Unilateral OECD Policies to Mitigate Global Climate Change

Stephen P. A. Brown

and

Hillard G. Huntington

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Stephen P. A, Brown*
and
Hillard G. Huntington**

*Research Department, Federal Reserve Bank of Dallas

**Energy Modeling Forum, Stanford University

Abstract

This article offers an alternative perspective for thinking about climate change policy when the developing countries are not participating. If industrialized countries cooperate with each other to reduce their emissions, but comply at levels below those required under the Kyoto protocol, they will have incentives to adopt policies that are more costly to the world than a carbon tax. These incentives result from terms-of-trade gains that result if conservation lowers world prices lower for fuels the industrialized countries import. We consider cases where the industrialized countries act cooperatively and non-cooperatively to achieve these gains. Because the regional terms-of-trade effects of a particular policy cancel each other at the world level, participating nations have incentives to adopt policies that are more costly to non-participants than a carbon tax that minimizes world costs.

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1. Introduction

At the end of 1997 in Kyoto, the industrialized nations proposed to curtail their greenhouse gas emissions below their 1990 levels over the next 10-15 years. Developing countries are not obligated to impose such measures under this proposal. The prospects for reducing greenhouse gas emissions among a group of some but not all countries raise a number of interesting problems for those interested in achieving these environmental goals at the least cost.

Most recent analyses of climate change policy assume compliance with the Kyoto protocol. Under this approach, the industrialized countries are required to substantially reduce CO_2 emissions below baseline projections while the developing countries are not. Furthermore, the actors are presumed to use a carbon tax or an equivalent policy that achieves the lowest cost compliance for the world, and they do not consider policies that may be more cost-effective for themselves, but less cost effective from a world perspective.

The above approach produces some well-known results.[1] Cost-effective options for reducing CO_2 emissions in the developing countries are ignored, thereby increasing the costs to those groups that have agreed to act. In addition, non-participants will increase their CO_2 emissions above the baseline path because they will see lower energy prices, producing what has been called the "leakage effect." The leakage effect will reduce the benefits (damages avoided) by the reduced emissions in the industrialized countries. The combination of foregone opportunities in the developing countries and the leakage effect make it difficult to attract new participants to enter the agreement at a later time.

This paper offers an alternative perspective for thinking about policy when the developing countries are not participating. We assume that the international agreements will lead industrialized countries to reduce their CO_2 emissions while the developing countries do not, but that compliance may vary from that required under the Kyoto protocol.

Our approach yields some strikingly different results because small policy changes can yield substantial changes in the terms of trade for energy commodities. A country or group of countries can obtain wealth transfers by restricting the use of imported sources of energy and altering the terms of international trade. When conservation reduces the world price of a fuel, it reduces the cost of purchasing that fuel from abroad, which increases real wealth for the nations importing that fuel. Strategies to reduce the use of imported fuels reduce the cost of energy conservation for energy-importing nations but not for the world as a whole.

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[1] See for example the analysis contained in the volume by Weyant (1999).

Consequently, policies that appear cost-effective from a national perspective can differ substantially from those that are cost-effective from an international perspective, and vice-versa. As recent history suggests, individual countries will choose different policies from each other depending on which fuels they import and export. The policies pursued in individual countries are unlikely to minimize world or even OECD costs. As a result, global cooperation in reducing CO_2 emissions may be even more difficult than the traditional approach depicts.

Our analysis shows how the terms-of-trade shifts can influence a country's participation in energy conservation strategies. Section 2 develops a graphical representation of the costs associated with achieving abatement through reductions in three fuels: oil, natural gas, and coal. Section 3 presents a simulation model of world energy markets used to produce numerical estimates of the costs of various OECD strategies for curtailing CO_2 emissions. Section 4 presents the numerical cost estimates obtained from the model under several cooperative and non-cooperative strategies. These estimates show how different strategies for compliance might affect the distribution of costs throughout various regions of the world. Section 5 concludes with a summary of the key results of the possible consequences of countries having divergent interests in the partial implementation of the Kyoto accord.

2. Conceptual Approach

Reducing a nation's energy use decreases environmental damages, but it also imposes economic costs. Costs are incurred by energy conservation whenever the value that would have been obtained in using the energy is greater than the resources that would have been required to produce it. This component of costs is typically measured as a loss of consumer and producer surplus.

In addition, a nation's economy will incur gains or losses when the world prices of energy commodities that it imports or exports fall as a result of the conservation effort. These gains or losses, known as "terms-of-trade effects," are measured as the product of world price of the commodity and the country's net trade volume (either net exports or net imports) in the commodity. For energy sources that are exported, there are terms-of-trade losses that increase the country's cost of conservation. For energy sources that are imported, there are terms-of-trade gains that reduce the country's cost of conservation.

The cost of conservation may also be affected by any existing market distortions that exist prior to the conservation effort. The costs of conservation will be higher if previously existing distortions have caused too little of an energy source to be used, but they will be lower if the distortions have caused too much of the energy source to be used.

From a world perspective, however, the costs of any given level of energy conservation will be the sum of the resource costs imposed on all the affected countries. The gains in wealth obtained by one country or group of countries through improved terms-of-trade will be lost by another group, and these effects cancel out. Nonetheless, for a large country or group of countries, changes in the terms-of-trade can be an important component of the costs of energy conservation and may affect the strategies for energy conservation.

2.1 Costs of Conservation with One Fuel

Figure 1 shows how differently the world, the OECD and a member country of the OECD might view the costs of that particular country's effort to conserve one energy source, oil. One might consider a country like the United States, which imports oil but less of it than the OECD taken as a whole. Because we are examining the costs of one particular country's conservation efforts, the differences between the cost curves are the strictly the result of differences in the terms of trade. At the world level, the terms-of-trade effects for individual countries are exactly offsetting. Therefore, the curve representing the world's marginal cost of the country's oil conservation begins at the origin.[2]

The country's cost curve lies below the world curve and starts below the origin because the country can improve its terms of trade by depressing the world price of oil through its oil conservation efforts. The OECD cost curve shows how the country's oil conservation efforts affect OECD costs (including those incurred by the country). The OECD cost curve lies below the country curve because the OECD as a whole imports more oil than the individual country.

If the marginal benefits of oil conservation (which are the environmental damages avoided) are constant or declining, the country could find it desirable to conserve more oil than is desirable from a world perspective, but less oil than the OECD as a whole would prefer.[3] In fact, we often see this line of reasoning in international discussions. Many of the OECD countries have been more adamant about the United States reducing its oil consumption than the United States is itself. Many of the oil-exporting nations have condemned oil-conservation strategies as imposing costs on them.

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[2] For simplicity the first figure does not represent the costs of OPEC restricting its oil production below free market levels.

[3] For a more thorough analysis of this issue, see Brown and Huntington (1998).

2.2 Costs of Conservation with Multiple Fuels

The analysis extends to multiple fuels as well. Figure 2 presents cost curves for one country's CO_2 abatement through conservation of oil, natural gas and coal. The labels "World," "Country," and "OECD" identify the costs of the country's CO_2 abatement by each respective group. The differences in the curves represent differences in gains from terms of trade, as well as the costs of OPEC restricting its oil production below free market levels. The horizontal axis of each chart measures the level of CO_2 abatement, while the vertical axis displays the cost of conserving the respective fuel (measured in terms of dollars per reduction in CO_2).[4]

Our objective is to find the lowest cost methods for an OECD member country to achieve a given reduction in CO_2 emissions as seen from the perspective of the world, the individual country and the OECD. Holding the total reduction in CO_2 emissions constant allows us to concentrate on the conflicts that can arise over energy conservation strategies even if the environmental benefits are equal under each strategy considered.

First, we examine what energy conservation strategy the world would want the country to take. For any given conservation level, the world would want the country to conserve carbon-based fuels in a way that equalized the marginal costs of CO_2 abatement across fuels for the world, as is shown by the horizontal line labeled "W". If the country followed these guidelines, it would conserve the quantities of oil, natural gas and coal that would reduce CO_2 emissions by the quantities labeled "W" in each panel of Figure 2. The country's total reduction in CO_2 emissions is represented by the sum of these quantities.

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[4] For graphical analysis, we assume no interfuel substitution. Interfuel substitution complicates the analysis but does not alter the basic logic shown in the graphical analysis.

