LIMITING OIL IMPORTS: COST ESTIMATES FROM A RANGE OF U.S. MODEL PROJECTIONS

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Abstract

The costs of curtailing growth in U.S. oil imports are estimated based upon the supply and demand responses to price from six world oil models that were compared recently by the Energy Modeling Forum. Direct resource costs over the 1989-2010 period are estimated from U.S. results for a flat and a rising price case that span an \$18 per barrel difference by the year 2000 and beyond. To provide a more balanced perspective, the paper also includes estimates of some potential benefits from import-reduction policies--smaller wealth transfers during a disruption and lower oil prices without disruptions as a result of the policy. While keeping future oil imports at today's level appears to be quite costly, our results indicate some opportunity for economic gain with less aggressive import-reduction programs.

I. INTRODUCTION

U.S. concern about limiting oil imports had its root in the late 1950s, when the fear of inexpensive Middle East crude oil replacing domestic supply first became a real threat (Bohi and Russell, 1978). Rising U.S. import dependence was temporarily interrupted by the oil shocks of the 1970s, but many experts now anticipate a return to this long-run trend (U.S. Department of Energy, 1987). Moreover, this conclusion appears to be independent of the expected future oil price path (Energy Modeling Forum, 1991). Given these trends, it would not be surprising if U.S. policymakers sought to adopt aggressive, new policies to limit oil imports in the coming years.

Reinforcing this shift away from the consumption of gasoline and other petroleum products could be concerns about clean air and global climate change.

How easily could U.S. oil imports be curtailed by energy policymakers? This paper provides some estimates of the costs of curtailing the growth in oil imports, based upon the U.S. supply and demand responses to price from several world oil models that were compared by the Energy Modeling Forum (EMF) study referenced above. It should be emphasized that the study focused on the long-run dependence on Persian Gulf oil under alternative conditions (price paths, economic growth rates, etc.); it did not directly address the impact of limiting U.S. oil imports on market conditions. Specifically, the study did not explicitly consider a scenario incorporating both U.S. oil import reductions and OPEC price-setting assumptions.

The cost estimates assume that pricing policies are used to limit oil imports. If energy markets are operating efficiently, these estimates will provide a lower bound for the costs of other non-price instruments (e.g., end-use standards on oil consumption) for limiting imports. If significant market failures exist, the cost of import restrictions may be less than estimated here. To provide a more balanced perspective, estimates of several benefits from import-reduction programs--smaller wealth transfers during a disruption and lower oil prices without disruptions--are incorporated. These costs and benefits can be related to the level of imports in each projection, thereby extending the analysis to address several key issues: what level of import reduction would create offsetting costs and benefits and what level would be optimal for achieving the largest net gain.

II. RESULTS FOR TWO OIL PRICE PATHS

A. Models

The eight world oil models reporting U.S. results are listed in Table 1 with the name of the working group representative and affiliated organization.[1] Since the modelers used EMF standardized assumptions for prices, economic growth, and cartel capacity, these projections are not forecasts of the particular organizations.[2] Moreover, the institutional affiliation listed in Table 1 is given to identify the model rather than to indicate an official modeling framework of a particular organization.

The models were developed to prepare long-run projections of oil prices, oil production, and oil consumption and to study changes in these variables under alternative scenarios. They incorporate the behavior of three distinct types of decisionmakers: oil consumers, oil producers outside the cartel, and oil producers within the cartel. Most models report prices and supply-demand balances annually and focus exclusively on world oil markets.[3] Alternative fuel prices and interfuel substitution are not explicitly represented. Instead, competing fuel prices in the future are assumed to change with oil prices as they have in the past. The response of oil demand to changes in these other fuel prices is also based upon historical experience.

In these models, oil consumers respond to Gross Domestic Product (GDP), energy- saving trends in technology or economic structure (if present), and oil prices. Shifts in the economies' structures are seldom incorporated explicitly, because each region's economy is represented as one aggregate sector. The response of oil producers outside the cartel is governed by assumptions about trends in resource depletion and technology in addition to oil prices. By basing parameter values on historical experience, most models assume that past regulatory policies will be continued into the future. Some models may adjust these responses to reflect expected changes in regulation and fuel substitution.

This analysis is based upon the U.S. results only from scenarios with an exogenous oil price path. As a result, the assumptions about the oil producing cartel's behavior in each model were not utilized.

B. Projected Oil Imports

In two of the twelve scenarios of the EMF study, each modeler reported oil consumption and production estimates for a rising and flat oil price path. The flat path remained constant at \$18 per barrel (all prices are 1988\$) between 1988 and 2010, while the rising path increased steadily from \$18 to \$36 by 2000 and remained at \$36 through 2010. Both scenarios assumed a 2.6% per annum economic growth rate for the United States over the period.

The EMF results indicate that it is difficult to prevent oil imports from rising. If oil prices followed the flat price path of \$18 over the next decade, Table 2 shows that U.S. imports would grow from 7.0 MMBD in 1988 to a range of 9.0-22.9 MMBD in 2000 (the first column), depending upon the model. With the higher prices in the rising price scenario, U.S. oil imports in 2000 would be lower, but would still increase above 1988 levels in all but one model (ETA-Macro). As shown in the second column of this table, they would range from 5.5 to 15.0 MMBD. The last two columns indicate that the higher prices reduce oil imports with proportionately similar impacts on U.S. consumption and production in most models.

The starkly different U.S. import levels among models are characteristic of the EMF results in general. Unitary income elasticities, the absence of an oil-saving time trend, and strong oil demand growth in response to lower pre-1988 oil prices contribute to rapid U.S. oil demand growth in HOMS and FRB Dallas, leading to relatively higher import levels. The slower oil import and demand growth in OMS and CERI is due to the reverse set of conditions: income elasticities below unity, oil efficiency improvements unrelated to price, and the absence of a strong stimulative effect of lower recent oil prices on future oil demand. Additionally, greater depletion effects for U.S. production accentuate the shift towards increased dependence upon imports in some models, e.g., FRB Dallas.

