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A factor tariff raises the cost of production and reduces output in a small open neoclassical economy. In the present model the tariff also raises the price of the import competing factor, increasing its quantity supplied. Factor substitution, factor shares, and the price elasticity of factor supply determine adjustments to a factor tariff. Under some conditions, the tariff raises income. The model relates to economic growth and macroeconomic theory with an imported factor of production.

Keywords: factor tariffs, income, general equilibrium

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A Factor Tariff, Domestic Supply, and Income

The effects of changes in the international price of an imported factor of production on domestic production and income distribution are well known. The present paper extends this theory by explicitly considering a factor tariff and income. The small open economy produces with constant returns for two factors of production, one domestic and the other imported but with import competing supply.

Adjustments to the factor tariff depend on the price elasticity of the import competing factor, substitution between inputs, and factor shares of output and income. The tariff lowers output and payment to the domestic factor but increases quantity supplied of the import competing factor. Tariff revenue is concave in the tariff rate. Under some conditions, the tariff increases income. There may be tariffs that maximize tariff revenue and income.

The next section presents the competitive general equilibrium model followed by a section presenting the comparative static model. A third section focuses on adjustments to the factor tariff. A section on model simulations then illustrates adjustments under various assumptions across a range of factor tariffs.

1. An international factor of production in general equilibrium

The literature on the general equilibrium of a small open economy with an imported factor of production includes Kemp (1966), Jones (1967), Mundell (1971), Chipman (1971), Caves (1971), Jones and Ruffin (1975), Srinivasan (1983), Svensson (1984), Fergusen (1978), Thompson (1983), and Ethier and Svensson (1986). Its focus is the effect of exogenous changes in the international price of the imported factor on production and income distribution. The literature does not explicitly consider factor tariffs, tariff revenue, and income as in the present paper.

A related model with fixed input coefficients for imported intermediate goods begins with the fundamentals of Ruffin (1969). In that model Panagaria (1992) finds an ambiguous welfare effect of a tariff on an imported intermediate good that would occur in the present context with substitution between the import and a domestic factor.

In the present model the imported factor E combines with a domestic factor of production F to produce output x. The domestic factor F has perfectly inelastic supply with a flexible price f. The small open economy takes international price e of the imported factor and imports according to its marginal productivity. The price p of output is also exogenous for the small open economy. Including tariff rate t the domestic price of the factor is

$$e_D = (1 + t)e. \tag{1}$$

Domestic supply of the factor is assumed an increasing function of the domestic price, $S(e_D)$. A tariff raises e_D and increases the quantity supplied of the import competing factor. A higher elasticity of domestic supply favors more of a decrease in import due to the tariff and falling tariff revenue. The increased import competing factor is the source of the potential for the tariff to raise income. Total input E equals import M plus domestic quantity supplied, $E = M + S$. Endogenous variables are the domestic factor price f, import M, import competing domestic quantity supplied S, and output x.

Competition and homogeneous constant returns imply Euler's theorem with output exhausted by factor payments,

$$px = fF + e_DE. \tag{2}$$

Income y is the sum of payment to the domestic factor, payment to import competing domestic supply of the imported factor, and tariff revenue,

$$y = fF + e_DS + teM. \tag{3}$$

Euler's theorem with constant returns impliies income y equals the value of output less import spending, that is $y = px - eM$.

Given a constant international factor price e any change in e_D is due to the tariff, that is $de_D = edt$. For notation, the percentage change in the domestic price of the factor is

$$\tau' \equiv de_D/e_D = dt/(1 + t). \tag{4}$$

Total input is $E = M + S = a_E x$ where a_E is the cost minimizing unit input. Assuming homothetic production a_E is a function only of the relative factor price. Changes in E occur according to $dE = dM + dS = a_E dx + x da_E$. Expanding da_E to include factor price changes,

$$\psi_M M' + \psi_S S' = x' + a_E' + \sigma_{EF} f' + \sigma_{EE} \tau', \tag{5}$$

where primes ′ denote percentage changes. The shares in total E input of the import $\psi_M \equiv M/E$ and domestic supply $\psi_S \equiv S/E$.