Next, we consider the energy conservation strategy the country itself would prefer to undertake to achieve the same level of CO_2 abatement—recognizing the country will improve its terms-of-trade by conserving oil and natural gas and worsen its terms-of-trade by conserving coal. To minimize its costs, the country selects a fuel conservation policy that equalizes the marginal cost of CO_2 abatement across fuels, as is shown by the horizontal line labeled "C". Under these conditions, it would conserve the quantities of oil, natural gas and coal that would reduce CO_2 emissions by the quantities labeled "C" in each panel of Figure 2. The country's total reduction in CO_2 emissions is represented by the sum of these quantities and is equal to the total abatement obtained under the world's preferred policy. As is shown in the figure, the country would prefer to achieve the given reduction in CO_2 emissions with more oil conservation but less coal and natural gas conservation than would minimize world costs.

Finally, we consider the OECD view on the optimal strategy for the individual country. The OECD would prefer a fuel conservation policy that equalizes its marginal cost of CO_2 abatement across fuels, as is shown by the horizontal line labeled "O". Under these conditions, the country would conserve the quantities of oil, natural gas and coal that would reduce CO_2 emissions by the quantities labeled "O" in each panel of Figure 2. Again, the total abatement of CO_2 emissions is the same as in the other two cases.

Because the OECD imports greater quantities of oil than the country, it prefers that the country conserve more oil than would minimize costs for either the country or the world. The OECD would also prefer that the country's conservation of natural gas be less than would minimize costs for the world but more than would minimize costs for the country. Finally, the OECD would prefer that the country conserve less coal than would minimize the costs for either the country or world.

Without additional information about the underlying cost curves, it is not possible to completely predict by how much an individual country's CO_2 abatement and energy strategy might conflict with the interests of other OECD nations or the rest of the world. We do know, however, that countries cannot agree on what represents the best strategy for any particular member country to follow. Upon reaching an international agreement on how much CO_2 abatement each country should undertake, individual countries do not have incentives to conserve the fuels that will yield the lowest cost from an international or OECD perspective. Instead, market realities will encourage them to reduce their consumption of the fuels that will improve their terms of trade—that is lowering the price of the fuels that they import. These terms-of-trade effects are likely to complicate the problem of reaching a low-cost consensus position among participants.

An example of the importance of the terms-of-trade effect is readily apparent in the Btu tax that the Clinton Administration proposed for the United States in 1991. Table 1 shows the proposed taxes for crude oil, natural gas, and coal in terms of dollars per standard fuel unit, per million Btu, and per metric ton of carbon. From the world's perspective, the least-cost approach would have involved lower taxes on crude oil than coal or natural gas for a given amount of carbon, but the proposal would have placed a tax on the carbon content of crude oil 3.5 times that on the carbon content of coal.[5] The tax on the carbon content of natural gas would have been about 70 percent more than on the

[5] From the world perspective, the least-cost solution involves offsetting the effects of OPEC restricting its output of oil.

carbon content of coal. Taxes are greatest for the fuel with a highest import share (oil) and lowest for the fuel that the United States exports (coal).

3. Estimating the Costs of Various Strategies for CO_2 Abatement

To more thoroughly examine how terms-of-trade issues might affect strategies for CO_2 abatement, we develop a model of the world energy market and use it to estimate the costs of complying with the Kyoto accord under various scenarios. We consider three scenarios—one in which OECD countries act jointly to minimize world costs, one in which OECD countries act cooperatively to minimize OECD costs, and one in which two blocks of OECD countries act non-cooperatively to minimize their own costs. Analysis of the differing costs and their incidence under the three scenarios reveals an incentive for OECD countries to shift the costs of their CO_2 abatement through programs that target imported fuels more heavily.

3.1 A Model for Estimating the Cost of CO_2 Abatement

Following several previous studies, we use a welfare-theoretic framework built on top of a simulation model of the world energy market to compute the marginal costs of reducing CO_2 emissions in 2010 under alternative assumptions about which carbon-based fuels are conserved. Our analysis divides the world into five regions: the United States; other OECD countries; China, Eastern Europe and the former Soviet Union, (C/EE/FSU); OPEC members; and other less developed countries (other LDCs). Each policy begins from the same baseline case with the price, production, and consumption estimates shown in Table 2. These estimates are the reference case from a recent *International Energy Outlook* produced by U.S. Energy Information Administration.

Other world energy outlooks are quite possible for the year 2010, but those in Table 2 are widely distributed and well documented. Moreover, we view our numerical estimates as demonstrating the qualitative effects analyzed in previous sections rather than as precise quantitative estimates of a very uncertain problem. The projected energy demand conditions depend on a variety of assumptions about economic growth and the extent of energy-saving technological change in the absence of price changes. The energy supply conditions other than OPEC oil production incorporate assumptions about the resource base, engineering constraints on developing resources, and producer-country taxes and policies. OPEC production satisfies the excess demand in the oil market.

Table 2 also summarizes representative estimates of the long-run supply and demand responses to prices for the major regional areas in the analysis. These estimates are derived from a variety of sources. The oil price elasticities of supply and demand are based upon an Energy Modeling Forum study (1991) that compared ten major world oil market models.[6] Elasticities for other fuels were calibrated to estimates adapted from Bohi (1981) and Brown and Yücel (1995). The estimates in the table are comparable to those found in other recent modeling efforts and were used in construction of the simulation model.

Following Brown and Huntington (1998), the responses for C/EE/FSU are judgmental. The production and consumption decisions in these countries are likely to be influenced greatly by the forces of economic transition and to be less responsive to changes in world energy prices than found in other regions. In fact, if the supply and demand responses for C/EE/FSU were made comparable to responses for other country groups, the conservation scenarios considered here would result in sufficiently low world energy prices that would cause these economies to import significant quantities of energy. We consider such a result untenable and therefore assumed a smaller response to price than for other countries. To the extent that these countries respond more greatly to price, OECD reductions in emissions will be more greatly offset by increased emissions from C/EE/FSU, and the world costs of conservation would be higher, but the thrust of the current analysis would be unchanged.

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 times, but not at others.[7] The OPEC countries appear to be about 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.[8]

3.2 Calculating the Cost of CO_2 Abatement

We estimate the costs of several different policies that the United States and other OECD countries might undertake to reduce CO_2 emissions. In each policy, we allow world energy prices to adjust to restore a balance between supply and demand conditions

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[6] See Huntington (1992, 1993).

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

[8] 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 United States and other developed countries would not obtain wealth gains from lower world oil prices.

in each market. Analytically, we use taxes to reduce the consumption of carbon-based fuels in the two country groups. The tax approach assumes that conservation measures are applied across all end uses of a particular fuel.

Oil conservation in the United States and other OECD countries acts to depress the world oil price while it boosts the oil price faced by consumers in the United States and other developed countries. 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 United States and other developed countries incur by imposing conservation policies. It also stimulates oil consumption in countries not participating in the conservation efforts. Similar effects result from the conservation of other internationally traded fuels.

Using values from the simulations, we calculate the marginal cost of reducing CO_2 emissions under each of the scenarios.[9] This methodology follows a welfare-theoretic approach previously employed by Brown and Huntington (1994a, 1998) and Felder and Rutherford (1993). The resulting cost estimates take into account the direct welfare costs of a country's conservation efforts, transfers associated with changes in the terms of trade, and the effect that lower world energy prices will have on energy consumption in nonparticipating countries. The cost estimates also take into account the economic cost of OPEC cartelization.[10]

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[9] We develop equations for deriving these estimates in our appendix, "Some Analytics of CO_2 Abatement," that is available from the authors upon request.

[10] Our appendix that is available upon request discusses how we obtain the full cost of world conservation to the world in the presence of OPEC cartelization.

The cost estimates depend critically on the assumptions used in the model of world energy markets. 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 and consistent with our previous qualitative discussion.

To maintain the emphasis on the variation in costs under differing policies, 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 1991); and an explicit accounting for different types of goods (Felder and Rutherford 1993, and Pezzey 1992). We also abstract from the effects of pre-existing energy taxes and other taxes. Pre-existing taxes could be reduced to offset some of the costs of a new conservation policy (Hoel 1991), or they could be left in place, which would affect the estimated costs of imposing a new conservation policy (Newbery 1992).

4. The Costs of Various Strategies for CO_2 Abatement

The effects of an OECD abatement policy will depend importantly upon the objective in implementing that strategy. Each participating country might reduce emissions in a way that is most efficient from the world perspective. Under this approach, each nation might impose a carbon tax on each fuel based upon its carbon content. Most studies of carbon policies assume that countries follow this path.

Another strategy, however, might be that each country is fully aware that reductions in fuel use could yield terms-of-trade gains by decreasing the price of imported energy or terms-of-trade losses by decreasing the price of exported energy.[11] These considerations might encourage the nation to tax imported fuels more heavily than exported fuels in its effort to reduce carbon emissions. A third strategy might be that each country operates in the general OECD interests to maximize the real income of the industrialized countries as a whole. This section examines the influence of these different strategies on costs and the choice of fuels to be conserved.