III. MEASURING THE IMPACT OF IMPORT REDUCTION

Confronted with rising oil imports, policymakers are likely to seriously consider limiting imports for a range of reasons, including loss of international purchasing power, increased vulnerability to disruptions, and worsening trade balances.[4] The EMF scenarios just described can help to gauge how costly it would be to limit oil imports. To provide some balance to the discussion, the analysis assigns some arbitrary but reasonable estimates of benefits accruing to import-reduction strategies. It should be emphasized that by design, the study did not include a scenario incorporating both U.S. oil import reductions and OPEC price-setting assumptions. Hence, the study cannot shed much additional insight on the benefits.

We develop estimates of three separate impacts: the direct opportunity costs of curtailing imports below market-determined levels, the reduction in wealth transfers induced by oil disruptions when a nation imports less oil, and the wealth gains that accrue from a reduction in world oil prices. This measure incorporates only those impacts that are directly linked to the level of oil imports. This approach appears appropriate given the exclusive focus here on the value of limiting U.S. oil imports. The estimates exclude other costs that may result from oil disruptions, e.g., macroeconomic dislocations and greater military defense spending, but that do not necessarily depend upon incremental changes in the level of oil imports. Those analysts who believe these cost estimates to be too conservative can easily augment them to include these other costs.[5]

While the macroeconomic adjustment costs of past oil disruptions have been large, they have been experienced by all countries, regardless of their dependence upon oil imports. The lost output associated with declining real GNP--as opposed to the transfer of real wealth--appears to depend much more upon total oil expenditures in the economy and the degree of wage and price stickiness than upon the level of oil imports (e.g., see Hickman et al, 1987, pp. 48-51). Moreover, the macroeconomic adjustment costs are heavily influenced by the general economic policy climate. Fiscal and monetary accommodation could offset the transitory output losses, although at the expense of more inflation. Thus, a premium on reducing oil use exists only if policymakers feel constrained by current inflation rates from using accommodating monetary and fiscal policy (Nordhaus, 1980)--conditions that prevailed during the 1970s. As a result, this "inflation premium" for oil can range anywhere from zero (when the government does not feel constrained) to a very large number (when it fears any further inflation).[6]

The analysis also excludes any premium associated with a constraint of the U.S. balance of payments, suggested by Nordhaus (1980). With oil exporters failing to respend their revenues on U.S. goods and services, it has been argued that additional oil imports cause the economy's trade balance to deteriorate, requiring exchange rate adjustments for weakening the country's terms of trade to restore the balance. However, oil exporters appear to be attracted in the short run to dollar-denominated assets for holding their new-found wealth, until they decide on longer-run allocations (e.g., see Hickman et al, 1987, p. 41). These actions would mitigate the short-run balance of payments problems. Over the longer run, the trade balance problems appear to be influenced by the macroeconomic savings-investment imbalance rather by oil imports or by the propensity to spend of oil exporters.

For similar reasons, estimates of the reduced military spending associated with limiting oil imports are excluded, because it is difficult to discern an unambiguous conceptual relationship between appropriations for military spending and importing one less barrel of oil. Reducing the growth of oil imports by half may not have any effect on military spending in the Persian Gulf if the region remains politically volatile. On the other hand, reducing oil imports to zero or negligible amounts might convince policymakers that military expenditures in the region could be reduced without sacrificing direct economic security through the oil link. Military spending appears to have its biggest impact on reducing the probability of an oil disruption generated by military conflict in the Persian Gulf--a factor treated exogenously in this analysis.

A. Direct Opportunity Costs

In this paper, the flat price path will represent the case with no new import-reduction policies. Such a scenario is consistent with the view offered by Adelman (1989), who argues that there is no long-run trend of resource depletion and rising real oil prices in the future. However, it should be noted that in three EMF scenarios calling for an endogenous calculation of market-clearing prices (based upon the models' representation of OPEC's market strategy), all of the models revealed rising real oil prices over the next two decades.

Under certain circumstances, the U.S. results for the higher price path could be viewed as induced by an import-reduction policy. An import tariff, e.g., would increase domestic U.S. prices above world prices, stimulating U.S. production and discouraging U.S. consumption. If world oil prices are unaffected by the lower U.S. demand for imports, U.S. prices would rise by the full amount of the tariff--from the world level of \$18 to \$36 by the year 2000. Since there may be serious implementation issues associated with tariffs (e.g., see Sweeney (1991)), it may be more fruitful (as well as realistic) to consider the policy as a dual one: a subsidy to domestic producers and a tax on domestic consumption (e.g., on gasoline and other products).

Figure 1 shows the approach for measuring costs under these stylized conditions. The oil import demand curve represents the difference between U.S. consumption and production at any price. As prices increase, imports decline through more domestic production and less total consumption. Without the policy, oil markets clear at price P_w and import level M. U.S. oil prices rise from P_w to P'_d as a result of a tax and a subsidy both equal to $P'_d - P_w$. The demand curve for oil imports indicates that the level of imports falls from M to M' with the higher U.S. domestic price. The area marked "transfer" represents the net tax revenues generated by the policy--an internal income transfer from U.S. consumers to the U.S. government.[7] The area marked "loss" represents the direct resource costs of maintaining production above and consumption below the level that would be efficient at \$18 per barrel.[8]

Given that the models are oil-only frameworks, we make no effort to incorporate the general equilibrium effects of the policy on other markets. In particular, if oil producers in the Middle East are net savers, reductions in their income could push real world interest rates higher, hurting net-debtor countries like the United States. See, e.g., Bruno & Sachs (1985). These conditions would make oil import reduction more costly for the United States than is being represented in this single-market analysis.

