Some Implications of Increased Cooperation in World Oil Conservation

Stephen P. A. Brown
Senior Economist and Assistant Vice President
Federal Reserve Bank of Dallas

Hillard G. Huntington
Executive Director
Energy Modeling Forum, Stanford University

In this article, we evaluate the extent to which increasing cooperation beyond the Organization for Economic Cooperation and Development (OECD) to limit CO_2 emissions through oil conservation is desirable from a world perspective.

The classic problem of free riding arises when nations act to curtail emissions of carbon dioxide (CO_2) and other potential greenhouse gases. When damages from emissions are global rather than local, countries that do not participate in policies directed at reducing global climate change receive the benefits of other countries' actions without incurring the costs.

Past research and game-theoretic analyses have emphasized the gains from eliciting the cooperation of developing countries in an effort to limit global CO_2 emissions (Bohm 1993; Brown and Huntington 1994b; Eyckmans, Proost, and Schokkaert 1993; Hoel 1991b and 1994; Manne and Rutherford 1994; and Welsch 1995). Broader participation reduces the costs of achieving any given target of emissions reductions among those nations engaged in the coordinated policies. In essence, the cost curve for countries reducing their emissions shifts downward as participation expands to include more countries.

Recent estimates of possible climate-change damages allow us to examine the impact of cooperation on the optimal strategy for reducing CO_2 emissions. Because increased participation lowers the costs of coordinated policies to reduce emissions, it is likely to increase the amount of conservation that the participants would see as cost effective for any given set of estimates of the benefits of reducing emissions and avoiding environmental damage. Whether increased cooperation yields too little or too great a reduction in emissions from a world perspective depends critically upon the level of damage estimates—an empirical issue that at the moment is highly uncertain.

Reduced usage of fossil fuels, through higher efficiency equipment and changing economic structures and lifestyles, is the principal vehicle for CO_2 emissions abatement. Policies that discourage the use of coal, oil, and, to a lesser extent, natural gas contribute to reduced emissions of greenhouse gases and hence lower the potential damages from climate change. Analysis of abatement policies affecting the oil market can seem complex, because actions taken by one country or group of countries are likely to influence oil consumption in other parts of the world through their effect on the world oil price.

In this article, we evaluate the extent to which increasing cooperation beyond the Organization for Economic Cooperation and Development (OECD) to limit CO_2 emissions through oil conservation is desirable from a world perspective. To accomplish this task, we derive cost and benefit curves from recent studies of world oil markets and the nascent literature on the damages arising from changes in the world climate. Our analysis shows that the desirability of extending cooperation in global energy conservation policies is essentially an empirical issue rather than a conceptual one. In addition, the current evidence suggests that over the next two decades, the OECD will have an incentive to reduce its oil consumption by more than is optimal from a world perspective—even when its actions are evaluated on a precautionary approach to reducing CO_2 emissions.[1]

ESTIMATING THE COST OF OIL CONSERVATION

As in several previous studies, we use a welfare-theoretic framework built on top of a simulation model of the world oil market to compute cost curves for oil conservation under alternative assumptions about which countries are participating in the policy. The curves indicate how participants' costs change as the level of conservation increases. The cost curves include the direct resource costs associated with shifting inputs from other sectors into energy conservation activities, the wealth transfers associated with changes in the oil price, and the effects of increased oil consumption in nonparticipating countries.

The World Oil Market

Our analysis divides the world into four regions: the industrialized OECD countries; China, Eastern Europe and the former Soviet Union (C/EE/FSU); OPEC members; and other less developed countries (other LDCs). The simulation model is calibrated to reproduce the oil price, production, and consumption data shown in Table 1. The data in the table represent one of many possible oil-market outlooks for the year 2010. It is based on the midprice case in the U.S. Energy Information Administration's (EIA) *1993 International Energy Outlook*.[2]

The projected oil demand conditions depend on a variety of assumptions about economic growth, prices of competing fuels, and the extent of oil-saving technological change in the absence of price changes. The supply conditions outside of OPEC member countries incorporate assumptions about the resource base, engineering constraints on developing resources, and producer-country taxes and policies. In these projections, OPEC members satisfy the excess demand, but adjust the next period's price in response to market tightness.