4.1 Costs at Zero Compliance

Before considering the wide range of possibilities, it is useful to examine what are the costs of an OECD policy to curtail energy use close to the reference level of energy consumption (zero compliance). Table 3 summarizes the marginal costs of restricting either oil, natural gas, or coal at the reference prices and quantities projected in the *International Energy Outlook* (*IEO*). There are no terms-of-trade effects for the world because one country's gains are balanced completely by another country's losses.

Nonetheless, the analysis allows for oil prices being held artificially high and oil-consumption artificially low by the oil-producing cartel of the Organization of Petroleum Exporting Countries (OPEC). In essence, OPEC is already imposing a tax on oil use prior to any climate change policy. As a result, the world would prefer to leave oil alone

[11] The prices of imported and exported final products will also change. We have not developed a computable general equilibrium approach to capture these additional terms-of-trade effects because reliable data by industry is a major concern and the results are very sensitive to the chosen elasticities for each product. See Shiells and Reinert (1993). Our analysis captures the essential terms-of-trade concerns raised in our qualitative discussions.

initially. Starting at zero compliance, the world would incur costs greater than $10 per ton of carbon for small reductions in oil use.

Instead, the world would rather conserve natural gas and to a lesser extent coal. The world finds it extremely valuable to reduce natural gas because our assumptions allow considerable interfuel substitution between gas and oil. As natural gas use is reduced, oil consumption begins to grow from its artificially low value imposed by a monopolist producer. Small increases in oil consumption (at zero compliance) add benefits for the world, resulting in a net gain of more than $12 per ton (fourth row). Coal restrictions at zero compliance yield only a small world cost savings reflecting the somewhat limited interfuel substitution between coal and oil.

In contrast, the OECD (third row) would prefer to conserve oil rather than natural gas or coal. These countries suffer a loss of about $1.40 per ton if they reduce coal slightly or about $1.30 per ton if they reduce natural gas slightly. These costs contrast with gains of about $19 per ton for the OECD if they reduce oil consumption slightly. The relatively large gain from reducing OECD oil consumption reflects the large oil imports in the United States and the rest of the OECD.[12]

Although the costs of reducing coal and natural gas appear similar for the OECD, they clearly impose different costs for the United States (first row) relative to the other OECD countries (second row). Restricting coal use by a small amount would be less costly in the United States ($1.11 per ton) than elsewhere in the OECD ($1.69 per ton). This result is due almost entirely to the fact that Australia, a major coal exporter, has been included in the other OECD group. Had it been included with the United States, the net cost for these two countries would have been noticeably larger than for the rest of the industrialized nations.

4.2 The Costs of OECD Policies

We now examine the costs of carbon abatement policies at varying compliance levels between 0 and 150% of the total projected increase in OECD carbon emissions over the 1990-2010 period. In the absence of any policy action, baseline OECD energy consumption in 2010 is projected to yield about 384 million tons more of carbon emissions than it did in 1990.

We consider three of many possible strategies, which we identify as: "world cost minimizing," "OECD cooperative," and "non-cooperative." The world-cost-minimizing strategy assumes that the OECD adopts policies to reduce its CO_2 emissions in a manner that keeps world costs as low as possible. Essentially, the OECD imposes a carbon tax on its member countries, with appropriate adjustments to account for OPEC's restricted production of oil. The OECD cooperative strategy assumes that the OECD members adopt policies that minimize the total cost of the OECD countries for achieving each level of CO_2 abatement. The non-cooperative strategy divides the OECD into two blocks of countries: the United States and other OECD countries. Under this strategy the United States and the other block of OECD countries act independently of each other in an attempt to minimize their own costs while taking the behavior of the other country block as given. Equilibrium values are established through a Nash-Cournot solution.

Figure 3 displays the results for how these three differing strategies affect the OECD costs. These costs converge as the compliance rate moves towards 100% abatement of

[12] The OECD countries cannot capture for themselves the benefits of an energy-conservation policy that

the 1990-2010 increases in emissions because the terms-of-trade effects become smaller. At each compliance level, the OECD countries tax imported fuels more heavily than exported fuels. Due to this convergence of costs, we truncate the figures at 100 percent compliance, although our simulations extend to 150 percent compliance.

For compliance rates that are less than 80% of the 1990-2010 increases, the OECD nations find it substantially more expensive to adopt the world's best policy (an adjusted carbon tax) than to adopt one that favors their own interest. Even at 70% compliance rate, they pay an additional $10 per ton more to be good world citizens. They are better served by adopting a more selfish OECD policy.

As might be expected, the non-cooperative strategy results in somewhat higher OECD costs than the OECD cooperative strategy. Acting independently, each of the two blocks fails to take into account the terms-of-trade gains in the other block of OECD countries. Interestingly, the estimated differences in costs between the non-cooperative and OECD cooperative strategies are not very great—although this result could change if we further disaggregated the other OECD group into its component countries.

Whether it is acting cooperatively or non-cooperatively, the OECD can find a policy that reduces its own costs below a carbon tax (adjusted for OPEC's monopolistic position). It does so by taxing the fuels that it is importing more heavily than the fuels it is exporting. For the OECD, this action extracts income through lower import prices that more than offsets the increase in direct resource costs that result from the action.

As shown in Figure 4, the estimated costs for the United States are similar to those for the OECD. This finding suggests that the two OECD groups in this analysis are more

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boosts world oil production above the level set by the OPEC cartel.

similar to each other in terms of their imports and exports of energy than they are to the rest of the world.

Although the OECD can find policies that will reduce its costs relative to those resulting from a carbon tax, such policies will impose higher cost on the rest of the world. Figure 5 compares the world costs of the different strategies. Both the OECD-cost-minimizing and the non-cooperative strategies push world costs above those resulting from a carbon tax (adjusted for OPEC's monopolistic position). The differences between the non-cooperative and OECD cooperative cases demonstrate that enhanced cooperation among the OECD countries shifts more of the costs of OECD reductions in CO_2 emissions to the rest of the world *and* increases total world costs.[13]

After about 100% compliance, we estimate virtually no difference between the cases, because the terms-of-trade effects become very much smaller as emissions are reduced. Indeed, for studies that focus solely on how to implement the Kyoto targets and assume a baseline that is similar to that projected in the *IEO*, the terms-of-trade effects may be minimal and not require much attention.

Clearly, the assumed growth in baseline fuel demand (and CO_2 emissions) prior to the implementation of policy will be important to the estimates. If there are unexpected opportunities to reduce fossil fuel consumption below the levels in the *IEO* reference case prior to any policy action, the costs of achieving a given compliance rate with the policy would be less. Moreover, the terms-of-trade effects that distinguish one strategy from

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[13] The estimated cost curves would rise more steeply with compliance if the price elasticities of supply and demand for each fuel were lower. The cross-price elasticities of fuel demands also have an important role. Lower cross-price elasticities would allow countries to better separate fuels and target them for conservation, which would increase the divergence in costs between the cases.

another would become more important at higher compliance rates than is shown in the current charts.

In addition, countries may very well adopt more gradual policies. In fact, one might expect more gradual policies in contrast to the extremely ambitious targets set in the unratified Kyoto accord. Under the more gradual approaches, terms-of-trade effects are important. Countries will find it advantageous to adopt policies that are in their own self-interest, even if they are more expensive for the world.

4.3 Fuel Incidence of OECD Policies

The three strategies have very different effects on the consumption of coal, oil, and natural gas. Figure 6 shows what percentage of the U.S. reduction in carbon emissions is achieved through lower U.S. coal use at the margin for different compliance rates. The world-cost-minimizing case resembles a carbon tax and would primarily punish coal. In fact, more than 100% of the U.S. carbon reduction would be achieved through lower coal use for compliance rates of less than 40%. At these lower compliance rates, oil use would actually be expanded, as shown in Figure 7 below. The OECD cooperative and non-cooperative cases reduce coal use much more gradually, reflecting its important export position in the United States and the OECD.

As shown in Figure 7, the treatment of oil differs substantially from that for coal. In particular, U.S. oil use is penalized much more heavily in the cooperative OECD and non-cooperative cases than in the world-cost-minimization case. The differing treatment reflects oil's significant import position in the United States.

As shown in Figure 8, U.S. natural gas use is reduced slightly more in the world-cost-minimizing case than in the OECD cooperative and non-cooperative cases. The differences are relatively small, however, in comparison to those for the other fuels.