These results can be generalized to the case in which the world oil price is lowered by the policy. Figure 2 combines the import demand curve with one for import supply (representing the difference between total supply and demand outside the United States at each price). The import-reduction policy can be represented as before as a movement from P_w to P'_d. U.S. imports fall from M to M', and the direct resource costs of the policy for the United States can be calculated exactly as before. However, foreign oil producers and consumers absorb some of the tariff (or tax-cum-subsidy). The world oil price--the difference between the U.S. price and the tariff--declines from P_w to P_w'. The U.S. economy gains the amount indicated by the area marked "wealth gain"; each imported barrel can be bought at P'_w rather than the higher P_w. If this gain exceeds the loss, the policy makes the U.S. better off.

Thus, the direct resource costs associated with the policy are identical under these two conditions. The principal difference is that a larger tax and subsidy are required in Figure 2 for the same reduction in oil imports. For each model, estimates of U.S. production and consumption in the rising and flat price cases were used as shown in Figure 2. The costs of higher production and lower consumption were calculated separately for the 1989-2010 period, discounting each year's cost by 5% (real).

B. Security Gains

The lost wealth during a disruption equals the oil price change times the amount of oil imports (an average of the pre- and post-shock levels). Import-reduction programs provide security gains by lowering a country's imports and hence its exposure to wealth losses.[9] These gains have been calculated as the oil price change times the difference in import levels in the flat price scenario (before the policy) and those in the rising price scenario (after the policy).[10]

A 10% probability of a one-year price shock of $30 per barrel (1988$) occurring in any one year has been assumed in our estimates. This condition implies that there is a 65% chance that at least one such a disruption will occur over a decade. Given that there have been major price shocks in 1973-74, 1979-80, and 1990--about once a decade--this assessment does not appear to be too optimistic or pessimistic about the chances of another disruption.[11]

An increase of $30 per barrel appears representative of past oil shocks: from $3 to $12 in 1973-74 (times a deflator of 2.5 to obtain 1988$); from $12 to $30 in 1979-80 in 1979-80 (times a deflator of 1.6); and from $15 to over $40 in 1990. The assumed one-year duration is appropriate if one believes that future shocks will be more like the 1990 disruption than the previous two events.

The computed gain in each year was discounted at 5% per year and multiplied by .1 (the probability of a disruption) to derive the present value of expected disruption losses avoided over the 1989-2010 period.

C. Oil Wealth Gains

An import-reduction program can also cause world oil prices to decline, thereby allowing oil users to pay less for all remaining imports. Such wealth gains reflect increased international purchasing power for oil-importing nations and are sometimes also referred to as terms of trade gains. In this analysis, they are measured by the decline in the world oil price times the oil import level in the rising price scenario (after the policy).

The policy will reduce the world oil price less, the greater is its incidence on the United States. The United States will absorb more of the policy when its supply and demand: (a) form a smaller share of world supply and demand, or (b) are less price elastic than the foreign counterparts (see the appendix). The foreign sector's response to price incorporates the behavior of both consumers and producers. Cartel behavior will affect the response of foreign producers, but analysts do not agree on how to represent the cartel. Some analysts believe that the oil-producing cartel uses intertemporal optimization rules to maximize its discounted net profit over its planning horizon. Others think that the cartel sets prices on the basis of market tightness (the target capacity utilization rule) in an attempt to search through a very uncertain market environment for the best strategy. These different cartel strategies can lead to very different responses in the world oil price to an import-reduction policy.

Explicit modeling of cartel behavior would shift our focus far from the EMF results without providing a robust estimate for how much world oil prices would fall given the policy.[12] Instead, results are obtained here for various assumptions about how much of the tax is absorbed domestically and how much is transferred to foreigners. This analysis of tax incidence provides a simple way to summarize different states of the world oil market without requiring a lengthy discussion of cartel behavior.

The U.S. supply and demand price elasticities are assumed identical to their foreign counterparts here, but other conditions are considered in the appendix. The incidence on foreign oil producers and consumers under these conditions depends solely upon the relative importance of U.S. supply and demand in the total market indicated by the model in the flat price case.[13] Table A-2 in the appendix shows the corresponding world oil price and U.S. tax (with their sum equal to the $36 in the rising price case). The tax is larger than $18 because foreigners are absorbing some of the tax. The wealth gains from the lower oil price are calculated as the product of the reduction in oil price (below $18) and the oil import levels in the rising price case (i.e., after the policy). These gains have been discounted over the 1989-2010 period at 5% per annum.

IV. RESULTS

A. Estimated Gains and Losses

Table 3 summarizes the results based on each model for total discounted costs in 1988 $B disaggregated by direct losses, security gains, and wealth gains. The IPE results covering the 1990-2000 period only are reported separately at the bottom of the table. OMS estimates for the same period are included for comparison.

The direct opportunity costs are based directly upon U.S. results from the rising and flat price scenarios, while the other components depend upon the projected import levels in conjunction with assumptions about disruptions and oil price changes. Over the 1989-2010 period, the costs associated with higher production and reduced consumption range from $112 B (Gately) to $274 B (HOMS1). The models in the table have been ordered by the projected change in oil imports due to the oil price change. For a given tax (price increase), these direct losses will be greater for U.S. demands (supplies) that are more price responsive, ceteris paribus.[14] U.S. supply and demand in HOMS1 are the most price elastic of all models, while Gately's demand is the least price sensitive (in this price range where the oil price remains below its historical peak in 1981).[15] The IPE costs are substantially below the other estimates, even when adjusted for the shorter time horizon.

