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Author(s): Michael Mussa
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Tariffs and the Distribution of Income: The Importance of Factor Specificity, Substitutability, and Intensity in the Short and Long Run

Michael Mussa

University of Rochester

This paper analyzes the effects of changes in relative commodity prices on the distribution of income among factors of production in the context of two models of a simple, two-good economy. In the first model capital is treated as a specific factor in each industry, with labor mobile between industries. The assumption of specificity determines the direction of factor income changes, with magnitudes depending on substitutability between factors and on intensities of factor use within the two industries. In the second model, capital is viewed as a quasi-fixed factor. For the short run, this model is identical to the model first considered. For the long run, this model is identical to the Stolper-Samuelson model in which the direction and magnitude of factor income changes depend solely on relative factor intensities. The difference between the short-run and long-run determinants of changes in factor incomes gives rise to a conflict between factor owners' short-run and long-run interests.

Introduction

A primary effect and principal objective of commercial policy is frequently to protect or enhance the incomes of specially favored groups. The modern theory of the effects of commercial policy on the distribution of income, the Stolper-Samuelson theory, however, is not adequate for analyzing much of the clamor for protection. This theory envisions an economy in which factors of production are costlessly and instantaneously mobile between productive activities and emphasizes the effects of differences in relative factor intensities. The theory suggests that if automobile

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manufacturing is capital intensive, then General Motors will favor increases in the tariff on automobiles and the United Auto Workers will oppose such increases; and, if textile manufacturing is labor intensive, then textile workers will favor quotas on textile imports, and domestic textile manufacturers will oppose them. What the theory neglects is that, in the short run, at least, factors tend to be specific to particular uses.[1] The stamping machines and assembly lines of automobile manufacturers are not costlessly transformable into the looms and weaving mills of textile manufacturers. The skills of a tool-and-die maker in Detroit are not instantaneously interchangeable with those of a master weaver in North Carolina.

The objective of this paper, however, is not to criticize the Stolper-Samuelson theory, but rather to integrate it with an earlier "Marshallian" approach. An integration of the two approaches is desirable because each lays emphasis on a different set of important phenomena. The "Marshallian" approach emphasizes the distinction between the short run and the long run.[2] For the short run, it focuses on specific factors and on the degree of substitutability between these factors and highly mobile factors. For the long run, it recognizes that factors that are specific in the short run often can be moved to alternative uses. The analysis of the long run is complemented by the Stolper-Samuelson theory, which assumes complete mobility of factors and focuses on general equilibrium interactions between factor endowments and the factor intensities of different productive processes.

The two approaches will be integrated within the context of two related models of a simple, two-good economy.[3] In the first model, capital will be treated as a fixed factor that is specific to the industry in which it is used, while labor will be assumed to be free to move between industries. These assumptions about factor mobility will suffice to determine the direction of changes in factor incomes in response to changes in output prices: the income of capital in each industry rises more than proportionately with increases in the price of its own output and falls with increases in the price of the other output; the income of labor rises less than proportionately with increases in either output price. The magnitude of factor income changes, however, will be shown to depend on the substitutability between labor and capital in each industry and on the factor intensities of the two industries.

The second model will preserve the structure of the first, except that

[1] In the introduction to their classic article, Stolper and Samuelson (1941) take note of the potential importance of specific factors, but do not integrate such factors into their formal analysis. In the more recent literature, specific factors have received relatively little attention. A notable exception is Jones (1971).

[2] For an excellent summary of the "Marshallian" approach to the analysis of the effects of commodity price changes on factor incomes, see Pigou (1906, especially pp. 55–59).

[3] In a recent paper, brought to my attention by the editor of this *Journal*, Mayer (1974) analyzes similar models, focusing on a slightly different set of issues.

capital will be treated as a quasi-fixed factor that is specific to a given industry at a moment of time, but free to move between industries in the long run. For the short run, this model is identical to the first model. For the long run, it is identical to the Stolper-Samuelson model. By using known properties of the Stolper-Samuelson model, it will be shown that the short-run and long-run determinants of the behavior of factor incomes are very different and that these differences necessarily imply a conflict between factor owners' short-run and long-run interests.

