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A tariff on imported energy in a small open economy alters production, redistributes income, and generates tariff revenue. The present paper includes tariff revenue in a general equilibrium economy producing two traded goods with imported energy and domestic capital and labor. An energy tariff reduces energy intensive output and domestic factor income but payment to one domestic factor may rise as might the other output. Tariff revenue, not included in the related theoretical literature, is shown to be concave in the tariff. A simulation illustrates these general equilibrium properties including the revenue maximizing tariff.

Keywords: Energy tariffs, tariff revenue, general equilibrium

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Energy Tariffs, Production, and Income in a Small Open Economy

A tariff on an imported factor of production in a small open economy lowers the import, shrinks the production frontier, and reduces domestic factor income. The present paper examines a competitive economy producing two traded goods with imported energy and domestic capital and labor, extending the theory by explicitly including tariff revenue. This model is the simplest that addresses two underlying issues in the debate over energy tariffs, namely energy intensive output and domestic factor income distribution.

If energy is an intensive factor for one of the goods, the tariff raises payment to the other intensive factor but lowers payment to the middle factor. Output of the energy intensive good falls but the other output may rise. Opposing interests in energy tariffs can be expected. Tariff revenue is shown to be concave in the tariff, extending this property to a competitive general equilibrium economy. A simulation illustrates these properties including the tariff that maximizes tariff revenue.

There is ample motivation for examining the effects of tariffs on energy imports. Energy tariffs have one definite advantage over other taxes, offering governments a reliable source of revenue when other taxes may be difficult to collect. Across energy importing countries, tariff revenue maximization may be a common policy goal. Kline and Weyant (1982) make the point that energy tariffs have the advantage of reducing dependence in importing countries, but their negative economic impacts are documented by Hebatu and Semboja (1994).

Energy tariffs in the form of border carbon taxes would facilitate reaching carbon dioxide emission targets. Proost and Regemorter (1992) find tariffs on embodied carbon dioxide are effective in attaining abatement targets. Dissou and Eyland (2011) find tariffs are effective but at a higher cost than emission taxes, while Böhringer, Bye, Fæhn, and Rosendahl (2012) find tariffs compare more favorably. The higher domestic price resulting from an energy tariff also substitutes for alternative energy subsidies.

The present paper does not include any externality but contributes with a general equilibrium model that separates energy intensive production, allows redistribution of domestic factor income, and includes tariff revenue in income. Effects on the pattern of production and income distribution are central if underlying issues in the political debate surrounding energy tariffs.

The first section introduces the general equilibrium of the small open economy followed by a section that develops the comparative static model. The third section provides model background on domestic factor endowments and product prices. The fourth section analyzes the effects of an energy tariff on energy imports, outputs, domestic factor prices, and income. A final section simulates a Cobb-Douglas economy across a range of energy tariffs, illustrating the tariff that maximizes revenue.

1. Factor tariffs, output, and income

Imported energy input is an example of an internationally mobile factor of production introduced by Mundell (1957) to the theory of production and trade in a small open economy. This literature, focusing on exogenous changes in the world price of the imported factor, includes Kemp (1966), Jones (1967), Chipman (1971), Caves (1971), Jones and Ruffin (1975), Ferguson (1978), Srinivasan (1983), Svensson (1984), Fergusen (1978), Thompson (1983), and Ethier and Svensson (1986). The present paper extends this theory by explicitly considering an input tariff and including tariff revenue in income distribution.

There is a related literature on imported intermediate goods entering production with fixed unit inpu coefficients. Ruffin (1969) develops the fundamentals model of utility maximization with a tariff on an imported intermediate good. Panagaria (1992) finds the tariff has an ambiguous utility effect. In the present model, this ambiguous effect would be weakened due to the substitution of domestic factors for imported energy with the tariff.

The present neoclassical economy is pictured by the production possibility frontier in Figure 1. The small open economy produces at point P given the exogenous terms of trade $tt = -p_1/p_2$ where p_j is the price of good j. Assume good 1 is the export and good 2 the import with both p_1 and p_2 exogenous for the small open economy. The production frontier is determined by endowments of domestic factors of production as well as energy imports.

* Figure 1 *

The small open economy is a price taker at the world energy price e. Export of energy intensive good 1 must cover import spending eE implying product trade starts at that point on the lower tt line. Real income in terms of the export is its intercept y on the x_1 axis.

An energy tariff shrinks the production frontier with more of a reduction in the potential to produce energy intensive good 1. At constant world prices, production of energy intensive x_1 falls but x_2 may rise as pictured in Figure 1. Import spending falls. Underlying these output adjustments, domestic factor income is redistributed and tariff revenue is generated. The present model is the simplest that allows arbitrary prices including tariffs or subsidies for imported energy and the two traded goods.

