



Energy tariffs in a small open economy[☆]

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ABSTRACT

Tariffs on imported energy alter production and redistribute income. The present paper examines a small open economy producing two traded goods with capital, labor, and imported energy. A tariff reduces import and domestic factor income but payment to one domestic factor rises. Energy intensive output falls but the other output may rise in the general equilibrium. Political opinions on the tariff would differ. Revenue is concave in the tariff suggesting that the government might set the tariff to maximize revenue. A simulation illustrates these general equilibrium properties across a range of tariffs.

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1. Introduction

A tariff on imported energy lowers import, shrinking the production frontier and reducing domestic factor income. The present paper examines a small open economy producing two traded goods with capital, labor, and imported energy. The model extends the underlying theory by explicitly analyzing a tariff and tariff revenue. The paper addresses underlying issues in the debate over energy tariffs including energy intensive production and income distribution.

For reference, assume that export production is energy intensive and import competing production labor intensive. A tariff lowers export production and the capital return, but raises the wage and may raise production of the import competing good. Opposing interests to energy tariffs would be expected in practice.

Tariff revenue is shown to be concave in the tariff, extending this assumed property to general equilibrium. Energy tariffs offer a reliable source of government revenue when other taxes are more difficult to collect. Revenue maximization may be a typical if implicit policy goal suggesting the present model may predict energy tariffs in practice.

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The literature on energy tariffs is motivated largely by issues of import dependence and emission control. Kline and Weyant (1982) make the point that energy tariffs reduce import dependence. Proost and Van Regemorter (1992) find tariffs on embodied carbon dioxide effectively attain emission targets. Dissou and Eyland (2011) similarly find that tariffs are effective but at higher cost than emission taxes, while Böhringer et al. (2012) find that tariffs compare favorably. Short of externalities, energy tariffs are expected to have negative economic impacts as documented by Hatibu and Semboja (1994). The present model offers a systematic framework to examine energy tariffs in the general equilibrium.

Section 2 introduces the general equilibrium model followed by a section developing the background of the model. Section 4 analyzes the comparative static effects of an energy tariff on production, domestic factor prices, and income. A final section simulates a Cobb–Douglas economy illustrating model properties including the revenue maximizing tariff.

2. The general equilibrium of energy tariffs

Internationally mobile factors of production are introduced to the theory of production and trade by Mundell (1957). The literature focusing on changes in the exogenous 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), Ferguson (1978), Thompson (1983), and Ethier and

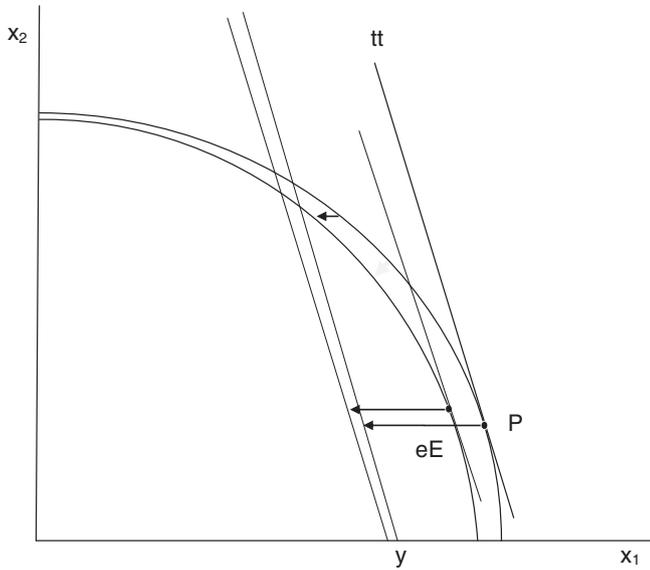


Fig. 1. A factor tariff and income.

Svensson (1986). The present paper extends this fundamental theory by analyzing a tariff and tariff revenue.

There is a related literature on imported intermediate goods entering production with fixed unit input coefficients. Ruffin (1969) develops the fundamental model analyzing the effects of a tariff. Panagariya (1992) finds a tariff that has an ambiguous utility effect. The present model focuses on production and allows input substitution when the tariff raises the domestic price of imported energy.

