

Do Oil Tariffs Lower Wages?

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Abstract

An oil tariff has potential to alter the pattern of production and income distribution across productive factors. This paper uses a general equilibrium model of production and trade with inputs of capital, labor, and international energy to examine the effects of an oil tariff. Under a range of conditions, higher energy prices created by oil tariffs would lower the ratio of wages to capital rents, and production of labor intensive goods would fall. This paper concentrates on the potential of oil tariffs to alter patterns of production and income distribution.

The pattern of production as well as the distribution of income among domestic factors of production will be altered by an oil tariff (OT). This paper examines the general equilibrium effects of an OT. Changes of the pattern of production and income distribution are not typically discussed in the debate over an OT, but may weigh heavily in the desirability of the long-run outcome. This paper uncovers conditions under which an OT would lower the wage of labor and shift production away from labor-intensive goods.

A competitive general equilibrium model of production with three factors (capital, labor, energy) is used to examine the comparative static adjustment to an OT. The three-factor production structure directly extends the two-factor Heckscher-Ohlin model developed by Samuelson (1953-4), Jones (1965), and others. Ruffin (1981), Jones and Easton (1983), Thompson (1986), and others have developed properties of the three-factor production structure. This paper utilizes a model with one internationally mobile factor of production, as developed by Srinivasan (1983) and Thompson (1983).

Under a range of feasible conditions, an OT will lower the wage and raise the return to capital. Production of labor-intensive manufactures would also likely decline with an OT, as production shifts toward capital-intensive goods.

Leamer (1991) and others have noted that the move toward free trade in United States will have a depressing effect on wages, especially for unskilled labor. Essentially, the United States has been a relatively labor scarce and labor dear country throughout its history. Over time, free trade tends to equalize the return to similar factors across countries, as discussed by Rassekh and Thompson (1993). The wage in the United States is being pulled down toward wages across its trading partners. This paper points out that an OT has the potential to intensify this trend in income redistribution.

1. Background for the model

The United States has been an exporter of oil for most of this century. An OT in the 1950s and early 1960s encouraged the domestic oil industry to "drain America first." During the 1960s, the United States became an oil importer. United States oil firms are currently very active worldwide. Much of the oil imported into the United States is produced, in part at least, by U.S. firms. Simply taking this value added away from the value of imported oil would reduce the overestimated trade deficit.

The international oil market is influenced heavily by the cartel OPEC. The dominant firm, competitive fringe model has been used by Salant (1976) to describe the international oil market. For comprehensive treatment of the international energy market, see Griffin and Steele (1986).

Assume for present purposes that the world price of oil (energy) is exogenous to the economy, and apply the "small country" assumption to the country's imports of oil from the international energy market. This assumption certainly characterizes the typical oil importing country. The United States consumes about 20% of the world's oil production, but very high tariffs would be necessary to enjoy any monopsony gains. The history of manipulation of the oil import market in the United States, as described by Bohi and Russell (1978), is replete with examples of stop-gap measures that have had no noticeable effect on international oil prices. In the model, the small open economy can import any quantity of energy at the exogenous world price e^* . Energy supply, in other words, is perfectly elastic at e^* .

An increase in the domestic price of energy above e^* would bring forth an increase in domestic production and a decrease in oil imports. While oil depletion is a dynamic optimization problem, this paper takes a simpler comparative static approach, assuming the time horizon is short enough that any change in the depletion rate would not affect basic resource scarcity. The time horizon is long enough, however, to allow substitution toward labor and capital input when the price of energy

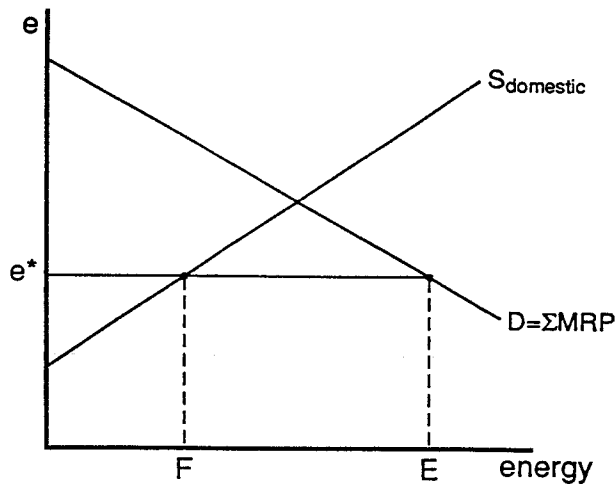


Fig. 1. The oil market.

rises. For an excellent summary of the interface between models of dynamic resource depletion and international trade, see Kemp and Van Long (1984). The literature does not, by the way, contain any dynamic models of production and trade with as many as three factors.