Let σ_E represent the cross price substitution elasticity of factor E relative to factor price f. Also σ_F is the elasticity of domestic factor F relative to the domestic price e_D. The two factors must be substitutes, $\sigma_F > 0$ and $\sigma_E > 0$. Cost minimizing input adjusts according to $a_E' = \sigma_E f' + \sigma_{EE} \tau'$ where σ_{EE} is the own elasticity with respect to e_D. The own substitution elasticities σ_{EE} and σ_{FF} are negative due to concavity of the cost function and Shephard's lemma. Linear homogeneity implies $\sigma_{FF} = -\sigma_F$ and $\sigma_{EE} = -\sigma_E$.

Input adjustment E′ in (5) simplifies to

$$\psi_M M' + \psi_S S' = x' + \sigma_E f' - \sigma_E \tau'. \tag{6}$$

Adjustment to changes in the domestic factor endowment occurs according to

$$F' = x' + \sigma_F f' - \sigma_F \tau'. \tag{7}$$

Competition implies revenue px is exhausted between factors according to (1). Dividing (1) by output x it follows that $p = fa_F + (1 + t)ea_E$. Differentiate to find $dp = a_F df + ea_E dt + [fda_F + (1 + t)eda_E]$. The bracketed expression disappears due to the envelope property of cost minimization. In elasticity form, price adjustment reduces to

$$p' = \theta_F f' + (1 + t)\theta_E \tau', \tag{8}$$

where the factor shares of output $\theta_F \equiv fa_F/p$ and $\theta_E \equiv (1 + t)ea_E/p$ sum to one.

Income $y = fF + (1 + t)eS + teM$ adjusts according to $dy = Fdf + fdF + tedE + eEdt$. Converting to elasticity form

$$y' = \varphi_F f' + \varphi_F F' + \varphi_S S' + \varphi_M M' + \varphi_E T\tau', \tag{9}$$

where $T \equiv (1 + t)/t$. Factor shares of income $\varphi_F \equiv fF/y$, $\varphi_E \equiv teE/y$, $\varphi_S = (1 + t)eS/y$, and $\varphi_M = teM/y$ sum to one. The domestic φ_F is greater than its output share θ_F while for the imported factor $\varphi_E < \theta_E$.

Assume domestic factor supply has a constant price elasticity $\sigma_S \equiv S'/e_D' = S'/\tau'$ leading to

$$S' = \sigma_S \tau'. \tag{10}$$

The factor tariff raises its domestic price and increases the quantity supplied.

2. The comparative static model

Combine (6) through (10) into the comparative static system with exogenous variables on the right hand side,

$$\begin{pmatrix} -\psi_M & \sigma_E & 1 & 0 & -\psi_S \\ 0 & -\sigma_F & 1 & 0 & 0 \\ 0 & \theta_F & 0 & 0 & 0 \\ -\varphi_E & -\varphi_F & 0 & 1 & -\varphi_S \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} M' \\ f' \\ x' \\ y' \\ S' \end{pmatrix} = \begin{pmatrix} \sigma_E \tau' \\ F' - \sigma_F \tau' \\ p' - \theta_E \tau' \\ \varphi_F F' + \varphi_E T\tau' \\ \sigma_S \tau' \end{pmatrix}. \tag{11}$$

The positive determinant of the system is $\theta_F \psi_M > 0$.

Changes in the domestic factor endowment F affect endogenous variables according to

$$M'/F' = \sigma/\theta_F\psi_M > 0$$

$$x'/F' = 1 \qquad (12)$$

$$f'/F' = S'/F' = 0$$

$$y'/F' = 1 + \varphi_F > 1,$$

where $\sigma \equiv \sigma_E + \sigma_F > 0$. An increase in F raises the marginal product of E leading to increased import M that raises the marginal product of F. The resulting insensitivity of the domestic factor price f to its endowment F is the factor price equalization property based on the same number of factors and exogenous prices. A larger domestic share ψ_S increases the elasticity of import M with the induced import generating a larger increase in tariff revenue.

