A Tariff on a Productive Factor and Import Competing Supply

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A tariff on an imported factor of production such as energy or capital reduces the import as well as output in the general equilibrium of a small open economy. The present paper shows real income may rise, however, due to an increase in the import competing quantity supplied. The present competitive economy produces a single exported output with two factors of production, one purely domestic. The import competing price elasticity, shares of income and output, and factor substitution determine general equilibrium adjustments to a tariff on the imported factor.

Keywords: energy tariffs, import competing supply, income, general equilibrium

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An increase in the global price of an internationally mobile factor of production lowers the import as well as output in a small open competitive economy. A tariff on an imported factor in an economy with import competing supply, however, raises its quantity supplied. In a small open economy that is a price taker in global markets for the imported factor and exported output, the present paper shows a tariff has the potential to increase real income depending on the import competing supply elasticity.

The primary motivation is a tariff on imported energy input. Figure 1 shows import competing energy relative to total energy consumption across some of the energy importing countries in the Americas and Europe in 2012. For instance, Spain supplied 26% of its own energy consumption and the US 83%. An energy tariff in these countries would raise the domestic price and the import competing quantity supplied, potentially raising income. An increase in income is favored by higher import competing shares as in the countries toward the right of Figure 1. A stronger import competing supply elasticity and weaker substitution in production also favor increased income due to a tariff.

* Figure 1 *

The literature on energy tariffs includes Kline and Weyant (1982) who make the point tariffs relieve import dependence, although Hebatu and Semboja (1994) point out associated negative economic effects. Proost and Regemorter (1992) note an energy tariff would reduce emissions. Dissou and Eyland (2011) find an energy tariff less efficient than an emission tax while Böhringer, Bye, Fæhn, and Rosendahl (2012) disagree. A related issue for a large economy

is the reduced international demand due and the possible Metzler (1949) paradox of a lower domestic price inclusive of the tariff, an issue examined by Thompson (2007).

The literature on internationally mobile factors of production begins with Mundell (1957) and includes Kemp (1966), Jones and Ruffin (1975), Thompson (1983), Ethier and Svensson (1986), and Facchini and Willmann (2005). Its focus is the general equilibrium adjustment to a change in the exogenous international factor price facing a small open economy producing two traded goods. While the present paper simplifies to a single exported output, it includes import competing supply.

The literature on variable factor supply includes Kemp and Jones (1962), Martin (1976), Zee (1983), and Hatzipanayotou and Michael (1995). Supply is perfectly inelastic for primary unproduced factors in competitive factor proportions trade models. With variable supply, an increase in the factor price raises its quantity supplied based on the underlying opportunity cost.

Ruffin (1969) develops a related model with import competing production of an imported intermediate good that has a fixed input coefficient in final good production. In this setting, an increase in the tariff may lower utility as developed by Panagariya (1992). The present model focuses on income rather than utility, allows substitution between the two primary factors, and includes import competing supply.

Summarizing, the present model combines international factor mobility with variable factor supply to examine the general equilibrium adjustments to a tariff on the imported factor. The competitive economy produces a single output with constant returns for two factors, one purely domestic with full employment. Export of the output balances trade with the imported factor for the price taking, small open economy. Exogenous variables are the domestic factor endowment and global prices of the imported factor and output. The level of the imported factor

and the import competing quantity supplied are endogenous, as are output, the price of the domestic factor, and income.

The first section presents the model followed by a section on the comparative static effects of a change in the tariff rate. The third section presents simulations with Cobb-Douglas production including sensitivity to tariffs and the import competing supply elasticity.

1. Production with an imported factor

The international factor E, equal to import M plus import competing quantity supplied S, combines with a domestic factor F to produce output x(E, F). Prices p of output and e of the imported factor are exogenous for the small open economy. The domestic factor F has perfectly inelastic exogenous supply and flexible price f ensuring full employment. The tariff rate t is the exogenous policy variable of interest. Endogenous adjustments occur for import M, import competing quantity supplied S, output x, domestic factor price f, and income y.

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

$$px = fF + (1 + t)eE. \tag{1}$$

Income y is the sum of payments to the domestic factor F, import competing quantity supplied S, and tariff revenue,

$$y = fF + (1 + t)eS + teM. \tag{2}$$

Output is implicity exported to balance trade leaving income, $y = px - eM$ directly from (1) and (2).

Quantity supplied S of the import competing factor increases in its price. The motivation is its opportunity cost in some other use. The opportunity cost for energy input is future use.