The domestic price of energy rises with an OT, and adjustments are forced onto the economy. The pattern of production and the factor markets must adjust to the higher energy price. The oil price rise is assumed not to be large enough to cause a switch to alternate backstop energy resources (hydroelectric, solar, wind, geothermal, etc.). For simplicity, energy is assumed to be an homogeneous input. The level of energy consumption is found to vary inversely with its international price in the general equilibrium. In other words, when the domestic price of oil increases with an OT, imports and overall use of oil fall.

Figure 1 presents a partial equilibrium picture of the energy market. Demand for energy is the sum of marginal revenue products across sectors. At the world price e^* , F would be supplied domestically while E would be consumed. The difference, $E - F$, is imported. An increase in the domestic price above e^* due to an OT would cause F to rise, while both energy consumption and imports fall.

For simplicity in the general equilibrium model, domestic supply is neglected. Domestic oil production would employ some labor and capital (and energy). Including domestic production of oil, essentially an intermediate product, would complicate the general equilibrium model a good deal. Oil production is capital-intensive, and an expansion in

its output would intensify the downward pressure on wages caused by an OT. Also, if domestic oil production is a relatively small industry, the distortion of neglecting it entirely in the model should not be too gross.

Another simplifying assumption is that there are only two types of finished goods. Goods are aggregated into one group that is more labor-intensive (good 1) and another that is more capital intensive (good 2). Detailed factor intensities of the U.S. economy are presented by Leamer (1984) and Thompson (1991).

This paper also assumes the economy is a price taker in the international markets for each of the two types of goods. Under such a high level of aggregation, it is doubtful whether any country would have international market power. Production adjusts to ensure full employment of domestic capital and labor. Any excess supply of the final goods would be exported, and any excess demand would be imported.

There is yet another assumption at work, namely that all three pairs of factors are substitutes. There is evidence that both capital and energy substitute for labor as in Berndt and Wood (1975). Some studies suggest that capital may be complementary with energy, but in the long run the two are considered substitutes as discussed in Griffen and Steele (1986). In applied studies, Morishima elasticities of substitution, which are more appropriate bilateral measures, suggest substitutability even when Allen elasticities point to complementarity. Technical complementarity between capital and energy would create a wider range of possible comparative static results in the three-factor adjustment process, as described by Thompson (1985).

Application of such a simple model of production and trade is meant to isolate important broad trends. Each of the simplifying assumptions can be relaxed, but the resulting model becomes less tractable and more difficult to analyze and interpret. The model of this paper would apply more suitably to oil importing economies that are small and highly involved in international trade.

2. The 3 × 2 international energy model

Production functions are assumed to be homogeneous of degree one (constant returns to scale) in each sector. Each firm minimizes its cost of production by adjusting the amount of input i ($i = K, L, E$) per unit of output j ($j = 1, 2$). The cost-minimizing amounts of each factor used to produce a unit of each good are represented by

$$a_{ij} = a_{ij}(w, r, e^*), \quad (1)$$

where w is the wage and r the return to capital. The a_{ij} factor mix terms are functions of the vector of factor prices, and are used by firms

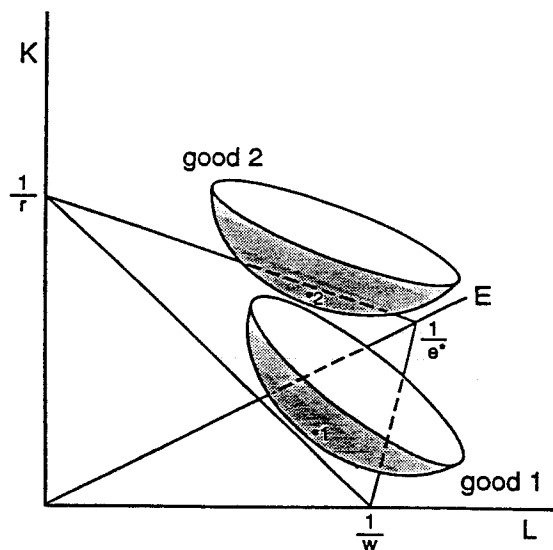


Fig. 2. The 3×2 cost minimization.

in each sector to minimize cost.

