LDC COOPERATION IN WORLD OIL CONSERVATION*

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*The views expressed in this article are those of the authors and should not be attributed to the Federal Reserve Bank of Dallas or Stanford University. The authors would like to acknowledge Helmut Frank and two anonymous referees for their helpful comments.

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LDC Cooperation in World Oil Conservation*

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Environmental concerns are leading many industrialized countries to consider measures which would reduce their consumption of oil, as well as other energy sources. The reluctance of the developing countries to join in these conservation efforts will reduce the policy's effectiveness. This paper explores the conditions under which the exclusion of important oil consumers (like developing countries) would weaken unilateral OECD actions to conserve oil.

Oil conservation undertaken unilaterally by the OECD can lead to lower world oil prices, and offsetting increases in oil consumption elsewhere. We provide estimates of these offsetting effects and how they influence the costs of participating in the policy. We also examine the effect of adding and excluding countries to a coordinated policy of oil conservation.

INTRODUCTION

At the United Nations Conference on Environment and Development in June 1992, most U.N. member countries agreed to report on their plans for stabilizing greenhouse gas emissions thought to be contributors to global climate change. While the treaty fell short of committing the nations to specific emission reductions and timetables, it is clear that efforts to limit the use of fossil fuels and their associated greenhouse gas emissions are only just beginning. At the

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meeting in Rio de Janeiro, the European Community proposed a carbon tax for developed countries to achieve emissions reductions, although unilateral efforts since then to impose such taxes in individual countries have been largely unsuccessful to date. However, a reluctant participant in that 1992 conference, the United States, has recently reversed its policy on targets with the Clinton Administration's proposal for voluntary energy conservation measures to mitigate emissions.

Over the next decade or two, energy conservation programs will be featured prominently in efforts to limit carbon dioxide emissions.[1] Substitution toward less carbon-intensive energy sources is a longer-term strategy. Moreover, conservation efforts are likely to be focused on the developed countries, because many less developed countries are extremely reluctant to participate in coordinated strategies, without significant economic incentives to offset expected costs of limiting emissions within their borders. Imposing comparable limits on the developing world is considered too severe, given the expected strong growth in fossil fuel use in many developing countries due to population growth, industrialization, urbanization, and the shift toward commercialized energy sources.[2]

In such a policy environment, many industrialized countries will be considering measures to reduce their consumption of oil as well as other fossil fuels.[3] They may implement such measures, even though other nations, particularly from the developing world, may not join them in such actions. This paper explores the conditions under which exclusion of important oil consumers (like the developing countries) would weaken unilateral OECD actions to conserve oil, and under what conditions LDCs might find it less costly to join.

OIL CONSERVATION POLICIES

The impact of climate change policy on oil markets is uncertain, given that oil use could expand at the expense of coal use but contract in response to shifts toward natural gas, carbon-free renewables, and energy efficiency. The

1. A growing literature has developed on the merits and limitations of mandated conservation, e.g., see Brown and Phillips (1991), Chandler et al. (1988), and National Academy of Sciences (1991).

2. This fact is recognized in many economic evaluations of climate change policy, which routinely assume that countries outside the OECD will be subjected to less restrictive controls on fossil fuel use and emissions. A common assumption is that the developing world can increase its emissions to 50% above current levels, while the industrialized countries are constraining their future emissions to current levels or below. See Manne and Richels (1991) and the Energy Modeling Forum projections discussed in Gaskins and Weyant (1993) and Weyant (1993).

3. Our analysis does not incorporate the environmental benefits of reducing energy use, but see Hall (1990, 1992).

replacement of oil by natural gas and the shift toward conservation are expected to be particularly strong over the next few decades—the time frame of interest in this paper. Moreover, these developments may be reinforced by other considerations—urban traffic congestion and deteriorating air quality—that contribute to a political commitment to reduce the growth in oil consumption.

Nations could adopt a range of economic incentives and regulatory standards to reduce energy and oil use. There have been proposals for carbon taxes and tradeable emissions permits that would provide economic incentives to reduce fossil fuel use. These policies make explicit the costs of reducing fossil fuel consumption by increasing energy costs. However, policymakers may rely on the more familiar end-use standards on automobiles and other energy-using equipment, or on programs to directly influence behavior such as traffic control and parking restrictions. These command-and-control mechanisms often obscure but do not eliminate the costs associated with conservation.

Although philosophically disparate, both market incentives and nonmarket restrictions impose costs on would-be energy consumers. Hence, both can be considered in terms of how much conservation is achieved at different cost levels. We make the simplifying assumption that when regulatory standards are adopted, policymakers correctly identify the least-cost options and implement them before more costly ones. To the extent that this does not happen, our cost estimates will tend to understate the costs of conservation.

A REPRESENTATIVE MARKET OUTLOOK

Table 1 shows one of many possible future oil market outlooks for the year 2010. It is based upon the oil price, production, and consumption levels projected for the mid-price case in the Energy Information Administration's 1993 International Energy Outlook. The table reports supply and demand conditions for the industrialized OECD countries, OPEC members, the other less developed countries, and the former Soviet Union, Eastern European and China (SU/EE) planned economies. The projected oil demand conditions depend on assumptions about economic growth, prices of competing fuels, and the extent of oil-saving technological progress in the absence of price changes. The supply conditions outside OPEC member countries incorporate assumptions about the resource base, engineering constraints on developing resources, and producer-country taxes and policies. OPEC members satisfy the excess demand, but adjust the next period's price in response to market tightness.

The second column of the table summarizes representative estimates of the 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) comparing ten major world oil models and are quite similar to those used by the EIA in developing the projections shown in the first column.[4] The LDC demand response is consistent with Dahl's survey (1992) of the numerous published econometric studies of oil demand in different countries. These response parameters form the basis for our cost estimates for achieving different levels of world oil conservation under alternative assumptions about which countries are included and excluded from the policy.