For capital the opportunity cost is current consumption. The tariff raises the relative price in the present inducing owners of the import competing factor to increase quantity supplied.

The price elasticity of the import competing factor supply in the comparative static model is $\sigma_S \equiv \hat{S}/\hat{e}_t > 0$ where $e_t \equiv (1 + t)e$ is the domestic price of the imported factor including the tariff and the hat ˆ indicates percentage change. In the comparative static model (10) below,

$$\hat{S} = \sigma_S \hat{e}_t. \tag{3}$$

A change in the tariff rate affects e_t according to $de_t = edt$ assuming e is constant at the world level. In elasticity form $\hat{e}_t \equiv de_t/e_t = dt/(1 + t)$ is the percentage change in the tariff rate relative to its base. Total demand E for the imported factor is $a_E(.)x$ where $a_E(.)$ is the cost minimizing unit input. With homothetic production functions $a_E(.)$ is a function of factor prices alone.

The total change in input E is $dE = dM + dS = a_E dx + x da_E$. Converting to elasticity form,

$$\psi_M \hat{M} + \psi_S \hat{S} = \hat{x} + \hat{a}_E, \tag{4}$$

where $\psi_M \equiv M/E$ is the import share of E input and $\psi_S \equiv S/E = 1 - \psi_M$ the import competing share.

Cost minimization implicit in the $\hat{a}_E$ term in (4) introduces technical substitution between the two inputs. Let σ_{Ef} represent the cross price elasticity of E relative to domestic factor price f, and σ_{Fe} the cross price elasticity of domestic factor F relative to e_t. The two factors must be substitutes, $\sigma_{Ef} > 0$ and $\sigma_{Fe} > 0$. These cross price elasticities vary with output.

The cost minimizing input $a_E(f, e_t)$ adjusts according to

$$\hat{a}_E = \sigma_{Ef}\hat{f} + \sigma_{Ee}\hat{e}_t, \tag{5}$$

where σ_{Ee} is the own price elasticity of E with respect to e_t. The two own substitution elasticities σ_{Ee} and σ_{Ff} are negative due to concavity of the cost function and Shephard's lemma. Moreover, linear homogeneity implies $\sigma_{Ff} = -\sigma_{Fe}$ and $\sigma_{Ee} = -\sigma_{Ef}$ as a simplification in the model (10).

Input E adjustment including (5) in (4) expands to

$$\psi_M\widehat{M} + \psi_S\hat{S} = \hat{x} + \sigma_{Ef}\hat{f} - \sigma_{Ef}\hat{e}_t. \tag{6}$$

The similar condition for domestic factor F is

$$\hat{F} = \hat{x} - \sigma_{Fe}\hat{f} + \sigma_{Fe}\hat{e}_t = 0, \tag{7}$$

where $\hat{F} = 0$ to focus on a ceteris paribus change in the tariff rate.

Divide the competitive pricing condition (1) by output x to find $p = fa_F + e_ta_E$ and differentiate to find price adjustment $dp = a_Fdf + ea_Edt + [fda_F + e_tda_E]$. The bracketed expression disappears due to the cost minimization envelope property. In percentage terms,

$$\hat{p} = \theta_F\hat{f} + \theta_E\hat{e}_t = 0, \tag{8}$$

where factor shares of output are $\theta_F \equiv fa_F/p = fF/px$ and $\theta_E \equiv e_ta_E/p = e_tE/px = 1 - \theta_F$. In the small open economy $\hat{p} = 0$ to isolate a change in the tariff rate.

Income $y = fF + e_DS + teM$ adjusts according to $dy = Fdf + fdF + e_DdS + tedM + eEdt$ or in percentage terms

$$\hat{y} = \varphi_F\hat{f} + \varphi_S\hat{S} + \varphi_M\widehat{M} + \varphi_t\hat{e}_t, \tag{9}$$

where $T \equiv (1 + t)/t$, the three income shares are $\varphi_F \equiv fF/y$, $\varphi_S \equiv e_tS/y$, and $\varphi_M \equiv teM/y$, and $\varphi_t \equiv \varphi_S + \varphi_MT$. The income share φ_F is greater than the factor share θ_F for the domestic factor while for the imported factor $\varphi_E < \theta_E$.

