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THE OUTLOOK FOR U. S. OIL DEPENDENCE

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ABSTRACT

Market share OPEC lost in defending higher prices from 1979-1985 is being steadily regained and is projected to exceed 50% by 2000. World oil markets are likely to be as vulnerable to monopoly influence as they were 20 years ago, as OPEC regains lost market share. The U.S. economy appears to be as exposed as it was in the early 1970s to losses from monopoly oil pricing. A simulated 2-year supply reduction in 2005-6 boosts OPEC revenues by roughly half a trillion dollars and costs the U.S. economy an approximately equal amount. The Strategic Petroleum Reserve appears to be of little benefit against such a determined, multi-year supply curtailment either in reducing OPEC revenues or protecting the U.S. economy. Increasing the price elasticity of oil demand and supply in the U.S. and the rest of the world, however, would be an effective strategy.

ACKNOWLEDGEMENT

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1. THE "OIL PROBLEM"

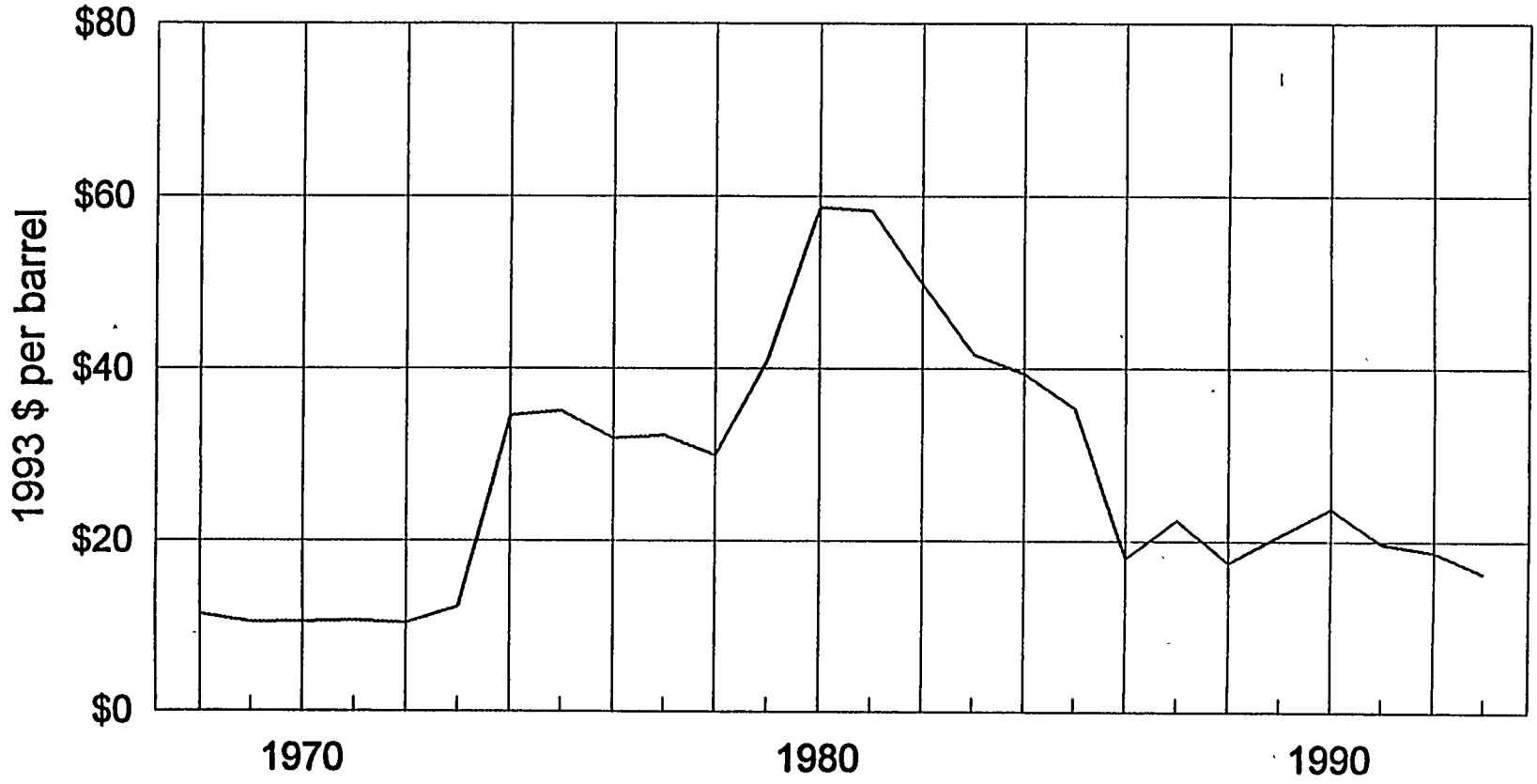
1.1 INTRODUCTION

In October 1973, the Arab members of the Organization of Petroleum Exporting Countries (OPEC) announced an oil boycott against countries that aided Israel during the "October War." From September 1973 to December 1973, they reduced their crude oil production by 4.2 MMBD. World oil prices doubled between October 1973 and January 1974 (Figure 1). Again in 1979-80 a 5.4 MMBD loss of production from Iran and Iraq, about 9% of world production, resulted in another doubling of the price of oil. In both instances, OPEC members restrained production in succeeding years, electing to keep prices at the new higher levels. From May to December of 1990, total oil output from Kuwait and Iraq fell by 4.8 MMBD, about 7.6% of world oil production. From the second to the fourth quarter of 1990, oil prices again nearly doubled, from $17.50 to $33 per barrel (1993 $).[1] This latest price shock was short-lived in comparison to the others, as Saudi Arabia put its enormous slack capacity to use, expanding production by 3 MMBD to make up most of the lost supply (Tatom, 1993, p. 138).

The cost to the United States of oil price shocks and supply manipulation by the OPEC cartel has been enormous. Recent estimates put the cumulative costs from 1972 to 1991 at over $4 trillion 1993 $ (Greene and Leiby, 1993). Monopoly pricing of oil hurt the U. S. economy in three different ways. First, by making oil scarcer, higher oil prices reduced the output the economy was capable of producing with the same resources. Second, sudden, drastic price changes further reduced domestic product because wages and prices cannot