Response estimates for the former SU/EE region are judgmental. Their production and consumption decisions are likely to be influenced significantly by the forces of economic transition, resulting in smaller responses to changes in world oil price levels. Indeed, if their supply and demand responses were made comparable to the other country groups' responses, many of the conservation scenarios considered here would push world oil prices sufficiently lower to cause these economies to import significant quantities of oil. We consider this result untenable, and have therefore assumed smaller responses to price than in other countries. To the extent that these countries possess greater responses to price, the estimated costs of achieving different world oil conservation targets will 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. The cartel appears to operate like an imperfect cartel during some times, but not others.[5] These countries appear to be as uncomfortable with a rapidly increasing market share (as happened with the relatively low oil prices of the 1960s) as with its dramatically shrinking share in the aftermath of the price shocks of the 1970s and 1980s. The analysis assumes two cases: one in which OPEC maintains a constant price, and one in which it maintains a constant market share.

To emphasize the substantial difference in incentives under various program designs, our analysis abstracts from a number of important considerations that would be incorporated in a more refined analysis. These conditions include, explicitly accounting for different types of goods (Felder and Rutherford, 1993; Pezzey, 1992), the design of taxes and redistributive mechanisms (Hoel, 1991b), and the effect of pre-existing energy and other taxes, which could be reduced to offset the negative impacts of the new conservation policy (Hoel, 1991b) or which would affect the estimated costs of imposing new taxes (Newbery, 1992). Similarly, removing subsidies in the energy sector in LDCs could reduce energy use while improving economic efficiency, in contrast to the taxes considered here.

4. The estimates are derived in Huntington (1992, 1993).

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

UNILATERAL OECD AND COORDINATED WORLD POLICIES

Exempting certain countries increases the costs of meeting a given world consumption target for those countries participating in the conservation strategy. Furthermore, these costs can increase when conservation induces lower oil prices and more oil consumption elsewhere. We provide here estimates of the costs of unilateral conservation policies limited to the OECD countries, and compare these costs with a coordinated policy encompassing both industrialized and less developed countries. These estimates are derived by considering how world oil market balances are affected by alternative policies.

Table 1. Baseline World Oil Market Conditions, 2010

	Quantity (Mbd)[a]	Price Elasticity[b]
Consumption		
OECD	45.6	-0.47
non-OPEC LDCs	17.9	-0.30
former SU/EE	15.3	-0.15
OPEC	7.1	-0.30
Total	85.9	
Production		
OECD	15.4	0.43
non-OPEC LDCs	12.2	0.40
former SU/EE	15.3	0.30
OPEC	42.7	*
discrepancy[c]	0.3	n.a.
Total	85.9	

a Base-Priced Case from EIA's 1993 International Energy Outlook. Price in 2010 is $29.30 per barrel (1991$).

b Percent change in quantity for each one percent change in price. Based upon Energy Modeling Forum (1991), except for former SU/EE elasticities which are based upon the authors' judgement.

c Includes net stock withdrawals.

* OPEC response varies depending upon case. See text.

Alternative policy cases were examined by reducing oil consumption in participating countries from the 2010 levels shown in Table 1, and allowing the world oil price to adjust to restore a balance between oil supply and demand conditions. Analytically, a tax was used to reduce oil consumption. The tax approach assumes that conservation measures are applied across all end uses.

Although taxes differ from marginal costs, a larger tax represents a more costly policy on the margin, whether it be a higher oil price or more stringent end-use standards.

Table 2 contains results for different levels and types of cooperation between two sets of countries—the OECD and LDC nations—ranging from unilateral OECD action to complete coordination of conservation policies among market economies (excluding OPEC members). In the unilateral OECD strategy, the total world 1991 level is targeted through oil demand reductions in the industrialized countries only.[6] Two different joint policies are considered. In the first, both OECD and LDC countries separately seek to stabilize their respective 2010 levels of oil consumption at 1991 levels. In the second, both groups apply a uniform policy to meet a joint target equal to total 1991 oil use in the two sets of countries.

The inferred taxes for all policies are substantial, indicating that any environmental and other benefits of oil consumption stabilization need to be large to justify such a policy. Their magnitude suggests that governments would use end-use controls that made these costs less visible rather than explicit taxes. If future oil supply and demand respond more to price than has been observed from past historical behavior, these costs would be reduced. The precise levels of the required taxes for stabilization are of little interest here, due to the uncertainty of the parameters used to represent the responses to price. The relative magnitudes between cases, however, is quite relevant to the discussion of the effects of policy coordination.

A unilateral OECD policy requires a tax significantly greater than the baseline price (in the absence of the policy) in order to maintain world consumption (outside OPEC and the former SU/EE) at its 1991 level. In this case, all of the conservation is concentrated in the industrialized countries, forsaking some less expensive opportunities in the developing ones.

When each group seeks to meet separate targets equal to their respective 1991 consumption levels, the policy is relatively modest for the OECD but very expensive for the LDCs. The high cost for the latter primarily occurs because an LDC policy of no growth in oil consumption requires substantially greater reductions in their projected oil consumption than is required for the OECD countries. A secondary contributing factor is that these economies experience a more costly adjustment for each barrel reduced (given their smaller price elasticity). With a tax more than six times as great as the OECD tax, the reluctance of developing countries to participate in such a plan is not at all surprising.

6. The analysis targets the same total world consumption level in each policy in order to allow direct comparison of costs for policies producing comparable benefits.

Table 2. Required Taxes for Stabilizing World Oil Consumption at 1991 Levels[a] (1991$/Barrel)

	World Oil Price	Required Tax: OECD	Required Tax: LDC
Constant World Oil Price	29.30	34.20	0
Unilateral OECD Policy	29.30	13.90	95.10
Separate Targets	29.30	23.40	23.40
Uniform Policy/Joint Target			
Changing World Oil Price	18.20	73.00	0
Unilateral OECD Policy	18.20	28.00	150.00
Separate Targets	18.20	40.60	40.60
Uniform Policy/Joint Target			

[a] The 1991 targets require a reduction in world oil consumption of 13.9 million barrels per day to offset the growth in OECD and LDC consumption, as projected in the EIA baseline.

The burden on the LDCs can be substantially reduced by specifying a joint target equal to the sum of the two group's consumption in 1991. This uniform policy imposes equal taxes on the two groups. The LDC tax falls from $95 in the previous case of separate targets to $23 in this case, while the OECD tax rises from $14 to $23.