A change in the output price p leads to adjustments according to

$$M'/p' = \sigma/\theta_F > 0$$

$$f'/p' = 1/\theta_F > 0$$

$$x'/p' = \sigma_F/\theta_F > 0 \qquad (13)$$

$$y'/p' = (\varphi_F + \varphi_E\sigma)/\theta_F\psi_M > 0$$

$$S'/p' = 0.$$

Cobb-Douglas production implies $\sigma = 1$ and $E'/p' = y'/p' = f'/p' = 1/\theta_F$. The higher price attracts factor import raising the marginal product of the domestic factor and output. Domestic quantity supplied S is unaffected. In percentage terms output x increases less than import M due to diminishing marginal productivity.

Income y increases in (13) along with the domestic factor price and tariff revenue due to the higher output price. A larger factor share for the import magnifies these positive price effects as

does a higher degree of substitution except for the effect on the domestic factor price f. A larger domestic share ψ_S increases effects on M and y. A larger ψ_S implies more of the impact stays home.

3. Adjustments to the factor tariff

Effects of the factor tariff have unambiguous signs except for the effect on income,

$$M'/\tau' = -(\psi_S T\sigma_S + \sigma)/\psi_M\theta_F < 0$$

$$f'/\tau' = -\theta_E/\theta_F < 0$$

$$x'/\tau' = -\sigma_F/\theta_F < 0 \qquad (14)$$

$$S'/\tau' = \sigma_S > 0$$

$$y'/\tau' = [(\varphi_S\psi_M - \varphi_M\psi_S)\sigma_S - \varphi_M]/\psi_M.$$

Import M falls more than output x in percentage terms. The domestic factor price f and output x both fall due to the diminished factor of production. Without substitution, output x and domestic quantity supplied S would remain constant. Domestic quantity supplied S increases with its higher price but does not offset the lost import M. A larger factor share for the import magnifies effects of the tariff on import, output, and the domestic factor price.

The effect of the tariff on income y is ambiguous. Tariff revenue plus the increased payment to the import competing domestic factor may more than offset the reduced payment to the domestic factor. The expression in parentheses is positive, $\varphi_S\psi_M - \varphi_M\psi_S = eSM/yE$. In the model with no competing domestic supply, income falls according to $y'/\tau' = -\varphi_M/\psi_M < 0$.

From M'/τ' in (14) the tariff that maximizes tariff revenue is $t^R = (\sigma - \psi_R)/\psi_R$ where $\psi_R \equiv \psi_M\theta_F - \psi_S\sigma_S$. A higher domestic supply price elasticity σ_S favors a positive t^R. The following simulations illustrate the tariff that maximizes tariff revenue.

The tariff t^y that maximizes income occurs where $y'/\tau' = 0$ implying $t^y = \psi_S\sigma_S$. With no domestic supply $t^y = 0$. A stronger price elasticity of supply σ_S implies a higher t^y. The tariff increases ψ_S suggesting a positive t^y as illustrated in the following simulations.

4. Simulated factor tariffs

The following simulations picture adjustments to a tariff rate t ranging from 0 to 1 with Cobb-Douglas production and e = p = F = 1. The simulations show tariff revenue R is concave in the tariff rate and can be maximized given import competing supply.

Figure 1 presents the model with no import competing supply S and the import factor share $\theta_E = 0.3$. As the tariff increases import E and output x both fall considerably. Tariff revenue R almost compensates for the declining domestic factor price f. Assuming the smaller factor share $\theta_E = 0.1$ the economy exports the factor if t > 0.5. A larger factor $\theta_E > 0.5$ leads to sharp decreases in both import M and output x with the tariff.

* Figure 1 *

Figure 2 pictures the same model with factor share $\theta_E = 0.3$ but competing domestic supply. Domestic supply price elasticity is $\sigma_S = 1.1$ with S set to 0 at t = 0. At t = 0 tariff revenue R = 0 at the maximums of both output x and domestic factor income fF. Tariff revenue R is maximized at t = 0.44. Payment (1 + t)eS to the domestic factor increases at an increasing rate. Income is maximized at t = 0.20. Imports M are eliminated at the prohibitive tariff t = 1.05. With stronger domestic supply elasticity, a higher tariff rate is required to eliminate imports. As the domestic elasticity approaches zero the economy converges to the model in Figure 1.