Table 1
Baseline World Oil Market Conditions, 2010

	Quantity (10^6 bbl/day)[a]	Price elasticity[b]
Consumption		
OECD	45.6	–.47
C/EE/FSU[c]	15.3	–.15
OPEC	7.1	–.30
Other LDCs	17.9	–.30
Total	85.9	
Production		
OECD	15.4	.43
C/EE/FSU[c]	15.3	.30
OPEC	42.7	*
Other LDCs	12.2	.40
Discrepancy[d]	.3	n.a.
Total	85.9	

[a] Midprice case from EIA's *1993 International Energy Outlook*. Price is $29.30 per barrel (1991$).
[b] Percent change in quantity for each 1 percent change in price. Based on Energy Modeling Forum (1991), except for C/EE/FSU, which is based on the authors' judgment.
[c] China, Eastern Europe, and the former Soviet Union.
[d] Includes net stock withdrawals.
* OPEC responds to hold a constant market share. See text.

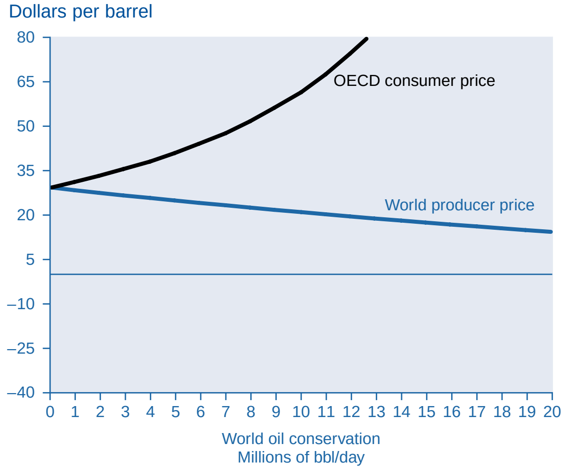
Table 1 also summarizes representative estimates of the long-run supply and demand responses to price for the major regional areas in the analysis. They represent mean estimates derived from an Energy Modeling Forum study (1991), which compared ten major world oil market models, and are similar to those used by the EIA in developing the projections shown in the first column. The estimates in the table were used in construction of the simulation model.[3]

The responses for the C/EE/FSU region are judgmental. Their production and consumption decisions are likely to be influenced greatly by the forces of economic transition, resulting in smaller responses to changes in world oil prices than found in other regions. In fact, if the supply and demand responses for the C/EE/FSU were made comparable to responses for other country groups, the conservation scenarios considered here would push world oil prices sufficiently low that we would estimate these economies would import significant quantities of oil. We consider this result untenable and therefore assume a smaller response to price than for other countries. To the extent that these countries yield a greater response to price, the estimated costs of achieving various world conservation targets without cooperation from these countries would be larger than reported here.

The response of oil producers within OPEC is highly uncertain. To date, formal modeling of OPEC decisions has been far from reliable. OPEC appears to operate like an imperfect cartel during some periods but not during others.[4] The OPEC countries appear to be about

Figure 1

Oil Price Under an OECD Conservation Tax



as uncomfortable with a rapidly increasing market share (as accompanied the relatively low prices in the 1960s) as they are with a rapidly decreasing market share (as occurred in the aftermath of the price hikes of the late 1970s and early 1980s). The analysis presented here assumes that OPEC acts to maintain a constant market share.[5]

The Cost of Conservation

We examine conservation policies by reducing oil consumption in participating countries below the levels shown in Table 1 and allowing the world oil price to adjust to restore a balance between oil supply and demand conditions. Analytically, we use a tax to reduce oil consumption in the participating groups of countries. The tax approach assumes that conservation measures are applied across all end uses.

As shown in Figure 1, an oil conservation tax applied in the OECD acts to depress the world oil price while it boosts the oil price faced by consumers in the OECD. A reduced world oil price has two important effects. It yields transfers from oil exporting countries to oil importing countries that operate to offset some of the costs that OECD incurs by imposing conservation policies. It also stimulates oil consumption in countries not participating in the conservation efforts.

Using values from the simulations, we construct cost curves using Equation B.4 from the box titled "Some Analytics of Oil Conservation." This methodology follows a welfare-theoretic approach previously employed by Brown and Huntington (1994a) and Felder and Rutherford (1993). The resulting cost curves take into account the direct welfare costs of a country's conservation efforts, transfers of wealth from oil exporting to oil importing countries, and the effect that lower world oil prices will have in stimulating oil consumption in nonparticipating countries. The cost curves also take into account the economic cost of OPEC cartelization.[6]

Construction of the cost curves depends critically on the assumptions used. In particular, assumptions that world oil production or OECD oil consumption is more responsive to price would tend to work against the conclusions presented below. Nonetheless, sensitivity analysis using a range of plausible assumptions about the outlook for 2010 and the responsiveness of consumption and production to changes in price yielded overall conclusions similar to those reported below.