The cost of a unit of either good can be written

$$c_j = a_{Lj}w + a_{Kj}r + a_{Ej}e^*. \quad (2)$$

Consider the unit isocost plane where cost equals one. Figure 2 pictures the flat unit isocost surface. With $c_j = 1$, the vertex of isocost plane on each axis equals the inverse of that factor's price, according to (2). The endpoint on the energy axis, $1/e^*$, is set by the exogenous price of energy e^* . The slope of the isocost line is given the vector of factor prices (w, r, e^*) .

Unit value isoquants for each of the two goods are also pictured in Figure 2. These bowl-shaped isoquants include all input combinations that yield an output of one unit (in value) of either good,

$$x_j = 1/p_j^*. \quad (3)$$

These neoclassical isoquants are continuous, smooth, and convex to the origin. As factor prices change, substitution between inputs occurs along the surface of these unit value isoquants.

Cost minimization implies producing on the unit value isoquant at a point tangent to the unit isocost hyperplane. With free mobility of factors across sectors, factor prices are the same in both sectors and the unit isocost plane must support both isoquants. Cost-minimizing

factor mix terms are determined at the tangencies of the two isoquants and the isocost plane.

An exogenous increase in e^* due to an OT would push the endpoint $1/e^*$ on the E axis in Figure 2 inward. Adjustments in both w and r must occur as the unit isocost plane rotates and stays tangent to the two stationary unit value isoquants. The range of possible adjustments in domestic factor prices and outputs depends on the degrees of factor intensity and substitution.

This paper assumes the factor intensity ranking

$$a_{E1}/a_{E2} > a_{L1}/a_{L2} > a_{K1}/a_{K2}. \quad (4)$$

Energy is the most intensive input, or the extreme input, in sector 1. Capital is the extreme input in sector 2. Labor is the middle factor, using the terminology of Ruffin (1981). Relative to capital, labor is used intensively in sector 1. The factor intensity ordering with energy the middle factor is also examined.

Given the factor intensity ranking (4), an OT leads to an unambiguous decrease in w and an increase in r . The supporting isocost surface must rotate as pictured in Figure 3, sliding along under the surfaces of the unit value isoquants. Prices of the extreme factors on each end of the factor intensity ranking are positively related to each other and negatively related to the price of the middle factor, labor. An OT in this model unambiguously lowers wages and raises the return to capital.

From the factor intensity ranking (4), consider the notation

$$\begin{aligned} b_1 &\equiv a_{E1}a_{L2} - a_{E2}a_{L1} > 0 \\ b_2 &\equiv a_{L1}a_{K2} - a_{L2}a_{K1} > 0 \\ b_3 &\equiv a_{E1}a_{K2} - a_{E2}a_{K1} > 0 \\ d_1 &\equiv b_1 + b_2 > 0 \\ d_2 &\equiv b_1 + b_3 > 0 \\ d_3 &\equiv b_1 - b_2. \end{aligned} \quad (5)$$

Note that the sign of d_3 is ambiguous. If L is closer to K in the factor intensity ranking (4), $d_3 > 0$. If L is closer to E in (4), $d_3 < 0$.

Substitution between any two factors h and k is summarized by the cross price term

$$s_{hk} = \sum_j x_j \partial a_{hj} / \partial w_k. \quad (6)$$

If $s_{hk} > 0$, factors h and k are substitutes. If $s_{hk} < 0$, they are complements. With constant returns to scale and convexity of the isoquants,

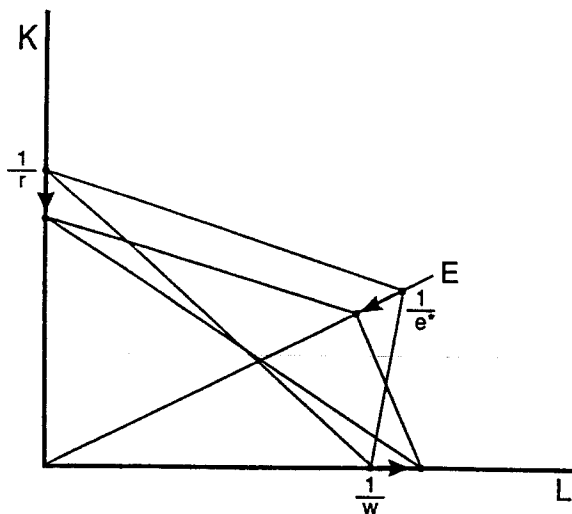


Fig. 3. A carbon duty and factor prices.

