

40. The Stolper-Samuelson box

Henry Thompson

General equilibrium economics stresses the interplay between output markets and input markets in the whole economy. The Stolper-Samuelson (1941) production box solidified the link between prices of products and prices of inputs in a competitive neoclassical economy examining the particular issue of a tariff and the real wage.

In the production box with two factors and two products, the intuitive property is that a higher price raises the demand and relative price of the factor intensive in that product. The Stolper-Samuelson theorem relates directly to the underlying theorem of Heckscher (1919) and Ohlin (1933) stating that a country would import the product using its relatively scarce factor intensively, a tariff reducing imports and making the scarce factor more expensive. The production box mirrors the exchange box of Edgeworth (1904) and Pareto (1906) that complete the general equilibrium economy conceptualized by Walras (1874).

Figure 40.1 is a production diagram with inputs of capital K and labor L for products 1 and 2. Cost minimization implies that the slope of the convex neoclassical isoquant for product 1 equals the slope of the isocost line. That is, the marginal rate of substitution equals the wage rent ratio w/r . Positive diminishing marginal productivity implies convexity of the isoquant. Product 2 has a similar cost-minimizing equilibrium.

The production box in Figure 40.2 combines the two products with the origin O_2 for product 2 in the upper right hand corner. The length of the box is the endowment of labor $L = L_1 + L_2$ and its height the capital endowment $K = K_1 + K_2$. Equilibrium in production determines factor prices and the distribution of factors between sectors.

With perfect factor mobility between sectors, the wage would be the same in each sector, as would the return to capital. Cost minimization and factor mobility together imply that the economy operates on the locus of tangencies of isoquants, namely the contract curve CC in Figure 40.2. Neoclassical homothetic production implies a unique contract curve. Product 1 is capital intensive with the contract curve above the diagonal, and K_1/L_1 greater than K_2/L_2 . Moving northeast along the contract curve,

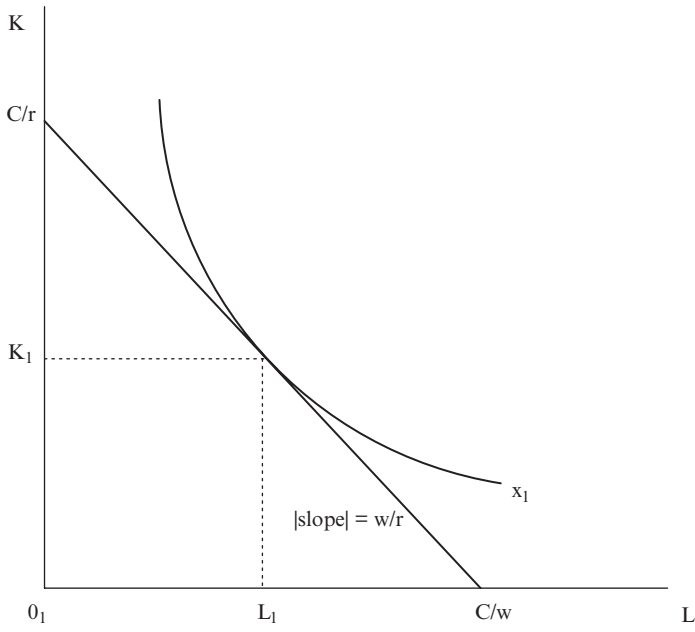


Figure 40.1 Cost minimization

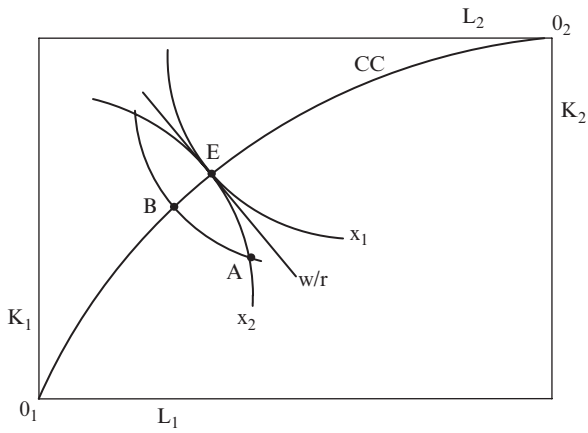


Figure 40.2 Equilibrium in the production box

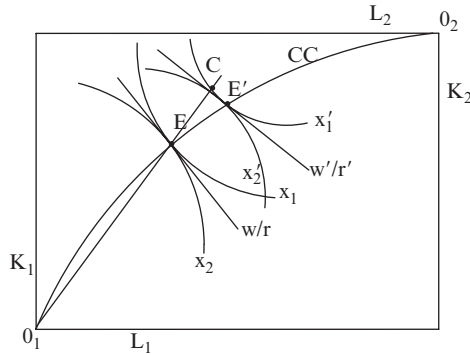


Figure 40.3 A tariff on product 1 and factor prices

the output of product 1 expands, and the wage/rent ratio w/r falls, but the capital/labor ratio remains higher in industry 1.

Homothetic production implies an equal slope of all isoquants along any ray from the origin. One implication is that the contract curve does not cross the diagonal. If a point on the diagonal is on the contract curve, every other point would be as well. This necessary lack of a factor intensity reversal, however, is unique to the two-dimensional model.