I. Factor Specificity and the Direction of Income Changes

Consider a two-commodity, three-factor model with the following properties. (1) There is a single mobile factor, labor, which is used in the production of both commodities, X and Z. (2) There are two specific factors, capital in X and capital in Z, which are used only in their respective industries, and which are in fixed supply to those industries. (3) The production functions for the two commodities are each linear homogeneous in their respective inputs and have the standard neoclassical properties of differentiability and of positive and declining marginal physical products for each of the inputs, specifically,

$$X = F(L_X, K_X), \tag{1}$$

$$Z = G(L_Z, K_Z). \tag{2}$$

(4) The total quantity of labor used in both industries is equal to the fixed aggregate supply of labor; that is,

$$L_X + L_Z = \bar{L}. \tag{3}$$

Given an initial relative price of X in terms of Z (within the range of nonspecialization), say P_X^0, the distribution of the labor force, the level of the wage rate, and the income of capital in X and capital in Z may be determined with the aid of figure 1. The length of the horizontal axis is equal to the total supply of labor, $\bar{L}$. The vertical axes passing through 0_X and 0_Z measure the wage of labor in terms of units of Z per unit of labor. The curve labeled $VMPL_X(P_X^0)$ is plotted relative to the origin 0_X and shows the value of the marginal product of labor in X as a function of L_X. The vertical position of this curve depends on the given value of the relative price of X, P_X^0. The curve labeled $VMPL_Z$ is plotted relative to the origin 0_Z and shows the value of the marginal product of labor in Z as a function of L_Z. Its position is independent of the commodity-price ratio. The point of intersection, (L^0, w^0), determines the equilibrium distribution of the labor force and the equilibrium value of the wage rate. The income of labor in X and the income of labor in Z are shown by the corresponding rectangular areas under the wage line, $w = w^0$. The incomes of the two types of capital are shown by the corresponding

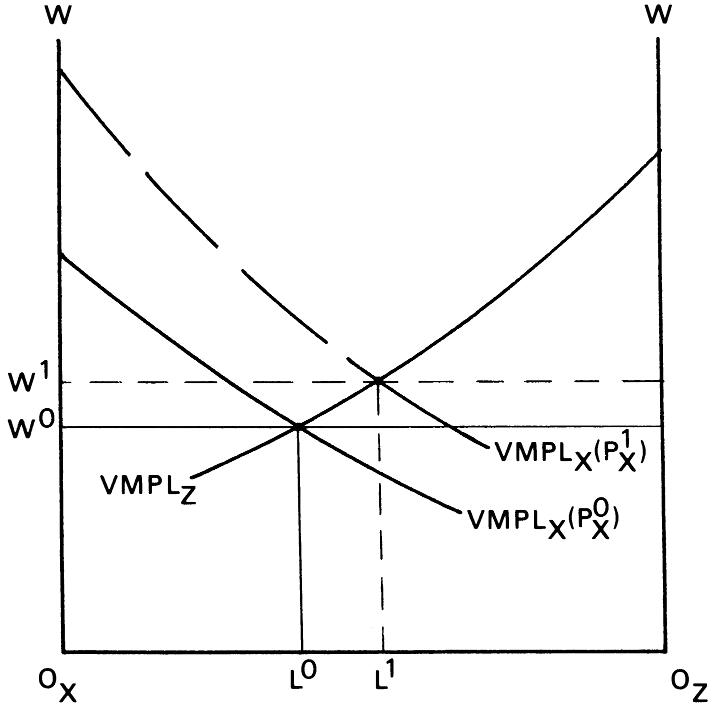

FIG. 1.—Equilibrium wage rate and allocation of the labor force

triangular regions between the wage line and the respective value of marginal product curves.

An increase in P_X, say from P_X^0 to P_X^1, shifts the $VMPL_X$ curve proportionately upward, resulting in a new equilibrium at (L^1, w^1). The increase in the wage rate (measured in terms of Z), however, is less than the proportionate increase in the relative price of X in terms of Z. Labor, the mobile factor, gains in terms of Z but loses in terms of X. In contrast, capital in X gains in terms of both commodities, and capital in Z loses in terms of both commodities.[4] The loss to capital in Z is apparent from the fact that the increase in the wage rate reduces the size of the triangular region which corresponds to the income to capital in Z. The gain to capital in X can be seen by considering only the units of X which were (and still are) produced by the original amount of labor, L^0. The value of these units of X rises proportionately with the increase in P_X. The cost of the labor employed in producing these units rises,