[1]Prices in this paper are 1993 dollars, except where indicated otherwise.

Figure 1. Crude Oil Prices, 1968-1993
Refiner Acquistion Costs of Imported Crude Oil



U.S. Dept. of Energy, Annual Energy Review 1993, table 5.20.

adjust quickly enough to maintain full employment of the factors of production. Thus, in the short-term, the economy could not even attain the lower long-run potential gross domestic product (GDP). Finally, monopoly pricing transfers the wealth of U. S. citizens to the owners of foreign oil in the form of monopoly rents. Each one of these was a major component of the $4 trillion loss the economy suffered over the past two decades.

But will this ever happen again? Today oil supplies are abundant. Oil prices are relatively low and OPEC appears to be in disarray. Is the oil problem over? That is the question this paper addresses. It begins by considering the nature of the oil market and the factors that allow OPEC to wield monopoly power. Oil resources, according to our best estimates, are as concentrated as ever in the Persian Gulf and in the OPEC nations. With the rest of the world (ROW) drawing down its reserves at nearly twice the rate at which OPEC is using its reserves, OPEC's share of world oil supply must rise, and that is exactly what is happening. With an increase in market share comes a greater ability to raise prices. Fundamental economics ordains that the potential market power of the OPEC cartel depends on its market share, the ability of consumers to reduce oil use in response to higher prices, and the ability of ROW producers to expand oil supply in response to a reduction by the cartel. Not only is OPEC's market share rising toward its historic high point, but recent studies (cited below) provide no evidence of increases in the price elasticities of world oil supply and demand. Greater market share and continuing world dependence on OPEC oil will give the cartel the opportunity to raise oil prices. The chance to gain enormous wealth will give them the motive. In a public speech in March of 1993, Francisco R. Parra, former Secretary General of OPEC and senior executive of Petroleos de Venezuela made it clear that he understood both.

> "To most observers, it seems obvious that the individual and collective interests of OPEC member countries would be well served by a speedy and substantial increase in the price of crude oil - say, to $25 - to be followed over a period of time by a series of smaller ones to at least keep pace with inflation."

"It also seems obvious that OPEC has the collective power to achieve such an increase in prices. Why not do so?"

"The prize is $5 billion per month." (Parra, 1994, pp. 18-19, p. 23.)