To maintain the emphasis on the substantial difference in market response to the inclusion of additional countries, our analysis abstracts from a number of important considerations that would be incorporated in a more refined analysis. These considerations include alternative policies for distributing conservation goals across countries (Whalley and Wigle 1991, and Brown and Huntington 1994b); the design of taxes and redistributive mechanisms (Hoel 1991b); and an explicit accounting for different types of goods (Felder and Rutherford 1993, and Pezzey 1992). We also abstract from the effects of preexisting energy taxes and other taxes. Preexisting taxes could be reduced to offset some of the costs of a new conservation policy (Hoel 1991b) or be left in place, which would affect the estimated costs of imposing a new conservation policy (Newberry 1992).

Similarly, for some LDCs, removing subsidies to the energy sector could reduce energy use and improve economic efficiency, which contrasts to our assumption that conservation is achieved through taxes that impose costs on the economy. Alternatively, some LDCs may have supply-constrained energy consumption, and the costs of their conservation efforts would be higher than we estimate here.

DIFFERING INCENTIVES FOR OIL CONSERVATION

In Figure 2, the cost curve labeled "World" shows how much each additional barrel of world oil conservation costs all nations collectively. The construction of this curve assumes that conservation is first adopted wherever it is cheapest. The curve incorporates the efficiency losses resulting from the OPEC cartel restricting output below free market levels, as well as the direct costs associated with shifting resources

Some Analytics of Oil Conservation

We use a welfare-theoretic approach to derive formulas for the marginal cost of oil conservation. For any country (or country grouping), social welfare in the oil market is the sum of its consumer and producer surpluses:

$$W_i = \int_0^{Q_{Di}} P_{Di}(Q)dQ - P_W Q_{Di} + P_W Q_{Si} - \int_0^{Q_{Si}} P_{Si}(Q)dQ. \tag{B.1}$$

In the above equation, W_i denotes the welfare country i obtains from the oil market, Q_{Di} the quantity of oil demanded in country i, P_{Di} country i's demand price (the market's marginal valuation of consumption excluding externalities) at each quantity (Q), P_W the world price of oil, Q_{Si} the quantity of oil production in country i, and P_{Si} country i's oil supply price (marginal cost of its oil production excluding externalities) at each quantity (Q).

THE COST OF GROSS CONSERVATION

If the marginal cost of conservation is defined as the welfare lost in country i's oil market by reducing its oil consumption on the margin, the negative of the first derivative of W with respect to Q_D yields the marginal cost of conservation:

$$MC_i = P_{Di} - P_W + \frac{\partial P_W}{\partial Q_{Ci}} Q_{Mi}. \tag{B.2}$$

In the above equation, MC_i denotes the marginal cost of conservation, Q_{Ci} the quantity of conservation (where $\partial Q_{Ci} = -\partial Q_{Di}$), and Q_{Mi} the quantity of net oil imports for country i. As Equation B.2 shows, the gross marginal cost of oil conservation is the difference between the domestic and world prices of oil ($P_{Di} - P_W$) minus the transfer obtained by reducing the price of imported oil ($\partial P_W / \partial Q_{Ci}$ is negative).

THE COST OF NET CONSERVATION

The net effect of conservation actions taken by a country or group of countries is the quantity of its conservation minus the induced change in oil consumption in the rest of the world. The change in oil consumption in nonparticipating countries depends on how their consumption is affected by a change in the world oil price and how the conservation actions in the participating countries affect the world oil price. Therefore, the relationship between a change in participant conservation and the net change in world oil conservation can be expressed as

$$\frac{\partial Q_{CW}}{\partial Q_{Ci}} = 1 - \frac{\partial Q_{DX}}{\partial P_W} \cdot \frac{\partial P_W}{\partial Q_{Ci}}. \tag{B.3}$$

In the above equation, Q_{CW} denotes world oil conservation and Q_{DX} the quantity of oil consumption by nonparticipating countries.

Following Felder and Rutherford (1993) and Brown and Huntington (1994a), Equations B.2 and B.3 can be combined to express the marginal cost of net world oil conservation for country (or country grouping) i. Specifically, multiplying the marginal cost of the gross conservation in country i by the net change in world conservation resulting from country i's conservation yields

$$MC_{Wi} = \left(P_D - P_W + \frac{\partial P_W}{\partial Q_{Ci}} Q_{Mi} \right) \cdot \left(1 - \frac{\partial Q_{DX}}{\partial P_W} \cdot \frac{\partial P_W}{\partial Q_{Ci}} \right)^{-1}. \tag{B.4}$$

In the above equation, MC_{Wi} denotes the marginal cost net world oil conservation to country i.