Marginal costs of this policy in any year are the differences between the rising and flat price paths, e.g. $18 per barrel in the year 2000 and beyond. In general, the average cost to replace a barrel of oil imports through either more production or less consumption is about $8. (See

Table A-1). This common result reflects the size of the uniform wedge between domestic and imported prices being imposed in each model. Models with higher price elasticities of supply and demand will show both greater costs (the numerator) and more reduced imports (the denominator) than other models.

Uncertainty about the probability of a disruption or the magnitude of the oil price shock can be easily ascertained. Halving the disruption probability will reduce the security gains by half. Doubling the price shock will cause the gains to double as well. This characteristic is one of the advantages in our adopting a relatively simple approach for estimating these effects.

B. Break-Even and Optimal Levels of Import Reduction

While the direct resource costs--representing from 0.2% to 0.5% of real GNP--are substantial, the security and wealth gains are sufficient to produce total gains from the import-reduction strategy in several cases. Given that the level of import reduction was arbitrarily defined by two exogenous oil price paths, it is interesting to ask whether these results can be used more generally to examine at what level of import reduction does this strategy appear to generate net benefits, and more importantly, what is the optimal level of import reduction that would produce the most benefits based upon the estimates in Table 3.

Such an exercise can be quite illuminating. Assume that the oil import demand and supply curves are indeed linear functions of price, as shown in Figure 2. Importantly, although it remains linear in all periods, each function can change over time to incorporate the dynamic adjustment of oil consumption and production to price changes. Thus, the changes in price from P_w to P_d' and from P_w to P_w' in Figure 2 can be related linearly to the change in oil imports. In this way, the present values of the costs and benefits can be related to the level of imports and import reductions observed in the two scenarios.

From Figure 2, it can be readily seen that the direct resource costs will be a function of the change in the U.S. price times the change in import quantities, or equivalently, the import reduction squared. The security benefits are a simple function of the import reduction resulting from the policy--M'-M in Figure 2. And finally, the wealth gains are related to the product of the import level after the policy and the change in world oil price, or equivalently, the import level M' times the import reduction.

Each of these components can be calibrated to the EMF scenario by fitting these relationships to two different set of conditions. In the absence of any import reduction, all costs and benefits are zero. In the rising price case, oil imports are reduced by the amounts shown in Table 2 and benefits and costs are generated as indicated in Table 3. A parameter can be developed for each benefit or cost component that satisfies these two conditions as well as the functional form described in the preceding paragraph. These parameters are explained in the appendix.

These parameters allow us to represent the effect of different import reduction levels for each model. Table 4 compares the reported import levels for the flat and rising price case with two new cases that were not simulated by the modelers. In the break-even column, import levels are reported that would cause benefits to fully offset costs for that particular model. In the optimal column, import levels are shown that would provide the most benefits for that particular model; import reductions above or below this level would cause benefits to begin falling. The final column provides an estimate of the tariff associated with this optimal level of import reduction. This concept has been widely discussed as the oil import premium and reveals the amount by which the market price (private cost) of imported oil understates its true social cost.[16] The tariff label should not be construed as necessarily supporting an oil import tariff; rather, it is a generic concept that implies that policy intervention of some form might prove to be beneficial as long it entails costs that do not exceed the tariff estimate.

In Table 4, the HOMS1 estimate for the break-even import level is above the level reported for the rising price case, a result that confirms the negative net benefits estimated for that model for the initial import-reduction strategy represented in Table 3. Thus, this initial policy is too ambitious in limiting oil imports. As policymakers relax this import limit to allow imports to increase above 10 MMBD by 2000, import reduction becomes less costly. At an import level of about 12 MMBD, import reduction begins to produce net gains rather than costs in this model. These gains are maximized at an import level of almost 16 MMBD. The estimate of the optimal tariff (import premium) is $7.90 per barrel in 1988$.

This same general pattern applies to all the remaining models except IPE, although in several instances the break-even level of imports is lower than the level in the EMF rising price scenario. These results indicate that arbitrary limits on oil imports, such as maintaining current levels, can be very costly.[17] Even the $18 tariff implied by the two EMF scenarios, which fails to keep imports from growing, is much too aggressive if policymakers wish to extract the most benefits from import reduction. The estimates of the optimal tariff range from about $8 to $14 per barrel and are comparable to other widely cited estimates of the monopsony and security components of the oil import premium for unilateral action taken by the United States. The relevant premium was estimated to range from $8 to $14 per barrel in Energy Modeling Forum (1982). Plummer (1981) reports estimates that are very similar.

Efforts to target the level of imports are also hindered by the difficulty in determining what that level should be. The optimal levels of oil imports shown in the table range from 10.8 to 19.7 MMBD in 2000.

As discussed previously, the IPE results terminated in the year 2000 and thus may not be comparable to the other model results. The relatively high optimal tariff estimate for this model reflects that this model projects quite low oil import levels that are extremely insensitive to price changes in the short run.

V. SUMMARY

The results from the EMF scenarios reveal rising U.S. oil imports in most projections, even if real oil prices double over the next twelve years. If real oil prices remain constant, the U.S. import dependence will become more precarious. Policies to reduce oil imports under these conditions are likely to be intensified.

The projections reported in the EMF study suggest that oil imports are not easily reduced. Even aggressive policies, such as doubling the U.S. price, do not ensure declining imports over time. In this analysis, we estimate that such a policy would cost more than $100 B but less than $300 B in net present value terms (1988$) over the 1989-2010 period, or 0.2% to 0.5 % of the discounted GNP stream. This estimate could be lower if U.S. oil consumers and producers are inefficient in their decisions (e.g., due to imperfectly available information). On the other hand, it could be higher if these import-reduction policies take the form of controls that are not targeted towards the activities that can reduce oil use with the least cost.