The two isoquants have the same slope and the production equilibrium point E in Figure 40.2. At any point such as A off the contract curve, the slopes of the isoquants are unequal. At point A , the marginal value of labor is higher in sector 2, labor is bid into that sector, capital is similarly bid into sector 1, and the economy converges to equilibrium at some point between B and E on the contract curve.

A tariff raises the price of the import-competing product, shifting production in its direction along the contract curve and leading to the Stolper-Samuelson factor price adjustment. Figure 40.3 illustrates the effect of a tariff on imported product 1. Output increases from x_1 to x_1' as sector 2 output declines from x_2 to x_2' and both capital and labor move to sector 1.

Expansion of capital-intensive sector 1 increases the relative demand for capital, lowering the wage/rent ratio. Homothetic production implies an equal w/r along ray O_1C in Figure 40.3 and the tariff-induced equilibrium at E' is below point C on isoquant x_1' . The relative wage falls from w/r to w'/r' , demonstrating the Stolper-Samuelson theorem that an increase in the relative price of the capital-intensive product raises the relative price of capital.

This general statement shows that the Stolper-Samuelson theorem has application beyond tariffs, applying to any price change regardless of its

source. Other applications include price changes induced by changes in domestic taxes, tastes, income, regulation, restructuring, monopoly power or technology. The model can also be modified to examine the impact of factor market distortions such as minimum wages, union contracts, labor subsidies and investment taxes.

As the expanding capital-intensive import-competing sector 1 becomes more labor intensive, sector 2 might be expected to become more capital intensive, but both sectors become more labor intensive. The decrease in labor-intensive production explains this paradox.

The algebra of the Stolper-Samuelson theorem developed by Samuelson (1953) and Jones (1965) lay the foundation for extending the general equilibrium model to include more inputs or products in Chipman (1966), Ethier (1974) and Jones and Scheinkman (1977). The rich possibilities of more factors are illustrated in the model with simply a third factor developed by Ruffin (1981) and Thompson (1985). Beyond the two-dimensional model, defining factor intensity is problematic, as illustrated by the 3x3 model of Thompson (2001). One consistent result is that a tariff must raise the real return to some factor of production and lower some other real return, the magnification effect of Jones (1965).

The algebraic model, along with improved production data, has led to highly detailed computable general equilibrium models that expose the myriad links between tariffs and wages. It is little exaggeration to say that the Stolper-Samuelson theorem was the stimulus for these advances in economic thought. Another advantage of the algebraic model is that the theoretical assumptions can be relaxed parametrically, as in Thompson (2003), who shows that the Stolper-Samuelson theorem is robust.

The Stolper-Samuelson production box provides underlying intuition on the link between product prices and factor prices, and keeps attention focused on cost minimization and substitution. The Stolper-Samuelson theorem also expands awareness from partial to general equilibrium, to include the secondary effects of changing prices on the economy. The Stolper-Samuelson production box will remain a crucial component of economic thought.

REFERENCES

- Chipman, John (1966), 'A survey of the theory of international trade: Part 3, the modern theory', *Econometrica* 34, 18–76.
- Edgeworth, Francis (1904), 'The theory of distribution', *Quarterly Journal of Economics* 18, 149–219.

- Ethier, Wilfred (1974), 'Some of the theorems of international trade with many goods and factors', *Journal of International Economics* 13, 201–224.
- Heckscher, Eli (1919), 'The effect of foreign trade on the distribution of income', *Ekonomisk Tidskrift*, reprinted in Harry Flam and June Flanders (eds) (1991) *Heckscher-Ohlin Trade Theory*, Cambridge, MA: The MIT Press.
- Jones, Ron (1965), 'The structure of simple general equilibrium models', *Journal of Political Economy* 73, 557–572.
- Jones, Ron and José Scheinkman (1977), 'The relevance of the two-sector production model in trade theory', *Journal of Political Economy* 85, 909–935.
- Ohlin, Bertil (1933), *Interregional and International Trade*, Cambridge, MA: Harvard University Press, reprinted in Harry Flam and June Flanders (eds) (1991) *Heckscher-Ohlin Trade Theory*, Cambridge, MA: The MIT Press.
- Pareto, Vilfredo (1906), *Manual of Political Economy*, 1971 translation of 1927 edition, New York: Augustus M. Kelley.
- Ruffin, Roy (1981), 'Trade and factor movements with three factors and two goods', *Economics Letters* 8, 177–182.
- Samuelson, Paul (1953), 'The prices of goods and factors in general equilibrium', *Review of Economic Studies* 21, 1–20.
- Stolper, Wolfgang and Paul Samuelson (1941), 'Protection and real wages', *Review of Economic Studies* 9, 58–73.
- Thompson, Henry (1985), 'Complementarity in a simple general equilibrium production model', *Canadian Journal of Economics* 18, 616–621.
- Thompson, Henry (2001), 'International trade with three factors, goods, or countries', *Keio Economic Studies* 38, 43–52.
- Thompson, Henry (2003), 'Robustness of the Stolper-Samuelson factor intensity price link', in Kwan Choi (ed.), *Handbook of International Trade*, Boston, MA: Blackwell.
- Walras, Leon (1874), *Elements of Pure Economics: Or the Theory of Social Wealth*. 1954 translation of 1926 edition, Homewood, IL: Richard Irwin.