The same qualitative results hold when the conservation policy is allowed to reduce the world oil price received by producers. The lower part of Table 2 shows the results when OPEC allows the world price to fall in order to maintain its market share at its level without the conservation policy. Taxes must increase in all cases if the same consumption targets are to be met. Otherwise, the prices paid by consumers (equal to the world oil price plus the tax) will be too low. The absolute tax ($/barrel) changes the most in the unilateral OECD policy case,[7] because the lower world oil price stimulates demand in the exempt regions outside the OECD beyond the baseline levels shown in Table 1. On average, a 10 million b/d reduction in OECD oil consumption nets only about a 7.4 million b/d reduction in world oil consumption, given the price responses indicated in Table 1. The missing 2.6 million b/d "leaks" from the conservation policy in the form of higher oil use in the less developed countries (including OPEC) and former Soviet Union, Eastern Europe and China. This leakage

7. Hoel (1991a) 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 OECD conservation affects foreign oil consumption only through world oil prices precludes such an outcome.

reduces to 1.4 million b/d when the LDCs cooperate in decreasing the combined OECD and LDC consumption by 10 million b/d. Our OECD leakage factor is comparable to Felder and Rutherford's (1993) average global leakage estimate when simulating a unilateral OECD cut of 2% per annum in carbon dioxide emissions.[8]

The possibility of oil price reductions resulting from conservation strategies introduces a new component into the cost estimates not shown in Table 2. Lower oil prices will transfer wealth from foreign producers and consumers to domestic consumers in countries that are not totally self-sufficient in oil. These transfers augment an importing country's wealth, and hence operate counter to the costs imposed by the tax in participating countries, and are provided freely to oil-importing nonparticipants. These impacts are summarized in Table 3, which shows that the LDCs gain from unilateral OECD action, but lose significantly from joining a strategy with separate targets for OECD and LDCs.[9] A uniform policy of equal tax rates for both sets of countries not only reduces the world costs but also comes closest to equalizing the burden across the OECD and developing nations.

In meeting separate targets, the OECD gains for two reasons: (1) more opportunities for low-cost conservation (more price-elastic demands), and (2) greater reliance upon oil imports (resulting in more wealth gains from lower oil prices). These gains diminish, but remain positive, when uniform policies (equivalent taxes) are applied to both LDC and OECD countries. Thus, OECD gains from joint coordination with the less developed nations. Only by acting unilaterally does the OECD lose from the conservation policy.

In contrast, the LDCs as a group lose from joint coordination, with the largest costs occurring when both groups try to reach separate targets. This group of countries experiences a net gain from unilateral OECD action. Their wealth transfer gains are considerably smaller than those for the developed countries in all policy cases, reflecting the greater oil self-sufficiency of the LDCs as a group. As will be discussed shortly, aggregating the LDC countries into one group masks important differences among them, some of which may stand to gain considerably more from cooperating with the OECD than is indicated in the table.

8. Their leakage estimate is based upon a general equilibrium model of international trade that distinguishes between energy-intensive and other goods, includes other energy in addition to oil, and incorporates shifts in energy demand and emissions due to the relocation of energy-intensive industries to less developed countries.

9. We use a welfare-analytic approach to derive the producer and consumer surplus losses and the wealth transfer associated with each policy. The authors will provide a mathematical appendix upon request.

Table 3. Net Total Costs for Achieving 1991 Consumption Targets in 2010 (Millions of 1991 US dollars per day)[a]

	OECD Alone	Separate Targets	Uniform Policy
OECD	285	-186	-52
LDC	-88	332	5.5
World[b]	537	486	293

Note: Each policy reduces world oil consumption by 13.9 million barrels per day and the world oil price from $29.30 to $18.20.

[a] Sum of producer and consumer surplus losses minus wealth transfer.

[b] Includes costs to OPEC and former SU/EE planned economies.

OECD INCENTIVES FOR COOPERATION

Figure 1 illustrates the nature of the OECD costs for unilateral OECD action as conservation is intensified. These costs incorporate the two components discussed above, and are expressed in terms of the costs of achieving the next increment of oil conservation. These additional or marginal costs, measured in dollars per barrel along the vertical axis, increase with the total level of achieved conservation, measured in millions of barrels per day along the horizontal axis. At low levels of conservation, the positive wealth transfers into the OECD countries dominate the negative opportunity costs associated with shifting resources away from other activities, and toward technologies and processes that save oil. As a result, the marginal costs are less than zero; it pays the OECD countries as a group to initiate low levels of conservation even without any environmental gain. In this sense, modest conservation efforts provide certain countries dependent upon oil imports, "a lunch that they are paid to eat." As conservation efforts increase, however, more expensive conservation opportunities must be found, resulting in a rising cost for conservation. This effect is reinforced by lower oil imports resulting from increased conservation. Lower import levels reduce the size of the wealth transfer per dollar reduction in oil price.

Two cost curves are represented in Figure 1. The lower schedule displays the marginal costs of gross OECD conservation before accounting for the conservation lost outside the OECD through the leakage effect. Thus, the OECD will incur an additional cost of $14 for an additional barrel of reduction when its conservation target within the OECD is 10 million b/d. If instead the OECD seeks to achieve a 10 million b/d net reduction in world oil consumption, it must reduce its own consumption by more than 10 million b/d to offset the increase in oil demand outside the OECD. The marginal costs to the OECD of achieving varying levels of net world conservation (i.e., gross OECD conservation minus leakages outside the OECD) is depicted by the higher schedule in the same figure. According to this schedule, OECD's marginal cost would escalate to $41 if it targeted a net reduction of 10 million b/d in world oil consumption. The difference between these two curves emphasizes the importance of accounting for the leakage effect in evaluating the costs of unilateral action.

INCENTIVES FOR LDC PARTICIPATION

Would LDCs be more, or less interested in joining a conservation agreement as the number of conserving nations are increased? In part, the answer depends upon whether the cost of joining rises or falls as the number of nations is expanded. The incentives to participate will also depend upon how the number of participants affect the benefits of joining.