Output and income are related through import spending. In the competitive constant returns economy, the value of output x is exhausted by payments to the three factors,

$$x \equiv \Sigma_j p_j x_j = wL + rK + (1 + t)eE, \quad (1)$$

where p_j is the price of good j, L is the labor endowment, K is the capital endowment, w is the wage, r is the capital return, e is the price of imported energy, E is the level of energy import, and t is the energy tariff. Factors are paid marginal products in each sector.

Income y is domestic factor payment plus tariff revenue,

$$y \equiv rK + wL + teE, \tag{2}$$

equivalent to output less import spending $y = x - eE$ due to the competitive factor markets. An increase in the tariff t lowers imports E as factor prices r and w adjust.

The effects of the tariff depend on the two production functions reflected in the comparative static model by factor shares of sector revenue, industry shares of factor employment, and substitution elasticities between the three factors. Tariff effects also depend on levels of domestic factor endowments, output prices facing the small open economy, and the level of the tariff itself.

2. The comparative static model with imported energy

Imported energy is utilized according to $E = \Sigma_j a_{Ej} x_j$ in the two sectors j = 1, 2 where a_{Ej} is the cost minimizing energy input per unit of output j. By Shepard's lemma a_{Ej} is the partial derivative of the cost function with respect to energy input. The neoclassical constant returns production functions have positive and diminishing marginal products.

Energy

imports change according to $dE = \Sigma_j(a_{Ej}dx_j + x_j da_{Ej})$ or in elasticity form,

$$E' = \Sigma_j \lambda_{Ej}(a_{Ej}' + x_j'), \tag{3}$$

where primes ′ denote percentage changes and industry utilization or employment shares $\lambda_{Ej} \equiv a_{Ej}x_j/E$ sum to one. Given constant returns, the homogeneous unit energy inputs a_{Ej} depend only on relative factor prices. Employment conditions for domestic capital and labor are similar to (3).

Energy imports E are endogenous in the model while domestic factor endowments K and L are exogenous.

Given the exogenous world energy price e, the domestic price $e_D \equiv (1 + t)e$ changes according to $de_D = edt$. The model focuses on the percentage change in the domestic price e_D due to a tariff,

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

Substitution elasticities capture adjustments in the cost minimized factor mix terms to changing factor prices. As an example, the cross price substitution elasticity of capital relative to the domestic price of energy $\sigma_{KE} \equiv \Sigma_j \lambda_{Kj}(a_{Kj}'/\tau')$ is the industry share weighted sum of cross price elasticities.

Capital may be a complement relative to the price of energy as found by Berndt and Wood (1975). In the present context, the energy tariff would lower capital input per unit of output reducing capital demand and strongly increasing labor demand. Griffin and Gregory (1976) find instead that capital substitutes for energy, suggesting increased capital demand due to an energy tariff and less of an increase in the demand for labor. The literature on the substitution of capital with respect to the price of energy is reviewed by Thompson (2006).

In the present two sector model, production functions differ between sectors raising the possibility of capital as a complement with energy in one sector but a substitute in the other. Factor intensity of the two sectors is critical to the adjustment process, as are the sizes of the sectors. Adjustments of outputs and domestic factor prices interplay in the general equilibrium. Potential adjustments to the energy tariff expand considerably with the possibility of complements in production.

Own substitution elasticities, describing sensitivity of unit inputs to their own prices, are negative. Linear homogeneity implies elasticities for each input across factor prices sum to zero, $\sigma_{iE} + \sigma_{iL} + \sigma_{iK} = 0$ where i = K, L, E. If capital is a complement with respect to the domestic price of energy, σ_{KE} and σ_{EK} are negative. Concavity implies own effects outweigh cross effects, $\sigma_{ii}\sigma_{kk} - \sigma_{ik}\sigma_{ki} > 0$ for i, k = K, L, E.

Unit energy inputs adjust according to $a_{Ej}' = \sigma_{EK}r' + \sigma_{EL}w' + \sigma_{EE}\tau'$ expanding adjustment in energy imports in (3) to

$$E' = \sigma_{EK}r' + \sigma_{EL}w' + \sigma_{EE}\tau' + \Sigma_j\lambda_{Ej}x_j'. \tag{5}$$

Adjustments to changes in exogenous endowments of domestic capital K and labor L are similar.