At the same time, some level of import reduction may be justified. Limiting oil imports will reduce U.S. expenditures on oil imports during future oil disruptions and may cause oil prices to decline in undisrupted markets. When these benefits are incorporated in the analysis, there exists a level of import reduction in each model that produces net benefits. U.S. oil imports by 2000 are projected to range from 13.2 to 22.9 MMBD in the EMF study if inflation-adjusted oil prices remain constant. According to the analysis conducted here, import reduction would continue to generate net benefits as long as U.S. oil imports were not pushed below the 7.9-14.5 MMBD range. These net benefits could be maximized by allowing imports to be somewhat higher, in the 10.8-18.7 MMBD range.

This analysis confirms previous values for the oil import premium (including the monopsony power and security components only) that lie in the $10 per barrel range. These estimates imply nothing about which import-reduction policies should be pursued, but only that whatever policies are chosen should not cost more than $10 per barrel to implement.

The analysis has included only those benefits that are directly attributable to lower oil imports. While macroeconomic dislocations stemming from price shocks and military expenditures for Persian Gulf stability are direct and serious consequences of oil disruptions, it is far from clear how incremental changes in oil import levels will ameliorate these impacts. This conservative approach to including benefits underscores the case for some level of oil import reduction, based upon effects widely accepted by many analysts. However, it should also be emphasized that the approach has excluded some issues, e.g., OPEC retaliation,[18] that may overstate the benefits of import reduction. Similarly, the focus on the oil market alone may obscure the important role that cartel oil producers play as suppliers of low-cost savings in the world economy. Thus, the approach contains potential biases for both understating and overstating the value of limiting oil imports.

APPENDIX

The costs for import-reduction policies were not estimated directly by the models using shifts in the U.S. supply or demand curve and market-clearing prices. Instead, the estimates were derived implicitly from results reported for standardized oil price paths. This appendix explains the specific computations.

Import-Reduction Costs

The direct import-reduction costs were estimated as the lost producer and consumer surplus associated with reducing imports below the no-policy case (flat oil price path). Figure 1 shows these losses to be equal to the triangular area represented by:

$$\Delta W = -\frac{1}{2}\,(P_d' - P_w)\,(M' - M)$$

$$= -\frac{1}{2}\,(P_d' - P_w)\,[S' - S) + (D - D')]$$

where P_d equals the domestic U.S. price, P_w the world price, M the U.S. import level, and D the domestic demand, and S the domestic supply. The prime denotes a variable's value after the policy has been implemented. Values from the flat price path were used to represent P, D, and S; those from the rising price path were used to represent P′, D′, and S′. These costs remain the same for the different cases employing various assumptions about the effects on world oil prices.

The yearly costs are discounted at 5% real and summed over the 1989-2010 period. These cumulative discounted costs are divided by the cumulative reduction in imports (discounted at 5% real) to derive the costs per barrel shown in Table A-1.

Security Gains

The security gains are the difference between disruption costs, with and without the policy.

$$\Delta W = \frac{1}{2} \Delta P \, [M + (M+\Delta M) - M' - (M'+\Delta M')]$$
$$= \Delta P \, [M-M'] \quad when \quad \Delta M = \Delta M'$$

where Δ P is the oil price shock and all other variables have been defined above. Expected cumulative costs were obtained by discounting each year's cost at 5% real and multiplying by .1 (the probability of disruption).

Wealth Gains

The gains in U.S. wealth resulting from a lower world oil price were estimated from the rectangular area in Figure 2 represented by:

$$(P_w - P'_w) \, M'$$

where the terms have been defined above. The reduction in the world oil price is discussed below. Once again, these wealth estimates are cumulative gains, discounted at 5% real. Total losses in Table 3 are the net effect of combining the direct import-reduction costs, the net disruption costs (or gains) from implementing the policy, and the wealth gains.

Effect on World Oil Price

The estimated wealth gains in Table 3 assume that the tax incidence on foreign oil producers and consumers equals the share of world oil supplies that are consumed or produced (an average) within the United States. This situation would prevail if the price elasticities for supply and demand equalled each other and were the same across all regions. This result can be seen by starting with the equation balancing world oil supplies and demands,

$$S_u(P\text{-}T) + S_c(P) + S_n(P) = D_u\ (P+T) + D_o(P)$$

where S equals supply, D demand, P Price, T the U.S. tariff, and the subscripts u, c, n, and o refer to the United States, the producer cartel, non-OPEC (excluding U.S.), and other demand (excluding U.S.) regions, respectively. Differentiating this equation and rearranging terms yields:

$$\frac{dP}{P} = -\frac{A_u}{A}\,\frac{dT}{P}$$

where $A_u = (D_u/D)\ \beta_u + (S_u/S)\ \alpha_u$

$$A = A_u + (S_c/S)\alpha_c + (S_n/S)\alpha_n + (D_o/D)\beta_o$$

and α and β are the price elasticities of supply and demand, respectively, for each region. This expression reduces to:

$$\frac{dP}{P} = -\frac{1}{2}\left[\frac{Du}{S} + \frac{Su}{S}\right]\frac{dT}{P}$$

when $\alpha_i = \beta_i$ and $S = D_n + D_o = S_u + S_n + S_c$. This equation was used to calculate the policy's incidence on foreign oil producers and consumers and the change in the world oil price (from \$18 per barrel). Table A-2 reports these effects and the size of the U.S. tax required to raise U.S. domestic prices to the rising price path (about \$36 per barrel).

