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ASSESSING THE ECONOMIC COST OF UNILATERAL OIL CONSERVATION

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ABSTRACT

This article examines the costs of U.S. oil conservation policy by using parameters from five world oil models used in a recent Energy Modeling Forum study. Variation in the estimated cost of U.S. conservation across the models suggests that taxing oil consumption would better serve economic efficiency than government controls on oil consumption levels. Furthermore, the analysis shows that unilateral U.S. conservation lowers the world oil price and stimulates non-U.S. oil consumption. When this effect is taken into account, the estimated cost of achieving a given level of world oil conservation through unilateral U.S. action can be substantially greater than the cost of achieving the same level of U.S. oil conservation.

I. INTRODUCTION

In recent years, increasing attention to global environmental problems, energy security, and declining U.S. oil production have revived calls for energy conservation. The benefits and costs of energy conservation remain controversial. Hall (1990, 1992) has provided comprehensive estimates of the externality costs associated with energy consumption. Others, such as Brown and Phillips (1991), Chandler, et. al. (1988) and the National Academy of Sciences (1991), have provided estimates of the costs of conservation.

Previous cost studies have tended to assess the costs of holding U.S. oil consumption at a predetermined level and/or relied upon a single supply curve of conservation. Cost estimates such as these are greatly affected by the projected growth of oil consumption, as well as individual model parameters. A more general approach is to use a number of world oil models to estimate supply curves of oil conservation. Using differing models, with varying parameters, provides a richer set of assumptions with which the cost of conservation can be assessed. Varying supply estimates permits an assessment of the extent of uncertainty about the cost of conservation and is helpful in determining whether specific conservation mandates can serve economic efficiency.

With increasing attention to global environmental issues, policymakers in the United States may be concerned about the net effects of domestic oil conservation policies on global oil conservation. As the United States reduces its oil consumption, it reduces world oil prices and triggers offsetting gains in world oil consumption. These effects can be incorporated in estimated supply curves of world oil conservation achieved through unilateral U.S. policy. Such supply curves can be useful in determining an efficient level of conservation policy when the perceived benefits are primarily global.[1]

To estimate supply curves of oil conservation for the United States, we used a three-step process. First, we obtained projected prices and quantities, as well as price elasticities of supply and demand from five world oil market models that participated in the eleventh Energy Modeling Forum study, International Oil Supplies and Demands. We then used parameters from each model in simulation analysis to estimate how U.S. oil conservation would affect prices and quantities on the world oil market under a variety of assumptions. Finally, we combined welfare analysis with our simulation results and the model parameters to derive supply curves of conservation for each of the five models.

II. ANALYTICAL FRAMEWORK

We use welfare analysis as a basis to provide estimates of the marginal cost of oil conservation. The welfare-theoretic approach has the advantages of being well grounded in economic theory and relatively straight forward to implement and interpret. Assessed at different quantities of conservation, estimates of marginal cost can be combined to provide an estimated supply curve of oil conservation.

A. The Cost of U.S. Conservation

Hall (1990, 1992) provides comprehensive estimates of the externalities associated with energy consumption. If the reduction of externalities is regarded as the social benefit of oil conservation, then the cost of U.S. conservation can be regarded as the welfare lost (exclusive of externalities) by reducing U.S. oil consumption below its free market quantity.[2] Under this definition of cost, the marginal cost of conservation is the loss in U.S. welfare that results from a marginal reduction in consumption. This relationship can be expressed as:

$$MC_C = P_D - P_W + \frac{\partial P_W}{\partial Q_C} Q_M \qquad (1)$$

In the above equation MC_C denotes the marginal cost of conservation, P_D the U.S. price of oil, P_W the world price of oil, Q_C the quantity of U.S. oil conservation, and Q_M the quantity of U.S. oil imports. (A derivation of equation 1 is provided in the appendix.)

If the United States is concerned only with domestic conservation, equation 1 can be used to provide estimates of the cost of conservation. The marginal cost of conservation is equal to the difference between the market's valuation of additional oil consumption, P_D, and the world price of oil, P_W, plus the amount by which a marginal increase in U.S. oil conservation alters the cost of U.S. oil imports, $(\partial P_W/\partial Q_C)\cdot Q_M$. If U.S. oil conservation has no effect on world oil prices, then the marginal cost of conservation is simply the difference between the U.S. market's marginal valuation of oil consumption and the world price of oil.

Theoretically, U.S. conservation can have a negative or positive effect on the world oil price and, therefore, on the U.S. oil import bill. Because the United States is a large consumer of oil, its conservation puts downward pressure on world oil prices. Some conservation measures also would make U.S. oil demand more inelastic, which would give a well-functioning OPEC cartel an incentive to raise prices. Because many conservation measures would have only moderate effects on the elasticity of U.S. oil demand and Griffin (1985) and Dahl and Yücel (1991) have shown OPEC to be less than a perfect cartel, U.S. conservation efforts generally can be expected to reduce world oil prices and, consequently, the U.S. oil import bill.

B. The Global Effects of Unilateral Conservation

In theory, U.S. oil conservation can lead to changes in oil consumption in the rest of the world that range from enhancing to completely offsetting U.S. conservation policy.[3] In practice, U.S. conservation actions are likely to be partially offset by increased oil consumption in the rest of the world. As U.S. oil conservation reduces the world oil price, it induces an increase in oil consumption outside the United States. The net effect is that the change in world oil conservation is somewhat less than the change in U.S. oil conservation that results from a unilateral policy.

Combining these factors, the net effect of U.S. actions on world oil conservation can be expressed as follows:

$$\frac{\partial Q_{CW}}{\partial Q_C} = 1 - \frac{\partial Q_{DX}}{\partial P_W} \cdot \frac{\partial P_W}{\partial Q_C} \qquad (2)$$

In the above equation, Q_{CW} denotes world oil conservation and Q_{DX} the quantity of oil consumption outside the United States. (A more thorough examination of the relationships between U.S. conservation, world oil prices, and net world conservation is provided in the appendix.)

C. The Marginal Cost of Unilateral Conservation

If analysts are concerned with the global effects of a unilateral oil conservation policy, equation 1 could provide an inadequate measure of the cost. When U.S. oil conservation stimulates oil consumption outside the United States, the marginal cost of achieving world conservation through unilateral policy will be somewhat higher than the marginal cost of U.S. conservation.

Equations 1 and 2 can be combined to derive an expression for the marginal U.S. cost of achieving world oil conservation through unilateral policy. Specifically, dividing MC_C (the marginal cost of U.S. conservation) by $\partial Q_{CW}/\partial Q_C$ (the change in net world oil conservation with respect to a change in U.S. oil conservation) yields:

$$MC_{CW} = \left(P_D - P_W + \frac{\partial P_W}{\partial Q_C} Q_M\right) \cdot \left(1 - \frac{\partial Q_{DX}}{\partial P_W} \cdot \frac{\partial P_W}{\partial Q_C}\right)^{-1} \qquad (3)$$

In the above equation, MC_{CW} denotes the marginal cost to the United States of achieving world oil conservation through its unilateral efforts.

As equation 3 shows, the effects that U.S. oil conservation has on the cost of U.S. oil imports and on foreign oil consumption are related through the world oil price. As U.S. conservation lowers the world oil price, it reduces the cost of U.S. oil imports and brings about an increase in oil consumption outside the United States. If U.S. conservation has no effect on the world oil price ($\partial P_w/\partial Q_c = 0$), both the cost of U.S. oil imports and foreign oil consumption will remain unchanged.