[4] Marshall (1961, p. 664), summarizes these results in the following words: "The employer stands as a buffer between the buyer of goods and all the various classes of labor by which they are made. He receives the whole price of the one and pays the whole price of the others. Fluctuations of his profits go with fluctuations of the prices of the things he sells, and are more extensive: while those of wages of his employees are less extensive."

but by less, proportionately, than the increase in P_X. Hence, the return to capital, on just these original units, must rise by more, proportionately, than the increase in P_X. Since capital in X also earns a positive amount on the additional units which are produced, it follows that capital in X must gain in terms of both goods.

The assumption of specific capital and mobile labor determines the direction of factor income changes in response to commodity-price changes. The property of "specificity," however, should not be conceived of as a wholly technological matter. If P_X is so high that all labor is specialized in the production of X, then the income of labor will respond in exactly the same way as the income of capital specific to X to an increase in P_X: both will increase proportionately with the increase in P_X. "Specificity" is an economic, as well as a technological, matter.

The results of the present model concerning the responses of factor incomes to changes in commodity prices can be interpreted in terms of the "Marshallian" concept of "rents". "Rents" are payments to factors of production in excess of what they can earn in their best alternative use. Since capital in each industry is specific to that industry, the incomes of both types of capital can be thought of as rents. In a sense, the payments to labor can also be thought of as "rents." For while the supply of labor to each industry is not absolutely fixed, the total supply of labor to both industries is fixed, and the supply of labor to any one industry is less than infinitely elastic. In fact, the supply curve of labor facing the X industry is precisely the $VMPL_Z$ curve looked at from the origin 0_X. It is because this supply curve is positively sloped that an increase in the demand for labor in X cannot be absorbed without an increase in the wage rate.

II. Substitutability, Intensity, and the Magnitude of Income Changes

In the model of the preceding section, the direction of factor income changes is completely determined by the assumption of specific capital and mobile labor. The magnitudes of factor income changes, however, depend on the substitutability between labor and capital in the two industries and on the intensities with which the two factors are used in the two industries. In this section, we will examine the magnitude of the factor income change, first for labor, then for the two specific types of capital, and finally for capital as a whole.

A. The Income of Labor

A formal expression for the change in the equilibrium wage rate may be obtained by using the labor-market equilibrium condition[5]

$$L_X^d(w/P_X, K_X) + L_Z^d(w, K_Z) = \bar{L}, \tag{4}$$

[5] An alternative approach to deriving a number of the results discussed in this section is given in Jones (1971).

where L_X^d and L_Z^d are the labor-demand functions for the two industries (the inverse of the *VMPL* functions). Differentiating equation (4), holding K_X and K_Z constant, we obtain

$$\hat{w} = \frac{\lambda_{LX}\zeta_X}{\lambda_{LX}\zeta_X + \lambda_{LZ}\zeta_Z} \hat{P}_X \equiv \eta \hat{P}_X, \tag{5}$$

where $\hat{w} \equiv dw/w$, $\hat{P}_X \equiv dP_X/P_X$,[6] and λ_{Li} is the fraction of the labor force employed in industry i, and ζ_i is the elasticity of demand for labor in industry i. The magnitude η, which is defined in (5), is the elasticity of the wage rate with respect to the relative price of X. By making use of the fact that the elasticity of demand for labor in each industry can be written as

$$\zeta_i = \frac{\sigma_i}{1 - \theta_{Li}}, \tag{6}$$

where σ_i is the elasticity of substitution between labor and capital in industry i, and θ_{Li} is the distributive share of labor in the value of output in industry i, the elasticity η may be rewritten as[7]

$$\eta = \frac{\lambda_{LX}\left(\frac{\sigma_X}{1 - \theta_{LX}}\right)}{\lambda_{LX}\left(\frac{\sigma_X}{1 - \theta_{LX}}\right) + \lambda_{LZ}\left(\frac{\sigma_Z}{1 - \theta_{LZ}}\right)}. \tag{7}$$

The result (6) shows the importance of factor substitution and factor intensity (as measured by distributional shares) for the responsiveness of the wage rate to changes in P_X. Holding the λ's and θ's constant, when σ_X is large and σ_Z is small, the behavior of the wage rate follows very closely the behavior of P_X. Geometrically, the reason for this is that the $VMPL_X$ curve is very flat, while the $VMPL_Z$ curve is very steep; vertical shifts in the $VMPL_X$ curve, therefore, result in virtually equal changes in the equilibrium wage rate. The same result obtains when θ_{LX} is large and θ_{LZ} is small, and for the same reason. Factor substitutability and factor intensity affect the responsiveness of the wage rate in the same way because both have similar effects on the elasticities of demand for labor in the two industries. From equation (5) it is apparent that these elasticities are the determinants of the elasticity of the wage rate with respect to P_X.

