industries within each country;
u_i^t, the unemployment rate; and
ε_i^t, random error.

The Stolper-Samuelson theorem predicts a_1 will be positive (negative) if the isolated industry j is labor (capital) intensive. The aggregate price of other goods p_o is included as an exogenous variable. To construct this price index for industry j, output in industry j is first subtracted from manufacturing output, $y_o = y_M - y_j$, where y represents the value of output in 1980 US dollars. The size of industry j relative to the other industries is $\sigma_j \equiv y_j/y_o$. For industry j, the aggregate price index of the other goods is $p_o = \Sigma_{l\neq j}\sigma_l p_l$. Aggregation reduces the model to two industries. In theory, the price of this other good is held constant to isolate the Stolper-Samuelson effect for the industry in question. In the data, there is variation in prices across countries and time. Including p_o allows interpretation of the other coefficients in (1) as though the aggregate price of other goods were constant. The parameters are thus partial derivatives in the comparative static model.

In the Heckscher-Ohlin model, changes in K and L should have no effect on w/r, the factor-price equalization result. Including K and L in (1) effectively holds endowments constant to concentrate on the effect of price changes captured by a_1.

The coefficient of variation of wages c is the standard deviation of the wage divided by its mean. In theory, wages are equal across industries within a country due to the assumptions of labor homogeneity and mobility. Ideally, c would be zero, but there is some variation in wages across industries. Including the coefficient of variation has the effect of controlling this industrial wage variability. The price coefficient a_1 can be interpreted as though wage variability were constant.

The unemployment rate u is included because of the theoretical assumption of full employment. There is, however, variation in unemployment across countries and time in the data. Changes in unemployment might affect the general-equilibrium ratios of wages to rent or capital to labor. Including u makes the other coefficients, most importantly a_1, partial derivatives holding unemployment constant.

Reliable figures for the return to capital, included in the dependent variable in (1), are not available. The ratio of wages to rents, however, directly affects the ratio of capital to labor, which is reported in the data. In the following estimations, the endogenous capital-labor ratio in each industry serves as a proxy for the ratio of wages to rents.

In the Stolper-Samuelson theorem, any change in p_j should be due to a change in the international market or in the demand for good j. An observed change in p_j could, however, be caused by a shift in technology or supply. Deardorff and Hakura (1993, p. 27) point out that in studying the Stolper-Samuelson process, the source of price changes must be known. A negative technology shock, for instance, would decrease domestic supply and raise the price of output. There is then some ambiguity with respect to the final position of the unit-value isoquant, which would shift away from the origin with the technology shock, but toward the origin with the resulting higher price. The net effect could be a unit-value isoquant farther from the origin, which would mean a lower relative wage occurring along with the higher price of the labor-intensive good. A price change would then be associated with the opposite of the predicted Stolper-Samuelson effect.

Output of industry j is used as a proxy for price. The assumption is that technology changes have larger effects on the unit-isoquant position than the related price changes when supply shocks occur. This assumption works better with more elastic demand. In these competitive models, the typical assumption is perfect competition, which fits this high level of aggregation. If isolated industry j is labor intensive, higher output is then accompanied by an increase in the ratio of wages to rents. In the process, the capital-labor ratio rises. Higher outputs in capital-intensive industries are associated with lower capital-labor ratios.

Industrial output is normalized by total manufacturing output. The share of industry j output in total manufacturing output, s_{ji}, becomes the exogenous variable of interest. Output shares control for the different sizes of the same industry across countries, reflecting performance of each industry relative to all manufacturing. Output shares are not used to proxy the price of the other sector because $s_u = 1 - s_j$.

This analysis leads to the estimation of

$$\left(K/L\right)^t_{ji} = b_0 + b_1 s_{jt} + b_2 p^t_{0i} + b_3 K^t_i + b_4 L^t_i + b_5 c^t_i + b_6 u^t_i + \eta^t_{ji}, \tag{2}$$

where η^t_{ji} is the random error term. The Stolper-Samuelson variable s_{ji}, the share of isolated industry j in manufacturing, is lagged to allow for adjustment over time.