To facilitate cost comparisons, we consider policies that achieve equal climate change benefits achieved through identical net reductions in world oil consumption. The key unknown is which countries would participate and which ones would not. Presumably, economic self-interest would play a critical role, although political objectives cannot be totally discounted. The decision would involve the balancing of the economic and political benefits of slowing climate change through oil conservation with the costs of reduced oil consumption. For any single country or groups of country, the wealth transfer from foreign producers to domestic consumers is an important consideration influencing the costs of participation. For net oil importers, this cost component will be negative (i.e., a benefit) when conservation reduces world oil prices.

Agreements to meet a specified world conservation target become less costly as more countries join. This is demonstrated in Figure 2, where curves indicating how different target levels affect world marginal costs are shown under different assumptions about which countries join. The top cost schedule reveals the costs when only the OECD pursues conservation. Each of the five lines below it represents the effect of adding countries representing another 20% (1/5) of LDC oil demand to the agreement. The lowest cost curves result when first the former Soviet Union and Eastern Europe and then the OPEC countries join—both occurrences having a rather low probability due to these regions reliance upon oil production.

The costs to participating countries similarly decline as more countries join the effort. In Figure 3, the conservation cost curve for participants continually shifts downward as the agreement attracts new members. These are total costs per barrel of original consumption (before implementation of the conservation policy) and show the net cost of participating compared to free riding. As such, these estimates exclude costs borne on the supply side. These curves indicate that participation by others can influence the incentive for a country to join.

Figure 1. Marginal Cost of OECD Conservation

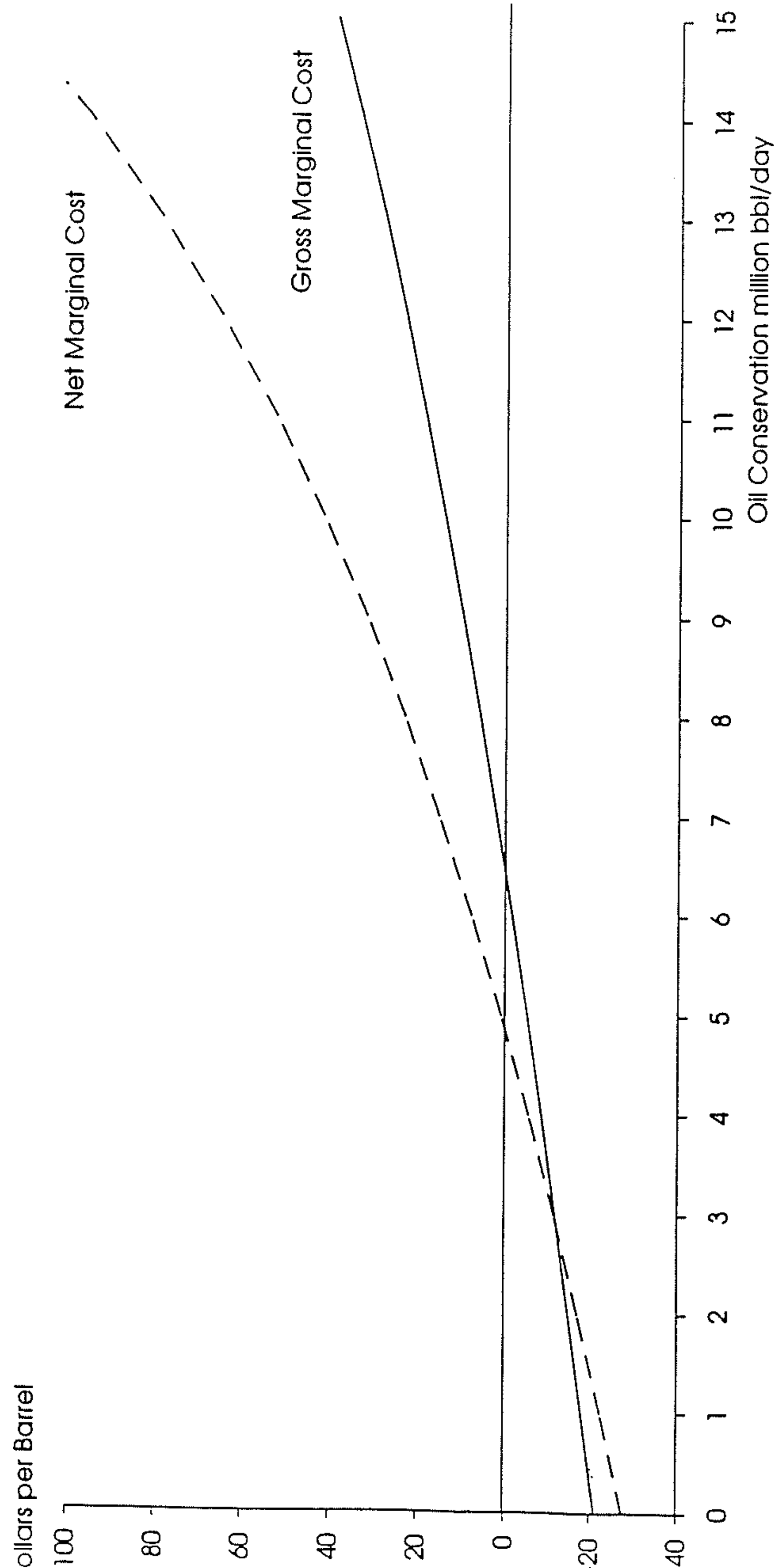


Figure 2. World's Marginal Cost of Net World Conservation (by participation level)