5. Conclusions

As we have seen, the composition of a country's energy imports and exports can influence how the country will develop its policies to reduce CO_2 emissions. For an imported fuel, conservation reduces the world price and yields the importing country a gain in the terms of trade. For an exported fuel, conservation yields the exporting country loss in the terms of trade. These effects vary across country by the amount of each fuel imported and exported. From a world perspective, however, the effects exactly cancel. Consequently, energy conservation strategies that would minimize costs for the United States or other OECD countries can differ substantially from those that would minimize costs for the world.

At levels of CO_2 abatement in the OECD that are lower than currently estimated for compliance with the Kyoto accord, terms-of-trade effects appear to dominate the direct welfare losses associated with energy conservation. As a result, OECD strategies or those of individual countries could diverge substantially from that which would minimize world costs. At the relatively high levels of energy conservation that are currently estimated for compliance with Kyoto accord, we estimate the direct welfare losses associated with energy conservation dominate the terms-of-trade effects, and find the differences in policy are smaller.

Nonetheless, terms-of-trade effects could be important in international agreements to reduce greenhouse gases—either because countries choose a more gradual approach to reducing emissions of greenhouse gases than is proposed in the Kyoto accord, or because technological change reduces the baseline projections of emissions more than is currently anticipated. The possibility that countries will pursue self-interest in setting energy conservation policy adds to the issues that must be balanced in achieving the cooperation necessary to reduce greenhouse gases through viable international agreements. International trade in pollution rights will not lessen these conflicts as long as governments can determine through which fuels the compliance will be achieved.

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APPENDIX: SOME ANALYTICS OF CO_2 ABATEMENT

We use a welfare-theoretic approach to derive formulas for the marginal cost of CO_2 abtatment achieved through the conservation of carbon-based energy. For any country (or country grouping), the economic welfare obtained from the market for a particular source of energy is the sum of consumer and producer surpluses:

$$W_{ij} = \int_0^{Q_{Dij}} P_{Dij}(Q_j)\,dQ_j - P_{ij}Q_{Dij} + P_{ij}Q_{Sij} - \int_0^{Q_{Sij}} P_{Sij}(Q_j)\,dQ_j \qquad \textbf{(A1)}$$

In the above equation, W_{ij} denotes the economic welfare country i obtains from the market for energy source j, Q_{Dij} the quantity of primary energy j demanded in country i, P_{Dij} country i's demand price for energy source j (the market's marginal valuation of consumption excluding externalities) at each quantity (Q_j), P_{ij} is the market price of energy source j in country i, Q_{Sij} the quantity of energy j produced in country i, and P_{Sij} the domestic supply price of energy source j in country i (marginal cost of its oil production excluding externalities) at each quantity (Q_j)

A. *The Cost of Gross CO_2 Abatement*

The most direct way to measure the cost of reducing CO_2 emissions is the welfare losses occurring in the energy markets that results from altering energy consumption to reduce emissions. Assuming no other distortions in domestic energy markets and no significant international trade in non-carbon energy, we sum over the marginal effects of the emissions reduction policy on each carbon energy source to obtain the marginal cost of compliance for country i:

$$MC_i = \sum_{j=1}^{n}\left((P_{Dij} - P_{Wj})\frac{\partial Q_{Cij}}{\partial E_i} + Q_{Mij}\frac{\partial P_{Wj}}{\partial E_i}\right) \quad \textbf{(A2)}$$

In the above equation, MC_i denotes the gross marginal cost of reducing CO_2 emissions through the conservation of carbon energy sources, P_{Wj} is the world price of energy source j, Q_{Cij} the quantity of energy source j that is conserved (where $\partial Q_{Cij} = -\partial Q_{Dij}$), Q_{Mij} country i's imports of energy source j, and E_i is the reduction in country i emissions under the policy whose costs are being estimated. As equation A2 shows, the gross marginal cost of reducing emissions is the difference between the domestic and world prices of each carbon energy source (P_{Dij} - P_{ij}) weighted by the shares of each fuel conserved for a one-unit reduction in CO_2 emissions, minus (plus) the transfers obtained (lost) by reducing the price of imported (exported) carbon energy, noting that $\partial P_{Wj}/\partial E_i$ is negative.

B. *The Cost of Net CO_2 Abatement*

The net effect of the CO_2 abatement actions taken by a country's or group of countries is the quantity of their abatement minus the induced change in CO_2 emissions in the rest of the world. The change in CO_2 emissions in nonparticipating countries depends on how their consumption of fossil energy is affected by a change in world energy prices and how the conservation actions in the participating countries affect the world oil price. Therefore, the relationship between a change in participant CO_2 emissions and the net change in world CO_2 emissions can be expressed as:

$$\frac{\partial E_W}{\partial E_i} = 1 - \sum_{j=1}^{n} E_j \frac{\partial Q_{DXj}}{\partial P_{Wj}} \frac{\partial P_{Wj}}{\partial E_i} \quad \textbf{(A3)}$$

In the above equation, E_W denotes the amount by which world CO_2 emissions are reduced, E_j the

CO_2 emissions associated with consuming one unit of carbon energy *j*, and Q_{DXj} the quantity carbon energy *j* consumed by nonparticipating countries.

Following Felder and Rutherford (1993) and Brown and Huntington (1994a, 1998), equations A2 and A3 can be combined to express the marginal cost of the net world reduction in CO_2 emissions for country (or country grouping) *i*. Specifically, multiplying the marginal cost of the gross reduction in CO_2 emissions for country *i* by the net change in world CO_2 emissions resulting from country *i* reducing its CO_2 emissions yields:

$$MC_{Wi} = \sum_{j=1}^{n}\left((P_{Dij} - P_{Wj}) \frac{\partial Q_{Cij}}{\partial E_i} + Q_{Mi} \frac{\partial P_{Wj}}{\partial E_i} \right) \cdot \left(1 - \sum_{j=1}^{n} E_j \frac{\partial Q_{DXj}}{\partial P_{Wj}} \cdot \frac{\partial P_{Wj}}{\partial E_i} \right)^{-1} \qquad \textbf{(A4)}$$

In the above equation, MC_{Wi} denotes the net marginal cost to country *i* of its actions to reduce world CO_2 emissions.

As equation A4 shows, the effects that conservation of carbon energy has on the cost of energy imports and on nonparticipant consumption of carbon energy are related through the effects that conservation has on the world prices for these fuels. As cooperative conservation lowers the world prices of carbon energy, it reduces the cost of country *i* energy imports and brings about an increase in nonparticipant fossil energy consumption. If conservation has no effect on world energy prices, however, the energy-importing countries will obtain no terms-of-trade advantages through their conservation of carbon energy, and the consumption of fossil energy will not be stimulated in nonparticipating countries.

C. *The World Perspective*

From the world perspective, the cost of reducing CO_2 emissions through the conservation of carbon energy is the sum of costs borne by each country. From this perspective, net transfers cancel to zero. For every country or group of countries that obtaining transfers from reduced prices for carbon energy, another country or group of countries yields an offsetting transfer, and $M_{ij}(\partial P_{Wj}/\partial E_i)$ is exactly offset in the other countries.

Accounting for the offsetting transfers, as well as the distortion in world oil markets resulting from OPEC restraining its production of oil below free market levels, we alter equation A4 to obtain:

$$MC_W = \left(\sum_{j=1}^{n} \left((P_{Dij} - P_{Wj}) \frac{\partial Q_{Cij}}{\partial E_i} \right) + \frac{\partial Q_{Ci1}}{\partial E_i} S_{O1} (P_{W1} - C_{O1}) \right) \left(\frac{\partial E_W}{\partial E_i} \right)^{-1} \quad \text{(A5)}$$

In the above equation, MC_W denotes the net marginal cost to the world of country i's actions to reduce emissions, Q_{Ci1} the amount oil conserved, S_{O1} OPEC's share of world oil production, and C_{O1} OPEC's cost of oil production.