6. Results of the Stolper-Samuelson Estimation

Equation (2) is estimated in a pooled regression for each industry across the 12 sample countries over the 16 years. Although the countries are all developed industrial economies, they differ in institutions, public policy, and business laws. To control for this heterogeneity, (2) is estimated with a separate constant term for each country.

Preliminary tests indicate heteroskedasticity and first-order autocorrelation. The Parks (1967) method is applied because it assumes residuals are heteroskedastic, contemporaneously correlated, and serially correlated of first order in pooled data. The model is estimated in logarithms, and the coefficients are interpreted as elasticities.

Regression estimates of (2) are reported in Table 2. The Stolper-Samuelson theorem in the present model predicts that in the labor-intensive industries (TX, OM, WD, ME) an increase in s_j would cause an increase in the capital-labor ratio. In the capital-intensive industries (PA, FD, NM, CH, BM) an increase in s_j should lower the capital-labor ratio. This prediction holds for five of the nine industries: OM, ME, PA, NM, and BM. The coefficients for WD and FD have the right sign, but are insignificant. Significant opposite signs are found in only TX and CM. The Stolper-Samuelson prediction is thus rejected in only two of nine industries. Among the labor-intensive industries, OM and ME have correct and significant positive signs, and WD has the correct sign but is insignificant. In three of the five capital-intensive industries, correct significant negative effects occur. The signs of the other two industries do not coincide with theory, and CH has a significant positive sign. The Stolper-Samuelson mechanism performs about as well in both labor- and capital-intensive industries.

Table 2. Stolper-Samuelson Estimation: Regression Results of Equation (2) with Dependent Variable $(K/L)_i$

Industry[b]	In variable[a] (t-statistic)						R^2[c]	MSE[d]
	S_{ji}	p^t_{0i}	K^t_i	L^t_i	c^t_i	u^t_i		
TX	−0.08	−0.04	1.08	−0.84	−0.20	0.05	0.16	1.02
	(16.4)	(4.73)	(40.9)	(31.9)	(11.2)	(6.23)		
OM	0.04	−0.03	0.91	−0.66	−0.12	0.07	0.72	1.01
	(1.81)	(4.17)	(16.6)	(15.3)	(3.95)	(7.40)		
WD	0.07	0.002	0.90	−1.59	0.07	−0.03	0.97	1.05
	(1.24)	(0.17)	(24.2)	(11.6)	(2.21)	(3.02)		
ME	0.25	0.01	0.95	−1.04	0.10	0.01	0.69	1.05
	(31.3)	(1.70)	(106.7)	(82.6)	(18.6)	(2.31)		
PA	−0.27	−0.01	0.64	−0.93	0.02	0.04	0.97	1.03
	(9.86)	(2.00)	(23.4)	(35.2)	(2.44)	(5.50)		
FD	0.05	−0.02	0.73	−0.68	−0.02	0.03	0.97	1.02
	(1.46)	(3.12)	(27.4)	(20.8)	(1.13)	(4.20)		
NM	−0.35	−0.04	0.77	−0.77	0.05	0.06	0.98	1.03
	(30.8)	(19.3)	(53.5)	(63.6)	(9.01)	(22.6)		
CH	0.05	−0.004	0.84	−0.77	0.06	−0.02	0.56	1.07
	(2.28)	(0.63)	(31.1)	(19.8)	(4.81)	(3.18)		
BM	−0.24	−0.02	0.77	−1.24	0.01	−0.002	0.90	0.99
	(26.7)	(5.16)	(56.4)	(54.5)	(0.61)	(0.62)		

[a] S_{ji}, output share; p^t_{0i}, other prices; K^t_i, capital endowment; L^t_i, labor endowment; c^t_i, coefficient of variation in wages; u^t_i, unemployment.
[b] TX, textiles; OM, other manufactures; WD, wood, wood products; ME, machinery, equipment; PA, paper, printing, publishing; FD, food, beverages, tobacco; NM, nonmetallic minerals; CH, chemicals; BM, basic metals; MF, aggregate manufacturing.
[c] R^2, goodness of fit.
[d] MSE, mean square error.