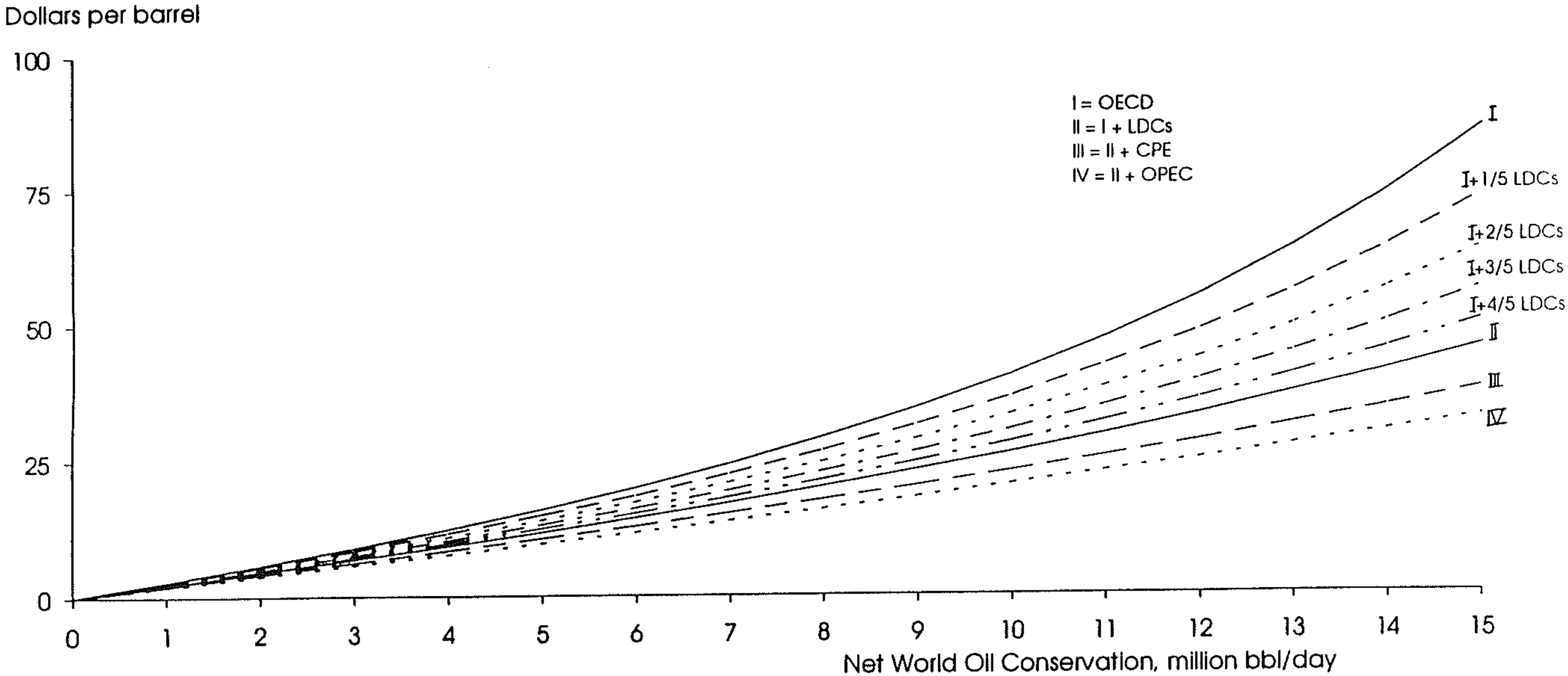


Figure 3. Total Cost for a Representative LDC to Join (by participation level)