FIGURE 1

The Cost of U.S. Oil Conservation to Reduce CO_2 Emissions

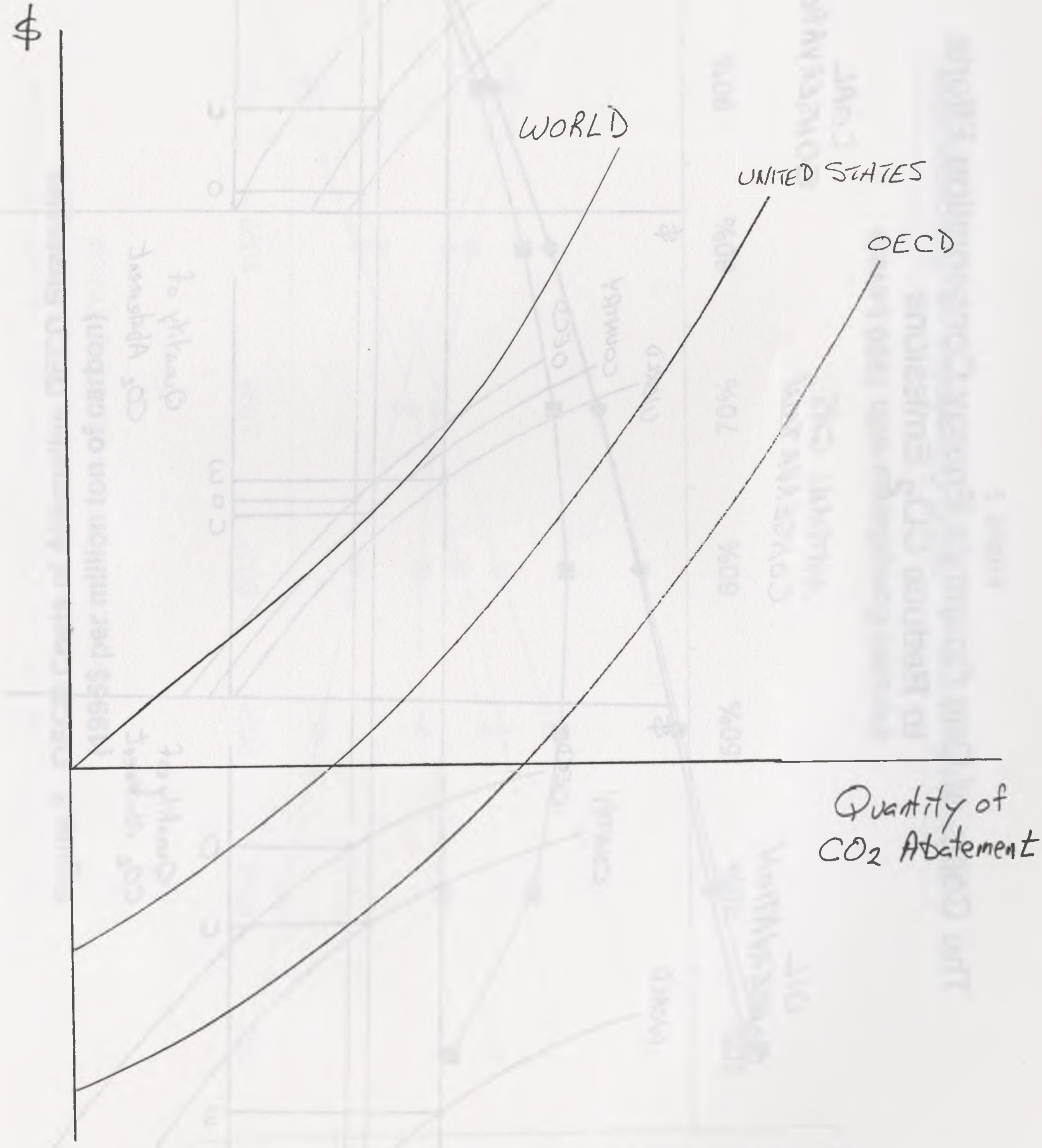

FIGURE 2

The Costs of One Country's Energy Conservation Efforts to Reduce CO_2 Emissions

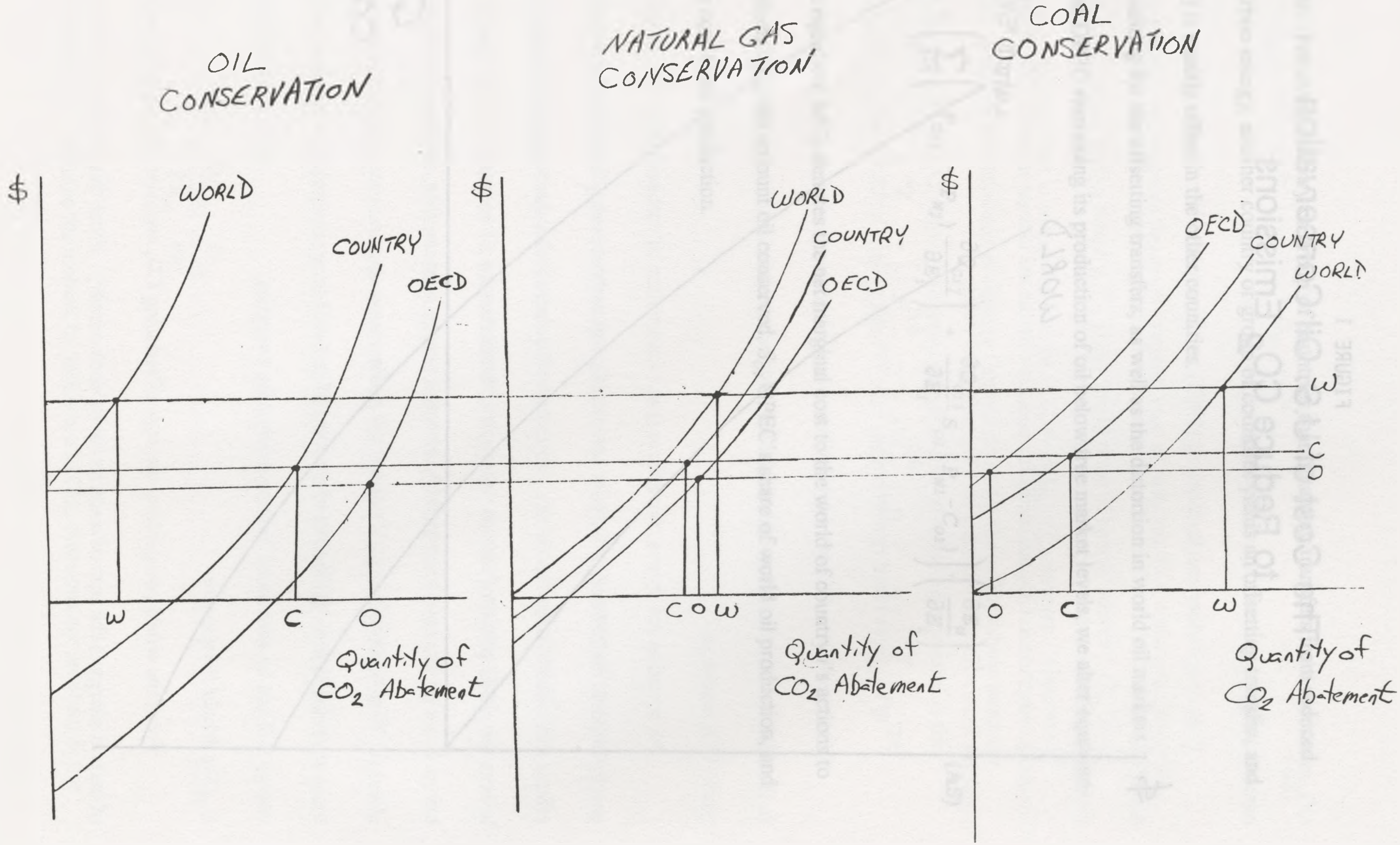

Figure 3. OECD Costs of Alternative OECD Strategies (1995$ per million ton of carbon)