Next, the factors that determine the impact of oil price increases on the U. S. economy are examined. Unfortunately, it appears that future oil price shocks would be just as harmful to the U. S. economy as those of the past. Recent studies reaffirm that oil price increases cause gross national product (GNP) to fall and prices to rise (e.g., Moosa, 1993) and suggest no significant differences between the impacts on the U. S. economy of the 1990 price shock and those of 1973-74 and 1979-80 (Tatom, 1993; Mork, Olsen and Mysen, 1994). The reason is that little of fundamental importance has changed. The cost of oil as a percent of U. S. GNP, a key determinant of the macroeconomic impact of a price shock, was 1.5% in 1973. It was 1.5% in 1992, as well. Oil imports, the other key determinant of the loss of U. S. wealth during a price shock, supplied 35% of U. S. oil use in 1973 and peaked at 46% in 1977. U. S. petroleum imports were 44% in 1993 and averaged 46% through the first 10 months of 1994 (U. S. DOE/EIA, 1995a, table 1.8). Of course, the U. S. now has the strategic petroleum reserve, 592 million barrels of oil to be drawn on in a supply emergency. The real issue for world oil prices is total world stocks, however. In 1973 petroleum stocks held by Organization for Economic Cooperation and Development (OECD) countries amounted to 2.6 billion barrels, about 44 days of total world consumption. At the end of September 1994, OECD stocks totaled 3.7 billion barrels, equal to to 57 days of world oil use. Government-owned reserves accounted for nearly all of the increase, totaling 919 million barrels or 14 days additional supply (U. S. DOE/EIA, 1995c, tables 1.1c, 1.3 and 1.6). If used properly the additional reserves will help, but are unlikely to prevent a determined supply reduction by OPEC nor protect the U. S. economy from its effects.

Finally, the potential future costs of monopolistic oil supply and supply curtailments are explored using a simple simulation model. Beginning with a U. S. Department of Energy forecast as a Base Case, a two-year supply reduction comparable in size to those of the past,

is simulated. Such a supply cutback, beginning in 2005, is likely to cost the U. S. economy half a trillion dollars. The Strategic Petroleum Reserve, indeed, the strategic stocks of all OECD countries combined, appear to be an ineffective defense against such a supply reduction. Increasing the short- and long-run elasticities of oil demand and supply by 50% to 100% on the other hand would be an effective strategy. This, however, would require major advances in the technology of transportation energy use and liquid fuels supply.

1.2 IS THE WORLD "RUNNING OUT OF OIL"?

The answer to this question seems patently obvious: Yes, the world's oil resources are ultimately finite and subject, eventually, to being exhausted. But we are interested in a different question: is the economic theory of exhaustible resources the appropriate theoretical context for analyzing the world oil market today? Interestingly, the answer to this question turns out to be no. Leading oil market economists have concluded that the brilliant theory of depletable resources developed by Hotelling (1931) is not particularly useful to describe the world oil market, primarily because it pertains to a strictly limited, known quantity of oil. As Adelman (1990, p. 9) has pointed out over and over again,

> "Oil reserves are not a one-time stock to be used up, but an inventory, always being consumed and replenished by investment, in new and especially in old fields."

The basic result of the Hotelling analysis is that in the long run the net price of oil (price minus marginal extraction costs) will rise steadily at the rate of interest.

Despite several noteworthy efforts to modify the Hotelling model to capture the reality of the world oil market (e.g., Stiglitz, 1976; Gilbert, 1978; Alsmiller, et al., 1985; Marshalla and Nesbitt, 1986), it remains an unrealistic representation of the nature of oil resources

(Watkins, 1992; Banks, 1986). Mabro (1992, p. 3), has fingered perhaps the most critical issue.

> "The geophysical limits may bite one day, but this day of reckoning is so far ahead as to have, on any conceivable assumption about discount rates, no impact on price."

This view has been echoed most recently by Gordon (1994, p. 4) who points out that in most cases resource exhaustion is not a pressing problem either because the exhaustion costs are too low to matter or because the constraint on resources is nonbinding.

History is very instructive with respect to false fears about resource depletion. Yergin (1991, pp. 51-52) described the situation facing the Standard Oil Trust in the early 1880s.

> "There was always the fear that the oil would run out. ...And who knew when? Could the industry survive even another decade?...Various experts cautioned that the Oil Regions would soon be depleted. In 1885, the State Geologist of Pennsylvania warned that 'the amazing exhibition of oil' was only 'a temporary and vanishing phenomenon--one which young men will live to see come to its natural end."

Adelman (1989, p. 19) made the following acerbic observation about U.S. reserves in the second half of the twentieth century.

> "No area in the world is as drilled-up today as this country was (excluding Alaska) in 1945; 'Remaining recoverable reserves' were 20 billion barrels. In the next 42 years, the 'lower 48' produced not 20 but 100 billion, and had 20 billion left. Equally important, there was no increase in real cost before 1973;"
>
> "Was this 100-billion barrels-plus, and stable costs, a miracle, like Moses striking the desert rock to get water? Hardly. The lesson is that oil reserves are not a fixed stock to be allocated over time, but an inventory, constantly consumed and replenished by investment."