III. EMF STUDY PROVIDES PARAMETERS FOR ANALYSIS

Five models of the world oil market used in the eleventh Energy Modeling Forum (EMF) study provide the parameters we use in our analysis of the costs of oil conservation. From each model, we obtained a set of projected world oil prices and quantities, as well as inferred elasticities of supply and demand for use in our analysis. The use of parameters from a number of models provides a richer set of assumptions from which the cost of unilateral oil conservation can be assessed.

A. The Models

The eleventh EMF study, International Oil Supplies and Demands, focused on the supply and demand trends over the 1988-2010 period for various scenarios and their implication for the world's dependence upon Persian Gulf oil. For the EMF study, proprietors of 11 economic models of the world oil market simulated 12 different scenarios with standardized input assumptions. An EMF working group comprised of leading analysts and decision-makers from business, government, and academia analyzed and compared these results, emphasizing the reasons for and implications of the observed differences among models.

The analysis here is restricted to the five models shown in Table 1. Of the 11 models included in the EMF study, two did not report results for the cartel case, a market-clearing scenario used to represent baseline conditions here. Two other models did not report U.S. oil consumption separately. A fifth model did not project beyond the year 2000. And finally, the Gately model was excluded because a reliable estimate of the price elasticity of U.S. oil demand for the model could not be obtained for the range of prices required by the analysis here.[4] A comparison of all 11 models suggests that the five models we use represent well the range of models that participated in the EMF study.

Kress, et. al. (1992) describe each model's structure and key variables. Key input variables for determining oil consumption in the models include: the crude oil price and GDP (all models), and a time trend for autonomous improvements in oil efficiency, unrelated to price (OMS and DFI only). The demand functions for HOMS and FRB-Dallas are econometrically determined; those for OMS, DFI, and CERI are based upon judgmental parameters, which for some models are based partly upon available energy demand studies.

Regional disaggregation outside the United States varies across models. FRB-Dallas specifies individual demand equations for the major seven OECD countries (United States, Canada, Japan, West Germany, France, United Kingdom, and Italy). The remaining models aggregate the European countries into one region. On the supply side, CERI disaggregates non-OPEC production into 16 major regions, while the others usually distinguish only the United States from other non-OPEC regions.

B. Baseline Projections

For each of the five models, we obtained a baseline projection of prices and quantities for our analysis from a cartel scenario for which each modeler reported results. In the cartel scenario, OPEC was assumed to operate as a cartel and world economic growth was assumed to be 2.9% per year. Each model determined the market-clearing world oil price and quantities endogenously through the interaction of regional demands, supplies, and OPEC price-setting behavior.

C. Demand and Supply Elasticities

In the EMF study, results from the models were compared for a variety of scenarios, representing different exogenous oil price trajectories, economic growth paths, energy-saving technical progress, and oil-producing cartel behavior. For the analysis here, results from two model runs are used to infer estimates of price elasticities of regional supply and demand.

Table 2 reports key elasticities that we have inferred from the supply and demand projections that the modelers reported for two scenarios for which oil prices were specified exogenously. In one scenario, the world oil price is assumed to remain flat at $18 per barrel.[5] In the other scenario, the world oil price rises steadily from $18 per barrel until it reaches a plateau of $36 per barrel in 2000, at which the price is maintained through 2010. Both cases assume that the market economies grow by 2.9 percent per annum and the U.S. economy grows by 2.6 percent per annum. Because GDP is the same in both cases, the resulting responses are representative of pure price elasticities.

There are limitations to inferring a model's price elasticities from two scenarios (Huntington, 1992). Nevertheless, a more thorough analysis of how the EMF models represent OECD demand (Huntington, 1993) indicates that the price elasticities we have inferred from the flat and rising price scenarios are generally consistent with econometric response surfaces estimated from the results of all 12 scenarios, as well as those reported by the modelers themselves.

D. OPEC Supply

Four of the models (OMS, CERI, HOMS and FRB-Dallas) represent OPEC price setting with price-reaction functions. The fifth model, DFI, represents OPEC price setting with dynamic optimization. Although the 12 EMF scenarios contained two OPEC cartel cases--the base case used here and a high demand case--a comparison of these two scenarios did not reveal how the models would behave when U.S. policy is used to reduce oil demand.

Our analysis is based on three cases of OPEC supply for each model. Two cases rely on limiting assumptions. In one case, OPEC acts to hold price constant--that is, OPEC supply is perfectly elastic. In the other case, OPEC holds its production constant--that is, OPEC supply is perfectly inelastic. A third case relies on an the intermediate assumption that OPEC supply is unitary elastic. Although uniform assumptions about OPEC supply reduce the potential variation in cost estimates across models, the remaining variation is instructive.

Furthermore, our examination of the DFI, OMS and FRB-Dallas models indicates that a unitary OPEC supply elasticity may be a reasonable approximation for the models. Analysis of the DFI model indicated a supply elasticity somewhat less than unity when OPEC is pushed to expand its capacity substantially. A greater elasticity might be indicated when OPEC is not pushed to expand its capacity substantially--as would be the case when U.S. policy reduces world oil demand.

Direct analysis of the price-reaction functions in the OMS and FRB-Dallas models revealed relatively low supply elasticities when capacity is taken as given, but informal discussion with several modelers indicate that OPEC capacity figures are often adjusted on a judgmental basis when a scenario yields projected oil prices that are too high or low. Such adjustments increase the elasticity of OPEC supply.

IV. THE COST OF CONSERVATION

We used parameters from each of the five models described above in a series of simulation analyses to provide multiple estimates of the effects of U.S. oil conservation on prices and quantities on the world oil market. We then used equations 1 and 3 to estimate supply (marginal cost) curves of conservation for each of the five models under three assumptions about OPEC behavior. The three cases for OPEC supply include: one in which OPEC adjusts its output such that the world price of oil is unchanged, one in which OPEC has a unitary elasticity of supply, and one in which OPEC production is unchanged.

A. <u>If the World Oil Price Doesn't Change</u>

Figure 1 plots supply (marginal cost) curves of U.S. conservation for the year 2010 for each model under the assumption that OPEC adjusts its production to keep the world price of oil unchanged.[6] If the world price of oil does not change, the marginal cost of U.S. conservation at any given level of conservation is the price increase (implied tax on U.S. oil consumption) required to achieve that level of conservation. As Figure 1 shows, the marginal cost estimated for each model rises as the amount of U.S. conservation increases.[7]

Marginal costs rise more steeply for models in which U.S. oil consumption is less responsive to price ($\partial Q_D/\partial P_D$ is less negative). (The responsiveness of consumption to price is a direct function of the ratio of price to consumption in the cartel case, as well as the price elasticity of demand.) DFI has the most steeply sloped conservation curve because U.S. oil consumption is least sensitive to price in this model. CERI and FRB-Dallas have the least steeply sloped curves because they represent U.S. oil consumption as more sensitive to price. OMS and HOMS fall between these other estimates.

As Figure 1 shows, setting quantity targets for U.S. oil conservation policy yields widely varied marginal cost estimates across the models. Results from all of the models indicate that the first million barrels per day of oil conservation can be had for a marginal cost of less than $10 per barrel. For the HOMS, OMS and DFI models, the marginal cost of conservation rises above $20 per barrel before oil conservation reaches two million barrels per day. At two million barrels per day, the CERI and FRB-Dallas models still show the marginal cost of conservation below $10 per barrel. For the CERI and FRB-Dallas models, the marginal cost of conservation rises above $20 per barrel after oil conservation reaches four million barrels per day. At four million barrels per day, the HOMS, OMS and DFI models all indicate a marginal cost of oil conservation over $50 per barrel.