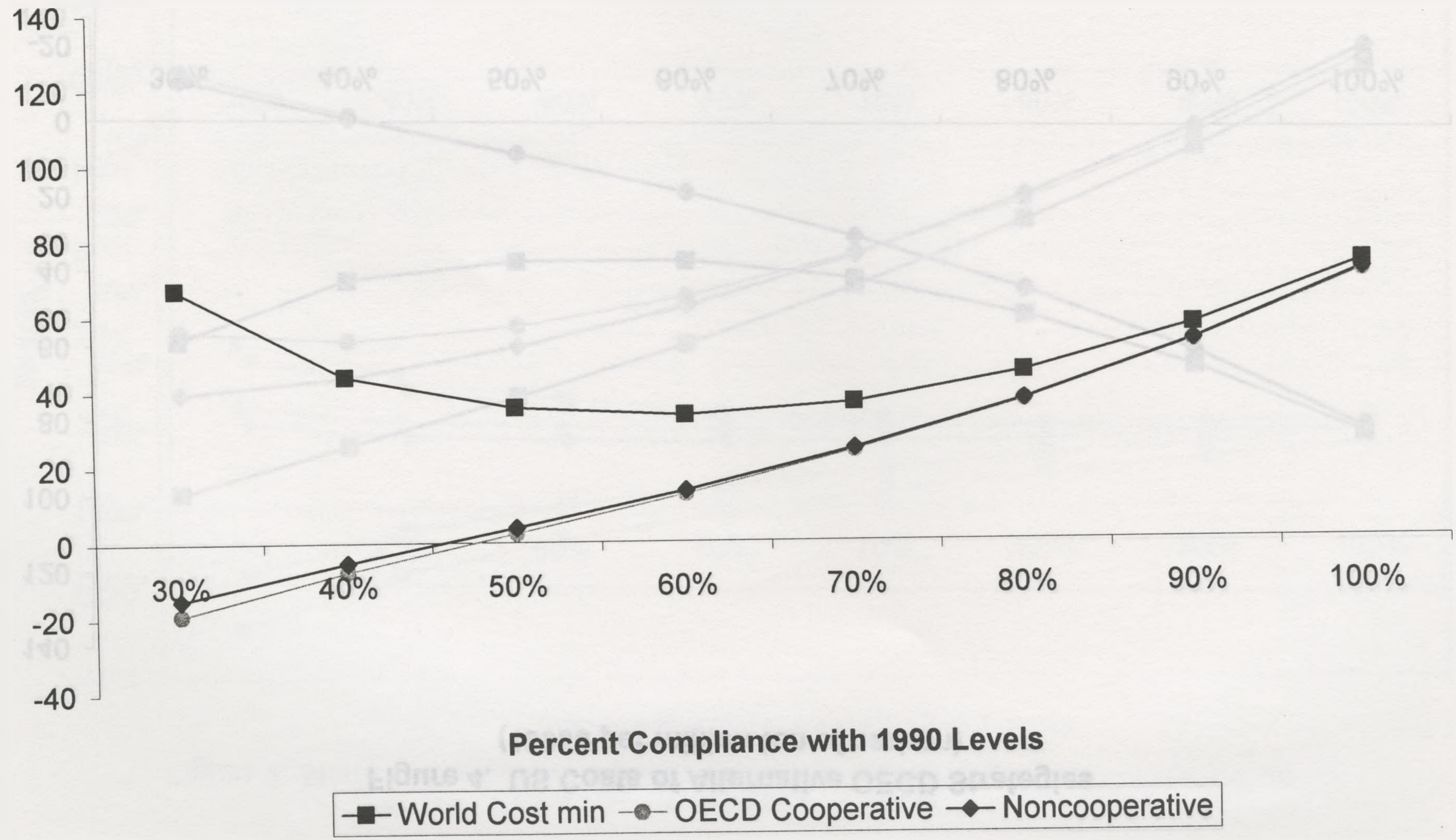

Figure 4. US Costs of Alternative OECD Strategies (1995$ per million ton of carbon)

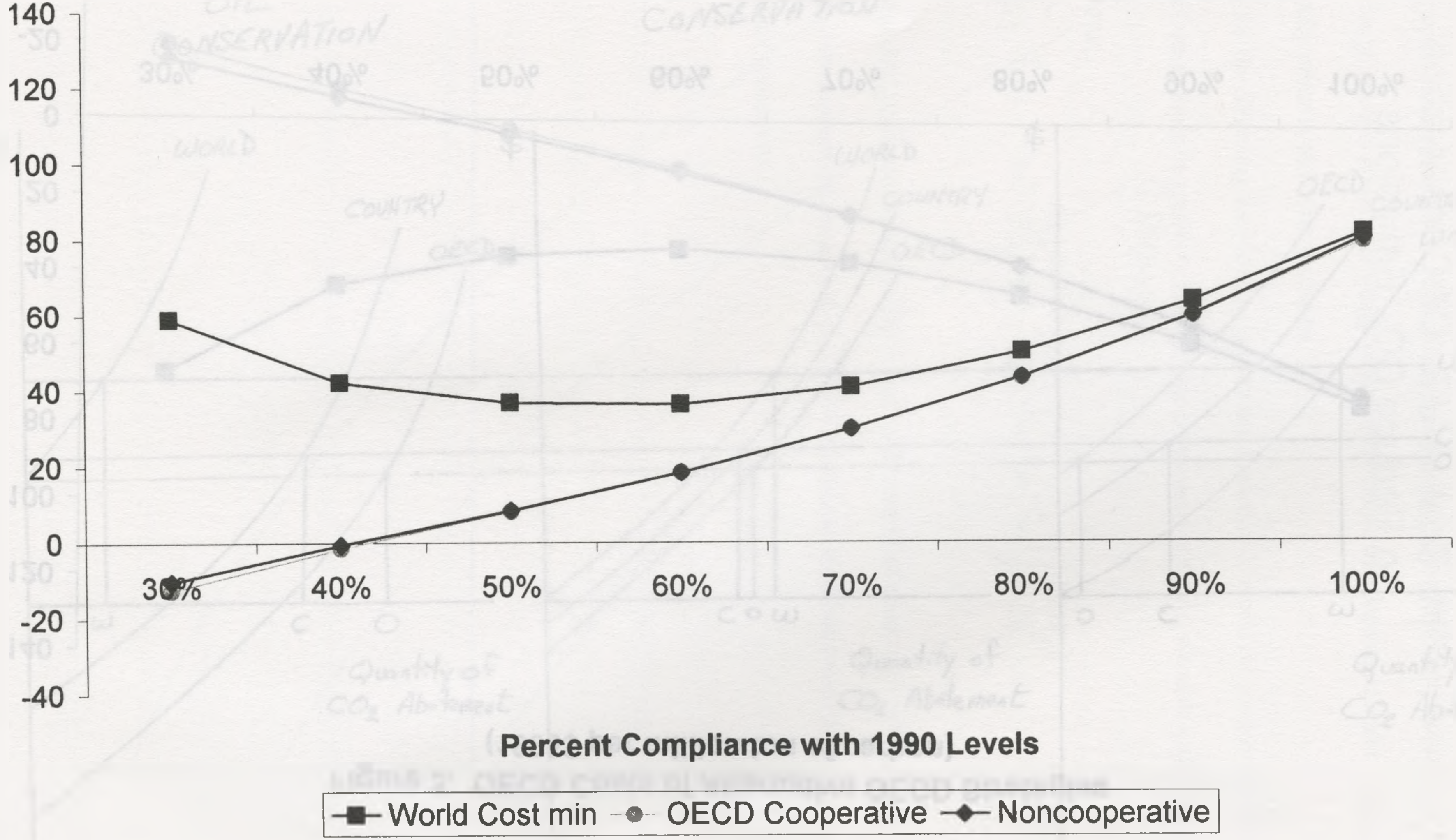

Figure 5. World Costs of Alternative OECD Strategies (1995$ per million ton of carbon)