Revenue in a sector is exhausted by payments to the three factors, $p_jx_j = wL_j + rK_i + (1 + t)eE_j$ for j = 1, 2. Divide by output x_j to link the output price to the three factor prices, $p_j = e_Da_{Ej} + wa_{Lj} + ra_{Kj}$. Differentiate to find $dp_j = ea_{Ej}dt + a_{Lj}dw + a_{Kj}dr + [e_Dda_{Ej} + wda_{Lj} + rda_{Kj}]$. The bracketed expression disappears due to the cost minimizing envelope property leading to the competitive pricing condition in elasticity form

$$p_j' = \theta_{Ej}\tau' + \theta_{Kj}r' + \theta_{Lj}w', \tag{6}$$

where the θ_{ij} are factor shares of the revenue and $\Sigma_i\theta_{ij} = 1$.

Income y = rK+ wL + teE in (2) changes according to dy = rdK + wdL + Kdr + Ldw + tedE + eEdt. In elasticity form

$$y' = \varphi_K(K' + r') + \varphi_L(L' + w') + \varphi_R(E' + T\tau'), \tag{7}$$

where $T \equiv (1 + t)/t$ and the three income shares $\varphi_K \equiv rK/y$, $\varphi_L \equiv wL/y$, and $\varphi_R \equiv teE/y$ sum to one. Tariff revenue $R \equiv teE$ and its share φ_R of income have not been included in the literature on international factor mobility.

Combine adjustments in energy imports in (5), similar employment conditions for domestic capital and labor, competitive pricing of the two traded goods in (6), and income in (7) into the comparative static system with exogenous variables on the right hand side,

$$\begin{pmatrix} -1 & \sigma_{EK} & \sigma_{EL} & \lambda_{E1} & \lambda_{E2} & 0 \\ 0 & \sigma_{KK} & \sigma_{KL} & \lambda_{K1} & \lambda_{K2} & 0 \\ 0 & \sigma_{LK} & \sigma_{LL} & \lambda_{L1} & \lambda_{L2} & 0 \\ 0 & \theta_{K1} & \theta_{L1} & 0 & 0 & 0 \\ 0 & \theta_{K2} & \theta_{L2} & 0 & 0 & 0 \\ -\varphi_R & -\varphi_K & -\varphi_L & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} E' \\ r' \\ w' \\ x_1' \\ x_2' \\ y' \end{pmatrix} = \begin{pmatrix} -\sigma_{EE}\tau' \\ K' - \sigma_{KE}\tau' \\ L' - \sigma_{LE}\tau' \\ p_1' - \theta_{E1}\tau' \\ p_2' - \theta_{E2}\tau' \\ \varphi_K K' + \varphi_L L' + \varphi_R T\tau' \end{pmatrix}. \quad (8)$$

The comparative static effects of the exogenous changes K', L', p_1', p_2', and τ' are derived with Cramer's rule. The present focus is the effects of an energy tariff through the domestic energy price τ'. Adjustments occur in the endogenous vector of energy imports E', domestic factor prices r' and w', outputs x_1' and x_2', and income y'.

Qualitative comparative static properties hinge on factor intensity described by relative factor shares θ_{ij} of sector revenue, or equivalently by relative industry shares λ_{ij} of factor employment. Assume energy is the intensive or extreme factor for exported good 1 and capital the middle factor in the ranking of relative factor shares

$$\theta_{E1}/\theta_{E2} > \theta_{K1}/\theta_{K2} > \theta_{L1}/\theta_{L2}, \quad (9)$$

with the same ranking of industry shares. Between energy and capital, the terms $\theta_{EK} \equiv \theta_{E1}\theta_{K2} - \theta_{E2}\theta_{K1} > 0$ and $\lambda_{EK} \equiv \lambda_{E1}\lambda_{K2} - \lambda_{E2}\lambda_{K1} > 0$ describe good 1 as energy intensive relative to capital.

Good 1 is also capital intensive relative to labor $\theta_{KL} > 0$ and $\lambda_{KL} > 0$, and energy intensive relative to labor $\theta_{EL} > 0$ and $\lambda_{EL} > 0$. By implication, energy is closer to capital than labor, $\theta_{EL} > \theta_{EK}$ and $\lambda_{EL} > \lambda_{EK}$. This factor intensity implies a negative determinant $\Delta = -\theta_{KL}\lambda_{KL}$ of the system in (8).

There are six possible factor intensity rankings, each with its own signs of θ_{ik} and λ_{ik} terms for i, k = K, L, E. Comparative static properties are sensitive to the intensity ranking. The critical alternative assumption is that energy is the middle factor as in $\theta_{K1}/\theta_{K2} > \theta_{E1}/\theta_{E2} > \theta_{L1}/\theta_{L2}$, leading to qualitatively different comparative static effects discussed in the results.