A conservation policy that sets targets for U.S. oil consumption based on historical use also yields widely varied estimates of marginal cost across the models. For each model, Table 3 shows the marginal cost of holding U.S. oil consumption in the year 2010 to the level established in 1988. Estimates range from lows of near $13 per barrel with the CERI and OMS models to highs near $30 with the HOMS and FRB-Dallas models.

For each model, Table 3 also compares assumed 1988 U.S. oil consumption with that projected for the year 2010. The difference indicates how much oil conservation the United States would have to achieve to keep its oil consumption from growing over the 22 year period from 1988 to 2010, according to each model.

In developing the cost estimates, differences in the projected quantities of oil consumption, as well as the responsiveness of consumption to changes in price contribute to the differences in cost estimates across the models. Although the FRB-Dallas and CERI models evidence a similar responsiveness in U.S. consumption to changes in price, the models provide the opposite ends of the cost estimates, because the FRB-Dallas model projected much higher consumption for the year 2010 than the CERI model. Similarly, HOMS shows a higher marginal cost than OMS because HOMS projected much higher consumption for the year 2010 than OMS. The OMS and CERI models provide similar marginal cost estimates because the lower projection for U.S. consumption with the OMS model offsets the fact that it shows U.S. oil consumption as less sensitive to price than the CERI model.

B. <u>If OPEC Supply Elasticity is Unitary</u>

Under the assumption that OPEC has a unitary supply elasticity, all of the models show that U.S. oil conservation reduces the world oil price. All of the models also show that a lower world oil price stimulates non-U.S. oil consumption. The effects of U.S. conservation on the world oil price and non-U.S. oil consumption alters our estimates of the marginal costs of oil conservation.

The estimated reductions in the world oil price and gains in non-U.S. oil consumption vary across the models. At one extreme, the DFI model shows non-U.S. oil consumption increasing by about 20 percent for each barrel of oil that the United States conserves. At the other extreme, the CERI and FRB-Dallas models show non-U.S. oil consumption increasing by about 30 percent for each barrel of oil that the United States conserves. The OMS and HOMS models show non-U.S. oil consumption increasing by about 25 percent for each barrel of oil that the United States conserves.

Figure 2 shows three supply curves of conservation for the OMS model for the year 2010. One of the curves represent the marginal cost of conservation when the world oil price does not change--that is by how much the oil price paid by U.S. consumers must rise to achieve given levels of conservation. The other two curves represent the marginal cost of U.S. oil conservation and marginal cost of achieving world conservation through unilateral U.S. actions when OPEC has a unitary supply elasticity.

As Figure 2 shows, a unitary OPEC supply elasticity alters the marginal cost of U.S. conservation from the scenario in which it is assumed that U.S. oil consumption has no effect on the world oil price. With a unitary OPEC supply elasticity, the marginal cost of conservation is negative at zero conservation because increasing conservation from this point will lower the price paid for oil imports. The marginal cost curve is also steeper with a unitary OPEC supply elasticity because the difference between the implied U.S. consumption price (P_D) and the world oil price (P_W) grows faster than P_D as conservation is increased and the value of reducing the price of oil imports falls as conservation reduces U.S. oil imports.

The unitary OPEC supply elasticity drastically steepens the supply curve of world oil conservation achieved through unilateral U.S. actions. With U.S. conservation stimulating non-U.S. oil consumption, a one-unit gain in world conservation through unilateral U.S. action requires more than a one-unit gain in U.S. conservation.

As Figure 3 shows, the models provide varying estimates of the supply curve of U.S. conservation for the year 2010, even with the common assumption that OPEC has a unitary supply elasticity. Results from all of the models indicate the first million barrels per day of oil conservation can be had for a marginal cost of less than $4 per barrel. The FRB-Dallas and CERI models show negative marginal costs at one million barrels per day. For the HOMS, OMS and DFI models, the marginal cost of conservation rises to about $15 per barrel around two million barrels per day. At two million barrels per day, FRB-Dallas model still shows a negative marginal cost and the CERI model shows a marginal cost below $4 per barrel. For the CERI and FRB-Dallas models, the marginal cost of conservation rises to $15 per barrel when oil conservation reaches about four million barrels per day. At four million barrels per day, the HOMS, OMS and DFI models all indicate a marginal cost of oil conservation over $50 per barrel.

As Figure 4 shows, the models also provide varying estimates of the supply curve of world conservation achieved through unilateral U.S. actions. Results from all of the models indicate the first million barrels per day of oil conservation can be had for a marginal cost of less than $9 per barrel. The FRB-Dallas model shows negative marginal costs at one million barrels per day. For the HOMS, OMS and DFI models, the marginal cost of conservation rises to about $30 per barrel around two million barrels per day. At two million barrels per day, the CERI and FRB-Dallas models still show marginal cost at or below $12 per barrel. For the CERI and FRB-Dallas models, the marginal cost of conservation rises to $30 per barrel when oil conservation reaches about four million barrels per day. At four million barrels per day, the HOMS, OMS and DFI models all indicate a marginal cost of oil conservation over $90 per barrel.

C. <u>If OPEC Production Doesn't Change</u>

Under the assumption that OPEC production does not change, all of the models show that U.S. oil conservation reduces the world oil price more than they did under the assumption that OPEC has a unitary supply elasticity. All of the models also show that the lower world oil price further stimulates non-U.S. oil consumption. If OPEC does not adjust its production to reduced U.S. oil consumption, any given change in U.S. consumption requires a greater reduction in non-OPEC supply and a greater increase in non-U.S. consumption to reestablish market clearing conditions. The adjustment requires a greater price reduction than would be needed if OPEC adjusts its production.

The intensified effects of U.S. conservation on the world oil price and non-U.S. oil consumption alters the estimates of the marginal costs of oil conservation. As Figure 5 shows for the OMS model, the greater ability of U.S. conservation to reduce the world oil price means a lower marginal cost of U.S. oil conservation at sufficiently low quantities of U.S. oil conservation. In this regard, all of the models show results similar to that obtained from the OMS model. The models show lower marginal costs because U.S. conservation has a greater impact in reducing U.S. import costs when it more sharply reduces world oil prices.

A perfectly inelastic OPEC supply also makes the estimated supply curves of U.S. conservation steeper. Under this elasticity assumption, the difference between the implied U.S. consumption price (P_D) and the world oil price (P_W) increases more sharply as conservation is increased. In addition, the value of reducing the cost of oil imports falls more sharply under this elasticity assumption.

At sufficiently high quantities of conservation--about four million to five million barrels per day--all of the models show about the same marginal costs for U.S. conservation that they do with a unitary OPEC supply elasticity. At four million barrels per day, the OMS model actually shows slightly higher marginal costs under the assumption that OPEC does not adjust its production. At high enough conservation levels--more than six million barrels per day--the other four models show higher marginal costs of conservation under the assumption that OPEC supply is perfectly inelastic.

The offsetting increases in non-U.S. oil consumption that result from U.S. conservation are considerable if OPEC supply is perfectly inelastic. Estimates range from a 45-percent offset (HOMS) to about an 85-percent offset (CERI) for every barrel of oil that the United States conserves. The OMS, FRB-Dallas and DFI models show non-U.S. oil consumption increasing by 50 to 70 percent for each barrel of oil that the United States conserves.