[6] We will use a caret to indicate the operation of taking a percentage change.

[7] I am indebted to Carlos Rodriguez for suggesting the rewriting of eq. (5) in the form of eq. (7).

B. The Income of Specific Capital

The income of capital in each industry is determined as a residual after payments to labor:

$$Y_{KX} = P_x X - wL_X; \qquad Y_{KZ} = Z - wL_Z. \tag{8}$$

By differentiating these equations, making use of the fact that the wage rate is equal to the value of the marginal product of labor in each industry, and expressing the results in elasticity form, it follows that

$$\hat{Y}_{KX} = \left(\frac{1}{\theta_{KX}}\right)(1 - \theta_{LX}\eta)\hat{P}_X, \tag{9}$$

$$\hat{Y}_{KZ} = \left(\frac{-1}{\theta_{KZ}}\right)(\theta_{LZ}\eta)\hat{P}_X, \tag{10}$$

where $\theta_{KX} \equiv Y_{KX}/P_x X = 1 - \theta_{LX}$ and $\theta_{KZ} \equiv Y_{KZ}/Z = 1 - \theta_{LZ}$. The slight asymmetry between (9) and (10) arises because Z has been taken as the numeraire.

The results in equations (9) and (10) demonstrate the importance of factor intensities and, indirectly, of factor substitutability for the magnitudes of $\hat{Y}_{KX}$ and $\hat{Y}_{KZ}$. The degree of substitutability between labor and capital in the two industries affects these results through its influence on η. From (7) it follows that an increase in σ_X or a decrease in σ_Z will decrease the absolute value $\hat{Y}_{KX}$ and increase the absolute value of $\hat{Y}_{KZ}$. The essential symmetry of this result may be seen more clearly when it is restated as follows: the greater the elasticity of substitution between labor and capital in a given industry, relative to what it is in the other industry, the more closely the income of labor and the income of capital in that industry mirror the behavior of the price of that industry's output. When σ_X is relatively large, both $\hat{w}/\hat{P}_X$ and $\hat{Y}_{KX}/\hat{P}_X$ tend to be close to unity.

The value of η can be thought of as determining the degree of "effective protection" which is afforded to the two types of specific capital. From the viewpoint of the owners of capital, labor is purchased input, just as material inputs would be purchased inputs if intermediate goods were used in production. If the price of the purchased input (i.e., the wage rate) were to remain constant when P_X rises, then the degree of "effective protection" afforded to capital in X (as measured by $\hat{Y}_{KX}$) would equal $\hat{P}_X/\theta_{KX}$. The fact that the wage rate rises when P_x rises means that the degree of "effective protection" which is afforded to capital in X is smaller than $\hat{P}_X/\theta_{KX}$ by the amount $(\theta_{LX}/\theta_{KX})\hat{w}$. From the standpoint of the owners of capital in Z, the increase in the wage rate which is induced by an increase in P_X means that capital in Z suffers from "negative effective protection" to the extent of $(\theta_{LZ}/\theta_{KZ})\hat{w}$.

The importance of factor intensities is also apparent in equations (9) and (10). The inverse of capital's share in each industry determines the "leverage" of that type of capital with respect to changes in relative commodity prices. When capital's share is unity, the income of capital moves in proportion with the price of its output. As capital's share decreases, the percentage change in the income of capital increases with the inverse of capital's share.