* Figure 2 *

Figure 3 introduces stronger constant elasticity substitution with CES = 1.67. Figure 3 compares to the Cobb-Douglas economy in Figure 1 with no domestic supply. There is less of a decline in the domestic factor price f than in Figure 1 due to the stronger substitution. Tariff revenue nearly compensates for the lower domestic factor price with import E falling nearly as much as output x. There are very small changes in domestic factor payment fF, income y, and output x. In the model with weak CES substitution approaching zero the economy collapses at low tariff levels due to sharp declines in import.

* Figure 3 *

Figure 4 shows the same economy with strong CES = 1.67 substitution as in Figure 3 but with domestic import competing supply at elasticity $\sigma_S = 1.1$. The decline in output x is less than in the Cobb-Douglas model of Figure 2. Tariff revenue R is maximized at $t^R = 0.41$ and income at $t^y = 0.09$. A weaker σ_S leads to less of an increase in import competing S and less of a decrease in income y. A higher σ_S eliminates imports M and more strongly increases y. A smaller factor share implies a smaller decrease in output x and larger increases in domestic quantity supplied S and income y.

* Figure 4 *

4. **Conclusion**

A factor tariff lowers import and output but raises the payment and quantity supplied of the import competing factor in the present model. The tariff increases income if the increased tariff revenue and supply of the import competing factor more than offset decreased payment to the domestic factor. Tariff revenue is concave in the tariff rate. Either tariff revenue or income can be maximized by the tariff, a relevant distinction for countries relying on imported capital or resource inputs.

There are issues related to factor tariffs that can be addressed with the present model as a foundation. Factor tariffs are transparent and easy to collect, and can be included along with taxes on output or domestic factor payment. A tariff for a large economy would lower the international demand and price, perhaps leading to a Metzler (1949) paradox with a lower domestic price inclusive of the tariff. For an economy producing numerous products with various domestic factors, the pattern of production and domestic factor income distribution would adjust to the factor tariff. The factor tariff would also diminish any externalities associated with importing or consuming the imported factor.

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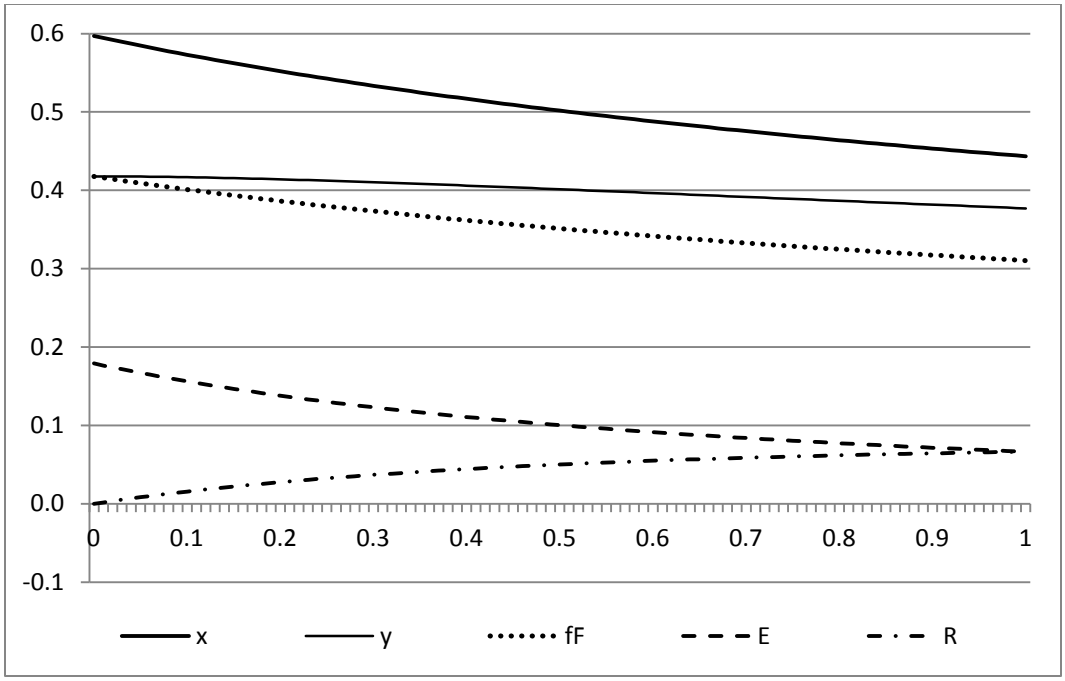

