Protection and Real Wages:
The Stolper-Samuelson Theorem

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> *Second only in political appeal to the argument that tariffs increase employment is the popular notion that the standard of living of the American worker must be protected against the ruinous competition of cheap foreign labor....Again and again economists have tried to show the fallaciousness of this argument.*

Thus begins Stolper and Samuelson's (1941) analysis of the effect of protection on real wages, a landmark contribution to the modern theory of international trade. The central result, now known as the Stolper-Samuelson theorem, is that "international trade necessarily lowers the real wage of the scarce factor expressed in terms of any good." The paper signals a transition in the debate among international economists concerning the welfare consequences of free trade, from largely verbal reasoning toward the use of formal general-equilibrium models. Derived in a simple framework of two homogeneous factors, each freely mobile between two domestic industries, the Stolper-Samuelson theorem is striking because it demonstrates that a productive factor's ability to relocate from an import-competing to an export industry does not prevent a loss in real income due to expanded trade. Moreover, it shows that the sharp redistributive consequences of trade do not depend on tastes or expenditure patterns.

Birth of a theorem

According to Samuelson (1994), the collaboration arose from Wolfgang Stolper's efforts to reconcile the new general-equilibrium trade theory with the work of earlier economists: "How can Haberler and Taussig be right about the necessary harm to a versatile factor like labor from America's tariff, when the Ohlin theory entails that free trade must hurt the factor that is scarce

relative to land?" Stolper's friend and junior colleague, first the sounding board, eventually became "the midwife, helping to deliver Wolfie's brain child." The infant prospered.

Earlier analyses of the effect of free trade on real wages had emphasized the implications of trade for productive efficiency. In the long run, free trade would increase demand for the country's comparative-advantage goods and thereby shift employment toward the domestic industries where labor is most productive. The classical economists had typically assumed a one-factor model or, equivalently, that productive factors were used in unvarying proportions both within and across industries. In either case, trade could have no redistributive consequences within a country. Although Stolper and Samuelson's teachers and contemporaries recognized the implications of changing factor proportions for income shares, their analyses were based on a partial-equilibrium model of a protected industry. While elimination of tariffs might cause the money wage to fall, the resulting reduction in the prices of the goods workers buy with their wages was presumed to be larger. The *real* wage was thus anticipated to rise, at least in terms of imported goods and most likely overall, though the effect would depend on the relative importance of imported and exported goods in workers' total expenditure.[1]

The general-equilibrium trade theory introduced by Eli Heckscher and Bertil Ohlin opened a new line of inquiry focusing on differences in relative factor intensity across industries and differences in relative factor abundance across countries.[2] Stolper and Samuelson adopted

[1] Stolper and Samuelson provide illustrative quotations and references. One quote from Haberler rejects the possibility of equalization of wages across countries unless labor is internationally mobile. As of 1941, Stolper and Samuelson agreed, noting that "there will be a tendency—necessarily incomplete—toward an equalisation of factor prices" due to trade. A few years later, however, Samuelson (1948, 1949) would show that, under stipulated conditions, free trade alone is sufficient to equalize factor prices. A footnote to Samuelson (1949) indicates that Abba Lerner presented essentially the same result in a 1933 paper prepared for a seminar at the London School of Economics. Perhaps due to Samuelson's acknowledgement, the paper was finally published as Lerner (1952).

[2] Ohlin's landmark treatise was published by Harvard University Press in 1933. The basic work by Heckscher and by his student Ohlin had been available a decade earlier, but only in Swedish. Heckscher's seminal 1919 article

this approach and coined the now-standard terminology "Heckscher-Ohlin theorem" to refer to the proposition that "each country will export those commodities which are produced with its relatively abundant factors of production, and will import those in the production of which its relatively scarce factors are important."

The Stolper-Samuelson analysis

Formalizing the logic of the Heckscher-Ohlin model, Stolper and Samuelson assumed two homogeneous goods A and B, each produced under constant returns to scale using labor L and capital K, but with good A using more capital relative to labor than good B. The two factors were assumed fixed in total supply but freely mobile between the country's two industries:

$$L_A + L_B = \bar{L} \text{ and } K_A + K_B = \bar{K} .$$

The two full-employment conditions together imply that the economy's overall capital-labor ratio $\bar{k}$ can be expressed as the weighted average of the capital-labor ratios k_A and k_B used in the two industries:

$$\lambda_A k_A + \lambda_B k_B = \bar{k} ,$$

where $\lambda_A = L_A / \bar{L}$ and $\lambda_B = L_B / \bar{L}$ are the shares of the total labor supply used in the two industries, $\lambda_A + \lambda_B = 1$. Thus, as the production mix moves toward specialization in good A and λ_A approaches unity, the capital-labor ratio used in A production must fall toward $\bar{k}$.