Formally, differentiating (9) and (10) with respect to θ_{KX} and θ_{KZ}, holding η constant, we obtain

$$\frac{d\hat{Y}_{KX}}{d\theta_{KX}} = \frac{-(1-\eta)}{(\theta_{KX})^2}\hat{P}_X, \tag{11}$$

$$\frac{d\hat{Y}_{KZ}}{d\theta_{KZ}} = \frac{\eta}{(\theta_{KZ})^2}\hat{P}_X. \tag{12}$$

It follows that the greater the intensity of capital in an industry, the more closely the income of that capital mirrors the price of its output (e.g., the greater θ_{KX}, the closer is $\hat{Y}_{KX}/\hat{P}_X$ to unity). On the other hand, the leverage effect says that the smaller the intensity of capital in a particular industry, the more strongly the income of that capital responds the price of its output (e.g., the smaller θ_{KX}, the larger is $\hat{Y}_{KX}/\hat{P}_X$). However, both of these conclusions may be reversed if the indirect effects of changes in factor intensities on the value of η (holding σ_X and σ_Z constant) are incorporated into the results (11) and (12).

C. The Income of Capital as a Whole

The question of what happens to the income of capital as a whole when P_x rises is likely to be interesting if ownership of the two types of capital is widely diversified within the capital-holding class. Diversification is to be expected if the claims to the ownership of the two types of capital are fairly easily marketable. In such a circumstance, the negative correlation between the incomes of the two types of capital which will be produced by relative price changes will provide a strong incentive to portfolio diversification and, hence, lead the capital-holding class to be more concerned with the income of capital as a whole rather than with the income of either specific type of capital.

The income of capital as a whole, Y_K, is given by

$$Y_K = Y - wL = (P_X X + Z) - wL. \tag{13}$$

If we differentiate this equation, making use of the fact that $dY = XdP_X$, and express the result in elasticity form, it follows that

$$\begin{aligned}\hat{Y}_k &= \frac{1}{\theta_K}(\hat{Y} - \theta_L\hat{w}) \\ &= \frac{1}{\theta_K}(\beta_X - \theta_L\eta)\hat{P}_X,\end{aligned} \tag{14}$$

where $\theta_K \equiv Y_K/Y$, $\theta_L \equiv Y_L/Y$, and $\beta_X \equiv P_X X/Y$. From equation (14) it is apparent that the income of capital as a whole may either rise or fall as a result of an increase in P_X. A decline is likely when the aggregate share of labor, θ_L, and the elasticity of the wage rate, η, are large, and when the share of X in the value of total output is small.

The second line of equation (14) is identical to the result given in equation (9) for the value of $\hat{Y}_{KX}$, except that the fraction β_X has replaced the number 1. As in the case of Y_{KX}, the inverse of θ_K determines the leverage of capital as a whole with respect to changes in P_X, and the value of η determines the degree of effective protection which is afforded to capital as a whole. The importance of the elasticities of substitution and distributional shares within industries for the value of $\hat{Y}_K$ is apparent from the roles which these parameters play in the determination of η.

III. Capital as a Quasi-fixed Factor

The analysis of the last two sections can be given an added dimension by viewing capital as a quasi-fixed factor.[8] In the short run, each unit of capital is specific to the industry in which it is engaged. The short-run effects of a change in relative commodity prices are exactly as described in the last two sections. Over time, however, capital can move from one industry to another in search of its highest reward. Long-run equilibrium requires that the distribution of the capital stock be such that the value of the marginal product of capital is equal in the two industries.

A. The Effects of a Shift of Capital

Starting from an initial long-run equilibrium, an increase in P_X leads to a short-run equilibrium in which the value of the marginal product of capital in X exceeds the value of the marginal product of capital in Z. Capital moves from Z to X. To determine the effect on the wage rate of a redistribution of the capital stock, differentiate the short-run equi-

[8] For many applied problems, it is appropriate to think of labor, as well as capital, as a quasi-fixed factor. See Oi (1962) on the subject of labor as a quasi-fixed factor.

librium condition (4) with respect to K_X and K_Z, impose $dK_Z = -dK_X$, and make use of the fact that linear homogeneity of the production functions implies $\partial L_i^d/\partial K_i = L_i/K_i$, to conclude that

$$\hat{w} = \frac{-1}{\lambda_X \zeta_X + \lambda_Z \zeta_Z} [(L_X/K_X) - (L_Z/K_Z)](dK_X/\bar{L}). \tag{15}$$