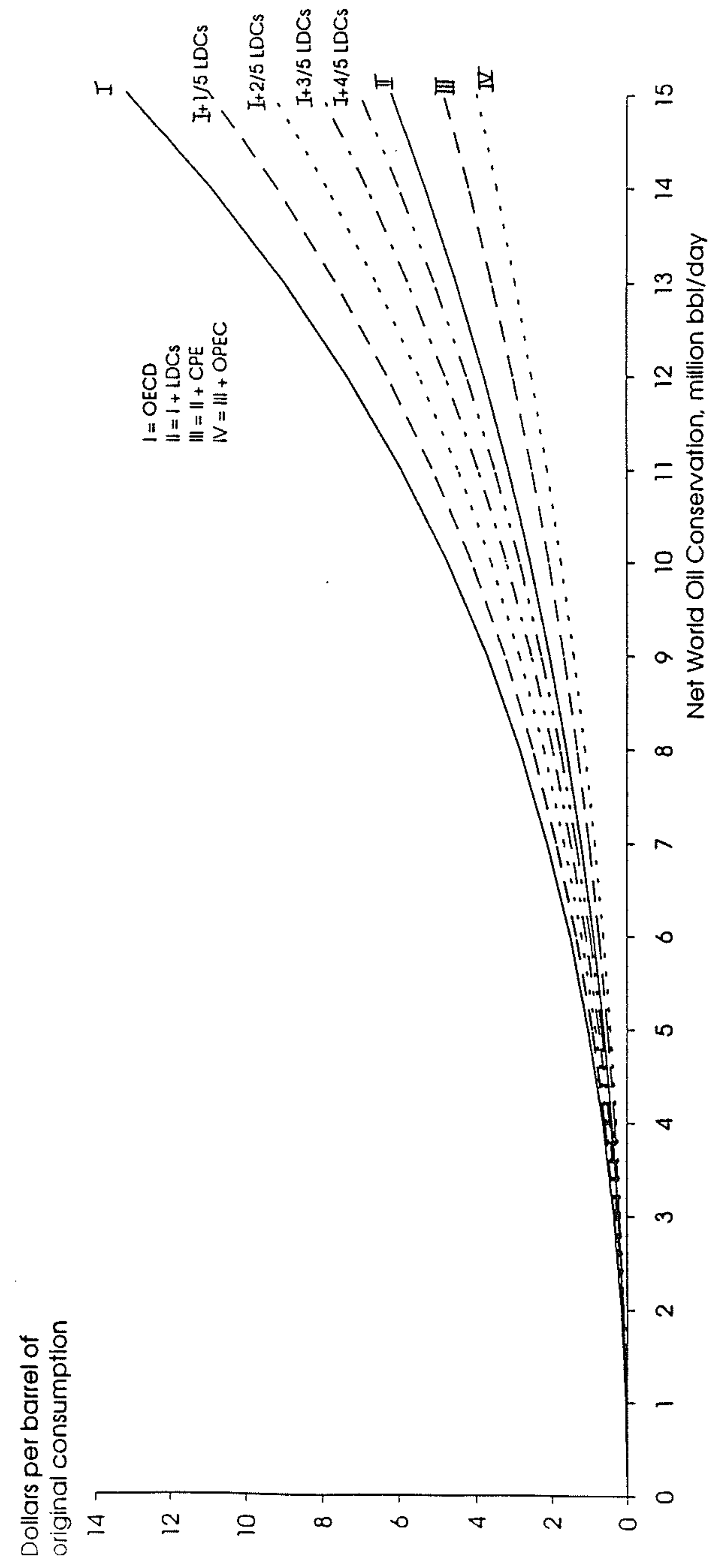
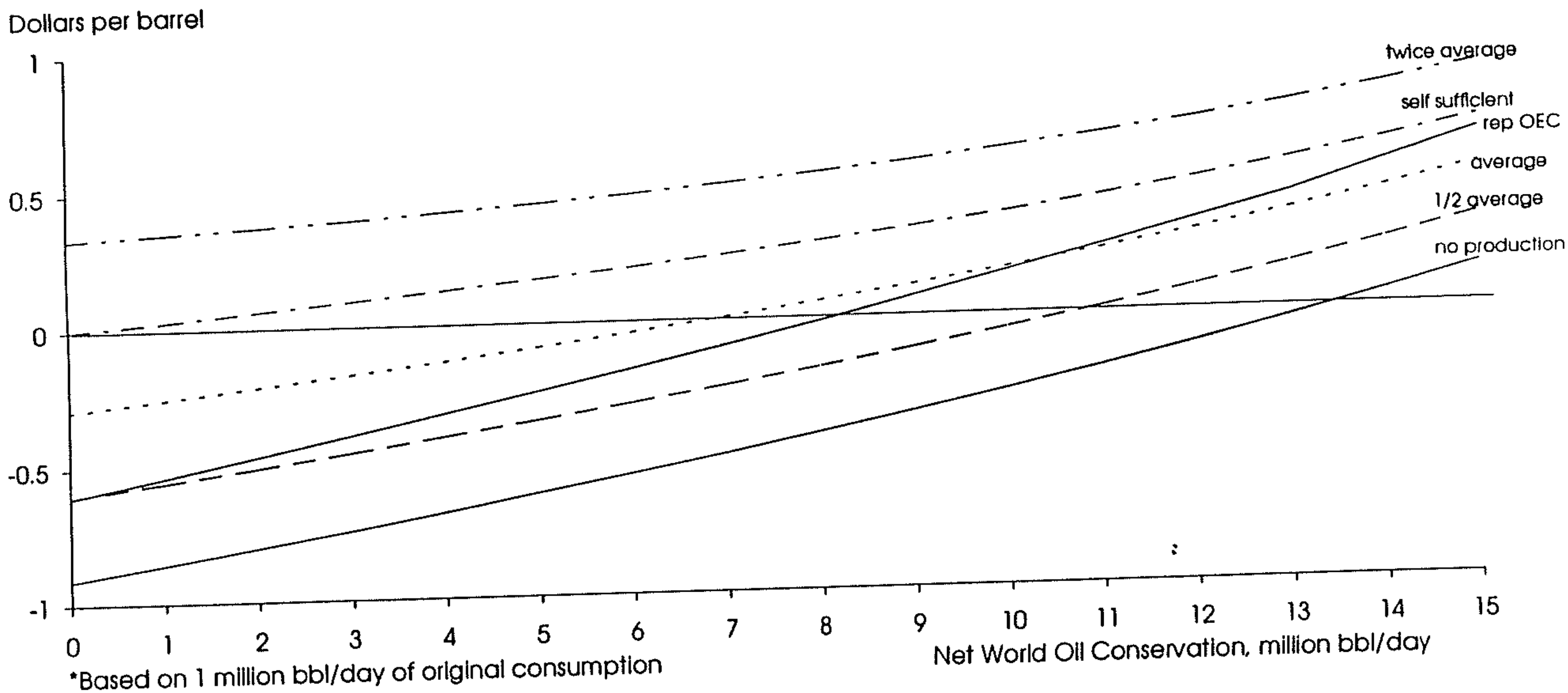


Figure 4. OECD and LDC Marginal Cost of World Conservation (by oil production level)



As a new participant enters the agreement, other participants can reduce their conservation efforts without jeopardizing the agreement's targeted level of world conservation. Wider participation also reduces the leakage effect, thereby requiring less gross conservation to achieve any given target of net conservation. Thus, participation costs for both potential and existing partners in the agreement decline as new participants join the program. In this respect, the act of joining the world conservation program is itself a further inducement for other nonparticipants to join the agreement. The decision to join contains elements of an externality; a new participant decreases the costs of others participating. Nonparticipating nations on the verge of joining the agreement might be induced to enter the agreement, purely as a result of some other nation's decision to join.

Thus, under a policy regime of a fixed world conservation target, existing participants have an incentive to expand membership in the agreement in order to reduce their costs. In searching for new players, they should look not only for nations that place a higher value on oil conservation and mitigating climate change impacts, but also those with the lowest cost of participation. Such low-cost nations include not only those with the lowest expected future demand growth and the best low-cost conservation opportunities (or most price elastic demands), but also those least self-sufficient in energy production. This latter point is sometimes missed in the discussion about different country's proclivity to be "green," but it constitutes a significant portion of our estimated costs of participating in a coordinated policy. While many factors influence a country's public position on international agreements, the past reluctance of both the United States and many LDCs to sign international treaties that would limit oil and energy use is totally consistent with their economic interests in the issue as revealed by their degree of self sufficiency in oil production.

If there were to be an OECD-LDC agreement to reduce world oil consumption, the different underlying cost conditions among participants would make it difficult to reach agreement on how much conservation should be targeted. Figure 4 shows the marginal cost curves for different types of countries in the agreement. By inspection, one can see that even if all nations had the same demand curve for limiting oil consumption (representing perceived benefits from reducing carbon dioxide emissions), they would demand different levels of conservation based upon differences in costs.