2. Comparative static effects of the tariff rate

Combine (3) and (6) through (9) into the comparative static system with the percentage change in the domestic price $\hat{e}_t$ due to a change in the tariff rate on the right,

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ -\psi_S & \sigma_{Ef} & 1 & -\psi_M & 0 \\ 0 & \sigma_{Fe} & -1 & 0 & 0 \\ 0 & -\theta_F & 0 & 0 & 0 \\ -\varphi_S & -\varphi_F & 0 & -\varphi_M & 1 \end{pmatrix} \begin{pmatrix} \hat{S} \\ \hat{f} \\ \hat{x} \\ \widehat{M} \\ \hat{y} \end{pmatrix} = \begin{pmatrix} \sigma_S \hat{e}_t \\ \sigma_{Ef} \hat{e}_t \\ \sigma_{Fe} \hat{e}_t \\ \theta_E \hat{e}_t \\ \varphi_t \hat{e}_t \end{pmatrix}. \tag{10}$$

Comparative static elasticities of the endogenous variables are solved with Cramer's rule. The determinant of the system is $\Delta \equiv \theta_F \psi_M > 0$.

The comparative static effects of the tariff in the general equilibrium are

$$\begin{aligned} \hat{f}/\hat{e}_t &= -\theta_E/\theta_F < 0 \\ \hat{x}/\hat{e}_t &= -\sigma_{Fe}/\theta_F < 0 \\ \widehat{M}/\hat{e}_t &= -(\theta_F\, \psi_S \sigma_S + \sigma)/\Delta < 0 \\ \hat{y}/\hat{e}_t &= [-\varphi_M \sigma - \theta_E \varphi_F \psi_M + \theta_F(\varphi_M \psi_S \sigma_S + \psi_M \varphi_t)]/\Delta \end{aligned} \tag{11}$$

where $\sigma \equiv \sigma_{Ef} + \sigma_{Fe} > 0$. Given that $\hat{S}/\hat{e}_t = \sigma_S$ the net of the tariff on E input is negative, $\hat{E}/\hat{e}_t = \widehat{M}/\hat{e}_t + \hat{S}/\hat{e}_t = -\sigma/\theta_F < 0$.

The domestic factor price f decreases with the tariff due to decreased marginal productivity from the reduced E input. A smaller factor share θ_F implies more dependence on E input and a larger decrease in f.

Output x also decreases with the reduced E input, and falls more with a smaller θ_F. Stronger substitution toward domestic factor F in the σ_{Fe} elasticity implies more of a decrease in

x due to a larger shift in the cost minimizing input mix toward the domestic factor. In the limit as substitution approaches zero, output x would not fall with the tariff.

Stronger substitution σ implies more of a decrease in import M with a more of a shift in the factor mix toward the domestic factor. Stronger price elasticity of supply σ_S also implies more of a decrease in M as import competing supply displaces more of the import. A higher import competing input share ψ_S implies more of a decrease in M, as does a larger factor share θ_E.

The tariff rate has an ambiguous effect on income y. Increases in payment e_tS to the import competing factor offsets reduced payment fF to the domestic factor. Tariff revenue teM is also included in income. Equivalently, income increases if import spending falls more than output. For an arbitrarily small tariff rate, the term φ_t would be large favoring a positive effect on income.

Weaker substitution σ favors increased income y due to the smaller decrease in import M and increased tariff revenue teM with the tariff. Increased income is also favored by a larger role of import competing supply including a larger income share φ_S, larger input share ψ_S, and a stronger supply elasticity σ_S.

Further assumptions and restrictions would be necessary to ensure concavity of income in the tariff rate. The point in the present general technology is that real income may increase with the tariff and may be maximized at a positive tariff rate as in the following simulations.

3. Simulated tariff rate and income

In the following simulations of Cobb-Douglas CD production, the tariff rate t ranges from 0 to 1 in discrete steps of 0.01. Moderate substitution and constant factor shares characterize

CD production. The domestic factor output share is set to $\theta_F = 0.6$. Exogenous variables are set to unit value $e = p = F = 1$. Import competing quantity supplied S starts with a zero tariff at 10% of total E input, $S = 0.02$. Sensitivity to the import competing price elasticity of supply σ_S is examined.

Figure 2 assumes a unit price elasticity of supply $\sigma_S = 1$. Variables are rescaled as indicated for ease of comparison. Import M falls by 86% over the range of tariff rates while output x falls 37% due to the offsetting 99% increase in domestic quantity supplied S. Income fF of the domestic factor also declines by 37% as its share of income falls from 0.94 to 0.65. Payment e_tS to the import competing factor increases from 0.02 to 0.08 at an increasing rate as its share of income rises from 0.06 to 0.25. Income is maximized at $t^y = 0.06$ where tariff revenue R accounts for 3% of income. The identical income path is derived as $y = x - M$. Tariff revenue R is concave in the tariff rate and maximized at $t^R = 0.55$ where it accounts for 12% of income.