Figure 1. Cobb-Douglas $\theta_E = 0.3$, output = x, income = y, factor payment = fF, factor import = E, tariff revenue = R

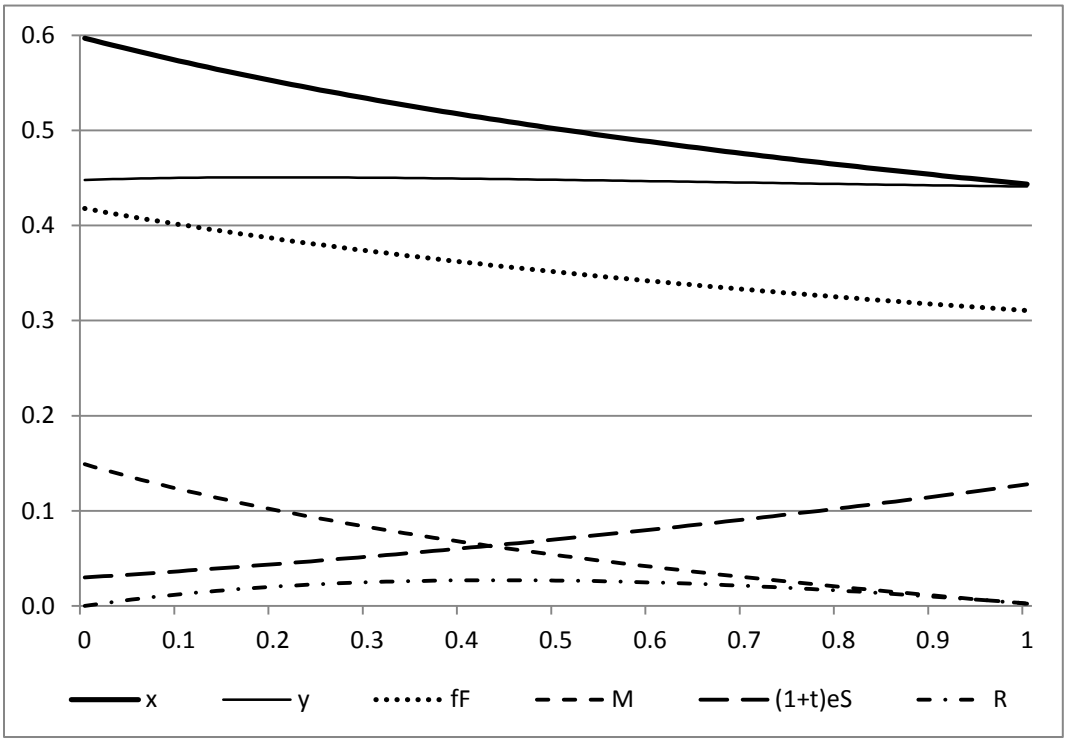

Figure 2. Cobb-Douglas $\theta_E = 0.3$, domestic supply S, output = x, income = y, factor payment = fF, factor import = M, tariff revenue = R