The capital endowment K^t_i coefficient is significantly positive in every industry, and the labor endowment L^t_i significantly negative, which indicates that factor endowments affect input ratios and underlying factor prices. A higher manufacturing capital endowment means a higher ratio of wages to rents and a higher capital-labor ratio in each industry. A higher labor endowment lowers both the wage-rent ratio and the industrial capital-labor ratio. This result implies that the static factor-price equalization property does not hold in this data set. Factor prices depend on factor endowments. Rassekh (1993) uses the same data, however, and finds dynamic wage convergence in each of these industries.

The coefficient of variation in wages c^t_i is significant except in FD and BM. Significance means that enough wage variation occurs across industries and time to affect the industry's capital-labor ratio. The significance of c^t_i indicates that labor is not homogeneous or completely mobile across industries. There are ways to modify the Heckscher-Ohlin model to include imperfections in the labor market and maintain the basic intuition of the Stolper-Samuelson theorem. Including c^t_i as a variable allows the share coefficient to be interpreted as though the variation in wages were constant. The unemployment term u^t_i is significant in every industry except BM, which indicates that unemployment generally affects the capital-labor and wage-rent ratios.

Table 3. Specific-Factors Model: Regression Results of Equation (3) with Dependent Variable L^t_i[a]

Industry[c]	*ln variable*[b] (+– *statistic*) S^t_{ji}	p^t_{0i}	K^t_{ji}	L^t_i	c^t_i	u^t_i	R^2[d]	*MSE*[e]
TX	0.07	–0.03	0.63	1.20	0.28	–0.03	0.99	0.004
	(0.79)	(1.90)	(7.18)	(12.4)	(6.55)	(2.37)		
OM	0.06	–0.002	–0.01	0.44	0.11	–0.06	0.99	0.008
	(2.00)	(0.20)	(0.64)	(4.34)	(2.60)	(4.54)		
WD	0.33	0.01	–0.02	1.41	–0.10	0.05	0.99	0.002
	(6.69)	(0.67)	(0.22)	(14.3)	(2.08)	(3.28)		
ME	0.05	–0.02	0.11	1.16	–0.02	0.02	0.99	0.001
	(2.62)	(7.25)	(7.75)	(43.6)	(1.56)	(7.16)		
PA	0.17	0.004	–0.09	0.53	0.06	–0.05	0.99	0.003
	(5.52)	(0.43)	(1.89)	(7.99)	(2.61)	(5.67)		
FD	0.06	0.02	0.19	0.52	0.06	–0.01	0.99	0.002
	(2.29)	(2.67)	(3.59)	(12.1)	(3.31)	(2.50)		
NM	0.22	0.04	–0.05	1.18	–0.08	0.01	0.99	0.007
	(9.21)	(5.04)	(2.88)	(21.1)	(3.02)	(1.39)		
CH	0.07	–0.02	0.33	0.77	–0.06	0.04	0.99	0.001
	(3.66)	(3.95)	(9.31)	(19.9)	(2.89)	(6.29)		
BM	0.02	0.02	0.08	1.10	–0.06	0.02	0.99	0.010
	(1.17)	(2.91)	(1.26)	(15.7)	(1.93)	(2.17)		

[a] This model is estimated with capital inputs of other industries individually included, but these coefficients are not reported.
[b] S^t_{ji}, output share; p^t_{0i}, other prices; K^t_{ji}, capital stock in industry j; L^t_i, labor endowment; c^t_i, coefficient of variation in wages; u^t_i, unemployment.
[c] TX, textiles; OM, other manufactures; WD, wood, wood products; ME, machinery, equipment; PA, paper, printing, publishing; FD, food, beverages, tobacco; NM, nonmetallic minerals; CH, chemicals; BM, basic metals; MF, aggregate manufacturing.
[d] R^2, goodness of fit.
[e] MSE, mean square error.

Adjustment in the capital-labor ratio and the underlying wage-rent ratio can be expected to take some time. Equation (2) was also estimated including various combinations of several lags of the share variable. To determine the long-run impact, an econometric procedure described by Harvey (1990, chapter 7) is applied. Accordingly, (2) is estimated for each industry with the first and second lags of the share variable. The equation is then re-estimated with three lags. To determine the optimum lags, the Akaike Information Criterion described by Harvey (1990, p. 176) is applied. Results suggest that OM and WD need three lags, while the other industries need only two lags. The reported parameters for the share variable in Table 2 are calculated by summing the coefficients of the optimum lags.