* Figure 2 *

Figure 3 illustrates a stronger import competing price elasticity $\sigma_S = 1.8$, the strongest consistent with imports at $t = 1$. Import M makes up the difference for optimal E input implying the same paths for output x and domestic factor income fF as in Figure 2. Import M is completely squeezed out, falling by 100% with the 244% increase in domestic quantity supplied S. The domestic factor share of income falls from 0.94 to 0.60. Payment e_tS to the import competing factor increases from 0.02 to the larger 0.14 as its share of income rises from 0.06 to 0.40. Income is maximized at the higher $t^y = 0.17$ where tariff revenue accounts for 7% of income. Tariff revenue R is maximized at $t^R = 0.44$ where it accounts for 10% of income.

* Figure 3 *

The higher price elasticity of supply σ_S in Figure 3 implies stronger effects of the tariff making it more favorable for the import competing factor. Income is maximized at a higher tariff rate. The two factors F and S have quite a bit at stake regarding the tariff. Higher and lower degrees of substitution with constant elasticity of substitution CES lead to similar results. For instance, with the weaker CES = 0.67 the domestic factor share θ_F falls from 0.66 to 0.57 while the other paths are similar to those in Figures 2 and 3.

4. Conclusion

In the present small open competitive economy, an increase in the tariff on an imported factor lowers import, output, and payment to the domestic factor but increases quantity supplied of the import competing factor. Real income increases if the increased payment to the import competing factor more than offsets decreased payment to the domestic factor. Equivalently, income increases if import spending decreases more than output.

Adjustments in the general equilibrium hinge on the price elasticity of import competing supply as well as factor shares, substitution, and the import share. The potential positive effect of the tariff on income relates to growth theory and macroeconomics as well as trade theory.

The intuition regarding possible second best improvement due to a tariff does not apply to the present purely competitive economy. The exogenous price of the imported factor determines its optimal input level including import and import competing quantity supplied. While a tariff lowers import, the import competing quantity supplied increases as does the factor price inside the country.

The present simulations suggest the model may have weighty policy implications in the debates over energy tariffs and taxes on foreign capital. The substantial income redistribution from the domestic to the import competing factor suggests there may be quite a bit is at stake.

Tariff revenue may be maximized where it could account for a good share of income. Tariff revenue maximization may in fact be a common if unstated policy goal for many governments.

In models with more goods and more domestic factors, the variety of shares as well as potential complements in production would lead to an array of adjustments to a tariff. Increased income, however, would remain possible.

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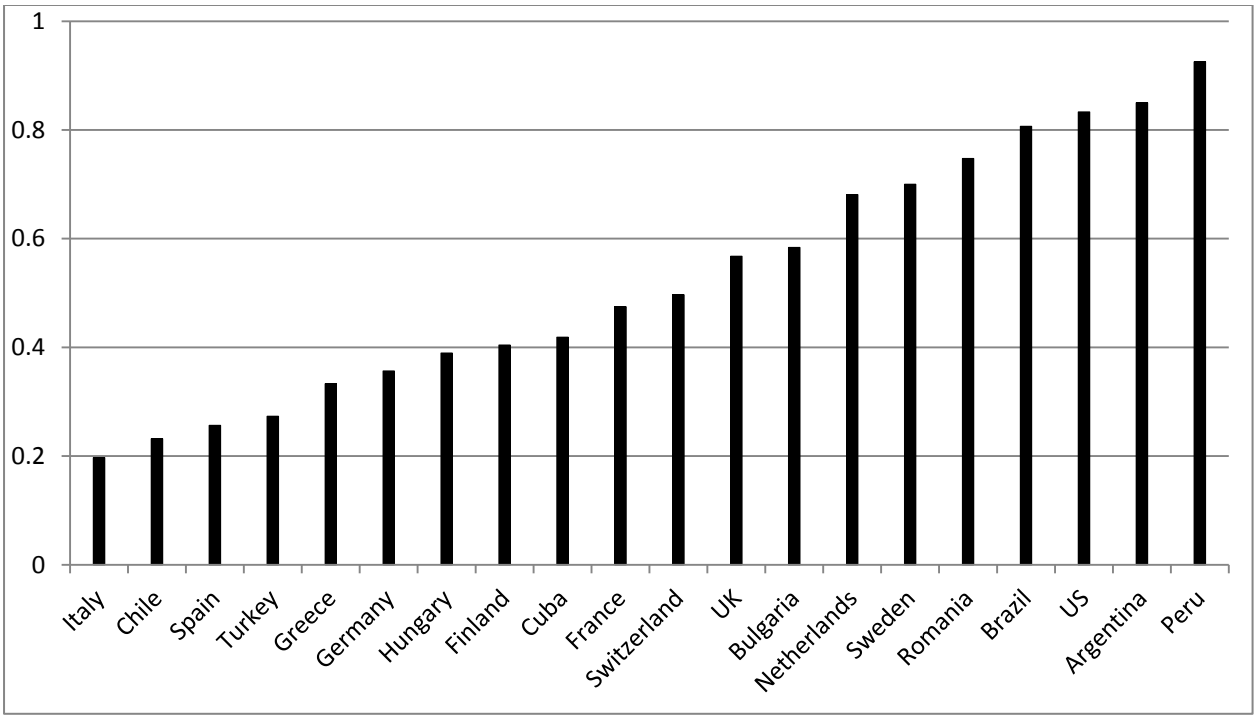