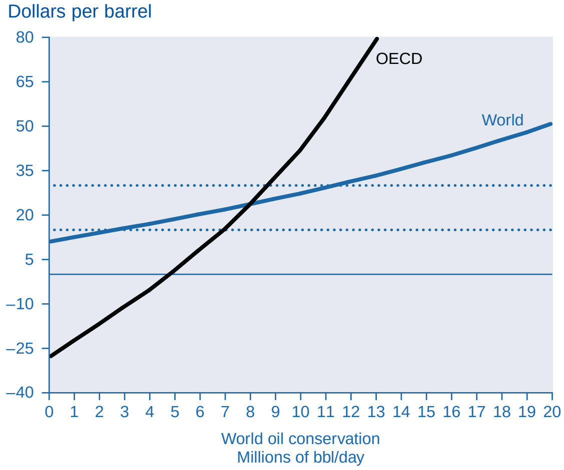
As Equation B.4 shows, the effects that cooperative oil conservation has on the cost of oil imports and on nonparticipant oil consumption are related through the world oil price. As cooperative conservation lowers the world oil price, it reduces the cost of country i's oil imports and brings about an increase in nonparticipant oil consumption. If conservation has no effect on the world oil price, however, both the cost of oil imports and nonparticipant oil consumption will remain unchanged.

toward oil conservation. The world curve does not incorporate any transfers, because any transfers the oil-importing nations obtain through the lower oil prices induced by conservation are exactly offset by transfers away from oil producers. The curve starts above zero to incorporate the economic efficiency losses associated with OPEC restricting its output.

The cost curve labeled "OECD" shows how much each additional barrel of world conservation costs the OECD countries if only they act to conserve oil. As such, this curve is constructed to reflect the increase in non-OECD consumption that will result from lower world oil prices induced by unilateral OECD action to conserve oil. At lower levels of oil conservation, the cost to OECD is negative because lower prices fostered by its conservation efforts transfer wealth from oil exporting nations to the OECD. At about 5 million barrels per day of world oil conservation, the marginal cost reaches zero and is positive thereafter.

Although the OECD cost curve lies below the world cost curve at lower levels of conservation, it rises more sharply with conservation for two reasons. The wealth transfer to the

Figure 2
Marginal Cost of World Oil Conservation



OECD becomes smaller as greater conservation reduces imports. In addition, the direct costs increase more sharply for the OECD curve than for the world curve because conservation projects can be selected from only OECD countries rather than worldwide. As a consequence, for conservation levels of about 8 million barrels per day and higher, the OECD cost curve lies above the world cost curve.

The OECD and world cost curves illustrate that the oil-importing OECD countries, acting as a group, have an incentive to select a level of oil conservation that is not optimal from a world perspective. Whether unilateral OECD action that is unmatched by other countries leads to too much or too little emissions reduction, however, cannot be determined by the cost information alone. This issue can be resolved only by knowing the estimated benefits of (or damages avoided by) oil conservation.

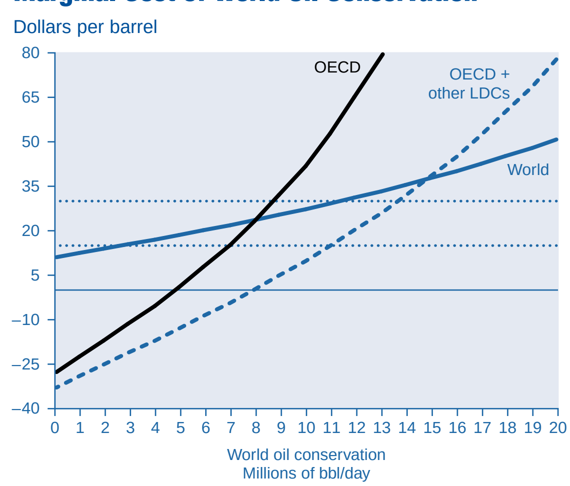
Previous analysis suggests a flat marginal damage curve. Summarizing the previous literature, Peck and Teisberg (1992) explain that marginal damage costs are essentially unaffected by the emissions levels in any given decade. This conclusion rests on the finding that temperature change depends upon gas concentration, which is not greatly affected by the emissions levels in any given decade. We adopt this characterization by assuming horizontal damage curves that depict a constant level of benefits for any level of oil conservation.