As Figure 5 shows for the OMS model, the size of the offsetting gains in non-U.S. oil consumption that result from U.S. oil conservation are reflected in the estimated supply curves of world conservation achieved through unilateral U.S. action. If OPEC supply is perfectly inelastic, the OMS model shows that the marginal cost of reducing world consumption by one million barrels per day through unilateral U.S. action would be more than $85 per barrel.

As Figure 6 shows, even with the common assumption that OPEC supply is perfectly inelastic, the models provide widely varying estimates of the marginal costs of achieving world oil conservation through unilateral U.S. actions. At one extreme, the CERI model shows the marginal cost of reducing world oil consumption by a half a million barrels per day would be more than $100 per barrel. In contrast, the FRB-Dallas model shows the marginal cost of reducing world oil consumption by three million barrels per day to be just over $90 per barrel.

V. COST ESTIMATES RECONSIDERED

The analysis presented here assumes that oil conservation can only be obtained by getting consumers to adopt techniques that they would find more costly to use than oil. In addition, it assumes that the political process will select the least costly methods for achieving oil conservation without incurring any costs for rent-seeking behavior. To the extent that these assumptions are not correct, our cost estimates may be too high or too low.

A. Engineering-Cost Studies

Some analysts, including the National Academy of Science Synthesis Panel on the Policy Implications of Greenhouse Warming (1991), have used engineering-cost studies to argue that supplies of conserved energy are available at a net savings of cost to consumers. To the extent that engineering-cost studies correctly represent the cost of energy conservation, the cost estimates presented here would be too high.

Market-oriented economists find this line of argument troublesome. In the absence of identifiable market imperfections or implicit life-style changes, the argument requires that individuals behave inefficiently by overlooking energy conservation options that would reduce costs. Among other factors, third-party purchases and the lack of information have been identified as possible imperfections in the energy market. Nonetheless, Cavallo and Sutherland (1993) have found that energy markets are no slower in adopting cost-saving technology than other markets, which suggests that supplies of conserved energy at a net savings of cost may be illusory.

B. The Political Process

An analysis of the political process through which oil conservation would be achieved suggests our cost estimates might represent lower bounds. To the extent that U.S. conservation policy alters free market decisions and prices, it creates opportunities for rent-seeking behavior. Among others, Tullock (1967, 1980) has argued that individuals who seek a rent have an incentive to expend real resources up to the value of the rent. In doing so, they dissipate the rent as costs.

The reduced cost of U.S. oil imports can be viewed as a rent created by U.S. oil conservation policy. Accordingly, rent-seeking behavior could generate costs as high as the benefit obtained by reducing the cost of oil imports. In our exercise, the marginal cost of U.S. conservation would rise up to the amount by which a marginal increase in U.S. conservation reduces import costs.

The use of instruments other than an oil consumption tax to achieve oil conservation could also contribute to the cost of conservation. Legislation aimed at specific oil conservation technologies, would create rents for the producers of specific technologies and give rise to further costs. In addition, Brown (1982) has shown that past attempts to legislate specific conservation technologies have been inefficient. The marginal cost per unit of energy saved varied considerably across the legislated technologies. The legislation also ignored many low-cost methods of conservation.

VI. CONCLUSIONS

The preceding analysis allows us to reach three conclusions. First, all of the models show that the first one million barrels of U.S. oil conservation can be obtained at a marginal cost below $10 (1988 dollars) per barrel. Some of the models show sharply rising costs after that point. Second, uncertainty about future oil market conditions suggests that taxation is preferable to government mandates for achieving oil conservation. Finally, world oil conservation achieved through unilateral U.S. actions could prove costly because U.S. conservation is likely to trigger offsetting gains in non-U.S. oil consumption.

Because the models show considerable variation in the estimated costs of oil conservation, the estimated cost of quantity-based targets, such as holding U.S. oil consumption at 1988 levels, can range from inexpensive to quite costly. In those cases where quantity-based targets prove inexpensive, the conservation policy does not represent much of a departure from conditions that would prevail in an unregulated market. If we take the variation across models to represent the extent of uncertainty about future oil market conditions, our findings suggest that conservation taxes would better serve economic efficiency than conservation targets. With conservation taxes, market forces can adjust the quantity conservation such that the marginal cost is equal to the tax, even when the costs are unknown.

Undertaken unilaterally, however, U.S. oil conservation is likely to reduce the world oil price and trigger offsetting gains in world oil consumption. The extent of these gains will depend on the responsiveness of non-U.S. oil consumption, OPEC supply and non-OPEC supply to changes in price, as well as the extent of U.S. conservation. The more responsive non-U.S. oil consumption is or the less responsive world oil production is to changes in price, the greater the gains in non-U.S. oil consumption.

To the extent that U.S. energy conservation policy is motivated by global concerns, unilateral actions could prove quite costly. Incorporating market feedback effects into the supply curve of conservation generally increases the estimated cost of conservation. For a intermediate case--one in which OPEC supply is assumed to be unitary elastic--the estimated marginal cost of achieving world conservation through unilateral actions ranges from $8 to $35 (1988 dollars) per barrel at a conservation level of two million barrels per day. For the same case, the estimates are $23 to $75 (1988 dollars) per barrel at a conservation level of three million barrels per day. For an extreme case--one in which OPEC supply is assumed to be perfectly inelastic--the estimated cost of conservation rises much more rapidly.

APPENDIX: SOME ANALYTICS OF U.S. OIL CONSERVATION

We use a welfare-theoretic approach to derive formulas for the marginal cost of oil conservation. For the United States, social welfare in the oil market is the sum of U.S. consumer and producer surpluses:

$$W = \int_0^{Q_D} P_D(Q)\partial Q - P_W Q_D + P_W Q_S - \int_0^{Q_S} P_S(Q)\partial Q \qquad \textbf{(A1)}$$

In the above equation, W denotes the U.S. welfare obtained from the oil market, Q_D the quantity of oil demanded in the United States, P_D the U.S. demand price (the market's marginal valuation of consumption excluding externalities) at each quantity (Q), P_W the world price of oil, Q_S the quantity of U.S. oil supplied, and P_S the U.S. oil supply price (marginal cost of U.S. oil production excluding externalities) at each quantity (Q).

A. <u>The Cost of U.S. Conservation</u>

If the marginal cost of conservation is defined as the welfare lost in the U.S. oil market by reducing U.S. oil consumption on the margin, the negative of the first derivative of W with respect to Q_D yields the marginal cost of conservation:

$$MC_C = P_D - P_W + \frac{\partial P_W}{\partial Q_C} Q_M \qquad \textbf{(A2)}$$

In the above equation MC_C denotes the marginal cost of conservation, Q_C the quantity of conservation (where $\partial Q_C = -\partial Q_D$) , and Q_M the quantity of U.S. oil imports.

B. <u>The Global Effects of Unilateral Conservation</u>

The net effect of unilateral U.S. actions on world oil conservation is simply the quantity of U.S. oil conservation minus the induced change in oil consumption in the rest of the world. The change in oil consumption outside the United States depends on how that consumption is affected by a change in the world oil price and how U.S. conservation actions affect the world oil price. Therefore, the relationship between a unilateral change in U.S. oil conservation and the net change in world oil conservation can be expressed as follows:

$$\frac{\partial Q_{CW}}{\partial Q_C} = 1 - \frac{\partial Q_{DX}}{\partial P_W} \bullet \frac{\partial P_W}{\partial Q_C} \qquad \text{(A3)}$$

In the above equation, Q_{CW} denotes world oil conservation and Q_{DX} the quantity of oil consumption outside the United States.

