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The present paper compares quantitative impacts of a free trade “program” of 1% price changes across simulations of general equilibrium models of countries and aggregates of skilled labor. These simulations of factor proportions and specific factors models illustrate two quantitative properties of competitive models of production and trade. First, factor intensity has a much stronger influence than factor substitution on the pattern of income redistribution due to price changes and foreign capital. Second, price changes associated with trade have a much stronger impact than foreign capital.

Key words: simulations, general equilibrium, trade, foreign capital

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Trade and Foreign Capital: Income Redistribution in Simulated Trade Models

Trade and foreign capital raise and redistribute income. In comparative static models of small open economies, changes in the prices of traded products and foreign capital cause factor price adjustments. The Stolper-Samuelson qualitative price link is based on factor intensity but limited intuition has evolved beyond the model with two factors and two products. Similarly, redistribution due to changes in the capital endowment has been difficult to generalize. Further, there is little insight into the magnitudes of these general equilibrium comparative static elasticities. The quantitative implications of specific factors of production have not been explored. Finally, the quantitative distortions due to aggregation have not been investigated.

Simulations of models of production and trade provide insight into these theoretical and applied issues. The present paper synthesizes a series of simulations of the general equilibrium model of production and trade developed by Jones (1965), Chipman (1966), Jones and Scheinkman (1977), Chang (1979), Ethier (1974), and Takayama (1982). This model is based directly on the theoretical insights of Edgeworth, Heckscher, Ohlin, Vanek, and Samuelson, and it remains the core of trade theory. Underlying assumptions are homothetic neoclassical production functions with constant returns, competitive pricing of homogeneous products in small open economies, and full employment of homogeneous factors of production with perfectly inelastic supply. These simulations are meant to be more theoretical

exercises than the applied computable general equilibrium trade models along the lines of Ballard, Fullerton, Shoven, and Whalley (1985) or Hertel and Tsigas (1988).

Factors of production in the present simulations are capital and various skill groups of labor. The labor data is from the eight skill categories reported by the US Census. Clark, Hofler, and Thompson (1988) show that none of these skill groups should be aggregated and the present arbitrary aggregations reveal the size of distortions predicted by theory. Capital is derived as the residual of value added from the Census of Manufacturing. The simulations include models with specific factors of production.

For notation, let w represent endogenous factor prices, p prices of finished products exogenous to the small open economy, and K the exogenous capital endowment. The present focus is on the sizes of general equilibrium $\delta w/\delta p$ and $\delta w/\delta K$ elasticities, the effects on factor prices of changes in prices and the capital stock. There is ample motivation, including the impacts of trade policy, protection, free trade agreements, and international capital taxes or subsidies.

Some Theoretical Preliminaries

Changes prices of traded products with endowments held constant affect factor prices in the general equilibrium $\delta w/\delta p$ matrix of elasticities. In the model with two factors and two products, the Stolper-Samuelson (19xx) theorem establishes a qualitative link between products and factors based on factor intensity. The magnification effect of Jones (19xx) generalizes to any number of factors and products and establishes that any ranked vector of percentage changes in product prices is flanked by percentage changes in factor prices. The

implication is that some factor owners must lose while others must lose in real terms due to changing prices. The simulated elasticities of factor prices with respect to product prices in the present simulations illustrate this magnified effect.

Foreign capital in the present models is assumed to directly affect to the exogenous capital endowment. The total capital endowment may be either home or foreign owned: $K = K_h + K_f$. For present purposes, assume foreign capital K_f is the source of exogenous changes in K . While national income increases with foreign capital, the entire increase goes to the owner of the added capital due to a competitive envelope property. National income is the sum of the payments to the factors of production. In the two factor model, $Y = wL + rK$. The change in income due to an increment of capital is $\delta Y/\delta K = r + L\delta w/\delta K + K\delta r/\delta K$. By Young's theorem $\delta w/\delta K = \delta r/\delta L$. It follows that $L\delta w/\delta K + K\delta r/\delta K = L\delta r/\delta L + K\delta r/\delta K$. Output is homogenous of degree 1 in inputs and marginal products are homogenous of degree 0. Factors are paid marginal products and by Euler's theorem, $L\delta r/\delta L + K\delta r/\delta K = 0$, implying $\delta Y/\delta K = r$ and the gains of some factors must be balanced by the losses of others.