Wealth Gains Under Alternative Policy Incidence

Alternative estimates of the wealth gains are based upon the assumption that foreign oil producers and consumers absorb 10% (20%) of the total tax. Denote this tax incidence as ϕ, which equals the negative of the proportional change in the world price divided by the relative size of the tax (as a percent of the new world price), or in logarithms:

$$\Phi = \frac{-\ln(P_w^{\prime} / P_w)}{\ln(P_d^{\prime} / P_w^{\prime})}$$

After substituting \$18 for the world price before the policy (P_w) and \$36 for the U.S. price after the policy (P'_d), the new world oil price equals:

$$P'_w = \exp[(\ln(18) - \phi \ln(36)) / (1- \phi)]$$

The sensitivity of the results to different assumptions about the incidence of the policy on foreigners and the United States is revealed in Table A-3. When foreign oil producers and consumers absorb 10% of the tax-cum-subsidy policy, world oil prices fall by \$1 for every \$10 in tax. Under these conditions, wealth gains are insufficient to produce net overall gains from the policy in all cases where costs could be estimated for the full 1989-2010 period. It is only when the world oil price falls by \$2 for every \$10 in tax--the 20% incidence case--that net gains are realized in some cases. The impacts in this latter case are similar to those in Table 3, in which the policy's incidence was determined by the U.S. share of total market supply and demand in each model. As with the security gains, these wealth effects rise or decline in proportion to the assumed change in the world oil price.

Computations for Break-Even and Optimal Import Reduction

Based upon the relationships discussed in the text, the net benefits of import reduction can be expressed as:

$$B = b_1(\Delta M)^2 + b_2 (\Delta M) + b_3 (\Delta M \cdot M) \qquad b_1 < 0,\quad b_2 > 0,\quad b_3 > 0$$

where M is the level of oil imports and ΔM is the import reduction below the unrestricted level (M_u) in the flat price case. The first term represents the direct resource costs, while the second and third terms comprise the security and wealth gains, respectively.

The parameters in this function were inferred from the import levels in the flat and rising price cases (shown in Table 2) and the associated benefits and costs (shown in Table 3). The direct costs were divided by the import reduction squared to derive b_1, the security gains were divided by the import reduction to derive b_2, and the wealth gains were divided by the product of the import reduction and the level of imports in the rising price case. The resulting parameter values for each model are shown in Table A-4.

The break-even level of import reduction (M_z) is derived by setting B=0.

$$M_z = \frac{b_2 + b_1 M_u}{b_1 - b_3}$$

The optimal level of import reduction (M_o) for maximizing net benefits can be determined by setting the first derivative of the net benefit function with respect to import reduction equal to zero.

$$\frac{dB}{dM_0} = (b_3 - 2b_1)M_u - b_2 + 2(b_1 - b_3)M_0 = 0$$

This condition yields

$$M_0 = \frac{b_2 + (2b_1 - b_3)M_u}{2\ (b_1 - b_3)}$$

The optimal tariff is calculated by multiplying the tax shown in Table A-2 by the ratio of the import reduction associated with the optimal import level and the reduction achieved in the rising price case. The optimal tariff estimates are similar if import levels for the year 2010 rather than 2000 are used.

Import reduction will not influence world oil prices if the oil-producing cartel is an intertemporal profit-maximizer (Nordhaus, 1980, and Nesbitt and Choi, 1987). Under these conditions, b_3=0, but there still exist break-even and optimal import reduction levels that are less than the unrestricted level.

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ENDNOTES

*. Energy Modeling Forum, Stanford University. Mark Rodekohr, Darwin Hall and three anonymous referees provided some very constructive comments. In particular, one of the referees suggested the estimates of the optimal tariff by employing the assumption of linearity in the oil import supply and demand curves. Informal discussions with John Weyant were also very helpful. Finally the author is indebted to the modelers participating in the EMF study. An earlier version of this paper was delivered in a session chaired by Stephen P.A. Brown and Dallas Burtraw at the Western Economic Association Meetings, San Francisco, CA, July 10-14, 1992. The author assumes the responsibility for any errors or omissions.

1. This table excludes two models used in the study that did not report any U.S. results and a third that reported U.S. production only. In addition, costs are not estimated for two models listed in the table because they reported the required outputs in five-year intervals only. These models also assumed intertemporal optimizing behavior that would be inconsistent with real oil prices remaining constant or increasing as rapidly as in the rising price path.

2. Those interested in long-run energy and oil projections are referred to the semiannual polls conducted by the International Energy Workshop (IEW), as reported by Manne and Schrattenholzer (1989).

3. Kress et al (1992) discuss and compare the various model structures in greater detail. Results from two versions of HOMS are analyzed in this paper. HOMS specifies oil demand as a linear function of price with a one-time permanent shift to a lower demand level in 1980. Oil supply functions are econometrically estimated, too. HOMS1 uses log-linear demand curves. Oil supply curves are calibrated to judgmental parameters used in OMS.

4. Not all of these public concerns are necessarily meritorious. For example, many economists believe that macroeconomic savings-investment rather than oil-market imbalances lead to the climbing trade deficit.

5. See Broadman and Hogan (1988) for some estimates of various macroeconomic effects and Hall (1993) for an estimate of the national security effects.

6. This issue is further complicated by the possibility that import-reduction policies resulting in higher domestic oil prices (e.g., a tariff) may also create macroeconomic losses (U.S. Department of Energy, 1987), although there are some important differences between unexpected foreign price shocks and anticipated domestic price shocks implemented under undisrupted market conditions (Hogan and Mossavar-Rahmani, 1987, pp. 82-98, and Huntington, 1988).

7. Some of the tax on consumers is rebated to producers through subsidies. The figure shows the net transfer from consumers to the government.

8. See Kline (1982) for a more detailed discussion of how to compute the effects of an import-reduction policy from scenario results. He also computes the cost per barrel--as is done here--by dividing cumulative costs by cumulative barrels saved (discounting both yearly costs and saved barrels by the same social discount rate).