Figure 2 also illustrates the situation for two hypothetical marginal benefit curves—one at $15 per barrel and one at $30 per barrel. When the marginal benefits of oil conservation are below about $24 per barrel, the OECD has an incentive to pursue more conservation than is optimal from the world perspective, as is illustrated along the $15 marginal benefit curve. In this range, the $15 curve intersects the OECD marginal cost curve to the right of its intersection with the world marginal cost curve. Unilateral OECD action could result in too much oil conservation from a world perspective.

Moreover, at benefit levels below about $24 per barrel, cooperation from the group of oil-importing countries previously identified as “other LDCs” will exacerbate the discrepancy between what is optimal from a world perspective and what participants would have the incentive to choose. As shown in Figure 3, cooperation between the OECD and the other LDCs shifts the participant’s cost curve for world oil conservation from the one labeled “OECD” to the one labeled “OECD + other LDCs.”[7] At benefit levels below about $24 per barrel, the equilibrium amount of oil conservation selected by the participating countries will be even greater—producing even more abatement of CO_2 emissions than would be optimal from a world perspective.

When the benefits are above about $24 per barrel, the OECD has an incentive to pursue less oil conservation than is optimal from a world perspective, as is illustrated along the $30 benefit curve. Under these conditions, the marginal benefit line intersects the OECD’s marginal cost curve to the left of its intersection with the world’s marginal cost curve. Unilateral OECD action could result in too little oil conservation. Some limited cooperation from developing countries could help ameliorate this problem by shifting the cost curve outward, but full cooperation from all developing countries would shift the curve far to the right, and the participants

Figure 3
Marginal Cost of World Oil Conservation



would seek more conservation than would be optimal from a world perspective unless the benefits of oil conservation were more than about $37 per barrel.

THE BENEFITS OF REDUCING CO_2 EMISSIONS

Damage estimates for CO_2 are in their infancy. Economic evaluations attempt to monetize both market and nonmarket impacts of greenhouse gas concentrations, and the resulting estimates vary considerably. Key uncertainties include the dynamics of the carbon cycle governing the effect of emissions on concentrations, the effect of concentrations on temperature change, and the consequences of temperature change on market and nonmarket damages. Differences in discount rates for evaluating potential impacts over horizons of 100 years or more account for a significant part of the differences in damage estimates. Finally, estimates vary depending upon the decade for which they are computed; estimated damages increase for later decades.

Table 2 reports estimates from several prominent studies providing monetized estimates of the marginal damages arising from CO_2 emissions in the decade 2001–10. Researchers usually report their estimates in U.S. dollars per ton carbon (tC), as shown in the first column. We convert these estimates to U.S. dollars per barrel of oil in the second column. In oil-equivalent terms, the mean damage estimates range from about $1 to $3 per barrel across different studies. Emphasizing the dramatic uncertainty in these estimates, the Fankhauser study (1994) provides a range from less than $1 per barrel to almost $6.50 per barrel, depending upon key parameter assumptions.

Hope and Maul (1996) use two economic-environmental assessment models—Intera and PAGE—to provide similar estimates to the range shown by Fankhauser without specifying the decade for their analysis. Using the PAGE model and what they identify as "the inner uncertainty range" of the Intera model, they find that damages from marginal CO_2 emissions range from $12 to $45 tC for the PAGE model and from $3 to $50 tC for the Intera model. The outer uncertainty range found with the Intera model—which should be accorded a very low probability because it combines many events, each of which is accorded only a 5 percent probability by experts—is $0 to $270 tC. Hope and Maul suggest that policymakers who take the threat of global warming seriously should use a precautionary principle and penalize sources of CO_2 with the high estimates found with the PAGE model or the inner uncertainty range of the Intera model, which would amount to $5.63 (PAGE) or $6.50 (Intera) per barrel of oil.

Table 2
Estimated Damages from CO_2 Emissions for 2001–10

Study	$/tC*	$/bbl†
Nordhaus (1991a,b)	7.3	.89
Nordhaus (1992)	6.8	.85
Peck and Teisberg (1993a,b)	12–14	1.46–1.71
Fankhauser (1994)		
Mean	22.8	2.78
5th percentile	7.4	.90
95th percentile	52.9	6.45

* Adapted from Fankhauser (1994).
† Authors' estimates based upon a conversion factor of $8/tC equals $1/bbl.