Further, if we make use of (6), this result can be rewritten as

$$\hat{w} = \frac{-(\theta_{LX} - \theta_{LZ})}{\lambda_X \sigma_X(1 - \theta_{LZ}) + \lambda_Z \sigma_Z(1 - \theta_{LX})} (r/w)(dK_X/\bar{L}), \tag{16}$$

where r is the rental rate on capital at the initial long-run equilibrium (measured in terms of Z).[9]

Since the elasticities which appear in the denominators of equations (15) and (16) are negative, it follows that the direction of the change in the wage rate which results from the shift of an initial unit of capital from Z to X depends only on the long-run relative factor intensities of the two industries, as measured by either the factor ratios or by distributional factor shares. As suggested by the Stolper-Samuelson theorem, the wage rate rises if and only if X production is relatively labor intensive.[10] Note, however, that the magnitude of the change in the wage rate which results from the shift of an initial unit of capital also depends on the degree of substitutability between labor and capital in the two industries.

Geometrically, what is happening is that the shift of capital shifts both the $VMPL_X$ curve and the $VMPL_Z$ curve of figure 1 to the right. The wage rate rises if and only if the horizontal shift of the $VMPL_X$ curve exceeds the horizontal shift of the $VMPL_Z$ curve, at $w = w^1$. The latter condition is satisfied if and only if the L_X^1/K_X^0 is greater than $L_Z^1 K_Z^0$.[11]

B. Long-run Equilibrium and the Stolper-Samuelson Model

In the long run, capital is completely mobile between industries, and the model presented in Section I reduces to the Stolper-Samuelson model in which direction of change in factor incomes induced by an increase in P_X depends only on the (long-run) relative factor intensities of X and Z.

[9] Recall that we are considering small changes, starting at a position of initial long-run equilibrium.

[10] If X production is capital intensive in the long run, then a large increase in P_x may result in a short-run reversal of the relative factor proportions (which is not the same thing as a "factor intensity reversal" in the Stolper-Samuelson model). In this event, the wage rate will initially rise as capital begins to shift. However, once the original relationship between factor proportions has been restored, the wage rate will start to fall and must eventually fall below its previous long-run equilibrium value.

[11] From linear homogeneity of the two production functions, it follows that the horizontal shift of the *VMPL* curve which results from the shift of one unit of capital is proportional to the labor-capital ratios in the respective industries.

The factor that is used relatively intensively in the production of X gains in terms of both goods, and the other factor loses in terms of both goods. Further, from Jones's results it is also known that, at least for small increases in P_X, the magnitude of factor income changes in the Stolper-Samuelson model depends only on factor intensities.[12]

Formally, differentiating the zero-profit restrictions for the two industries (which requires that the weighted sums of factor prices equal the respective output prices, where the weights are the amounts of labor and capital used to produce a unit of output) and expressing the results in terms of percentage changes, it follows that

$$\theta_{LX}\hat{w} + \theta_{KX}\hat{r} = \hat{P}_X, \tag{17}$$

$$\theta_{LZ}\hat{w} + \theta_{KZ}\hat{r} = 0. \tag{18}$$

Solving for $\hat{w}$ and $\hat{r}$ yields

$$\hat{w} = \frac{\theta_{KZ}}{\theta_{LX} - \theta_{LZ}} \hat{P}_X, \tag{19}$$

$$\hat{r} = \frac{-\theta_{LZ}}{\theta_{LX} - \theta_{LZ}} \hat{P}_X. \tag{20}$$

These results reveal great differences among the parameters that are important for determining the direction and magnitude of factor income changes in the long run, after redistribution of the capital stock is complete; and those that are relevant in the short run, in which capital is assumed to be fixed; or during the period of adjustment of the capital stock. In the short run, the direction of factor income changes is wholly determined by the assumption that labor is mobile while capital is immobile: labor gains in terms of Z and loses in terms of X when P_X rises, while capital in X gains in terms of both goods and capital in Z loses in terms of both goods. The magnitude of short-run changes in factor incomes depends on the degree of substitutability between capital and labor in the two industries and on the factor intensities in the two industries. During the period of adjustment, directions of income changes depend only on factor intensities, but magnitudes also depend on substitutability. In the long run, the direction of factor income changes depends only on the difference in factor intensities between the two industries, $\theta_{LX} - \theta_{LZ}$, and the magnitudes of factor income changes are independent of the degree of substitutability between capital and labor in either industry.[13] Further, the Stolper-Samuelson model, which is relevant for long-run

[12] See Jones (1965) for a more complete explanation of the derivation of the results discussed in this paragraph.