If consumers and producers are price takers, the effect of U.S. oil conservation on the world oil price can be expressed as a function of underlying demand and supply conditions.

$$\frac{\partial P_W}{\partial Q_C} = \left(\frac{\partial Q_{DX}}{\partial P_W} - \frac{\partial Q_{SW}}{\partial P_W} \right)^{-1} \qquad \text{(A4)}$$

In the above equation Q_{SW} denotes the quantity of oil supplied world wide.[8]

As is shown by taking the first derivatives of $\partial P_W/\partial Q_C$ with respect to $\partial Q_{DX}/\partial P_W$ and $\partial Q_{SW}/\partial P_W$, the greater the response of non-U.S. oil consumption or world oil production is to a given change in the world oil price, the smaller is the impact of U.S. oil conservation in reducing world oil prices. A change in U.S. oil conservation will induce a change in the world oil price such that the resulting change in non-U.S. oil consumption less the change in world oil production just equal the change in U.S. oil conservation. The more responsive either non-U.S. oil consumption is or world oil production is to a change in price, the smaller is the change in world oil price required to make the world oil market adjust to a change in U.S. oil conservation.

Combining equations A3 and A4, yields an expression that shows how supply and demand conditions affect the relationship between U.S. oil conservation and net world oil conservation.

$$\frac{\partial Q_{CW}}{\partial Q_C} = 1 - \frac{\partial Q_{DX}}{\partial P_W} \bullet \left(\frac{\partial Q_{DX}}{\partial P_W} - \frac{\partial Q_{SW}}{\partial P_W} \right)^{-1} \qquad \textbf{(A5)}$$

As indicated by the first derivative of $\partial Q_{CW}/\partial Q_C$ with respect to $\partial Q_{SW}/\partial P_W$, the more responsive world oil production is to a change in the world oil price, the more effective U.S. conservation is in achieving world conservation. Under these conditions, the world price changes less and the increase in non-U.S. consumption is smaller.

As indicated by the first derivative of $\partial Q_{CW}/\partial Q_C$ with respect to $\partial Q_{DX}/\partial P_W$, the more responsive non-U.S. consumption is to a change in the world oil price, the less effective U.S. conservation is in achieving world conservation. Under these conditions, the world oil price changes less, but given the greater responsiveness of non-U.S. oil consumption to price, the smaller change in price leads to a greater change in non-U.S. oil consumption.

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NOTES

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1. An alternative to the approach taken here is to make appropriate adjustments when measuring the benefits.

2. This definition of cost assumes that conservation is obtained by getting consumers to adopt techniques that they find more costly to use than oil.

3. Hoel (1991) examines a case in which one country's unilateral actions to reduce emissions could lead to an increase in global emissions. This outcome depends on the country's unilateral action weakening its bargaining position in a global negotiation on emissions. The assumption made in the present analysis that U.S. conservation affects foreign oil consumption only through world oil prices precludes such an outcome.

4. In the Gately model, demand elasticities vary with the direction and range of the price change. Therefore, the price elasticity of U.S. oil demand revealed by comparing the rising and flat price case would not necessarily

represent how the model would respond to the increases in the U.S. oil price considered here.

5. All reported prices are in 1988 dollars.

6. When U.S. conservation leaves the world oil price unchanged, there is no difference between U.S. and world conservation nor between the marginal cost of U.S. conservation and the marginal cost of world conservation achieved through a unilateral U.S. policy.

7. The EMF study did not provide cost estimates for U.S. oil conservation. The authors made the cost estimates presented here with parameters inferred from two scenario runs made with the identified models.

8. Note that $\partial Q_{DX}/\partial P_W = \eta_{DX} \cdot (Q_{DX}/P_W)$ and $\partial Q_{SW}/\partial P_W = \eta_{SW} \cdot (Q_{SW}/P_W)$, where η_{DX} is the elasticity of non-U.S. oil demand and η_{SW} is the elasticity of world oil supply.

Table 1
Models in EMF Study

Model	Working Group Contact*
EIA:OMS	Mark Rodekohr, Energy Information Administration
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 Reserserve Bank of Dallas
DFI-CEC	Dale Nesbitt, Decision Focus, Inc.

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

Table 2
Inferred Price Elasticities of Regional Supplies and Demands, 2010

	Demand:			Supply:	
	USA	Other OECD	NonOECD	USA	Other NonOPEC
OMS	-0.327	-0.465	-0.149	0.340	0.170
CERI	-0.441	-0.452	-0.455	0.196	0.144
HOMS	-0.308	-0.381	-0.280	0.522	0.510
FRB-D	-0.537	-0.528	-0.400	0.475	0.480
DFI	-0.185	-0.532	-0.190	0.499	0.981

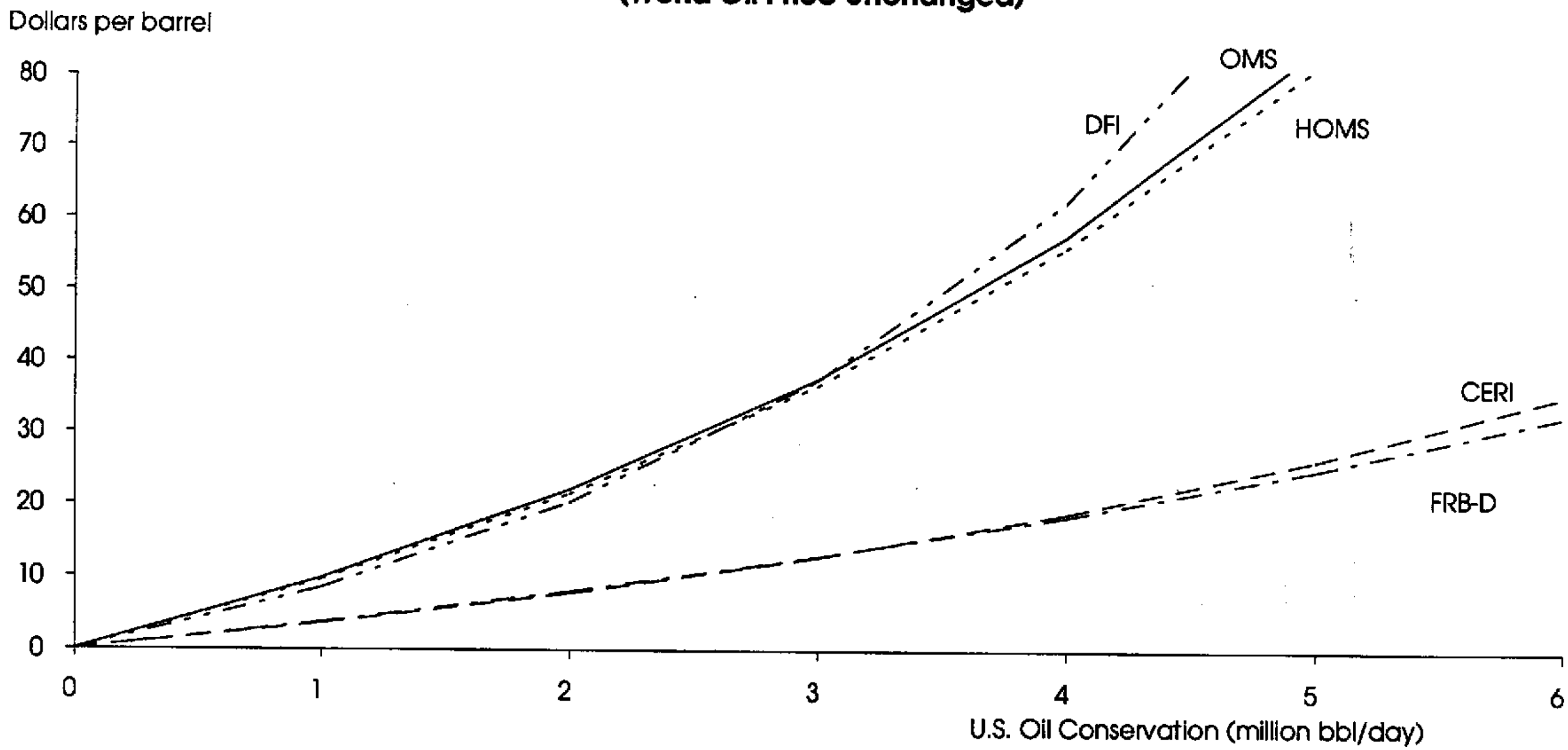
Note: Price elasticities have been inferred by comparing quantities supplied and demanded in the EMF rising and flat price cases.