Considering the reserves of the OPEC countries, one finds that putative "exhaustion dates" are so far in the future that it is hard to conceive how they could be relevant to OPEC pricing policy. At 1992 production rates, the proved reserves of Saudi Arabia would last 85 years, those of Kuwait 250 years, the U.A.E's 115 years, Iraq 135, Iran 75, and Lybia 40 years, according to *Oil and Gas Journal* estimates. Discounted at any reasonable market rate of interest, dollars 100 years from now are not worth much in comparison with dollars today.

Furthermore, Middle East OPEC countries can expand their reserves with little effort. Finding costs which, in non-OPEC areas are usually a significant component of production costs (Adelman, 1986b), in the Middle East are trivially low, as the Deputy Secretary General of OPEC has noted (Al-Chalabi, 1988c, p. 231).

> "Thirdly, the cost of finding a new barrel of oil in the Middle East is so low as to be an economically irrelevant factor, compared with the cost of finding one barrel outside OPEC. It is estimated that the cost of finding one barrel in the non-OPEC area is generally between $5 and $8, whereas in the Middle East is always less than $1 and could be as low as 10-20 cents." (1988 dollars, one assumes)

If oil is not an "exhaustible resource" then a much simpler model of world supply and demand can be used to understand the world oil market. Furthermore, there is no imperative that oil prices rise over time in a competitive market. This point is crucial because if it is not the inexorable economics of exhausting the world's oil resources that causes world oil prices to rise then it must be something else, and that something else turns out to be the exercise of monopoly power.

1.3 THE DISTRIBUTION OF WORLD OIL RESOURCES

By accident of geological history, the majority of the world's oil reserves are concentrated within the borders of a relatively few nations. The member states of OPEC hold the lion's

share of world oil resources by any measure. The *Oil and Gas Journal* estimates that OPEC countries contained 77% of the world's 996 billion barrels of proved reserves of crude oil. *World Oil*, which puts reserves in the former USSR 130 billion barrels higher has OPEC's share at 66% of 1,092 billion barrels (U. S. DOE/EIA, 1994c, table 36). Although there is no standard international definition of proved reserves, these estimates generally reflect crude oil resources that have been discovered and are economically and technically feasible to produce at prices similar to those prevailing in recent history. Certainly there are more petroleum resources in the world than reflected in the proved reserves estimates.[2]

Best estimates of the world's ultimately recoverable petroleum resources, discovered and yet to be discovered, however, also show OPEC dominance. The U. S. Geological Survey's world petroleum assessment puts "World Ultimate Resources" of oil at 2.3 trillion barrels, of which about 0.7 trillion barrels have already been produced. This leaves 1.6 trillion to be recovered, 60% more than reflected in proven reserves (Masters, Attanasi, and Root, 1994). Of the estimated remaining ultimate resources, OPEC countries hold just over 55% and the U.S. just under 6%.[3] At present, OPEC nations are producing at a rate of about 1% of their ultimate resources per year. The rest of the world, however, is drawing down their resources at an average rate of 1.9% per year. The trend is clear: an increasing OPEC share of world oil resources and of world oil production.