Even for those taking a precautionary approach to reducing CO_2 emissions, the available damage estimates fall well below $24 per barrel of oil. Combined with the cost curves of oil conservation presented above, these damage estimates suggest that unilateral action by the OECD will lead to excessive oil conservation and that adding oil-importing LDCs would exacerbate the problem.[8] At $0 to $33.75 per barrel, the outer uncertainty range found with the Intera model emphasizes the possibility (but low probability) of higher damage estimates and thus indicates the need for further study of the benefits of reducing CO_2 emissions.

CONCLUSION: THE COSTS OF EXTENDING COOPERATION

The preliminary evidence suggests that during the next two decades, OECD action to conserve oil to reduce CO_2 emissions is likely to result in more oil conservation than is optimal from a world perspective. For the OECD, cooperative oil conservation would reduce world oil prices and yield wealth transfers from oil-exporting countries to the oil-importing countries undertaking oil conservation policies. These wealth transfers are sizable and positive for the OECD nations, which collectively are heavily dependent upon oil imports. For relatively small oil-conservation strategies, as are suggested by the nascent literature on the damages from CO_2 emissions, these wealth transfers will dominate the direct costs of conservation and lead to excessive conservation from a world perspective. This result contrasts sharply with the standard perspective that unilateral OECD action is likely to lead to insufficient oil conservation.

Under these conditions, extending cooperation to the oil-importing developing countries will exacerbate the problem. Participants' costs will be reduced, leading to even larger discrepancies between emissions levels chosen by the self-interested participants and those seen as optimal from a world perspective.

These seemingly anomalous results are obtained precisely because the nations most likely to cooperate in conserving oil are likely to exclude the oil-exporting nations and thus ignore the costs that conservation imposes on the latter group. From a world perspective, transfers to energy-importing countries are exactly offset by transfers from net-energy-exporting countries. From the more limited perspective of the oil-importing countries participating in a coordinated energy conservation policy, these wealth transfers are not offset but operate as an incentive to conserve energy and reduce emissions. Because CO_2 damages are currently unpriced in the market, these additional incentives to conserve oil may be a good thing. Nonetheless, the current estimates of the costs of CO_2 damages are not high enough to justify concern that OECD countries do not have sufficient incentive to act unilaterally to reduce emissions.

These preliminary conclusions depend very critically upon the size of estimated damages from CO_2 emissions. If future estimates of damages should prove to be higher by a factor of 5—a possibility suggested by the outer uncertainty range of the Intera estimates—the analysis could be reversed. In such a case, our cost estimates would suggest that OECD countries would not have sufficient incentives to conserve oil, and eliciting cooperation from oil-importing LDCs could improve the outcome from a world perspective. In this respect, one implication of our analysis is that the desirability of extending cooperation in global energy conservation policies is essentially an empirical issue rather than a conceptual one.

In addition, our conclusions pertain only to CO_2 emissions with a global impact. The local and regional benefits from reducing energy use (the damages avoided from local pollution) may well be more important than the benefits derived from global strategies to reduce worldwide environmental threats (see Hall 1990, 1992).

NOTES

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1 The current analysis is limited to oil conservation and does not consider interfuel substitution. Substantial interfuel substitution could alter the analysis.

2 Although the EIA's 1993 outlook is dated, particularly in the $29.30 per barrel price forecasted for 2010, sensitivity analysis using a range of plausible assumptions about the outlook for 2010 yielded overall conclusions similar to the results reported below.

3 The estimates are taken from Huntington (1992, 1993).

4 Griffin (1985) and Dahl and Yücel (1991) provide empirical estimates of OPEC behavior that are broadly consistent with this view.

5 A sensitivity analysis using alternative assumptions that allow modest adjustments in OPEC's market share confirm our general findings. In the extreme, OPEC could maintain a given price and accept a substantial loss in market share in the face of reduced demand. Under these conditions, the OECD would not obtain wealth gains from lower oil prices with which to offset the direct costs of unilateral oil conservation policies.

6 To obtain the full cost of world conservation to the world in the presence of OPEC cartelization, we add marginal loss in producer surplus that results from OPEC restricting its output. That is the share of world oil coming from OPEC multiplied by the difference between the world price of oil and OPEC's full production costs including user costs.

7 The cost curve is constructed to reflect the gains in nonparticipant oil consumption that will result from lower world oil prices induced by the cooperative action to conserve oil. As such, it reflects participant costs of world oil conservation.

8 Sensitivity testing, through the use of parameters to replicate the behavior of several of the prominent energy models that participated in a recent Energy Modeling Forum study (1991), yielded qualitatively similar results.

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