Factor mobility and perfect competition together imply that the equilibrium factor returns w and r are equal across industries, and the return to each factor is equal to the value of its marginal product in that industry:

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finally appeared in English translation in 1950 in a collection of fundamental contributions to the theory of international trade published by the American Economic Association.

$$w = p_A \frac{\partial A}{\partial L_A} = p_B \frac{\partial B}{\partial L_B},\ r = p_A \frac{\partial A}{\partial K_A} = p_B \frac{\partial B}{\partial K_B}.$$

The ratio of the marginal physical products of the two factors must therefore be equal across industries:

$$\frac{\partial A / \partial K_A}{\partial A / \partial L_A} = \frac{\partial B / \partial K_B}{\partial B / \partial L_B}.$$

Stolper and Samuelson used an Edgeworth-Bowley box diagram to represent the model geometrically. Each point in the box represents a feasible full-employment allocation of the factors between the two industries.[3] Points along the contract curve indicate alternative efficient allocations of the two factors between industries and thus alternative efficient output combinations for the economy, with a one-to-one correspondence between points on the contract curve and points on the economy's production possibility frontier. At the corners of the box representing specialization in one of the two products, the capital-labor ratio in the industry of specialization must equal the country's overall capital-labor ratio. In between, where both goods are produced, the capital-labor ratios in the two industries change systematically, with both falling monotonically as the economy moves from production only of labor-intensive B toward production only of capital-intensive A. As a consequence of the changing capital-labor ratios in the two industries, the physical marginal product of labor must fall, and the physical marginal product of capital must rise, in both industries as the economy produces more A and less B.

The actual output combination produced depends on the relative price p_A / p_B. Although their original motivation was to shed new light on the effect of protection on wages, Stolper and Samuelson avoided further consideration of the details of trade by focusing on the resulting

[3] This appears to be the first use of the Edgeworth-Bowley box to analyze efficient production—earlier uses of the diagram had dealt with efficiency in exchange.

change in the domestic relative price of the goods.[4] Their result is thus applicable to a change in relative price that occurs for any other reason. Trade would reduce the relative price of the import-competing good, which by the Heckscher-Ohlin theorem was assumed to be labor-intensive B for the United States, a labor-scarce country.[5] The lower relative price of good B would cause a shift in the economy's production toward good A—a movement along the production possibility frontier and the contract curve in the Edgeworth-Bowley box. If each industry were to use the same factor proportions as before, the change in output mix would raise the country's total demand for capital and reduce its total demand for labor. Given fixed total factor supplies and full employment of both factors before and after the rise in relative price of good A, the new output mix would thus be feasible only if both industries were now to employ a lower capital-labor ratio, or equivalently, if there was a rise in the rental-wage ratio facing the firms in both industries. These lower capital-labor ratios imply a lower marginal physical product of labor in both industries and thus an unambiguously lower real wage (and higher real rental) measured in terms of *either* good. This outcome is independent of the pattern of consumption.

Stolper-Samuelson and the simple general-equilibrium model

Although the Stolper-Samuelson argument based on varying factor demand and fixed factor supply is intuitively appealing, their key result does not actually require fixed factor supplies. An alternative proof hinges on the observation that with constant returns and perfect

[4] Samuelson (1939) used the same simplification in examining a country's gains from trade.

[5] This was of course long prior to Leontief (1954) and illustrates the ready acceptance by international economists of the empirical validity of the Heckscher-Ohlin theory.

competition, both industries can maintain positive output only if both yield equal (zero) economic profits. As neatly laid out in Jones (1965),[6] the price of each good produced must in equilibrium be equal to its unit production cost:

$$p_A = a_{LA}(w/r)w + a_{KA}(w/r)r$$

$$p_B = a_{LB}(w/r)w + a_{KB}(w/r)r\,,$$

where $a_{ij}(w/r)$ indicates the cost-minimizing input of factor i in producing one unit of good j. With the assumption that the two industries differ in relative factor intensity, and given the money prices of the two goods, these two equations can be solved to obtain unique equilibrium factor rewards r and w consistent with production of both goods, as well as the real returns expressed in terms of either good.[7]