Figure 1. Import Competing Supply Relative to Total Energy Consumption,
US Department of Energy, 2012

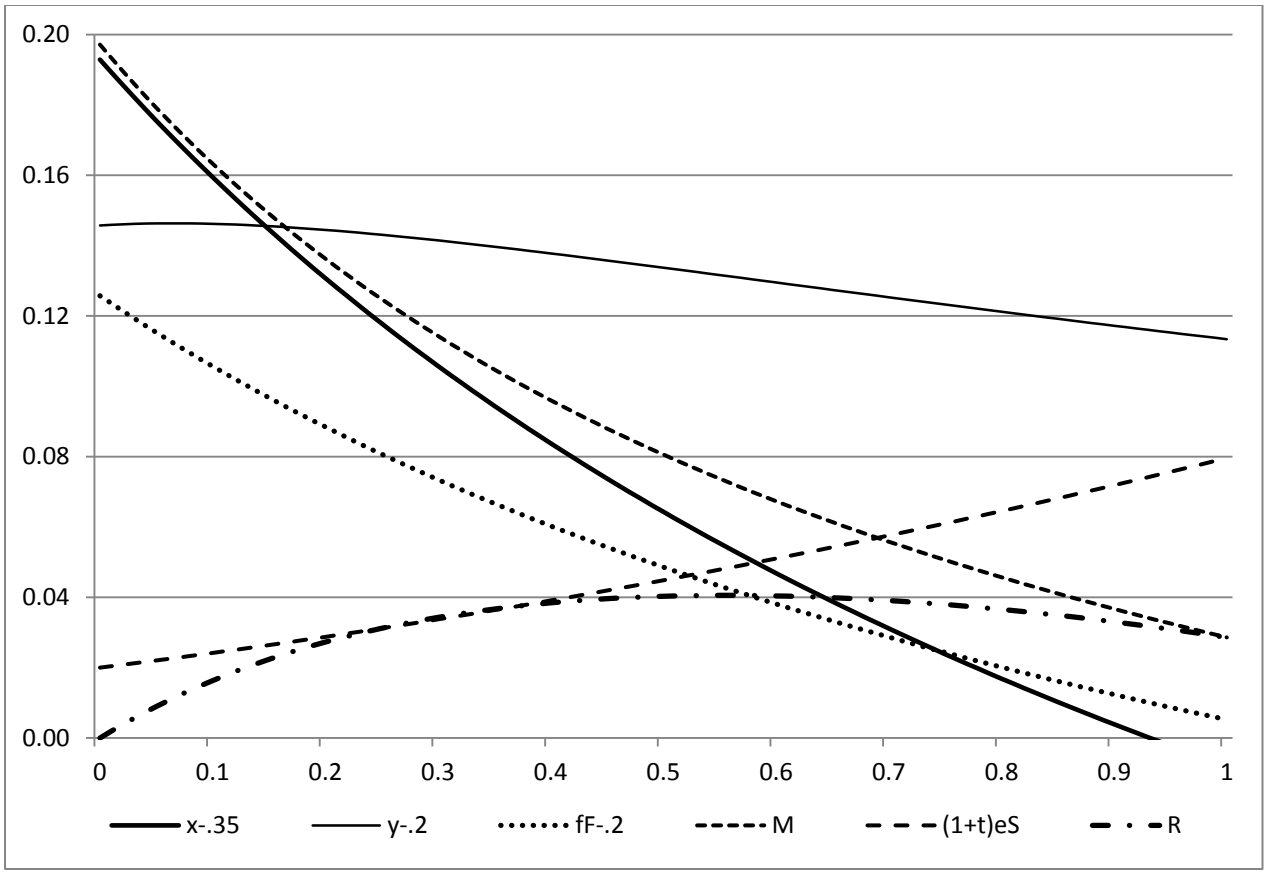

Figure 2. Simulation with $\sigma_S = 1$, output = x, income = y,

domestic factor payment = fF, import = M, domestic quantity supplied S, tariff revenue = R