3. Changes or differences in endowments and prices

This section presents model background on factor endowments and output prices. Changes or differences in domestic factor endowments affect energy imports in (8) according to $E'/K' = \lambda_{EL}/\lambda_{KL} > 0$ and $E'/L' = -\lambda_{EK}/\lambda_{KL} < 0$. Increased endowment of middle factor capital raises energy imports while increased endowment of labor, intensive in the other sector, reduces energy imports.

Energy imports are independent of substitution due to the lack of any factor price impacts in the factor price equalization property noted below. In other models with less aggregated inputs and outputs, substitution would have some influence on adjustments in energy imports to changes in domestic endowments. Projecting these comparative static results to compare two economies that are otherwise identical, the capital abundant one would import more energy,

If energy is the middle factor, the negative λ_{EK} implies energy imports increase with both K and L endowments. Comparing two such economies, if energy were closer to capital in intensity in the property $-\lambda_{EK} > \lambda_{EL}$ then the capital abundant country would import more energy.

The factor price equalization property holds with adjustments in factor demands exactly offsetting changes in factor supplies, $w'/L' = r'/L' = w'/K' = r'/K' = 0$. Factor price equalization is characteristic of models such as the present one with the same number of factors and exogenous prices. Trade between two such economies based on different domestic factor endowments would lead to equal factor prices.

Outputs follow factor intensity in Rybczynski type endowment effects. Each output has a positive link to the endowment of its intensive domestic factor and a negative link to the other. Good 1 output increases with capital, and good 2 with labor. Ruffin (1977) develops the comparison of two such economies with trade following the Heckscher-Ohlin pattern based on factor abundance and intensity.

Domestic factor endowments affect income according to

$$y'/K' = \varphi_K + \varphi_R\lambda_{EL}/\lambda_{KL} > 0 \qquad (10)$$

$$y'/L' = \varphi_L - \varphi_R\lambda_{EK}/\lambda_{KL}.$$

Income shares affect the direction and size of these factor endowment effects. An increase in capital raises income by its return, attracting energy and raising tariff revenue. The total adjustment y'/K' is the income weighted average of these two positive effects.

An increase in labor raises income by the wage but lowers energy imports and tariff revenue leading to its ambiguous effect on income. A positive effect of labor on income is favored by a larger labor share of income, as well as capital close to energy in factor intensity.

If energy is the middle factor, the positive λ_{EK} implies both capital and labor raise income. If capital and labor are more similar in factor intensity λ_{KL} becomes smaller and domestic factor endowments have larger effects on income.

The effects of changing prices on energy imports depend on substitution as well as intensity. For a change in the price of good 1,

$$E'/p_1' = (\theta_{K2}\sigma_1 - \theta_{L2}\sigma_2)/\Delta, \qquad (11)$$

where $\sigma_1 \equiv \lambda_{KL}\sigma_{EL} - \lambda_{EL}\sigma_{KL} + \lambda_{EK}\sigma_{LL} = (\lambda_{KL} - \lambda_{EK})\sigma_{EL} - (\lambda_{EL} + \lambda_{EK})\sigma_{KL}$ and $\sigma_2 \equiv \lambda_{KL}\sigma_{EK} - \lambda_{EL}\sigma_{KK} + \lambda_{EK}\sigma_{LK} = (\lambda_{KL} + \lambda_{EL})\sigma_{EK} + (\lambda_{EK} + \lambda_{EL})\sigma_{LK}$. There is a presumption that $\sigma_1 < 0$ and $\sigma_3 > 0$ implying $E'/p_1' > 0$ with an increase in the price and output of energy intensive good 1 raising energy imports. Energy imports could decrease, however, if energy is a strong substitute for labor with a large positive σ_{EL} and a complement with capital with a negative σ_{EK}. This unusual result is also favored by a large intensity difference between capital and labor in a large λ_{KL} term. A change in p_2 is similar with the presumption that $E'/p_2' = (-\theta_{K1}\sigma_1 + \theta_{L1}\sigma_2)/\Delta < 0$. Thompson (1983) shows imports must increase with at least one of the two product prices. In the present model, the strong presumption is that imports increase with the price of the energy intensive good.

Standard Stolper-Samuelson adjustments of domestic factor prices to changing product prices depend only on factor intensity. The production frontier is also locally convex in prices with x_m'/p_n' cofactors that are determinants of two factor production models.