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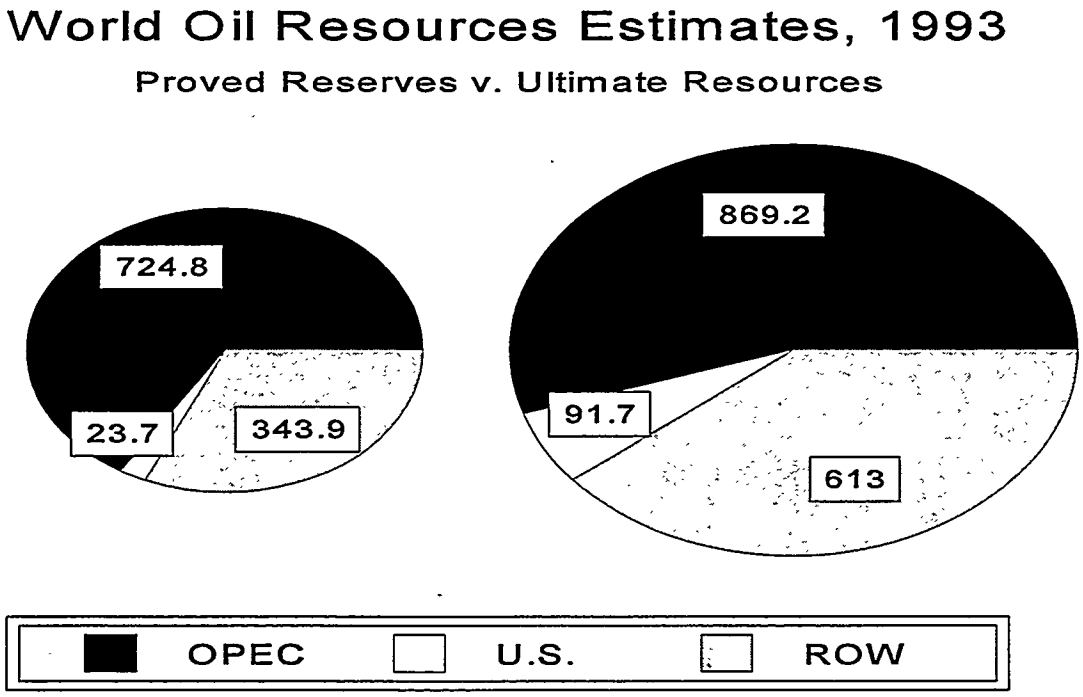
[2]Although acknowledging some uncertainy in their estimates, petroleum geologists seem confident in their general level. "We believe that, worldwide, recoverable conventional oil and gas exist in ultimate quantities approximating 2300 billion barrels (370 Gm^3) of oil and 12000 trillion cubic feet (340 Tm^3) of gas. These values are limited by our concepts of world petroleum geology and our understanding of specific basins; nonetheless, continued expansion of exploration activity, around the world, has resulted in only minimal adjustments to our quantitative understanding of ultimate resources." (Masters, Attanasi, and Root, 1994)

[3]The most recent U.S. Geological Survey (1995) assessment of technically recoverable resources puts the total slightly higher, at 112.6 billion barrels up from 91.7 billion barrels. Although a significant change for the U.S., this is only about 1% of the total world estimates.

Figure 2.



Source: U. S. DOE/EIA, 1994 c, Table 36; Masters, Attanasi, and Root, 1994, Table 1

Although world petroleum resources are ultimately finite, the world is not imminently "running out of oil" (Gordon, 1994). At 1992 consumption rates, the 1.6 trillion barrels of ultimate resources would last 65 years. There are, in addition, vast unconventional oil resources in the form of extra heavy oils, tar sands, and oil shale. Extra heavy oil deposits in the Orinoco province of Venezuela and tar sands in Western Canada together are judged to be equivalent to 0.6 trillion barrels of crude oil, roughly the proved reserves of the entire Middle East. These two deposits alone would add another 25 years at current consumption rates. Difficulty of recovery and processing, and adverse environmental impacts will increase the cost of these resources, however. The problem is not one of "running out of oil," it is rather a problem of the costs and environmental impacts of oil use.

1.4 THE INELASTICITY OF WORLD OIL SUPPLY AND DEMAND

After the concentration of resources within the boundaries of a few countries, the most important fact about the world oil market is the inability of supply and demand to respond quickly to shocks. Put another way, the short-run elasticities of oil demand and supply are very small relative to their long-run elasticity. The evidence is very consistent on this point: long-run oil market elasticities are about ten times greater than short-run elasticities (Table 1, below; Huntington, 1991, table 4; 1994, appendix; Greene, 1991, table 1). It is difficult to overemphasize the importance of this for understanding the operations of the oil market and the role of the OPEC cartel in it. It explains why prices can double or triple as a result of very small changes in supply. It explains why monopoly pricing of oil can yield enormous profits for several years, but only at the expense of market share and the erosion of monopoly influence (Adelman, 1986c, p. 325). It explains why the most profitable strategy for the OPEC oil cartel is a series of price shocks sandwiched between years of lower prices (Suranovic, 1994). There is a relatively high degree of consensus on this point in the literature and recent studies show the same magnitudes for price elasticities as older studies.