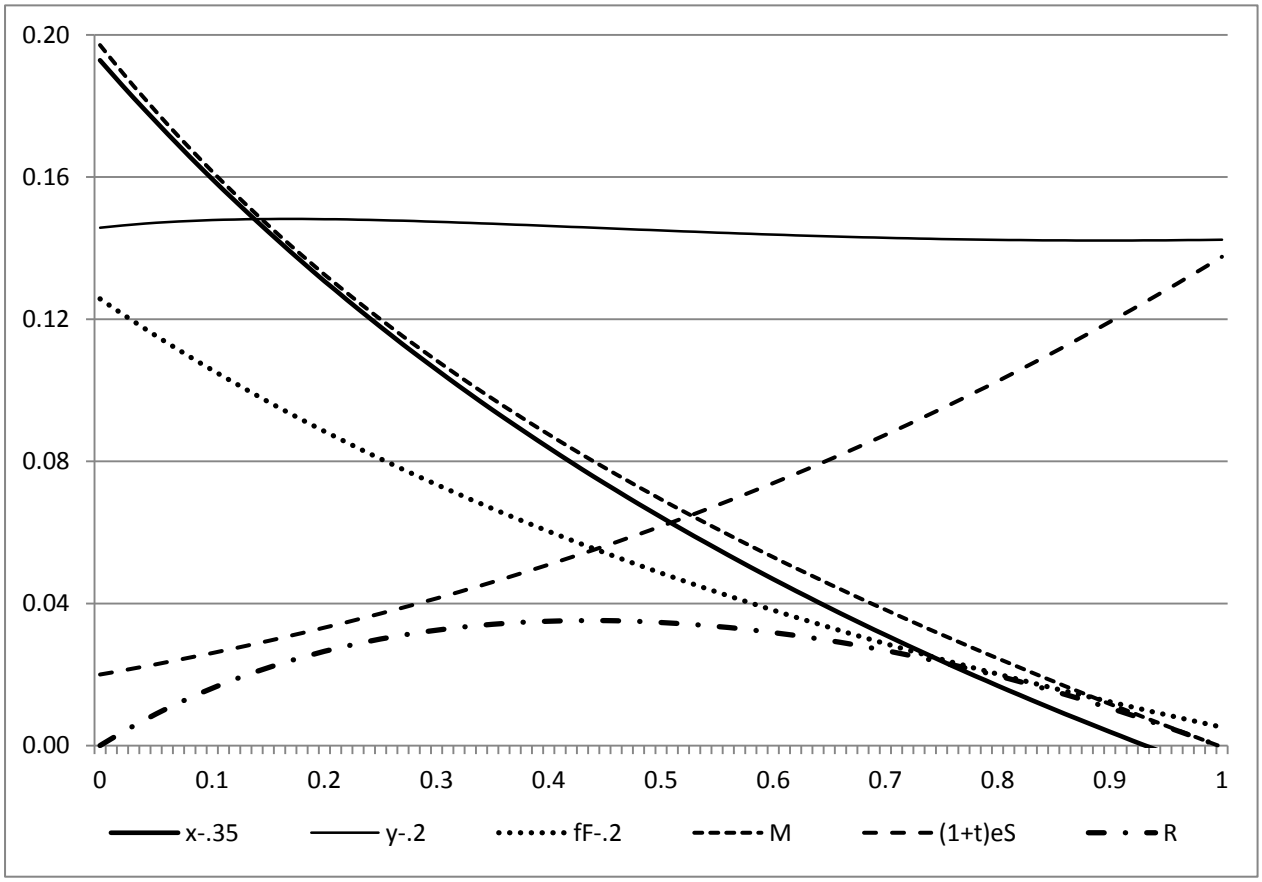

Figure 3. Simulation with $\sigma_S = 1.8$, output = x, income = y,

domestic factor payment = fF, import = M, domestic quantity supplied S, tariff revenue = R