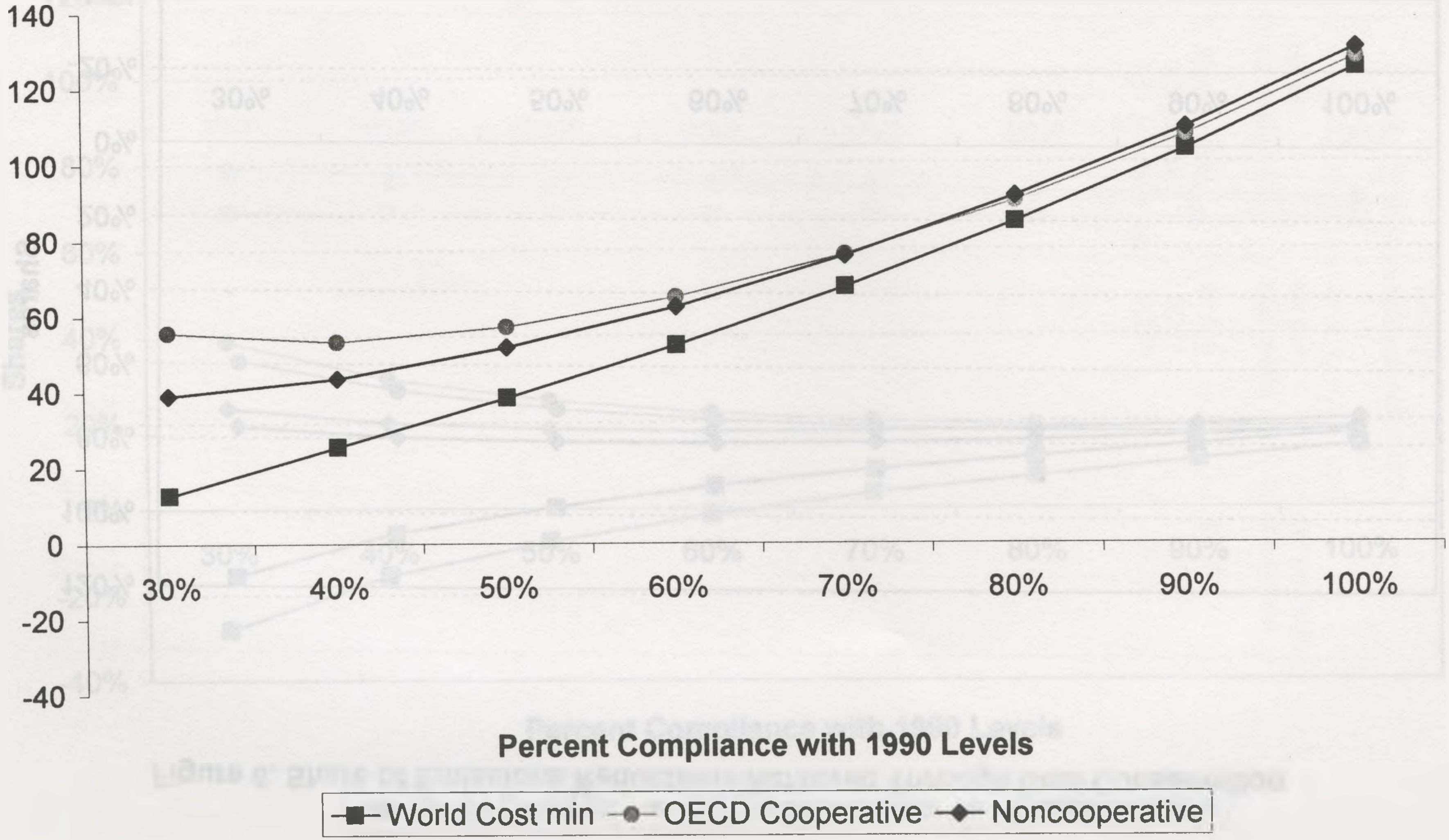

Figure 6. Share of Emissions Reductions Achieved Through Coal Conservation

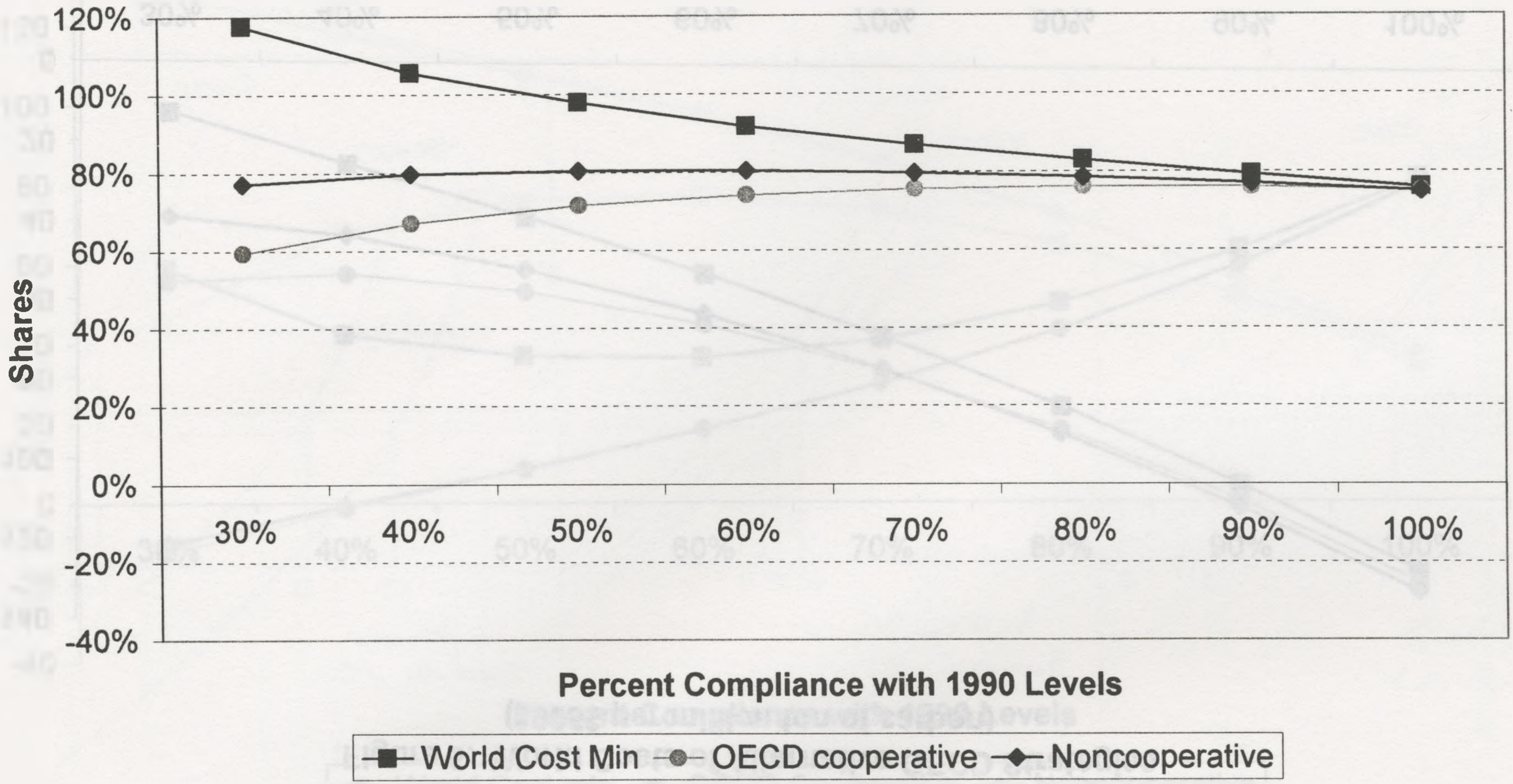

Figure 7. Share of Emission Reductions Achieved Through Oil Conservation

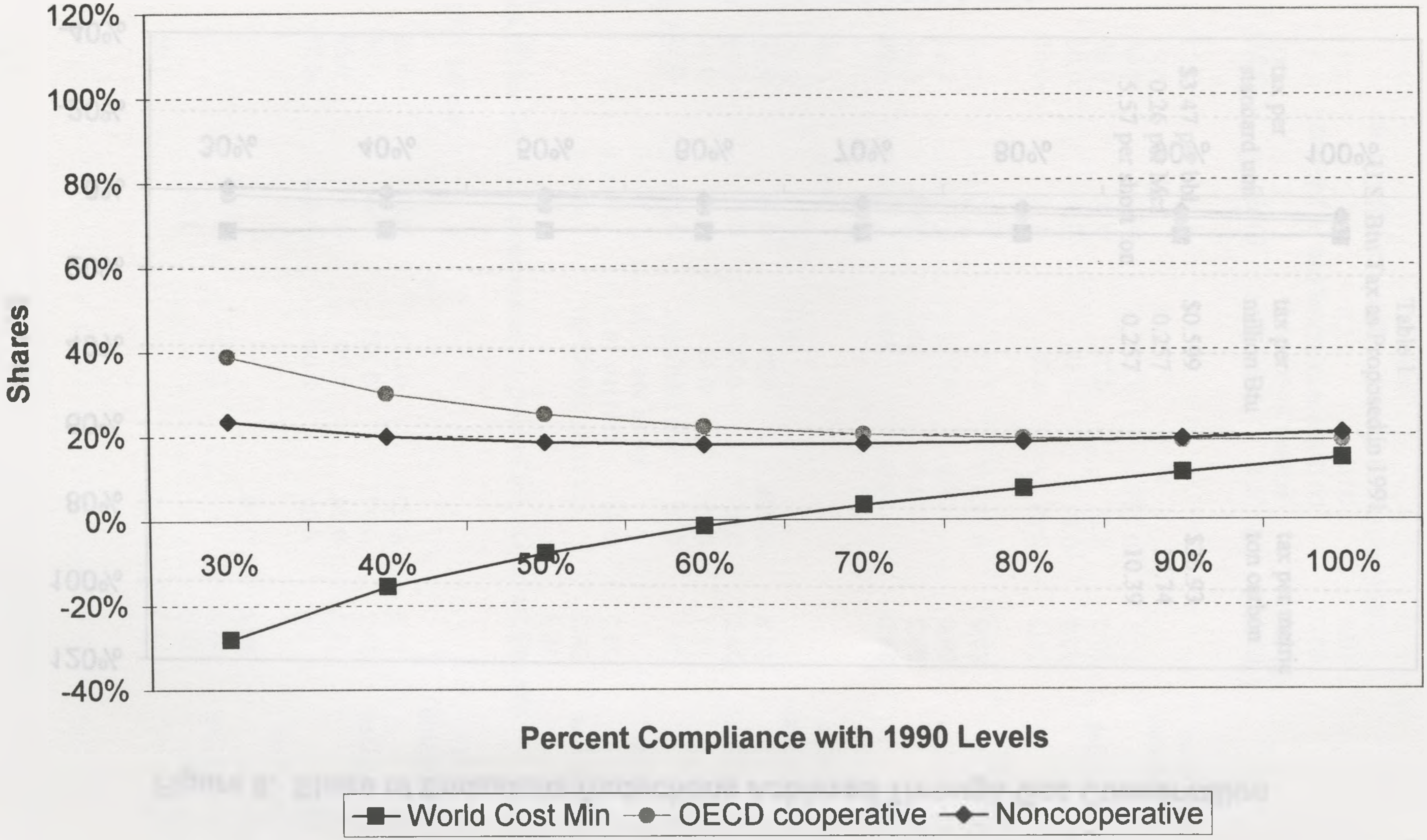

Figure 8. Share of Emissions Reductions Achieved Through Gas Conservation

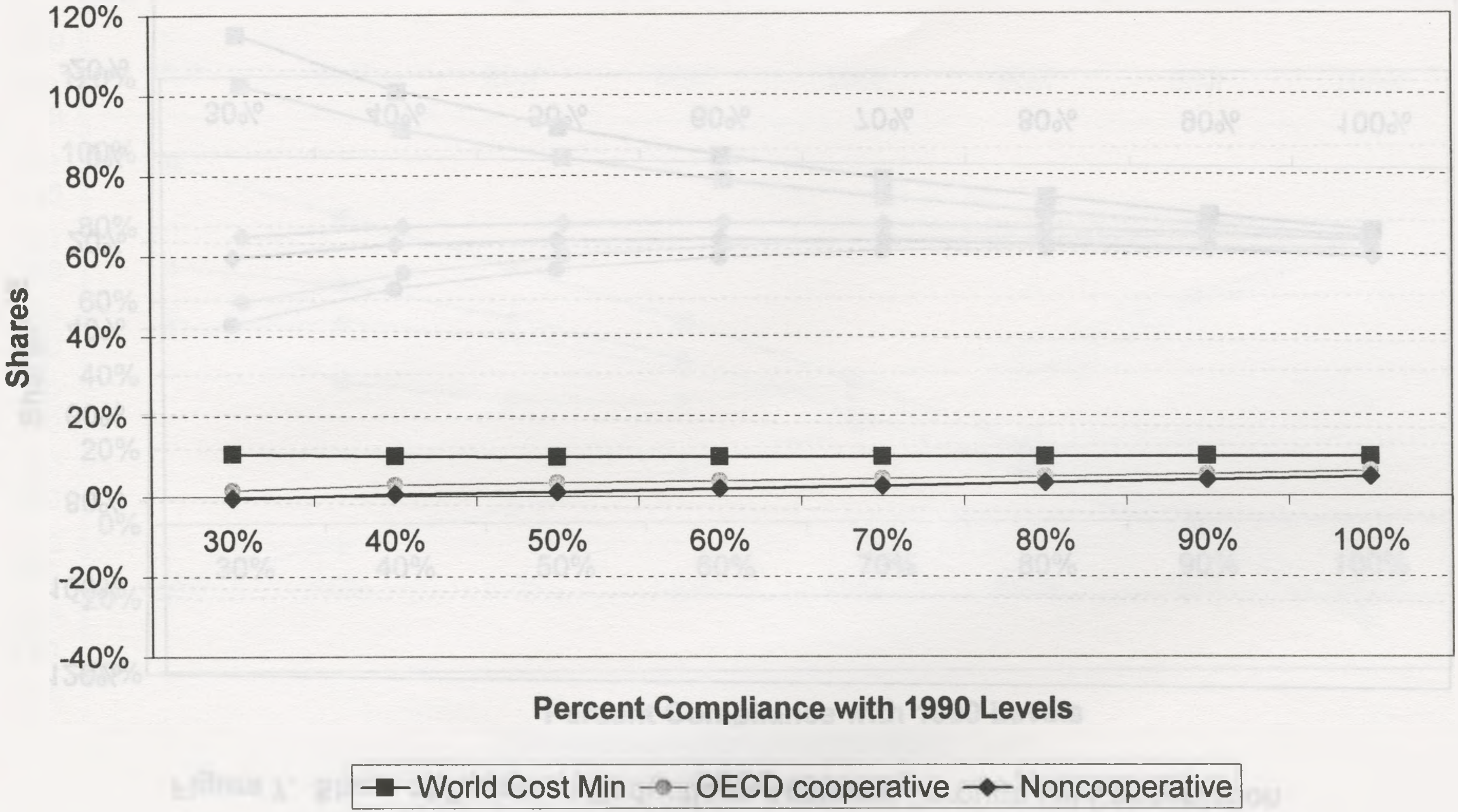

Table 1
U.S. Btu Tax as Proposed in 1991

Fuel	tax per standard unit	tax per million Btu	tax per metric ton carbon
Oil (Crude)	$3.47 per bbl	$0.599	$36.93
Natural Gas	0.26 per Mcf	0.257	17.74
Coal	5.57 per short ton	0.257	10.39

Table 2
Reference Case Quantities, Prices and Elasticities

	Quantity (10^{15}Btu)	Price elasticity of fuel on left with respect to price of Oil	Nat Gas	Coal	Other
United States					
Consumption					
Oil	42.5	-0.72	0.25	0.03	0.06
Natural Gas	29.2	0.25	-0.72	0.10	0.06
Coal	22.8	0.12	0.63	-0.96	0.06
Other	14.2	0.05	0.05	0.10	-0.50
Production					
Oil	17.9	0.51			
Natural Gas	24.9		0.51		
Coal	25.2			1.86	
Other	14.2				1.00
Other OECD					
Consumption					
Oil	58.8	-0.72	0.25	0.03	0.10
Natural Gas	34.2	0.25	-0.72	0.10	0.10
Coal	18.1	0.12	0.63	-0.96	0.10
Other	29.1	0.05	0.05	0.10	-0.50
Production					
Oil	25.7	0.43			
Natural Gas	24.2		0.43		
Coal	18.3			1.86	
Other	29.1				1.00
Ch/EE/FSU					
Consumption					