Jones derived corresponding "equations of change" that show the comparative statics of the model. To restore equilibrium, any change in the price of either good must be matched by an equal change in its unit cost of production. The proportional change in each good's production cost can be expressed as a weighted average of the proportional changes in the factor rewards, with a larger weight on the change in wages for the labor-intensive good:

$$\theta_{LA}\hat{w} + \theta_{KA}\hat{r} = \hat{p}_A$$

$$\theta_{LB}\hat{w} + \theta_{KB}\hat{r} = \hat{p}_B\,,$$

where θ_{ij} indicates factor *i*'s share in the total cost of producing good *j* and $\hat{x}$ is the proportional change in *x*. For the case considered by Stolper and Samuelson, where trade raises the relative price of capital-intensive good A, these conditions imply:

[6] Ronald Jones was Stolper's student at Swarthmore and then Samuelson's student at MIT.

[7] Factor supplies do enter by the back door. The required equilibrium condition that the price of each good must equal its production cost applies only if both goods are produced at home, i.e., if the country's factor endowment lies within its "cone of diversification."

$$\hat{w} < \hat{p}_B < \hat{p}_A < \hat{r}\,.$$

Jones called this relationship the magnification effect--a rise in the relative price of a good is accompanied by a *magnified* increase in the equilibrium return to the factor used intensively in its production and a decrease in the real return to the other factor.

Jones's reformulation of the Stolper-Samuelson theorem highlights its broad applicability. In the context of the basic model of two goods, two factors freely mobile between industries, constant returns to scale, and diversified production, Jones's version shows the "magnified" consequences for equilibrium real factor prices of *any* change in the relative price of the goods. Regardless of its cause, and even in a closed economy, a fall in the relative price of the labor-intensive good must be accompanied by a decrease in the corresponding equilibrium real wage and a rise in the real return to the other factor. The redistributive effect of adding or removing a tariff, or of moving toward or away from autarky, is a special case.

The proof based on equality of cost and production price also shows that the theorem holds even when each industry uses factors in fixed proportions, i.e., when the production isoquants are L-shaped rather than smoothly curved, as had been assumed by Stolper and Samuelson.[8] With additional assumptions (free trade, no factor-intensity reversal, a second country with the same production technology), Samuelson's factor-price equalization theorem follows directly from the same formulation of the model. When free trade equalizes product prices between countries, factor rewards in each country must satisfy the same set of equations

[8] The production possibility frontier in this case is made up of two linear segments, and the output combination at their intersection is the only one consistent with full employment of both factors. This output combination is consistent with a range of relative prices and corresponding factor rewards, even though the capital-labor ratios used in producing the goods do not change.

(unit cost must equal price for each of the two goods). This argument is similar in spirit to Lerner's (1952) geometric proof of factor-price equalization.[9]

Stolper-Samuelson's seminal role

As with other path-breaking papers, "Protection and Real Wages" did not immediately find favor with journal editors. Howard Ellis and Paul Homan of the *American Economic Review* read the paper and agreed (as stated in Homan's rejection letter to Samuelson) that it "is a brilliant theoretical performance" but also "a very narrow study in formal theory, which adds practically nothing to the literature." Not to mention "practically a complete 'sell-out'"—this no doubt because the key result might offer intellectual comfort to protectionists.[10] Still, a positive response from Ursula Hicks at the *Review of Economic Studies* came less than half a year later—and the rest is history.[11]

The huge literature built upon the Stolper-Samuelson theorem has proceeded in many directions, with contributors constituting a veritable who's who of international trade theory.[12] Theoretical papers, including several by Samuelson, have systematically explored the robustness

[9] Lerner's paper and a comment by I. F. Pearce in the same issue of *Economica* introduced the Lerner-Pearce diagram into general use. The Lerner-Pearce diagram can be used to prove the Stolper-Samuelson theorem, as demonstrated in Deardorff (1994). Because this proof does not require calculus, it is now used in some undergraduate textbooks. Although the proof appears in my 1967 lecture notes from Harry Johnson's course in international trade theory at the University of Chicago, I have been unable to track down its earliest appearance in the literature.

[10] As published, the paper ends with an effort to defuse any potential "political ammunition for the protectionist" by noting that "it is always possible to bribe the suffering factor…so as to leave all factors better off." Does a bigger pie really allow everyone to enjoy a larger slice? It is difficult to identify even a single case in which losers from a government policy choice have received full compensation, and in fact proposed changes in trade policy are often rationalized in terms of their anticipated redistributive consequences.