If the capital endowment and price of a factor are positively (negatively) related, they are foreign capital friends (enemies). Factor demands slope downward in the competitive general equilibrium, which is to say capital is its own enemy, $\delta r/\delta K < 0$. Some other factor has to benefit and disagreement over foreign capital policy is inevitable. Thompson (1983) shows factor friendship is intransitive, and two labor groups that favor foreign capital would oppose each other's immigration. Being enemies, on the other hand, is transitive. Two labor groups that oppose foreign capital would also oppose each other's immigration.

Simulations of Factor Proportions Models of Production and Trade

The foundation of factor substitution is a cost or production function. Elasticities of substitution are constant along isoquants with constant elasticity of substitution (CES) production as developed by Uzawa (1962). Cobb-Douglas production functions have unitary elasticities of substitution. Balistreri, McDaniel, and Wong (2002) point out that Cobb-Douglas technology appears to be a reasonable starting assumption for substitution between capital and labor in a study of 28 US manufacturing industries. In their study, Cobb-Douglas cannot be rejected as a null hypothesis for 20 of the industries and for 7 others the technology is Leontief. Flexible translog functions allow variation in the elasticity of substitution along isoquants and are typically estimated with systems of partial derivative factor share equations. In any case, factor shares dominate the derivation of the cross price elasticities used in the present model simulations.

In a model with translog production functions across US states in 1978, Thompson (1997b) estimates own substitution elasticities of -1.4 for skilled labor, -1.2 for unskilled labor, and -0.9 for capital. The strongest cross price elasticities are between skilled and unskilled labor, both about unit value, and capital is a weak substitute for both types of labor. Weak substitution between capital and labor is characteristic of all the present results and consistent with the evidence of Arrow, Chenery, Minhas, and Solow (1961). Free trade is projected to lower US prices of manufactures but raise prices of exported business services. These changing prices are found to have elastic effects on factor prices in the comparative statics. Table 1 reports the factor price adjustments for a free trade “program” with the price of

manufactures falling 1% and the price of business services rising 1%. The extremely elastic effects suggest labor has a great deal at stake in the move toward free trade. In stark contrast, foreign capital has nearly no effect at all as shown in Table 2. Results are very similar across a number of simulations assuming either CES or Cobb-Douglas production.

* Table 1 * Table 2 *

Elasticities of factor prices with respect to factor endowments are close to zero in all the present simulations, a property called *near factor price equalization* (NFPE). If the numbers of factors and products are equal, factor price equalization holds and $\delta w / \delta K = 0$. Regardless, outputs serve as “shock absorbers” for factor markets leaving only small impacts on factor demands.

In a 3x2 model of the US, Thompson (1995a) compares the influence of factor intensity versus substitution on the comparative static elasticities in simulations with translog, Cobb-Douglas, CES, and production with strong complementarity. The $\delta w / \delta p$ elasticities are consistent across all simulations. The $\delta w / \delta K$ elasticities are all nearly identical and very close to zero, the NFPE result.

With the eight disaggregated labor skill groups, Thompson (1990) reports own translog factor price elasticities somewhat larger in magnitude, from -1 to -3 . Nevertheless, factors remain weak substitutes because of the dominance of “factor intensity” in deriving the substitution elasticities. Aggregation lowers the estimated degree of factor substitution, a property anticipated in the theoretical literature. The disaggregated factor price adjustments to the free trade program in Table 1 are much smaller than in the aggregated model.

Aggregation exaggerates the $\delta w/\delta p$ elasticities, which are cofactors of factor shares that increase with aggregation. Although smaller than the aggregated $\delta w/\delta p$ elasticities, these effects remain elastic as implied by the magnification effect. Introducing trade would involve large price changes, implying even larger factor price adjustments. NFPE holds in Table 2 with foreign capital's inelastic effects on factor prices except for the wage of resource workers due to the very high share of capital in agriculture.