The present model is illustrated by the production frontier in Fig. 1 determined by the two production functions, domestic endowments of capital and labor, and the level of imported energy. The small open economy produces at point P given the terms of trade $tt = -p_1 / p_2$ where p_j is the exogenous world price of good j. For reference, assume good 1 is the export and good 2 the import.

The small open economy is a price taker in the global energy market at price e. Export of energy intensive good 1 must cover import spending eE as well as imports of good 2 implying that trade in goods 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 energy intensive good 1. Output x_1 falls but x_2 may rise as in Fig. 1. Energy import spending eE decreases implying lower terms of trade line. The tariff changes outputs, redistributes income between domestic capital and labor, and generates tariff revenue.

Assuming that competitive constant returns production, Euler's theorem implies that the value of output is exhausted by payments to the three factors according to

$$\sum_j p_j x_j = wL + rK + (1+t)eE, \quad (1)$$

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 world price of energy, E is energy import, and t is the tariff. Factors are paid marginal products in each sector. Income y equals domestic factor payment plus tariff revenue,

$$y \equiv rK + wL + teE, \quad (2)$$

equivalent to output less import spending $y = \sum_j p_j x_j - eE$.

Imported energy is utilized according to $E = \sum_j a_{Ej} x_j$ in the two sectors $j = 1, 2$ where a_{Ej} is the cost minimizing energy input per unit

of good j. Unit inputs are functions of the three factor prices assuming homothetic production.

Energy imports change according to $dE = \sum_j (a_{Ej} dx_j + x_j da_{Ej})$. In elasticity terms

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

where the prime ' denotes a percentage change and industry employment shares $\lambda_{Ej} \equiv a_{Ej} x_j / E$ sum to one. Constant returns imply that the unit energy inputs a_{Ej} are homogeneous in factor prices. Employment conditions for capital and labor are similar to Eq. (3).

The domestic energy price $e_D \equiv (1+t)e$ changes with the tariff according to $de_D = edt$. For reference the percentage change in e_D simplifies to

$$\tau' \equiv dt / (1+t). \quad (4)$$

An energy tariff would lower capital demand if capital is a complement relative to the price of energy as found by Berndt and Wood (1975). If capital is a substitute for energy as in Griffin and Gregory (1976) the tariff would increase capital demand. Production functions differ between sectors raising the possibility that capital could be a complement with energy in one sector and a substitute in the other. Thompson (2006) reviews the literature on applied capital/energy input substitution.

Elasticities of input substitution capture how cost minimized factor mix terms adjust to changing factor prices. As an example the cross price substitution elasticity of capital relative to the domestic price of energy is the industry share weighted sum of those cross price elasticities, $\sigma_{KE} \equiv \sum_j \lambda_{Kj} (a_{Kj}' / \tau')$. Linear homogeneity implies elasticities sum to zero across factor prices, $\sigma_{iE} + \sigma_{iL} + \sigma_{iK} = 0$ where $i = K, L, E$. If capital is a complement with respect to the price of energy, σ_{KE} and σ_{EK} are negative. Own effects must outweigh cross effects in the condition $\sigma_{ii} \sigma_{kk} - \sigma_{ik} \sigma_{ki} > 0$ for $i, k = K, L, E$.

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

$$E' = \sigma_{EK} \tau' + \sigma_{EL} w' + \sigma_{EE} \tau' + \sum_j \lambda_{Ej} x_j'. \quad (5)$$

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

Revenue in each sector is exhausted by factor payments, $p_j x_j = wL_j + rK_j + (1+t)eE_j$ for $j = 1, 2$. Dividing by output leads to the competitive pricing conditions $p_j = e_D a_{Ej} + w a_{Lj} + r a_{Kj}$. Differentiate to find $dp_j = e a_{Ej} dt + a_{Lj} dw + a_{Kj} dr + [e_D da_{Ej} + w da_{Lj} + r da_{Kj}]$. The bracketed expression disappears due to the cost minimizing envelope property, leading to

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

where the θ_{ij} are factor shares of revenue that sum to 1.

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

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

where $T \equiv (1+t)/t$. The three income shares $\varphi_K \equiv rK/y$, $\varphi_L \equiv wL/y$, and $\varphi_R \equiv teE/y$ sum to 1.

Combine energy imports in Eq.(5), similar employment conditions for capital and labor, competitive pricing in Eq. (6), and income in Eq. (7) into the comparative static system,

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

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