A change in the price of good 1 affects income according to $y'/p_1' = [(\varphi_K\theta_{L2} - \varphi_L\theta_{K2})/\theta_{KL}] + \varphi_R(E'/p_1')$. The expression in brackets is positive due to the spanning condition for full employment, $K/L > K_2/L_2$, implying a net positive effect of an increase in p_1 on domestic factor payments. A larger income share φ_R of tariff revenue and increase in energy imports favor increased income. Analysis of a change in p_2 is similar with an ambiguous outcome due to falling energy imports.

4. Adjustments to an energy tariff

An energy tariff lowers imports in (8) according to

$$E'/\tau' = -\Delta_{32}/\Delta < 0, \qquad (12)$$

where Δ_{32} is the negative determinant of the model with three domestic factors. Concavity of the two production functions implies $\Delta_{32} < 0$ as discussed by Chang (1979) and Thompson (1985). This *mutatis mutandis* downward sloping import demand is not apparent given the flexibility of the two outputs and two domestic inputs.

Elastic energy demand $E'/\tau' < -1$ follows if $-\Delta_{32} < -\Delta$ in a condition favored by stronger substitution. If energy demand is elastic, the tariff reduces import spending inclusive of the tariff. Weaker substitution would lead to inelastic energy import demand.

Effects of the energy tariff on domestic factor prices depend only on factor intensity,

$$r'/\tau' = -\theta_{EL}/\theta_{KL} < 0 \qquad (13)$$

$$w'/\tau' = \theta_{EK}/\theta_{KL} > 0.$$

Domestic factors have polar interests in an energy tariff with middle factor capital hurt while intensive labor benefits. Rising wages are consistent with expanding labor intensive output as the economy shifts away from energy intensive production. If energy were the middle factor, the negative θ_{EK} would imply both domestic factor prices fall with the tariff.

The energy tariff shrinks the production frontier as the two outputs adjust according to

$$x_1'/\tau' = (\lambda_{K2}\sigma_3 + \lambda_{L2}\sigma_4)/\Delta \qquad (14)$$

$$x_2'/\tau' = -(\lambda_{K1}\sigma_3 + \lambda_{L1}\sigma_4)/\Delta,$$

where $\sigma_3 \equiv \theta_{EL}\sigma_{LK} - \theta_{KL}\sigma_{EL} + \theta_{EK}\sigma_{LL} = \theta_{EL}\sigma_{LK} - (\theta_{KL} + \theta_{EK})\sigma_{EL} - \theta_{EK}\sigma_{KL}$ and $\sigma_4 \equiv \theta_{KL}\sigma_{EK} - \theta_{EL}\sigma_{KK} - \theta_{EK}\sigma_{KL} = (\theta_{KL} + \theta_{EL})\sigma_{EK} + \theta_{KL}\sigma_{LK} - \theta_{EK}\sigma_{KL}$ Both factor intensity and substitution affect these output adjustments with the presumption that $\sigma_3 < 0$ and $\sigma_4 > 0$.

The tariff must lower at least one of the two outputs as shown by Thompson (1983). Energy intensive output x_1 is presumed to fall as in Figure 1. An increase in labor intensive output x_2 is consistent with the rising wage w in (13).

If energy and capital were complements, the negative substitution elasticities σ_{LK} and σ_{KL} would favor a positive σ_3 and less of a decrease in x_1 due to the tariff. The higher domestic price of energy reduces the unit capital input with strong substitution toward labor, leading to the smaller decrease in x_1. A smaller share of capital employed in sector 1 reflected by a larger λ_{K2} also favors less of a decrease in energy intensive output x_1.

Income adjusts to the energy tariff according to

$$y'/\tau' = [\varphi_L(w'/\tau') + \varphi_K(r'/\tau')]/\theta_{KL} + \varphi_E(R'/\tau'), \quad (15)$$

where tariff revenue is $R \equiv teE$ and $R'/\tau' = T + E'/\tau'$. The first two terms in (15) simplify to $(\varphi_L\theta_{EK} - \varphi_K\theta_{EL})/\theta_{KL}$ reflecting the rising wage and falling capital return in (13). Direct substitution implies $\varphi_L\theta_{EK} < \varphi_K\theta_{EL}$ implying the tariff lowers domestic factor income.

A larger labor share φ_L favors less of a decrease in domestic factor income due to the increased weight on the rising wage. A larger θ_{EK} and smaller θ_{EL} also favor less of a decrease in domestic factor income with energy closer to labor in factor intensity.

The term $\varphi_R(R'/\tau') = \varphi_R(T + E'/\tau')$ in (15) captures the adjustment in tariff revenue. An increase in the tariff lowers the term $T = (1 + t)/t$ offsetting the decreased import. At lower tariffs T is high and tariff revenue R rises with the tariff. At higher tariffs T approaches 1 and the negative E'/τ' becomes more elastic.