Thompson (1997a) examines a similar model with CES production examining a wide variety of elasticities of substitution for sensitivity. The free trade program has slightly smaller effects than with translog production. Wages of handlers rise slightly and foreign capital has a weak positive impact on all wages. A wide variation in the degree of substitution has very little impact on the model's comparative static elasticities. These simulations reveal a robustness of comparative static elasticities across production technologies.

With CES production functions for some less developed and newly industrialized countries, Thompson (1995b) predicts unskilled labor would gain substantially with free trade characterized by higher prices for exported manufactures and lower prices for imported business services. In the 1% free trade program summarized in Table 3, unskilled wages increase up to 18% in Mexico. There should be opponents to free trade, however, with losses of skilled labor ranging up to 13% in Bolivia and losses to capital are as high as 5% in Argentina and Mexico. While disaggregation of labor would decrease these elasticities, free trade involves sizeable price changes. There is evidently quite a bit at stake in NICs and

LDCs when they move toward free trade. Internal opposition to free trade is easy to understand given the sizeable redistribution on income.

* Table 3 *

The underlying reason for the dominance of factor intensity is straightforward. Cost minimizing factor inputs are positive first derivatives of cost functions by Shephard's lemma: $\delta c / \delta w = a$. Factor shares are built from these first derivatives. Factor substitution elasticities are based on second derivatives of cost functions: $\delta a / \delta w = \delta^2 c / \delta w^2$. The own effects are negative and the interactive cross terms $\delta a_i / \delta w_k = \delta^2 c / \delta w_i \delta w_k$ are generally small, ensured by the additivity and concavity constraints. In the comparative statics, $\delta w / \delta p$ elasticities are cofactors of larger first derivatives while $\delta w / \delta K$ elasticities are cofactors of smaller second derivatives. In the special case of even models with an equal number of factors and products, $\delta w / \delta p$ elasticities are completely independent of substitution and $\delta w / \delta K$ elasticities are all zero.

Simulations of Specific Factors Models of Production and Trade

In a specific factors model of the Japanese economy, Thompson (1994) examines the potential effects of protection across industrial wages with Cobb-Douglas production. Protection of an industry has a positive elastic effect on that wage, weak negative effects on other industrial wages, and a weak positive effect on the return to capital. The example of a 1% change in the price of iron & steel, critical in trade policy debates, is reported in Table 4.

The underlying principle behind the quantitative difference in the effect on factor prices is that specific factors absorb most of the shock due to a price change. If factors are mobile

across sectors, there would be a dampened impact because that factor supply adjusts across industries. An increase in foreign capital has a slight negative effect on the return to capital and elastic effects on a few industrial wages but very inelastic effects on most industrial wages.

* Table 4 *

In a study of the effects of projected Nafta price changes on 17 Alabama manufacturing industries, Thompson (1996) utilizes industry specific capital with separate production and nonproduction labor and Cobb-Douglas production. The literature predicts that industries intensive in production labor will face increased import competition under Nafta. Testing various vectors of price changes for sensitivity, the output effects are inelastic with own output elasticities less than 0.1. Table 5 summarizes the results. Sector specific capital returns are very sensitive to price changes with returns adjusting as much as 20%. In the long run, such capital return shocks would alter investment and significantly affect outputs. The model projects long run output adjustments according to factor intensity after capital adjustments in the range of 20%. Across the simulations, production wages fall between 1% and 7% while nonproduction wages rise up to 3%.

* Table 5 *

In a study of Bolivia's entry into Mercosur, Toledo and Thompson (2001) combine CES production with the government projection of Mercosur price changes. Results are summarized in Table 6. Simulations of a specific factors model predict skilled and unskilled labor will suffer moderate wage declines, while capital returns vary widely according to the

projected Mercosur price changes. These factor price adjustments are robust over a range of sensitivity analysis.

A theoretical property is uncovered in these simulations, namely that $\delta w/\delta p$ elasticities are identical for any CES production function. proof.... Another similar case of an empirical finding uncovering a theoretical shortcoming is the finding of Thompson and Wickham (19xx) relating to the convexity of iso-xxx curves of Helpman and Krugman (19xx).