Table 3
U.S. Oil Consumption, World Oil Price, U.S. Demand Elasticity, and Implied Tax, 2010

	U.S. Oil Consumption (millions of bbl per day)					
	1988	2010	Change	World Price	U.S. Demand Elasticity	Implied U.S. Tax
OMS	17.6	18.9	1.3	53.90	-0.327	13.12
CERI	17.5	20.5	3.0	29.62	-0.441	12.78
HOMS	17.5	19.9	2.4	52.38	-0.308	27.38
FRB-D	17.5	23.5	6.0	44.38	-0.537	32.40
DFI	17.51	19.7	2.2	25.99	-0.185	23.90

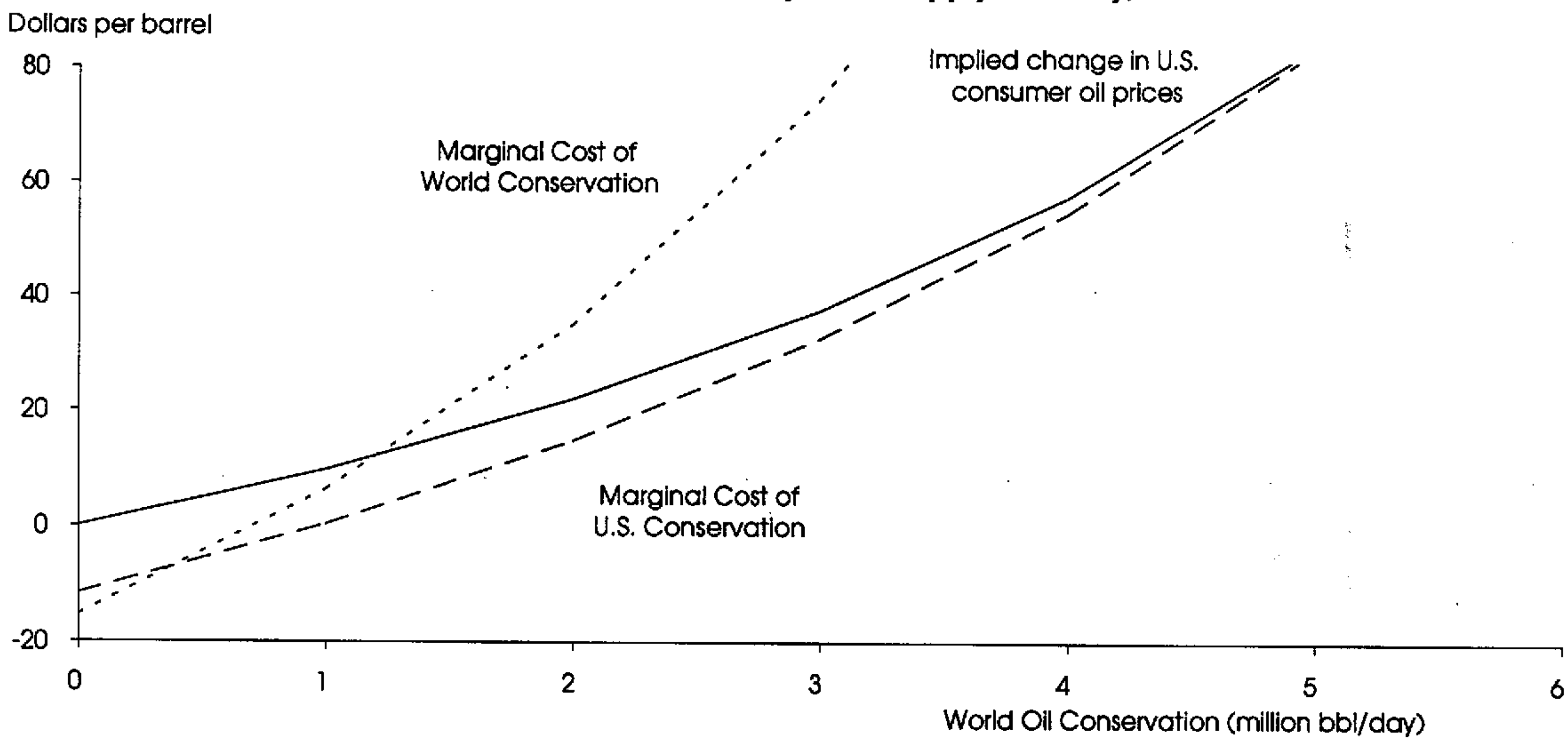
Note: Price and Implied Tax are in 1988$ per barrel.

Figure 1
Estimated Supply of U.S. Oil Conservation
(World Oil Price Unchanged)