The most comprehensive assessments of oil market supply and demand elasticities have been conducted by the Energy Modeling Forum (Huntington, 1991; 1993). These provide a consensus that the short-run elasticity of oil demand is less (in absolute value) than -0.1, and that the long-run elasticity is less than -1.0.[4] At an oil price of approximately $30/bbl., short-run price elasticities of demand in Huntington's 1993 study of nine major world oil models, range from -0.027 to -0.115, with a mean and median of -0.075. Long-run price elasticities of demand ranged from -0.157 to -2.544, with a mean of -0.562 and median of -0.437. Gately and Rappoport (1988) estimated a U.S. oil price elasticity of demand of -0.07 for one year and -0.38 over a ten-year period. In a recent simulation study, Huntington (1994) used short- and long-run elasticities of -0.06 and -0.6, respectively to represent both OECD and

[4]Throughout this paper, short-run applies to a period of one year.

non-OECD countries. Suranovic (1994) reports short-run price elasticities of -0.09 for the U.S., -0.06 for Japan and Europe, and -0.02 for the rest of the world outside of OPEC. A more recent study by Gately (1992) produced a short-run U.S. price elasticity of -0.066, while the short-run elasticity in developing economies was -0.01.

Oil supply is also very inelastic in the short-run. In Huntington's (1994) recent simulation analysis he chose supply elasticities of 0.04 and 0.4 for short- and long-run responses to represent both OECD and non-OECD supply. Suranovic (1994) reports values of 0.05 for U.S. short-run supply elasticity, 0.01 for Canada and Europe, and 0.05 for the rest of the world outside of OPEC. A previous assessment by Huntington (1991) of supply elasticities in eleven world oil models found average short-run elasticities of 0.05 for the U.S., 0.05 for the OECD, 0.03 for total non-OPEC world oil supply. The corresponding long-run elasticities were 0.39, 0.43, and 0.40. Again, these were calculated at oil prices in the vicinity of $30 per barrel. Al-Sahlawi (1989) reports an estimated supply elasticity for major non-OPEC producers of 0.03 for the short run and 0.60 for the long run.

These patterns of oil price responsiveness give the OPEC cartel enormous scope to influence oil prices in the short-run, but far more limited monopoly power over the longer term. This fact is crucial to understanding the past and possible future of the world oil market.

1.5 THE MONOPOLY POWER OF OPEC

The fact that OPEC, or at least a core group within OPEC, has acted as a monopolistic cartel in the past is widely accepted by oil market economists. The process by which from OPEC's inception in 1960 the member countries wrested control and ownership of their oil resources from foreign concession holders has been chronicled by Yergin (1991, Chs. 22-29). This together with the tightening of the world oil market in the early 1970s set the stage for the dramatic exercise of OPEC market power in the first oil price shock of 1973-74, when an

Arab OPEC cutback of 5 million barrels per day produced a net supply shortfall of 4.4 million barrels per day (Yergin, 1991, p. 614) and a tripling of the real price of oil.

Although OPEC does not control the entire world oil supply, it still has considerable monopoly power. In reality, absolute monopolies are rare. Even the Standard Oil monopoly at its peak in 1880 controlled 90%, not 100%, of U.S. refinery capacity (Yergin, 1991, p. 95). An additional complication is that OPEC is not a single entity but a cartel of sovereign states.[5] Technically, OPEC is an imperfect monopolistic cartel of the von Stackelberg type (Mabro, 1992). A von Stackelberg monopoly holds a large enough market share to influence prices, but its monopoly influence is limited by a nontrivial amount of competitive supply. Dr. Fadihl J. Al-Chalabi, Deputy Secretary General of OPEC described OPEC's role in just this way (Al-Chalabi, 1988b, p. 115).

> "As the only structured group of sellers in the world energy trade, OPEC can take pricing and production decisions which have a far-reaching impact on the world energy market. Other energy sellers are scattered in separate entities, with no common, coordinated policy action other than the objective of securing and maintaining a market share at a price high enough to allow them to continue investing in the industry."

This is as precise a definition of a von Stackelberg cartel as one could ask for.

OPEC looks like a cartel and talks like a cartel, but does it act like a cartel? Empirical studies by Dahl and Yücel (1991), Jones (1990), and Griffin (1985) have rejected the hypothesis that OPEC's behavior is consistent with that of competitive producers. Griffin clearly and concisely summarized the results of his empirical analysis (1985, p. 962).

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[5]Webster's Ninth New Collegiate Dictionary defines a cartel as, " **2** : a combination of independent commercial or industrial enterprises designed to limit competition or fix prices." Substitute states for commercial or industrial enterprises.

> "Perhaps the most striking aspect of the empirical tests is the clear-cut nature of the results. First, among OPEC countries, the partial market-sharing cartel model could not be rejected for all 11 countries, whereas frequent rejections are observed for the other theories. Second, in terms of the ability of the various models to explain production, the partial market-sharing cartel model dominates the competitive model. Third, in comparisons with 11 non-OPEC countries we observe the opposite tendency--the competitive model could not be rejected for 10 of the 11 non-OPEC producers."