At higher tariffs, the tariff lowers tariff revenue R. Substitution elasticities also become stronger at higher tariffs implying a more elastic E'/τ'. As a result the tariff lowers revenue at higher tariff levels. The following simulation illustrates concave tariff revenue with Cobb-Douglas production.

5. A simulated energy tariff

Consider the general equilibrium adjustments to a range of energy tariffs from 0 to 1 with Cobb-Douglas production functions. For energy intensive sector 1 the production function is $x_1 = K_1^{0.5}L_1^{0.2}E_1^{0.3}$ and for the labor intensive sector $x_2 = K_2^{0.4}L_2^{0.5}L_2^{0.1}$. Factor intensity maintains the ranking in (9) throughout the range of tariffs as industry shares adjust. Cobb-Douglas is a familiar but restrictive functional form with constant factor shares but simulations with constant elasticity and translog production functions produce similar results.

Fully employed domestic factor endowments are K = 100 and L = 10. The price e of imported energy and prices p_1 and p_2 of the two goods are standardized to 1. Factor endowments are chosen to be consistent with prices and production functions for feasible economic results across the range of tariffs. Adjustment paths to the rising tariff are not overly sensitive to changing parameters except for the Cobb-Douglas production coefficients.

The main behavioral assumptions are full employment and competitive pricing with factors paid marginal products in each sector. These constraints motivate the nonlinear optimization of income $y = wL + rK + teE$. Due to Euler's theorem, optimization of $y = p_1x_1 + p_2x_2 – E$ yields the identical outcome.

Figure 2 plots adjustments to a tariff rising from 0 to 1. Energy imports E declines by 83% from 8.3 at t = 0 to 1.4 at t = 1. Energy intensive output x_1 declines from 26.6 to 3.4 across the range of tariffs, as labor intensive x_2 increases from 3.4 to 17.4. Total output $x = x_1 + x_2$ declines by 31% from 30.0 to 20.8. These substantial adjustments in energy imports and outputs are characteristic of the constant factor shares in Cobb-Doublas production. Stronger constant elasticity substitution leads to a declining energy share with less of a decline in imports and smaller output adjustments.

* Figure 2*

Income y declines 11% from 21.7 to 19.4 across the range of tariffs. Income becomes more sensitive to the tariff as the rate increases with the income elasticity y'/τ' in (15) falling from -0.004 to -0.242. At higher domestic energy prices, income is more exposed to the increased domestic price of energy. At low tariffs, the reduced energy import spending nearly offsets falling domestic factor income. The effect of the tariff on income is weaker with stronger constant elasticity substitution.

Figure 3 shows the associated change in domestic factor payments due to the rising energy tariff. The capital payment rK declines 41% from 14.7 to 8.6 as the labor payment wL increases 34% from 7.0 to 9.4 across the range of tariffs. A higher energy tariff would always be favored by labor although total domestic factor payment declines 17% from 21.7 to 18.0 across the range of tariffs.

* Figure 3 *

Tariff revenue R rises from 0 to its maximum 1.62 at $t^R = 0.59$, the tariff of a revenue maximizing government. The tariff revenue share φ_R of income has a similar path that is maximized at $t^\varphi = 0.64$, with the negative effect of the tariff on domestic factor payment implying $t^\varphi > t^R$. Stronger constant elasticity substitution results in a higher revenue maximizing tariff.

The elastic effect of the tariff on energy imports E'/τ' becomes stronger as the tariff increases, falling from -2.16 to -3.33 over the range of tariffs. Energy imports become more elastic at higher tariff levels. Stronger constant elasticity substitution leads to less elastic energy imports.

The effect of the tariff on the domestic energy price diminishes as the tariff increases with τ' falling from 0.010 to 0.005 over the range of tariffs. The marginal effect of tariff revenue on income $M \equiv \varphi_E(T + E'/\tau')$ from (15) declines and becomes negative in Figure 3 at the revenue maximizing tariff t^R.

The energy import tariff can be analyzed in addition to other taxes. For instance, if the government taxes factor income at 10% government revenue rises from g = 2.2 at t = 0 to its maximum $g^* = 3.5$ at $t^g = 0.52$. The negative effect of the energy tariff on domestic factor payments implies $t^g < t^*$. A similar result follows with output taxes.

6. Conclusion

Other issues regarding energy tariffs can be mentioned. An energy tariff for a large economy lowers the international price. Weitzel, Hübler, and Peterson (2012) stress oil tariffs as a strategic tool to affect the terms of trade. A Metzler (1949) paradox with a lower domestic energy price inclusive of the tariff is feasible and perhaps likely in the global oil market as described by Thompson (2007).