* Table 6 *

Conclusion

The present simulations sharpen the focus of the competitive theory of production and trade. One lesson is that price changes can be expected to substantially alter factoral income distribution following patterns suggested by factor intensity or factor shares. Certainly, defining factor intensity remains a challenge with many factors and products. The theoretical literature has concentrated on isolating conditions under which there would be qualitative factor intensity links but has only produced limited intuition and application. The quantitative effects in these models follow patterns suggested by straightforward comparison of factor shares. Another lesson of the simulations is that specific factors are especially sensitive to price changes.

Foreign capital is found to have very small impacts on factor prices. The present simulations suggest factor price equalization at least nearly holds in competitive economies. Given the long run goal of raising unskilled wages in labor abundant countries, trade holds more potential than foreign capital.

Regarding future research along these lines, simulations can gauge the quantitative implications of the various theoretical extensions of the model: variable returns, nonhomothetic production, different production functions, different utility functions, international monopoly or monopsony power, heterogeneous products, heterogeneous factors, unemployment, elastic factor supply, joint production, and so on. The effects of aggregation can be examined in detail. Simulations can be applied to different countries or regions and can focus on specific policy issues. More detailed production data can be used with a focus on selected disaggregated industries.

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Wickham-Thompson

Table 1. US Factor Price Adjustments to “Trade Program” of 1% Price Changes

3 factor model with translog production*

Skilled wage	17%
Unskilled wage	-15%
Capital return	2%

Disaggregated wage adjustments with translog production**

Professional	2%
Technical	2%
Service	2%
Resource	-5%
Craft	-1%
Operators	-6%
Handlers	0%
Capital return	2%

* Thompson (1997b); robust for Cobb-Douglas, CES, and compliments, Thompson (1995a)

** Thompson (1990); robust for CES production, Thompson (1997a)

Table 2. US Factor Price Adjustments to 1% Increase in Foreign Capital

3 factor model with translog production*

Skilled wage	0.3%
Unskilled wage	-0.0%
Capital return	-0.3%

Disaggregated labor with translog production**

Professional	0.1%
Technical	0.1%
Service	0.1%
Resource	1.3%
Craft	0.1%
Operators	0.0%
Transport	0.1%
Handlers	0.1%
Capital	-0.3%

* Thompson (1997b); robust for Cobb-Douglas, CES, and compliments, Thompson (1995a)

** Thompson (1990); robust for CES production, Thompson (1997a)

Table 3. NIC and LDC Adjustment to 1% Trade Program*

	Unskilled wage	Skilled wage	Capital return
Mexico	18%	-2%	-5%
Argentina	13%	-2%	-5%
Ecuador	9%	-6%	-1%
Taiwan	7%	-3%	-4%
Bolivia	6%	-13%	-5%
Korea	6%	-4%	-1%
Venezuela	6%	-9%	-0%
Turkey	4%	-10%	-0%

* CES production, Thompson (1995b)

Table 4. Japanese Industry Specific Labor*

	$\Delta 1\%$ iron & steel price
Iron & steel wage	4%
Other industrial wages	-0.5% to -0.01%
shared capital	0.1%

	$\Delta 1\%$ in capital
Capital return	-0.3%
Nonmetallic minerals wages	2%
Agricultural wages	2%
Finance wages	1%
Iron & steel wages	1%
Other wages	0%

* Cobb-Douglas production, Thompson (1994)

Table 5. Nafta and Alabama Manufacturing with Industry Specific Capital*

Various vectors of price changes

Inelastic short run output effects: $\% \Delta < 0.1$

Specific capital returns: up to 20%

Similar long run output effects

Labor intensive industries lose:

Textiles Apparel Furniture

Capital intensive industries win:

Chemicals Transport equipment Machinery Instruments

Production wages

-1% to -7%

Nonproduction wages

up to 3%

* Cobb-Douglas specific factors model, Thompson (1995)

Table 6. Mercosur and Bolivia with Industry Specific Capital

Sector specific capital, shared skilled and unskilled labor*

	Projected price changes	%Δ Capital returns
Business services	-20%	-25%
Agriculture	-12%	-25%
Mining	4%	14%
Natural gas	8%	23%
Manufacturing	30%	47%
	%Δ Shared labor	
	Skilled wage	-6%
	Unskilled wage	-1%

* CES production, Toledo and Thompson (2001)