The basis for the conclusions of these formal statistical tests is obvious from an inspection of the oil production data of OPEC core members. When real prices tripled from 1973-1975, Kuwait, Lybia, Iran, and Saudi Arabia all *decreased* rather than *increased* output. Again in the 1979-1982 period, while oil prices skyrocketed as a result of lost supply from Iran and Iraq during their bitter war, all core members consistently cut back production (Figure 3; U. S. DOE/EIA, 1994a, Table 11.5). Competitive producers would have *increased,* not *decreased,* production in response to higher prices. OPEC producers cut production in order to maintain the high price. But by cutting production, OPEC members eventually weakened their own market power, leading to a reduction of revenues.

The gradual erosion of revenues and loss of market power finally led to a collapse of the cooperation among OPEC members necessary to restrict output, and the price "collapse" (to long-run monopoly price levels) in 1986. The head of OPEC's Energy Studies Department described the process as follows.

> "Against such a background, OPEC found it increasingly difficult to stabilize the oil market, maintain strong prices and prevent a large-scale decline in its revenues, from a high of $287 bn in 1980 to $131 bn in 1985. The decrease in revenues occurred in spite of strenuous efforts to maintain prices, by continually scaling down OPEC production and the institution and maintenance of production quotas for Member Countries since April 1982." (Al-Fathi, 1990, pp. 2-3; current $, one assumes.)