For an economy with domestic energy supply competing with the import, the tariff would increase quantity supplied. This increase in the domestic resource payment could result in higher income. Jones (1990) documents the positive effect of an oil tariff on US oil output and income.

The present adjustments to an energy tariff depend on production functions, domestic factor endowments, income shares, and the tariff level. An energy tariff lowers imports and shrinks the production frontier. Payment to the domestic factor intensive in the other sector rises as might the other output, while payment to the middle domestic factor falls. If energy is the middle intensity factor, a tariff lowers both domestic factor prices. At least one of the two outputs must fall with the tariff. These results suggest unanimous political opinion on energy tariffs cannot be expected.

There may be an energy tariff that maximizes tariff revenue. For many governments, the implicit goal of revenue maximization suggests the present model is relevant for predicting energy tariffs.

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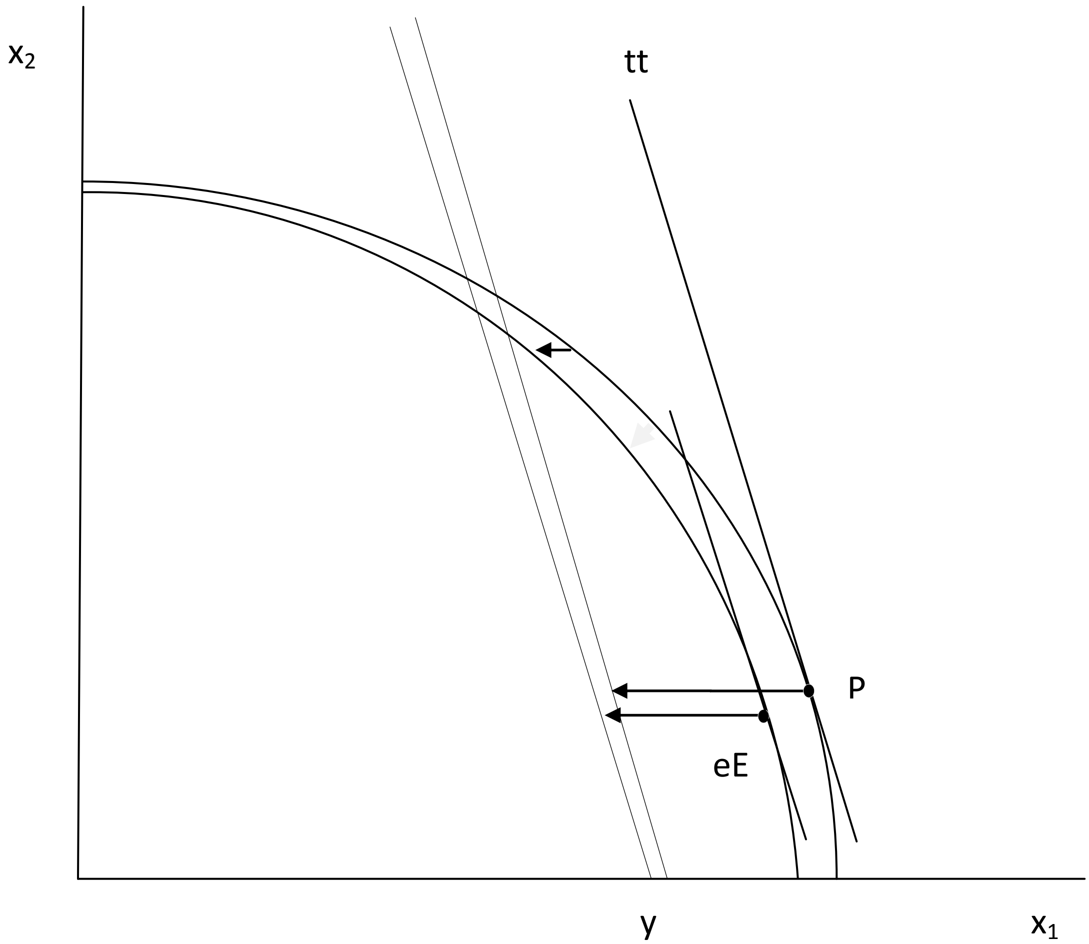