$s_{hk} = s_{kh}$, $s_{hh} > 0$, and $\sum_i w_i s_{ik} = 0$. Together these conditions imply that any one, but no more than one, of the cross price substitution terms s_{EL} , s_{EK} and s_{LK} may be negative. As discussed, empirical evidence suggests that s_{EL} and s_{LK} are positive, but there may be controversy over the sign of s_{EK} . This paper assumes all three cross price terms are positive.

The full employment conditions for labor and capital are stated

$$\begin{aligned} L &= \sum_j a_{Lj} x_j \\ K &= \sum_j a_{Kj} x_j. \end{aligned} \quad (7)$$

Differentiate (7) and introduce the substitution terms to derive

$$\begin{aligned} s_{EL} de^* + s_{LL} dw + s_{LK} dr + a_{L1} dx_1 + a_{L2} dx_2 &= dL \\ s_{EK} de^* + s_{KL} dw + s_{KK} dr + a_{K1} dx_1 + a_{K2} dx_2 &= dK. \end{aligned} \quad (8)$$

Changes in energy usage are similarly summarized by

$$s_{EE} de^* + s_{EL} dw + s_{EK} dr + a_{E1} dx_1 + a_{E2} dx_2 = dE. \quad (9)$$

Competitive pricing of good j is stated

$$a_{Ej} e^* + a_{Lj} w + a_{Kj} r = p_j. \quad (10)$$

Differentiate (10) and use a cost-minimizing envelope result to find

$$a_{Ej}de^* + a_{Lj}dw + a_{Kj}dr = dp_j. \quad (11)$$

Equations (8), (9), and (11) are combined into a comparative static matrix system with changes in the exogenous variables collected on the right side,

$$\begin{bmatrix} -1 & s_{EL} & s_{EK} & a_{E1} & a_{E2} \\ 0 & s_{LL} & s_{LK} & a_{L1} & a_{L2} \\ 0 & s_{LK} & s_{KK} & a_{K1} & a_{K2} \\ 0 & a_{L1} & a_{K1} & 0 & 0 \\ 0 & a_{L2} & a_{K2} & 0 & 0 \end{bmatrix} \begin{bmatrix} dE \\ dw \\ dr \\ dx_1 \\ dx_2 \end{bmatrix} = \begin{bmatrix} -s_{EE}de^* \\ dL - s_{EL}de^* \\ dK - s_{EK}de^* \\ dp_1^* - a_{E1}de^* \\ dp_2^* - a_{E2}de^* \end{bmatrix}. \quad (12)$$

Comparative static results are found with Cramer's rule. The determinant of the matrix in (12) is $\Delta = -b_2^2 < 0$. This paper concentrates on a comparative static increase in e^* due to an OT, with $dL = dK = dp_1^* = dp_2^* = 0$.

Consider the $\partial E/\partial e^*$ term, which shows the effect of an increase in e^* on the total input or import of E ,

$$\partial E/\partial e^* = (d_1^2 s_{EL} + d_2^2 s_{LK} + d_3^2 s_{EK})/\Delta < 0. \quad (13)$$

An OT implies a higher price of energy and causes the total input of energy to fall, assuming all three pairs of factors are substitutes. If energy and capital were strong complements ($s_{EK} \ll 0$), and labor only a weak substitute for both energy and capital, it would be possible that $\partial E/\partial e^* > 0$. An OT would then cause firms to switch away from capital input, and labor inputs would rise only slightly. The net effect on energy demand across sectors could then be positive. Insufficient substitution of capital and labor under those conditions would keep the economy from reducing its total energy input in the face of a higher energy price.

Domestic factor prices are affected by a higher price of energy according to

$$\begin{aligned} \partial w/\partial e^* &= b_2 b_3 / \Delta < 0 \\ \partial r/\partial e^* &= -b_1 b_2 / \Delta > 0. \end{aligned} \quad (14)$$

The wage must fall and the capital rent must rise, given the factor intensity condition (4).

If energy were the middle factor in the intensity ranking, both $\partial w/\partial e^*$ and $\partial r/\partial e^*$ would be negative. An OT would then lower both the wage and the return to capital.

The output effects of an OT are ambiguous in their signs:

$$\begin{aligned}\partial x_1/\partial e^* &= [a_{K2}d_1s_{EL} + (a_{L2} + a_{K2})d_2s_{LK} + a_{L2}d_3s_{EK}]/\Delta \\ \partial x_2/\partial e^* &= -[a_{K1}d_1s_{EL} + (a_{L1} + a_{K1})d_2s_{LK} + a_{L1}d_3s_{EK}]/\Delta.\end{aligned}\quad (15)$$

There is a strong presumption that $\partial x_1/\partial e^* < 0$ and $\partial x_2/\partial e^* > 0$, but ambiguity in the sign of d_3 leaves these results unclear. Both $\partial x_1/\partial e^*$ and $\partial x_2/\partial e^*$ cannot be positive since the resource base of the economy shrinks with an OT. The presumption that x_1 falls due to an OT rests on the assumption that energy is the extreme factor in industry 1 and the result that an OT leads to a decrease in total energy input.