7. An Empirical Specific-Factors Model

In estimating the specific-factors model, the capital input K^t_{ji} is assumed to be the specific factor in the isolated industry, and should be held constant. Therefore, K^t_{ji} becomes an exogenous variable. Industrial labor input L^t_{ji} is treated as the dependent variable. Capital input in each of the industries is also separately held constant. The following specific-factors equation is then estimated for each industry j:

$$L^t_{ji} = c_0 + c_1 s^t_{ji} + c_2 p^t_{0i} + c_3 K^t_{ji} + \sum_{h \neq j} c_h K^t_{hi} + c_4 L^t_i + c_5 c^t_i + c_6 u^t_i + \mu^t_{ji}. \tag{3}$$

Most variables in (3) are repeated from (2), and μ^t_{ji} represents a random-error term. Equation (3) is also estimated with a separate intercept for each country. The same discussion about using output shares as the Stolper-Samuelson variable applies in the specific-factors model.

A higher price in any industry in the specific-factors model lowers the ratio of wages to rents in the industry. In the present estimation, a higher output share in an industry should raise labor input. A positive c_1 is expected for every industry.

The total endowment of manufacturing labor is included as an exogenous variable. Coefficients for the total labor endowment and the capital inputs are not predicted to be zero as in the Heckscher-Ohlin model. Other industrial capital K^t_{ji} $(j \neq i)$ represents the input of capital in each of the other industries. An increase in the capital of another sector causes labor to be drawn away from sector j. Thus, the coefficients for K^t_{ji} are expected to be negative. An increase in the labor endowment L^t_i causes every industry to hire labor as wages fall. Thus, the coefficient c_4 should be positive.

Table 3 presents results from the pooled estimation of the specific-factors model in (3) for each industry. Heteroskedasticity and serial correlation of order one are again detected, and the Parks method is applied. The model is estimated in logarithms.

The coefficient c_1 of the output share s^t_{ji} is positive in every industry and significant except in TX and BM. The fact that c_1 is not negative in any industry is strong support for the specific-factors model.

An increase in the capital input K^t_{ji} in an industry should raise the labor input in the industry, as labor is attracted from other industries. Significant positive coefficients for K^t_{ji} occur in five industries (TX, ME, FD, CH, and BM) and only two significant negative signs occur (PA and NM). These coefficients are not reported to economize on space.

Increases in the labor endowment would be spread across industries, as the consistently significant positive coefficients indicate. The coefficient of variation in wages c^t_i is significant for every industry, as is unemployment u^t_i except for industry NM.

The Parks method used to estimate the two models does not automatically report the R^2. To calculate measures of goodness of fit, actual values of the dependent variables are regressed on their fitted values. The resulting measures are reported in Tables 2 and 3. These values should be interpreted only as an indication of goodness of fit because they may not have the usual distribution associated with ordinary least squares.

8. Conclusions

The specification in this paper captures the general-equilibrium predictions of the Stolper-Samuelson theorem and the specific-factors model using industrial data. In the Stolper-Samuelson theorem, the dependent variable is the ratio of capital to labor in each industry. Independent variables in the estimation are suggested by the assumptions of theory. In five of nine industries, results conform with the Stolper-Samuelson theorem, and its basic implication is rejected in only two industries. Treating industrial capital as specific and exogenous, an empirical specific-factors model is specified. Seven of nine industries conform with the basic prediction of the specific-factors model, and no industry presents a contradictory significant result.

The present paper's focus is on the general-equilibrium structure of production, not on differences in countries or on levels of international trade. Variation in output prices, positively correlated with outputs, typically have the predicted general-equilibrium effects on inputs. The Stolper-Samuelson theorem and specific-factors model apply across a wide range of common circumstances. These core theoretical models should not be dismissed offhand as empirically irrelevant.

The factor-proportions model springs from the way economists since Ricardo and Walras view an economy. There is a continuing challenge to formulate general-equilibrium models with many goods which clarify links between the prices of goods and the prices of factors. The present study shows that the Stolper-Samuelson theorem and specific-factors model, even in their simplest two-factor versions, have empirical content. Comparing the performance of the two models, the specific-factors model generates somewhat stronger results.

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