Figure 1. A factor tariff and income

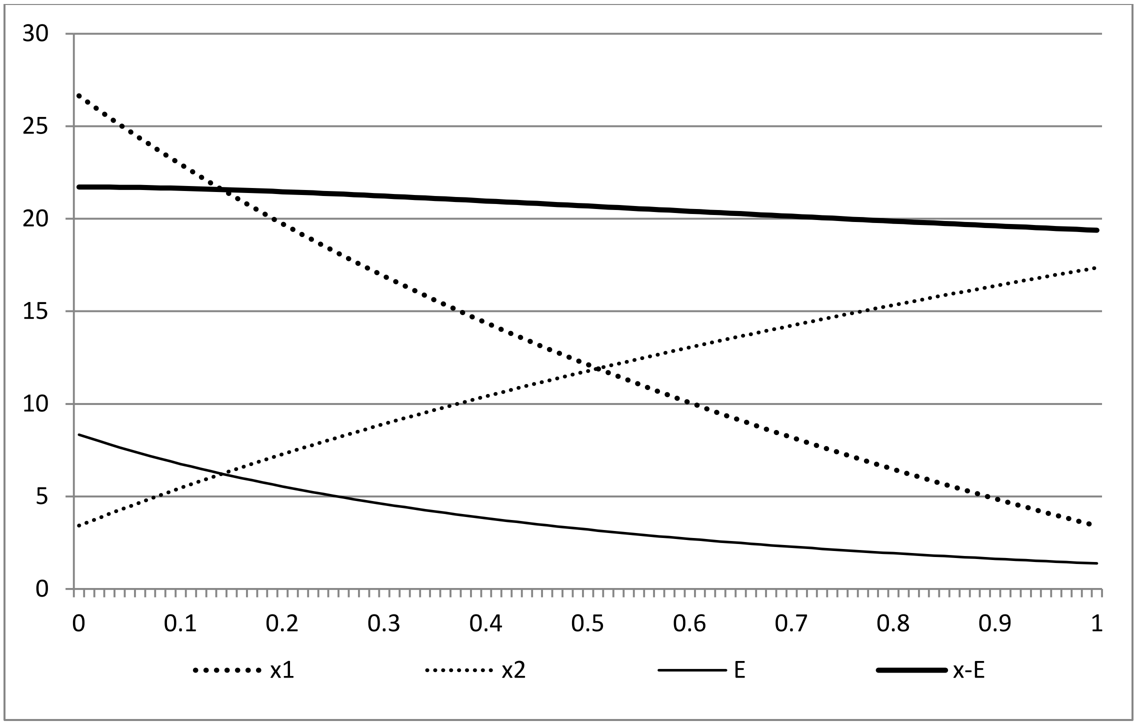

Figure 2. Outputs, import, and income

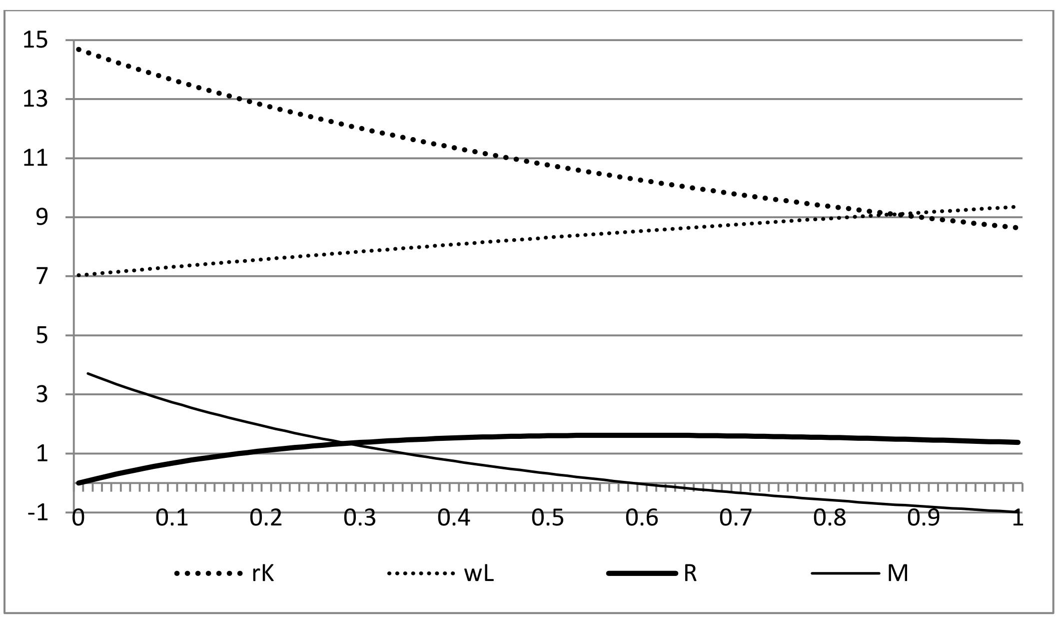

Figure 3. Factor payments and tariff revenue