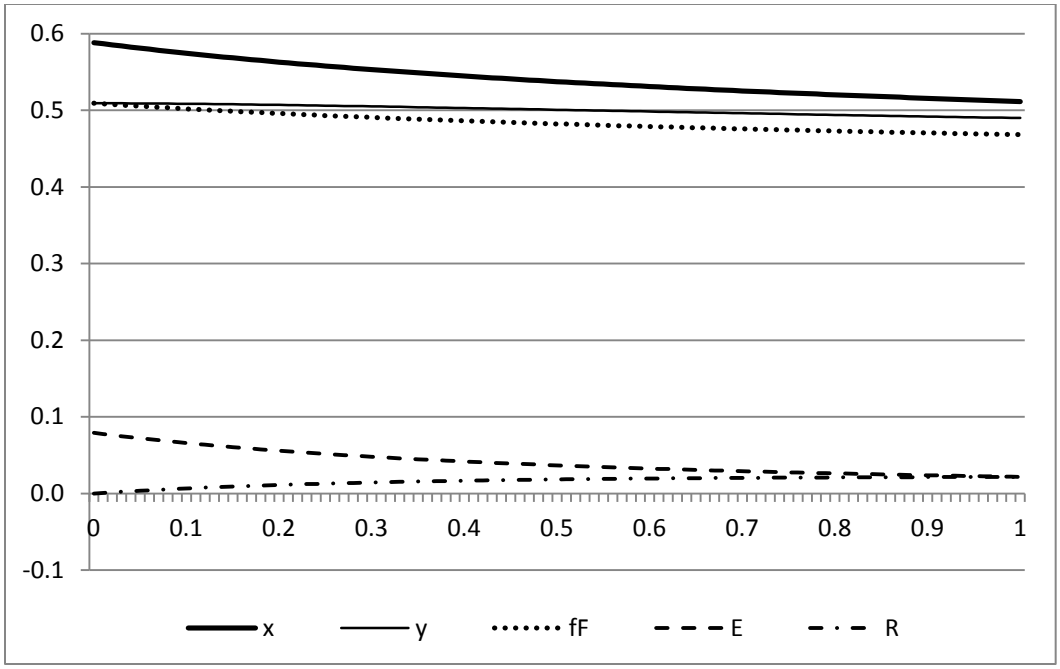

Figure 3. CES = 1.67, output = x, income = y,
factor payment = fF, import = E, tariff revenue = R

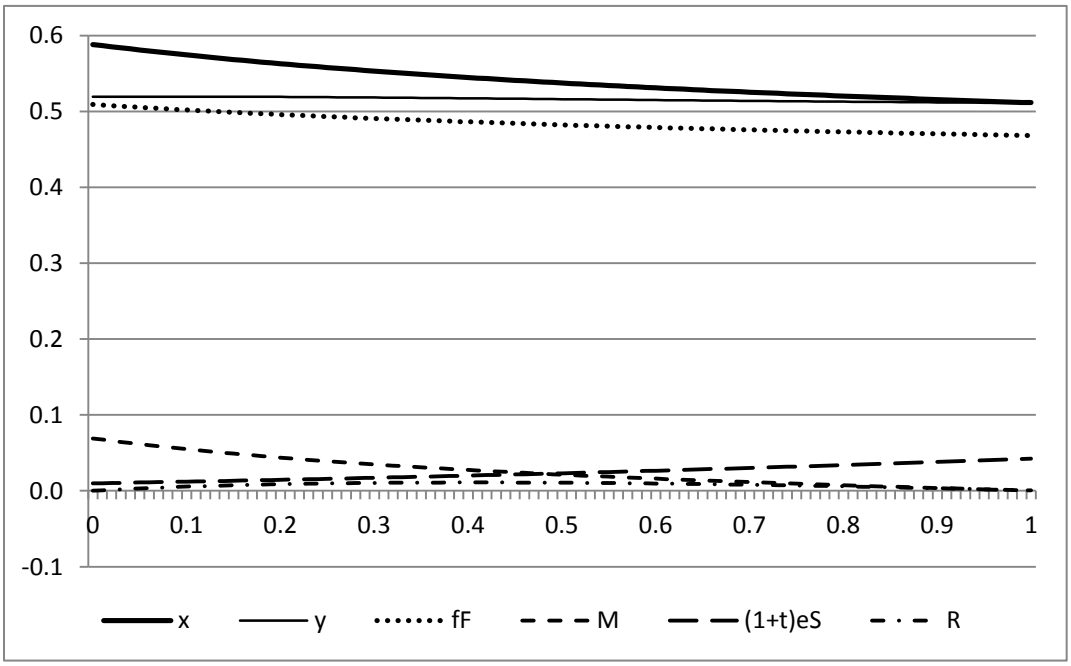

Figure 4. CES = 1.67, Competing domestic energy S, output = x,
income = y, factor payment = fF, import = M, tariff revenue = R