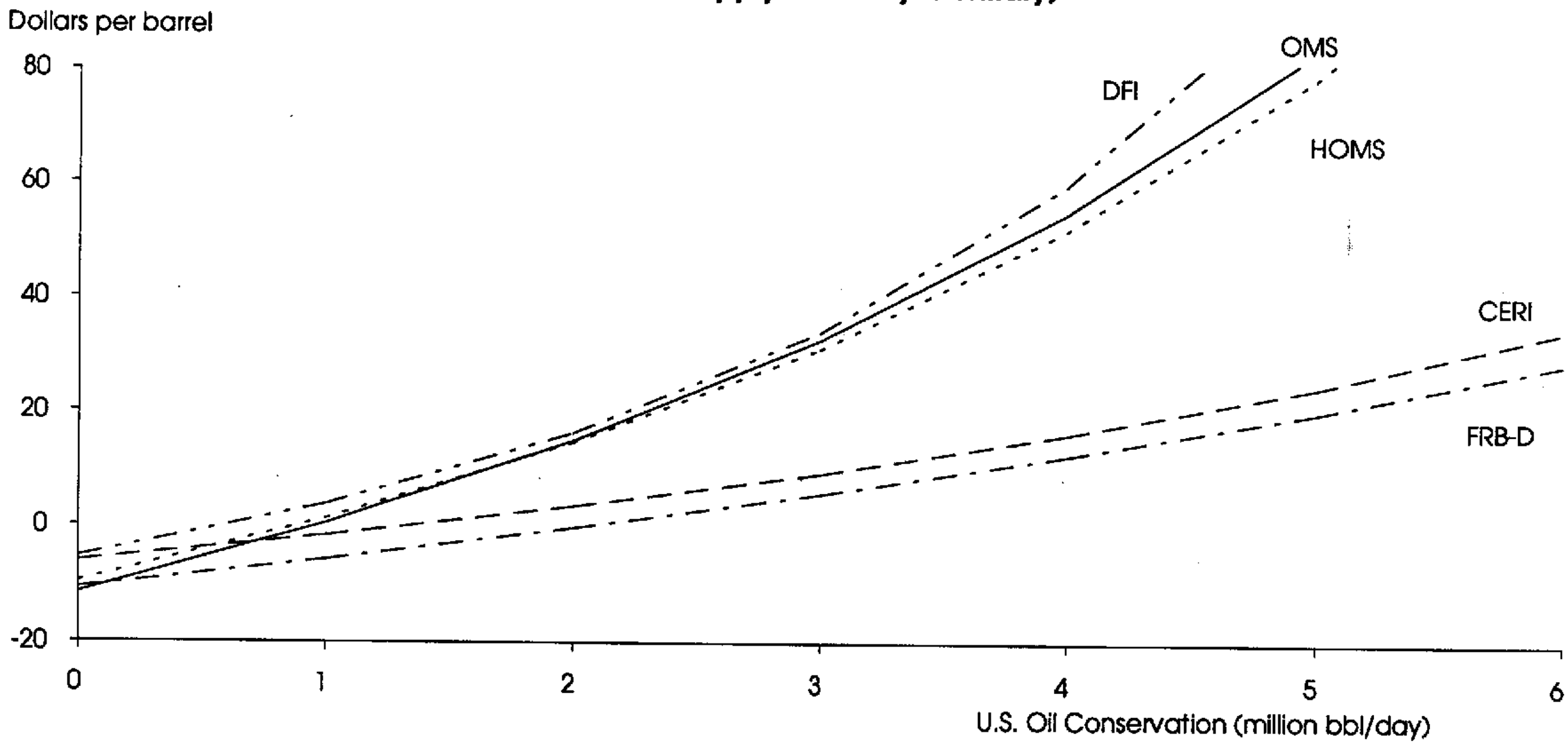
Source: Authors' estimates based upon individual model forecasts for an OPEC cartel scenario and parameters inferred from flat and rising price scenarios.

Figure 2
Estimated Supplies of Oil Conservation
(OMS Model, Unitary OPEC supply elasticity)



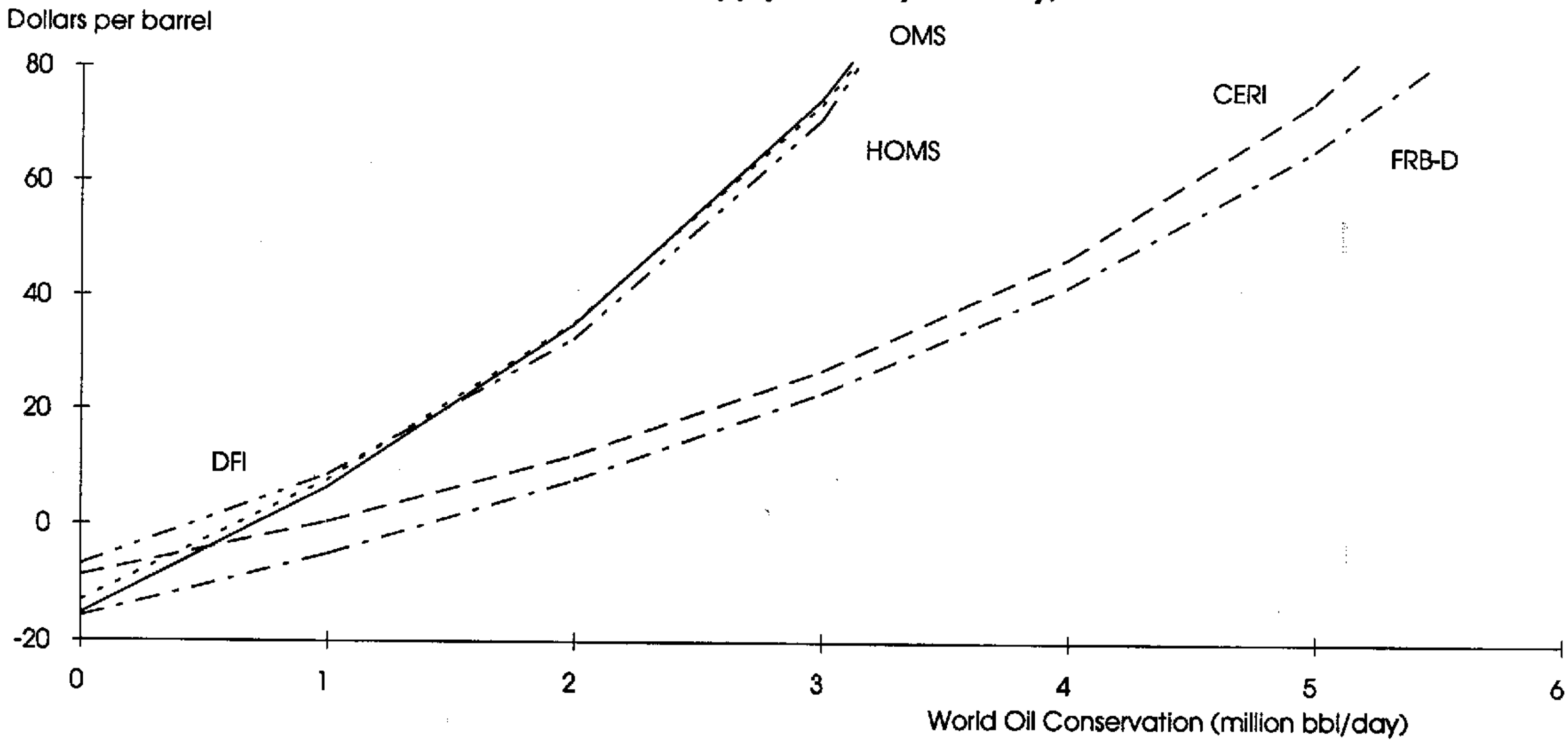
Source: Authors' estimates based upon individual model forecasts for an OPEC cartel scenario and parameters inferred from flat and rising price scenarios.