If energy were the middle factor, the $\partial x_j/\partial e^*$ results would remain ambiguous. While d_3 would be negative, both d_1 and d_2 could not be signed. Without specific information on the degree of factor intensity and the pattern of factor substitution, there is little more to presume about the signs of these $\partial x_j/\partial e^*$ results. Complementarity between E and K would also affect these results.

Full employment of domestic capital and labor is pictured in Figure 4. The capital-labor ratios in both sectors are projected onto the K - L plane. The endowment of capital and labor is indicated by point E , which is a projection implicitly including the total energy input. While energy input varies with a changing e^* , the endowments of capital and labor are constant. Output occurs at the projection of the expansion path where the parallelogram from E is completed to the two (projected) expansion paths.

When w/r falls with a OT, the K/L ratio falls in both sectors as firms respond to the higher relative price of capital. An increase in the output of capital-intensive good 2 is illustrated along with a decrease in the output of labor-intensive good 1. Under present assumptions, an OT lowers the relative output of the labor-intensive good. The story may not be as simple, however, as Figure 4 suggests. The expansion paths are only projections and hide adjustment in the third dimension to e^* (or w/e^* and r/e^*). The ratio K/L may rise or fall in either sector.

Summarizing, there are three possible comparative static output adjustments:

$\partial x_1/\partial e^*$	$\partial x_2/\partial e^*$
-	+
-	-
+	-

Output of the labor-intensive good 1 may rise, even in the face of higher wages and falling capital rent. The most intuitively appealing scenario, however, is the first on the list, in which an OT causes x_1 to fall and x_2 to rise.

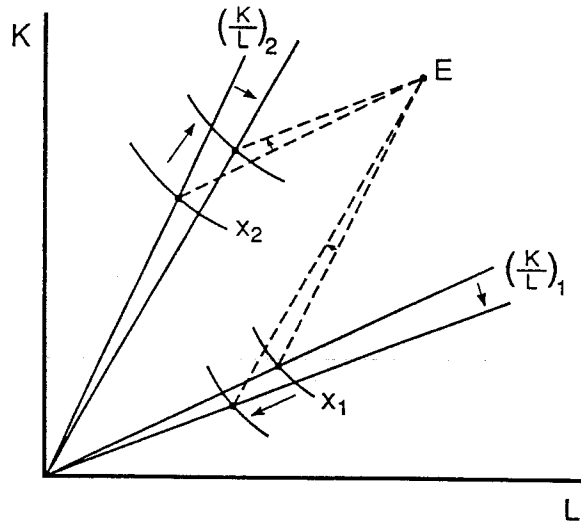


Fig. 4. Capital-labor substitution and output adjustment with a decrease in w/r .

3. Conclusion

The evolving pattern of prices in the United States is characterized by a falling price of labor-intensive manufactures relative to capital-intensive high tech products and business services. The resulting shift in factor prices is exactly what this model predicts with an oil tariff, namely a falling wage and a rising return to capital. While labor groups in the United States recognize that free trade is not in their immediate best interest, an oil tariff would also likely cut into the relative wage. The same political interest groups are heard to argue for both protectionism and oil tariffs.

This 3×2 international energy model is suggestive and rudimentary. More detail in the pattern of production, including more types of goods, intermediate products such as electricity, and more types of capital, labor, and energy input would improve the model. Negative pollution externalities could be explicitly included and linked to particular production processes. Various market structures could also be included, as in the computable general equilibrium models surveyed by Shoven and Whalley (1984). Oil depletion would require dynamic modelling that recognizes the potential of backstop resources and alternative energy sources.

Ideally, a computable general equilibrium model would be built on estimates of production or cost functions in each sector. The present

model shows how the degree of substitution between the various factors can influence comparative statics. The literature on energy substitution can be put to work in building applied general equilibrium models of energy, production, and trade.

Regardless of modifications and improvements to this basic model, the essential link between an oil tariff and wages would remain. The 3×2 international energy model in this paper puts forth the testable hypothesis that an oil tariff would lower labor's wage. Looking across oil importing countries, and over time, higher oil tariffs would be associated with lower wages. This is a proposition that can be empirically tested, and this paper is meant to stimulate such research.

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