Nations that are more self-sufficient in oil will have higher conservation costs curves. The top curve represents the marginal costs of participation for a stylized country using 1 million barrels per day but with twice the average domestic production for an LDC. The bottom curve indicates the costs for a similarly-sized country (in terms of consumption) that produces no oil domestically. The cost curve for a representative OECD country of the same size is also shown for comparison. The OECD cost curve slopes upward more rapidly because OECD oil demand is assumed in the analysis to respond more to price than does LDC demand.

PROSPECTS FOR COORDINATION

Free riding seriously weakens the effectiveness of unilateral OECD conservation efforts. The OECD has several options for encouraging LDC cooperation in world conservation policies.

The OECD countries could establish unilateral policies and hope that their leadership would induce other countries to join. Our analysis suggests that the costs of joining a conservation program that sets fixed consumption targets is prohibitive for most LDCs. Even when consumption targets are set higher (less restrictively) for the LDCs than for the OECD, their costs mount over time. Participation costs for countries outside the OECD drop dramatically when coordination means implementation of a uniform tax on consumption across all participating countries. As a result, these countries are more likely to follow the OECD under programs establishing uniform taxes rather than fixed consumption targets. Understanding this result is key for eliciting the LDC's cooperation in global conservation actions. Quantity-based constraints are likely to reduce cooperation by increasing the costs to these nations.

The LDCs may not follow the OECD's lead even with a policy that emphasized equal costs across nations. Under these conditions, the OECD's options become rather limited. The OECD countries could agree to make side payments to those less developed countries that agree to join the coordinated policy. Such an arrangement involves agreement among OECD countries not only on the form and magnitude of the policy but also on a financial mechanism, institution, or sharing agreement mutually acceptable to all parties.

During bargaining, LDCs facing high costs of conservation are likely to emphasize the costs they would bear as consumers *and* producers. Countries with lower costs are likely to argue that costs borne by producers will not be avoided in non-participating countries, and that subsidies should be based on the incremental cost of participation. Subsidy schemes that require lower cost countries to pay more than incremental cost to higher cost countries for their participation will yield only limited welfare gains to the lower cost countries. Therefore, such programs are likely to be limited in scope and size, resulting in less than complete LDC participation. In addition, some industrial nations might wonder why they joined the program when other quite prosperous economies outside the OECD are receiving subsidies to join. As a result, the effective use of side payments for eliciting cooperative behavior would appear quite limited.

The other side of subsidies would be joint OECD retaliation through trade restraints against countries that refused to join. Such intervention would clearly run counter to the spirit of GATT and the free-trade climate it is trying to engender. Undoubtedly, "protectionist" trade restraints could be disguised as "environmental" penalties under such a policy.

A more promising approach might be for the OECD to collectively make a "matching gift" offer to the LDCs who do not export oil. Under this scheme, the OECD countries would announce that they will implement a well-defined policy (a tax of specified amount or a fixed consumption target), if and only if, a given number of LDCs signed the agreement. The LDCs would receive no free-ridership benefits until the "matching gift" program was fully subscribed. Thus, as long as there were LDCs that had some demand for the public good, oil conservation, or lower world oil prices, these countries would sacrifice benefits if too few countries joined the program.

A strategy currently under discussion is joint implementation. Developed countries would receive credit for investments that reduced emissions in less developed countries. Under such a plan, an OECD country would not be constrained to finding conservation opportunities only under its own energy demand curve but could look overseas for additional low-cost conservation opportunities. Countries wouldn't care where oil conservation occurred, but would instead focus on the relative costs of achieving the next barrel of conservation. The major deterrents to such strategies are verification of the investments and their intended effects, and the fear among LDCs that key economic decisions are being made for them.

An important shortcoming of unilateral fossil fuel conservation programs is that they encourage energy consumption outside the coalition countries through lower world energy prices. Bohm (1993) has suggested that this deficiency might be rectified by offering inducements to remove carbon-based supply from the market. Reduced energy supplies would place upward pressure on prices, thereby encouraging energy conservation rather than consumption in countries paying the world price. Note, however, that some of the supply removed from the market would be offset by supplies brought forward by the higher, post-subsidy price. Thus, this policy contains some of the same problems inherent in the unilateral conservation program.

Moreover, the supply-removal subsidy produces some other difficulties as well. Verification that supplies were removed would be extremely complex. Acreage limits, such as used in U.S. agriculture, would prove impractical for a resource like petroleum that is found in common pools that can be produced in wells distributed across many locations. In addition, producers might accept the subsidy for production in the current year, and delay extracting the petroleum until a future period. Such behavior would shift the timing of emissions but would not appreciably mitigate climate change, which depends upon the cumulative concentration of greenhouse gases in the longer run.

OIL PRODUCER RETALIATION

The world conservation policies considered here would significantly reduce the wealth of oil-exporting countries. Our cost estimates assume that the major oil-producing countries of the Persian Gulf will not retaliate against the OECD countries for limiting their oil consumption. Such retaliation could include additional taxes imposed by oil producers to recapture some of the gains in wealth resulting from a lower world oil price.

However, retaliation by major oil-exporting nations is unlikely to improve their long-run economic position. Under most reasonable market conditions, Gulf producers would have economic incentives to reduce rather than increase prices, even if they were operating as a profit-maximizing cartel. Most oil-exporting countries face serious economic domestic problems that would make such a strategy prohibitively expensive as a long-run response. Obviously, political considerations could prevail given the emotional nature of the issue, causing short-run and perhaps painful disruptions in the oil market.

CONCLUSIONS

There are significant disincentives in the world oil market for many, smaller countries to impose unilateral oil conservation programs to meet environmental or other goals. These costs are particularly severe for the developing countries if the conservation agreement specifies that all nations must meet a target based upon some historically based consumption level. These problems are compounded if the less developed countries are characterized by lower price elasticities of demand, as suggested by historical analyses of oil consumption patterns.

Nations that are relatively self-sufficient in oil production bear an additional cost when they join a coordinated world conservation program. Lower prices, resulting from reduced world oil demand, transfer wealth from domestic producers to foreign consumers. As a group, non-oil-exporting LDCs are more self-sufficient in oil than the OECD, a condition which increases significantly the relative costs of participating in world conservation efforts for many of these countries.