Figure 3
Estimated Supply of U.S. Oil Conservation
(OPEC supply elasticity is unitary)



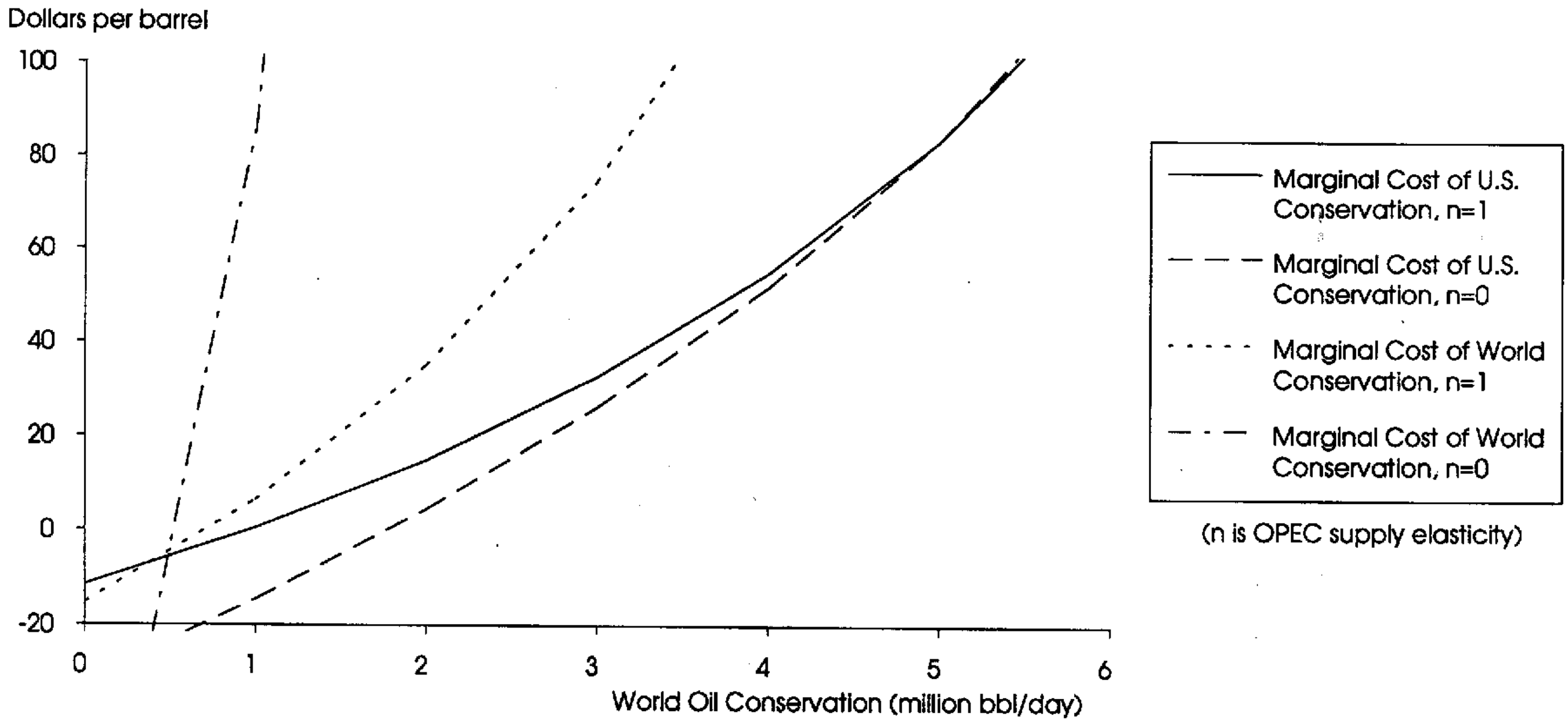
Source: Authors' estimates based upon individual model forecasts for an OPEC cartel scenario and parameters inferred from flat and rising price scenarios.

Figure 4
Estimated Supply of World Oil Conservation
(OPEC supply elasticity is unitary)



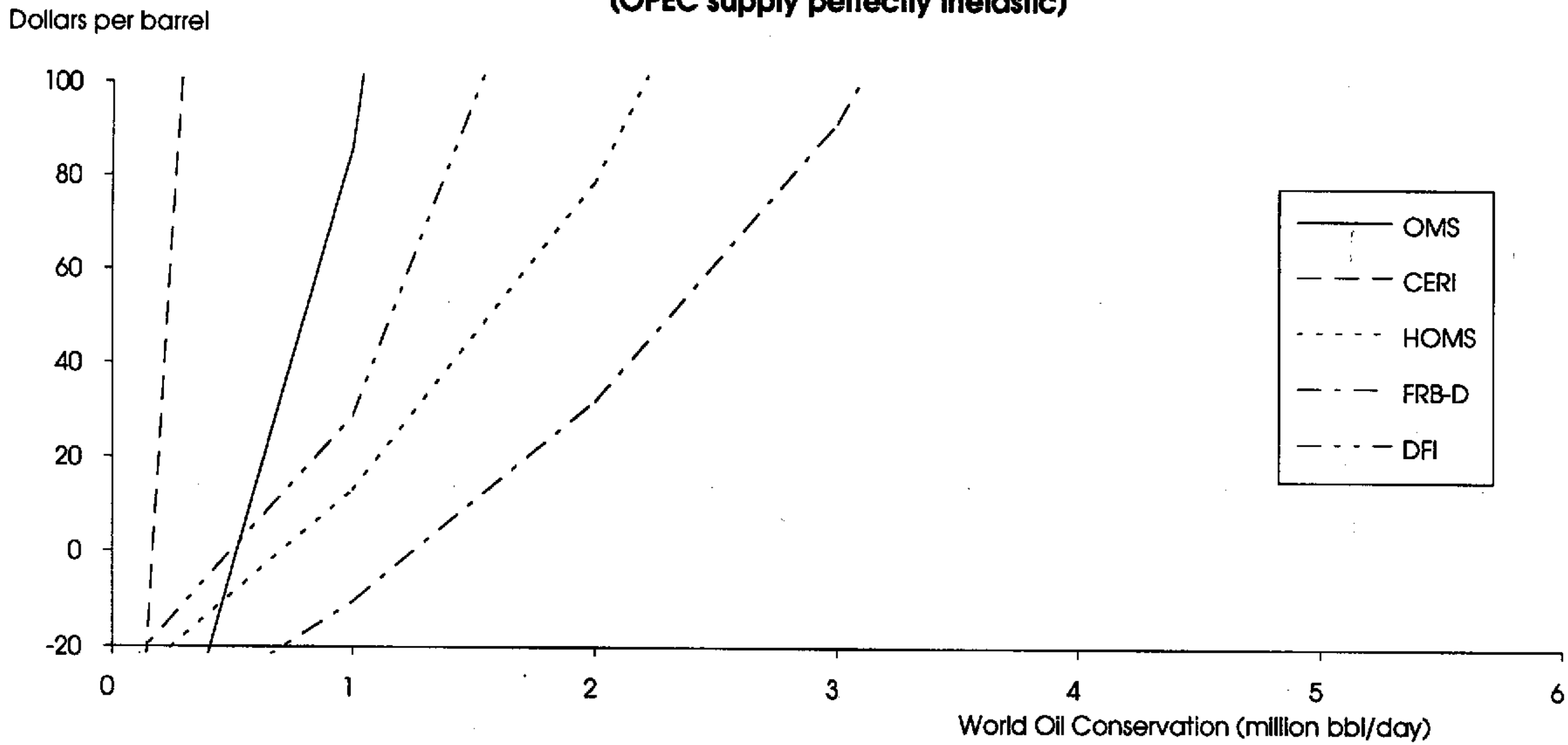
Source: Authors' estimates based upon individual model forecasts for an OPEC cartel scenario and parameters inferred from flat and rising price scenarios.

Figure 5
Estimated Supplies of Oil Conservation
(OMS Model)



Source: Authors' estimates based upon individual model forecasts for an OPEC cartel scenario and parameters inferred from flat and rising price scenarios.

Figure 6
Estimated Supply of World Oil Conservation
(OPEC supply perfectly inelastic)



Source: Authors' estimates based upon individual model forecasts for an OPEC cartel scenario and parameters inferred from flat and rising price scenarios.

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