9. We ignore any possible influence that import reduction might have on the size of a price shock through its effect on the availability of excess cartel capacity. Such an issue requires an explicit representation of cartel producer behavior.

10. This approach will estimate these gains exactly if the reduction in imports due to the price shock is the same in the two cases. This assumption appears reasonable.

11. Plummer (1981) and Energy Modeling Forum (1982) assumed a lower probability (5%) of a more serious disruption (loss of the Persian Gulf). U.S. Department of Energy (1987) assumed a major disruption occurred with certainty in the eighth year--1995.

12. See Gately (1981) for an analysis of how different assumptions about cartel behavior influences the effectiveness of oil-import-reduction programs.

13. See the appendix for a derivation of this result.

14. The reverse holds for a given reduction in import volume; these models would show a smaller loss.

15. See Huntington (1991) for estimates of the models' price and income elasticities that have been inferred from interscenario comparisons.

16. See Plummer (1981), Energy Modeling Forum (1982), and Broadman (1986) for early and rather extensive reviews of the available premium estimates.

17. This conclusion is consistent with results described by Brown and Phillips (1991), who use the FRB Dallas model included in the EMF study to examine a policy of maintaining total U.S. oil consumption at today's level.

18. While the cartel often talks about retaliation, it may not be in their long-run economic interest to do so or they may not be able to successfully coordinate such a response.

TABLE 1
Models Reporting U.S. Results in EMF Study

Model	Working Group Contact*
EIA:OMS	Mark Rodekohr, Energy Information Administration
IPE	Nazli Choucri, Massachusetts Institute of Technology
CERI	Anthony Reinsch, Canadian Energy Research Institute
HOMS	William Hogan, Harvard, and Paul Leiby, Oak Ridge National Laboratory
FRB-Dallas	Stephen P.A. Brown, Federal Reserve Bank of Dallas
Gately	Dermot Gately, New York University
DFI-CEC**	Dale Nesbitt, Decision Focus, Inc.
ETA-Macro**	Alan Manne, Stanford University

*Organization listed for identification purposes. Models and results do not necessarily represent official view of listed organization.

**Not included in the analysis because results were reported in 5 or 10 year intervals only.

TABLE 2
US Imports in 2000 with Flat and Rising Oil Price Paths

	US Imports, 2000 (MMBD)			Pct Change in	
	Flat	Rising	Change	Demand	Supply
EIA: OMS	13.2	8.2	-5.0	-17.8%	17.3%
Gately	14.0	10.0	-4.0	-10.1%	22.6%
IPE	9.0	7.8	-1.2	-5.6%	2.2%
ETA-Macro	19.3	5.5	-13.8	-45.3%	9.7%
CERI	14.3	8.0	-6.3	-21.7%	26.5%
HOMS	16.2	11.7	-4.5	-14.2%	21.2%
FRB Dallas	22.9	15.0	-7.9	-24.5%	18.0%
DFI-CEC	13.6	10.5	-3.1	-11.2%	13.3%
HOMS-I	19.7	10.0	-9.7	-26.7%	31.3%
Average	15.8	9.6	-6.2	-19.7%	18.0%

TABLE 3
Total Costs (NPV) of Import Reduction, 1989-2010

	Direct Losses	Security Gains	Wealth Gains	Total Gains
HOMS1	-274.7	103.8	90.5	-80.3
FRB Dallas	-218.2	81.7	152.1	15.6
CERI	-158.7	61.8	98.6	1.6
OMS	-136.9	26.0	102.6	-8.4
HOMS	-121.1	45.7	100.3	24.9
Gately	-112.0	42.7	124.1	54.8
Average	-170.3	60.3	111.4	1.4
Estimates for 1990-2000:				
OMS	-43.0	10.3	47.8	15.1
IPE	-11.3	5.5	52.1	46.2

Source: Author's estimates based upon results from a flat and rising price path simulated in the EMF study. Import-reduction scenarios were not simulated by the modelers.

Notes:
Costs are 1988$ discounted at 5% real over the 1989-2010 period.
OMS and Gately begin tax in 1990.

TABLE 4
Estimates of Break-Even and Optimal Oil Import Levels (MMBD) and Optimal Tariff (1988$/B), 2000

	Flat Price	Rising Price	Break-Even	Optimal	Optimal Tariff
HOMS1	19.7	10.0	12.1	15.9	7.90
FRB Dallas	22.9	15.0	14.5	18.7	11.01
CERI	14.3	8.0	7.9	11.1	10.71
OMS	13.2	8.2	8.4	10.8	10.27
HOMS	16.2	11.7	11.0	13.6	11.68
Gately	14.0	10.0	8.7	11.4	14.28
Average	16.7	10.5	10.4	13.6	10.51
IPE(*)	9.0	7.8	4.9	6.9	35.94

(*) Not included in averages.

TABLE A-1
Direct Costs (NPV) of Import Reduction, 1989-2010

	Costs (1988$) of:				$ per barrel:		
	Higher Supply	Lower Demand	Direct Total	Pct of GNP	Higher Supply	Lower Demand	Total
HOMS1	-60.8	-213.9	-274.7	-0.47%	-7.78	-7.98	-7.94
FRB Dallas	-25.3	-192.8	-218.2	-0.38%	-7.99	-8.01	-8.01
CERI	-37.9	-120.9	-158.7	-0.27%	-7.44	-7.79	-7.71
OMS	-35.1	-101.9	-136.9	-0.24%	-7.97	-7.89	-7.91
HOMS	-33.4	-87.7	-121.1	-0.21%	-7.96	-7.95	-7.95
Gately	-51.0	-61.1	-112.0	-0.19%	-8.11	-7.67	-7.86
Average	-40.6	-129.7	-170.3	-0.29%	-7.88	-7.88	-7.90
Estimates for 1990-2000:							
OMS	-10.9	-32.1	-43.0	-0.13%	-6.36	-6.22	-6.25
IPE	-1.7	-9.6	-11.3	-0.03%	-7.26	-6.05	-6.20

Source: Author's estimates based upon results from a flat and rising price path simulated in the EMF study. Import-reduction scenarios were not simulated by the modelers.