[13] This is apparent from the fact that the elasticities of substitution do not enter into (19) and (20). These results are unaffected by assuming a fixed-coefficients technology for which the elasticity of substitution in each industry is zero.

analysis, has a "knife edge" property which has no counterpart in the short run. From (19) and (20) it follows that for a given value of $\hat{P}_X$ the magnitude of the implied factor imcome changes becomes very large as the factor intensities of the two industries come close together. Thus, capital gains from an increase in P_X provided that X is relatively capital intensive, but capital gains the most when the intensity differential is the smallest.

Conclusion: The Conflict between Short-Run and Long-Run Interests

These differences between the determinants of short-run and long-run changes in factor incomes imply a conflict between factor owners' short-run and long-run interests with respect to commodity prices. Consider any policy which results in an increase in P_X. If X production is relatively capital intensive, then laborers gain in the short run in terms of X but lose in the long run in terms of both goods, and the owners of capital initially employed in Z lose in the short run in terms of both goods but gain in the long run in terms of both goods. On the other hand, if X production is relatively labor intensive, then, even though capital initially employed in X gains in terms of both goods in the short run, it loses in terms of both goods in the long run; and, even though labor loses in terms of X in the short-run, it gains in terms of both goods in the long run. Hence, no matter what the factor intensities of the two industries, there must be at least one factor whose long-run interest runs counter to its short-run interest. Further, if the factor intensities of the two industries are similar, then, in the long run, large changes in factor incomes will be required to accommodate small changes in commodity prices. Not only will some factor's short-run interest differ from its long-run interest, but it will differ a great deal.

Appendix

Generalization of the Results of Section II to an N Commodity, $N + 1$ Factor Model

The results which were obtained for the simple, two-good, three-factor model in Section II generalize in a straightforward way to a model with N commodities, each produced with its own specific capital and mobile labor.[14] Equilibrium in the distribution of the labor force requires that the value of the marginal product of labor be equated across industries. If a government policy produces a vector of commodity price changes $(dP_1, dP_2, \ldots, dP_N)$, then, differentiating the equi-

[14] The results presented in this Appendix can also be applied to the case where there are many different firms, each with its specific capital, all producing two or more commodities.

librium condition and expressing the result in the form of percentage changes, it follows that

$$\hat{w} = \sum_{i=1}^{N} \mu_i P_i, \tag{21}$$

where $\hat{P}_i \equiv dP_i/P_i$ and

$$\mu_i = \frac{\lambda_{Li}\zeta_{Li}}{\sum_{j=1}^{n} \lambda_{Lj}\zeta_{Lj}} = \frac{[\lambda_{Li}/(1 - \theta_{Li})]\sigma_i}{\sum_{j=1}^{n} [\lambda_{Li}/(1 - \theta_{Lj})]\sigma_j}, \tag{22}$$

where $\lambda_{Li} \equiv L_i/\bar{L}$, $\theta_{Li} \equiv wL_i/P_iX_i$, ζ_{Li} is the elasticity of demand for labor in industry i, σ_i is the elasticity of substitution between labor and capital in industry i, and X_i is the output of good i. Further, using the same procedures as in Section II, it follows that

$$\hat{Y}_{Ki} = \left(\frac{1}{\theta_{Ki}}\right)(\hat{P}_i - \theta_{Li}\hat{w}), \tag{23}$$

$$\hat{Y}_K = \left(\frac{1}{\theta_K}\right)(\hat{Y} - \theta_L\hat{w}), \tag{24}$$

where $\theta_{Ki} \equiv Y_{Ki}/P_iX_i$, $\theta_K \equiv Y_K/Y$, $\theta_L \equiv Y_L/Y = w\bar{L}/Y$, $Y \equiv \sum_{i=1}^{N} P_iX_i$, $\beta_i \equiv P_iX_i/Y$, and

$$\hat{Y} = \sum_{i=1}^{N} \beta_i\hat{P}_i \tag{25}$$

Inspection reveals that all of these results are direct analogues of the results for the two-good case and reduce to the two-good results when $N = 2$.

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