[11] Both letters are reproduced in Deardorff and Stern (1994). Young economists coping with today's publish-or-perish environment may take heart from the initial rejection of this iconic work but may weep with envy over the speed with which the paper went from inspiration to print.

[12] Several key contributions are reprinted in Deardorff and Stern (1994). The volume's annotated bibliography lists many others.

of the result by relaxing each of the assumptions used in the original derivation. One important strand focuses on a question that Stolper and Samuelson raised in their paper but did not subject to detailed analysis: how well does the theorem generalize beyond the special world of two goods and two factors? As summed up in Wilfred Ethier's (1984) survey of this literature, the Stolper- Samuelson theorem survives, but in a "nonexclusive" sense. With more goods and more factors, *at least one* factor stands to gain unambiguously from trade, and *at least one* factor stands to lose unambiguously. The basic message of the original theorem is thus maintained: even when free trade raises national income overall, some factors may lose in the absence of compensation. But identifying specific gainers and losers becomes more complex, and intuition based on the two-by-two case may prove to be an unreliable guide; Edward Leamer (1994) demonstrates the failure in a three-by-three world of several plausible generalizations of the two-by-two version of Stolper-Samuelson. For example, it is not necessarily true that a country's "scarce" factors will lose from trade.

Another direction of inquiry returns to the original sharp focus of the theorem and asks how well its predictions can explain observed behavior in the political sphere. In voting or lobbying, do factor owners act as if they believe the Stolper-Samuelson theorem? Stephen Magee (1980) showed that the rival "specific factors" model, with two immobile industry-specific factors and one mobile factor, is more consistent with the lobbying positions of labor and capital. In retrospect, this result should not be surprising. The Stolper-Samuelson theorem is based on perfect factor mobility within a country, and thus its implications are best understood as long-term tendencies. Even assuming that factor owners seek to maximize the present

discounted value of their lifetime earnings, the more immediate impact is likely to dominate.[13] Later work with William Brock and Leslie Young (Magee, Brock, and Young 1989), which modeled protection as endogenous, again found that the specific-factors model explains short-run lobbying (time series data), but that Stolper-Samuelson works better in explaining patterns of protection across countries (cross-national data).[14] A new generation of scholars has continued the debate, e.g., Eugene Beaulieu and Christopher Magee (2004).[15]

An essential tool for economists

Notwithstanding the hundreds or perhaps by now thousands of scholarly contributions that the Stolper-Samuelson paper has inspired,[16] its real significance may be somewhat different. By linking output prices to equilibrium factor rewards, Stolper and Samuelson filled an important gap in the general equilibrium model. Together with the other key elements of the Heckscher-Ohlin model, the stripped-down basic version of Stolper and Samuelson has become an essential part of the intellectual tool kit of every international economist and is now found in every international trade textbook.[17] Like the supply and demand curves of partial-equilibrium analysis, the simple Heckscher-Ohlin model provides the first back-of-the-envelope attack on an

[13] Robert E. Baldwin (1984) examined an intermediate model in which sector-specific labor skills give rise to labor rents. As a consequence, workers may not find it worthwhile to move between industries when relative output prices change.

[14] Magee (1994) provides a brief summary of the results.

[15] In this case it is literally a new generation; Christopher Magee is the son of Stephen P. Magee. He is also the student and coauthor of Robert E. Baldwin, an early and influential contributor to the literature on the political economy of trade policy.

[16] The inspiration has evidently continued into the 21st century. Econlit reports (as of March 14, 2005) mentions of Stolper-Samuelson in 41 new items published since 2000. This is an underestimate of continuing impact, as political scientists are making increasing use of the result.

[17] Given its enduring influence on subsequent economic analysis, the Stolper-Samuelson theorem may be appropriately regarded as a Schumpeterian innovation. Stolper and Samuelson were both students of the legendary Joseph Schumpeter.

endless variety of questions. The framework thus continues to be used to cast light on important policy issues relating to income distribution. For example, Lawrence and Slaughter (1993) chose the Stolper-Samuelson framework to contrast price changes due to increased international competition with biased technical change as alternative explanations of an increasing gap between the wages of skilled and unskilled workers. As long as economists maintain a lively interest in the division of national income among factors of production, Stolper and Samuelson will be there. The end is not in sight.

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