Oil	17.8	-0.225	0.075	0.01	0.05
Natural Gas	33.2	0.075	-0.225	0.04	0.05
Coal	13.1	0.04	0.20	-0.31	0.05
Other	6.5	0.02	0.04	0.04	-0.25
Production					
Oil	20.4	0.30			
Natural Gas	43.3		0.30		
Coal	14.3			1.24	
Other	6.5				1.00

OPEC					
Consumption					
Oil	11.3	-0.72	0.25	0.00	0.01
Natural Gas	5.6	0.25	-0.72	0.00	0.01
Coal	0.3	0.12	0.63	-0.96	0.10
Other	0.4	0.05	0.10	0.10	-0.50
Production					
Oil	72.6	*			
Natural Gas	5.6		0.40		
Coal	0.3			1.65	
Other	0.4				1.00
Other LDCs					
Consumption					
Oil	64.5	-0.45	0.15	0.02	0.08
Natural Gas	26.8	0.15	-0.45	0.10	0.08
Coal	68.5	0.08	0.40	-0.61	0.08
Other	17.0	0.04	0.08	0.08	-0.50
Production					
Oil	58.3	0.43			
Natural Gas	31.0		0.43		
Coal	64.7			1.86	
Other	17.0				1.00

World Reference Prices	$\$/10^6$Btu**	$/standard unit**
Oil	3.519	20.41 per barrel
Natural Gas	1.9553	2.01 per Mcf
Coal	0.7924	16.919 per short ton

*OPEC adjusts its production to maintain a constant share of the oil market. See text.

**Prices are in 1995 dollars.

Table 3. Marginal cost of an emissions reduction in a single fuel at zero compliance (1995$ per ton of carbon).

	Oil	Natural Gas	Coal
U.S.	-15.75	4.02	1.11
Other OECD	-22.81	-1.72	1.69
OECD	-19.12	1.27	1.39
World	10.20	-12.43	-0.45

Joint implementation by U.S. and other OECD countries at zero compliance.

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