Notes:
Costs are 1988$ discounted at 5% real over the 1989-2010 period.
OMS and Gately begin tax in 1990.

TABLE A-2
Impact on World Oil Prices When Foreigners Partially Absorb Tax, 2000

	Tax Incd	World Price	US Tax
HOMS1	17.8%	15.58	20.28
FRB Dallas	20.4%	15.08	20.92
CERI	22.4%	14.73	21.27
OMS	23.4%	14.56	21.44
HOMS	17.4%	15.65	20.21
Gately	22.8%	14.67	21.33
Average	20.7%	15.05	20.91
IPE	22.4%	14.73	21.27

Source: Author's estimates based upon results from a flat and rising price path simulated in the EMF study. Import-reduction scenarios were not simulated by the modelers.

Notes:
Oil prices are in 1988 $ per barrel.
OMS and Gately begin tax in 1990.

TABLE A-3
Total Costs (NPV) with Different World Oil Price Changes, 1989-2010

	Incidence = 10%		Incidence = 20%	
	Wealth Gains	Total Gains	Wealth Gains	Total Gains
HOMS1	46.6	-124.3	100.8	-70.1
FRB Dallas	68.8	-67.7	148.5	12.1
CERI	39.8	-57.1	86.1	-10.9
OMS	40.0	-71.0	86.3	-24.6
HOMS	54.1	-21.3	116.9	41.5
Gately	50.4	-18.9	108.7	39.4
Average	49.9	-60.1	107.9	-2.1
Estimates for 1990-2000:				
OMS	17.5	-15.2	38.1	5.4
IPE	18.1	12.3	39.4	33.6

Source: Author's estimates based upon results from a flat and rising price path simulated in the EMF study. Import-reduction scenarios were not simulated by the modelers.

Notes:
Costs are 1988$ discounted at 5% real over the 1989-2010 period.
OMS and Gately begin tax in 1990.

TABLE A-4

Inferred Parameters for Estimating Optimal Import-Reduction Levels and Tariff

	$\underline{b}_1$	$\underline{b}_2$	$\underline{b}_3$
HOMS1	-2.89	10.65	0.93
FRB Dallas	-3.47	10.31	1.28
CERI	-3.93	9.72	1.95
OMS	-5.33	5.12	2.48
HOMS	-5.95	10.13	1.90
Gately	-7.03	10.71	3.09
Average	-4.33	9.62	1.70
IPE(*)	-7.72	4.52	5.55

(*) Not included in averages.

Figure 1: Welfare Effects of Import-Reduction Policy

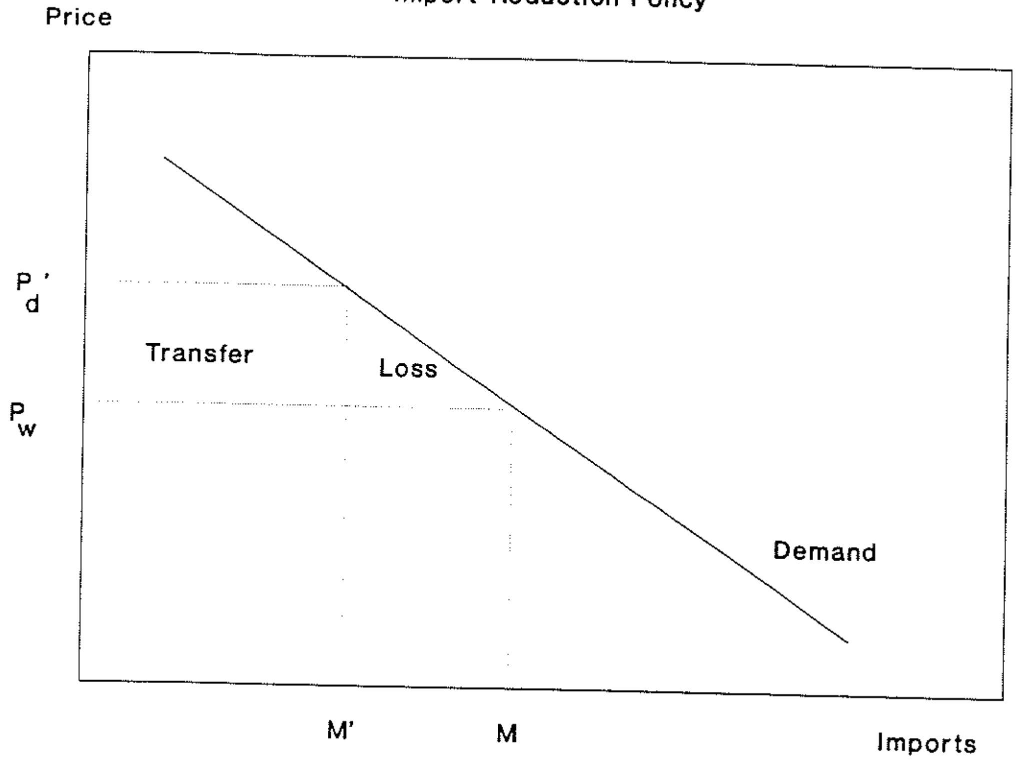

Figure 2: Welfare Effects When
Oil Prices Are Changed