The high costs of aggressive, unilateral action makes it less likely that individual countries will adopt such policies unilaterally. Coordination can reduce participation costs if the agreement can encompass more players. Under a policy regime that fixes a world conservation target, participating nations have incentives to find new partners in the developing world. Simultaneously, the act of new nations joining the agreement encourages new participants, because it reduces the participation cost for all countries.

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APPENDIX: 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:

$$W_i = \int_0^{Q_{Di}} P_{Di}(Q)\partial Q - P_W Q_{Di} + P_W Q_{Si} - \int_0^{Q_{Si}} P_{Si}(Q)\partial Q \qquad \text{(A1)}$$

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).

A. 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:

$$MC_i = P_{Di} - P_W + \frac{\partial P_W}{\partial Q_{Ci}} Q_{Mi} \qquad \text{(A2)}$$

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*.

The marginal cost concept expressed in equation A2 can be represented graphically. For expositional purposes only, consider an oil-importing country with no domestic production.

Focusing upon total costs, Figure A shows that the domestic demand curve intersects with a total supply curve (including imports) to determine an initial price Po and quantity Qo. When an internal tax raises the domestic price to Pt, oil consumption declines to Qdt. Shifting resources to oil-conservation activities causes a domestic consumer surplus (CS) loss represented by the shaded triangular areas. But reduced total consumption caused by domestic conservation lowers the world price to Pw, transferring wealth to domestic users and a domestic producer surplus (PS) loss as the world price moves down the domestic supply curve. The wealth gain is represented as the solid rectangular area and the producer surplus loss as the shaded area to the left of the domestic supply curve.

Figure B shifts the focus to marginal costs. If country i increases its conservation from Qt to Qt', the required tax or implicit cost rises from Pt to Pt' while the world oil price falls from Pw to Pw'. The incremental resource costs are indicated by the shaded rectangles and triangles; the wealth gains are shown by the horizontally aligned solid rectangle and triangle. As the incremental change in conservation approaches zero, the cost of conservation becomes the difference between the domestic price, Pt and the world price, Pw less the incremental reduction in world price times the quantity imported Qt, which is the same as equation A2. As conservation is intensified (moving consumption toward the origin), the resource costs become larger while the domestic wealth gains could move in either direction depending upon the shape of the foreign net supply curve.

B. Cooperative Conservation

If country *i* is pursuing conservation as a cooperative policy with other countries, the change in the world oil price brought about by country *i*'s conservation reflects both the effect of the conservation undertaken by the whole group of participating countries and the amount of conservation required of country *i* on the margin under the cooperative agreement. More formally,

$$\frac{\partial P_W}{\partial Q_{Ci}} = \frac{\partial P_W}{\partial Q_{CI}} \cdot \frac{\partial Q_{CI}}{\partial Q_{Ci}}$$

where Q_{CI} reflects the conservation undertaken by all countries participating in the cooperative agreement, including country *i*.

C. The Cost of Net Conservation

The net effect of participant actions on world oil conservation is simply the quantity of their conservation minus the induced change in oil consumption in the rest of the world. The change in oil consumption outside the participant group depends on how that consumption is affected by a change in the world oil price and how the conservation actions 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 follows:

$$\frac{\partial Q_{CW}}{\partial Q_{CI}} = 1 - \frac{\partial Q_{DX}}{\partial P_W} \cdot \frac{\partial P_W}{\partial Q_{CI}} \tag{A3}$$

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

Following Felder and Rutherford (1993), equations A2 and A3 can be combined with $\partial Q_{Ci}/\partial Q_{CI}$ to express the marginal cost of net world oil conservation for country (or country grouping) *i*. Specifically, multiplying the marginal cost of conservation in country *i* by the change in country *i*'s conservation with respect to a change in participant conservation and the change in participant conservation with respect to net world conservation yields:

$$MC_{Wi} = \left(P_D - P_W + \frac{\partial P_W}{\partial Q_{Ci}} Q_{Mi}\right) \cdot \frac{\partial Q_{Ci}}{\partial Q_{CI}} \left(1 - \frac{\partial Q_{DX}}{\partial P_W} \cdot \frac{\partial P_W}{\partial Q_{CI}}\right)^{-1} \tag{A4}$$

In the above equation, MC_{Wi} denotes the marginal cost of net world oil conservation to country *i*[1].

As equation A4 shows, the effects that cooperative oil conservation has on the cost of oil imports and on non-participant oil consumption are related through the world oil price. As cooperative conservation lowers the world oil price, it reduces the cost of country *i* oil imports and brings about an increase in non-participant oil consumption. If conservation has no effect on the world oil price, however, both the cost of oil imports and non-participant oil consumption will remain unchanged.

D. Market Conditions and Global Conservation

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

$$\frac{\partial P_W}{\partial Q_{CI}} = \left(\frac{\partial Q_{DX}}{\partial P_W} - \frac{\partial Q_{SW}}{\partial P_W} \right)^{-1} \tag{A5}$$

In the above equation Q_{SW} denotes the quantity of oil supplied world wide.[2]

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

Combining equations A3 and A5, yields an expression that shows how supply and demand conditions affect the relationship between participant oil conservation and net world oil conservation.

$$\frac{\partial Q_{CW}}{\partial Q_{CI}} = 1 - \frac{\partial Q_{DX}}{\partial P_W}\left(\frac{\partial Q_{DX}}{\partial P_W} - \frac{\partial Q_{SW}}{\partial P_W}\right)^{-1} \qquad (A6)$$

As indicated by the first derivative of $\partial Q_{CW}/\partial Q_{CI}$ 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 participant conservation is in achieving world conservation. Under these conditions, the world price changes less and the increase in non-participant consumption is smaller.

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

NOTES

1. If country (or country grouping) *i* is pursuing a unilateral conservation strategy, then $\partial Q_{Ci}/\partial Q_{CI}$ equals unity and equation A4 reduces to that found in Brown and Huntington (1994).

2. 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-participant oil demand and η_{SW} is the elasticity of world oil supply.