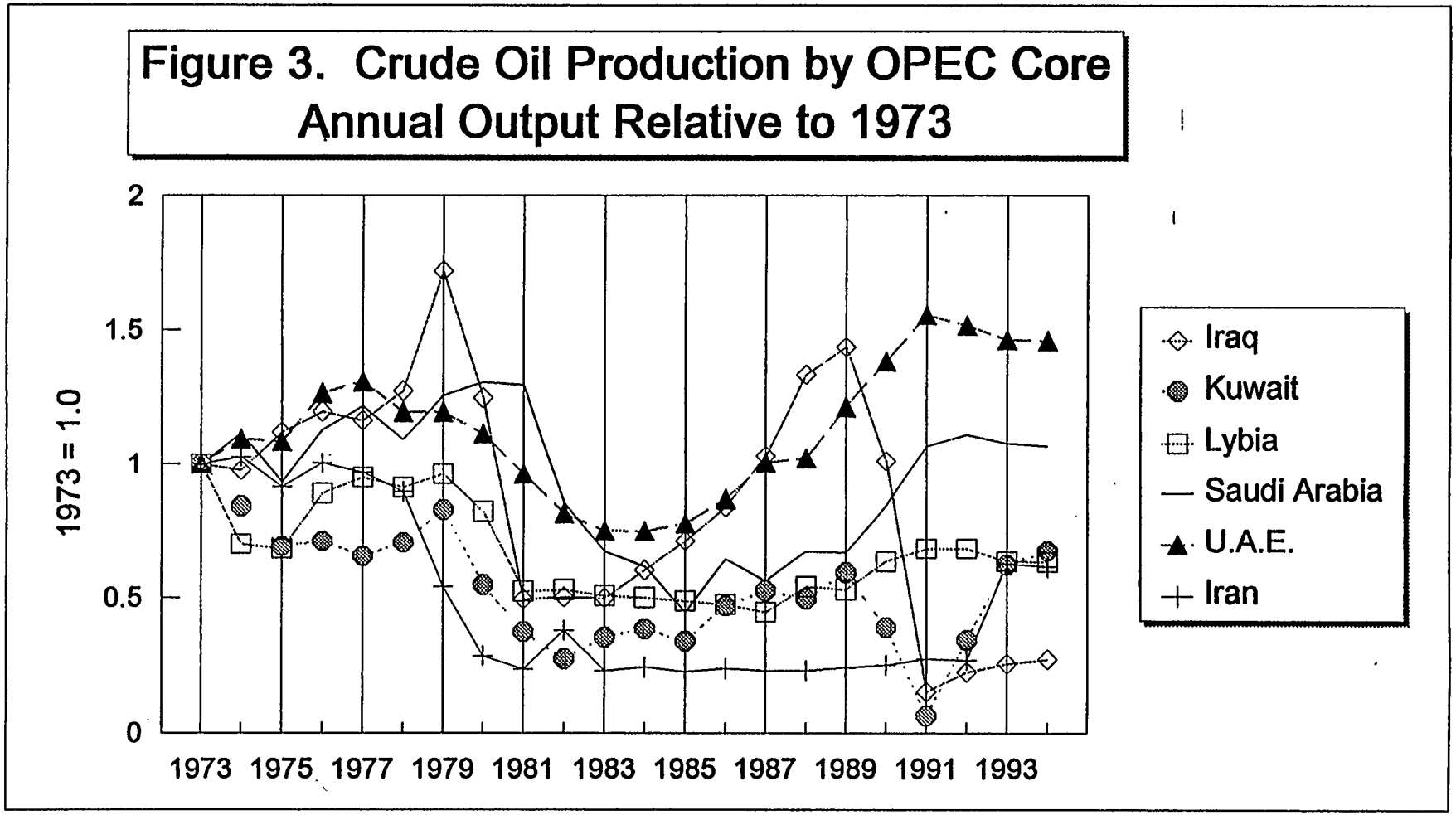


Figure 3. Crude Oil Production by OPEC Core
Annual Output Relative to 1973
1973 = 1.0
2
1.5
1
0.5
0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
Iraq
Kuwait
Lybia
Saudi Arabia
U.A.E.
Iran

Dr. Subroto, then Secretary General of OPEC offered the same view of the collapse of oil prices following OPEC's defense of high prices after the 1979-80 shock (Subroto, 1989, p. 7).

> "Since then, we have resorted to a range of agreements aimed at achieving equitable, sustainable levels of price and production in a stable operating environment. This has almost always involved our Member Countries sacrificing market share for the good of all producers and consumers. As mentioned earlier, this ultimately became too much of a burden, most notably in 1986 when the international oil price structure collapsed."

Not only has OPEC acted as a cartel, but it has earned enormous profits by so doing. Dr. Al-Chalabi, Deputy Secretary of OPEC recounted the windfalls produced by the 1979-80 and 1973-74 oil price increases (1988a, p. 5).

> "OPEC's income from oil rose from about $136 billion a year to the staggering figure of about $287 billion during the same period. This must have aggravated the economic impact of the 'first oil shock,' when OPEC's oil revenues rose from about $24 billion in 1972 to about $120 billion in 1974." (Again, one assumes current $.)

Finally, if OPEC producers were competitive, their marginal production costs should at least approximately satisfy the competitive market conditions that marginal costs of production equal the market price. Detailed and careful analyses by Adelman (1986; Adelman and Ward, 1980), have shown that this condition is not close to being satisfied. For example, in 1978 the investment needed to develop an incremental barrel of oil in the U.S. was 69 times what it was in Saudi Arabia (Adelman, 1986, p. 389 and table 1). Updating Adelman and Shahi's (1989) estimates of OPEC's finding and lifting costs for oil, Dahl and Yücel (1991) concluded that in all OPEC countries except Nigeria and Venezuela, costs were $2.20 per barrel or less (1993 $). Venezuela and Nigeria's costs were estimated to be less than $4 and Saudi Arabia's certainly less than $1 per barrel. With prices far above marginal costs, competitive producers would expand output. But OPEC members did not, and are not.

> "But there was obviously massive restraint in Saudi Arabia. The sum of marginal capital and operating cost...was about 1% of the price of $12.70." (Adelman, 1986, p. 391)

Several estimates have been made of what oil prices would be if the world oil market *were* competitive. The most recent estimate by Griffin and Vielhaber (1994) put the competitive market price at $7.25 per barrel ($6.60 per barrel in 1990 $). Other estimates include Adelman's (1989) $6.25 per barrel, Morison's (1987) range of $6.25 to $7.70 and Brown's (1987) range of $8.50 to $11.10 per barrel (all converted to 1993 $). All are obviously well below market prices since 1973.

To summarize, OPEC talks like a monopoly, acts like a monopoly and takes its monopoly profits to the bank. That OPEC has exercised and can exercise monopoly power in world oil markets means there is, *ipso facto*, a massive market failure in the world oil market. Furthermore, to correct the market failure probably requires collective action on the part of consuming nations, since the actions of individual consumers by themselves are not likely to have sufficient impact. This is important, because it implies that neither private conservation in response to higher monopoly prices nor private hedging in anticipation of future price shocks (such as should occur in futures markets) will correct the market failure.

But what of OPEC dissension and disarray? Has not the Persian Gulf War permanently poisoned relations among OPEC members? Perhaps. However, if there are hundreds of billions of dollars to be made, it would be prudent to remember Morris Adelman's admonition.

> "The rewards of monopolizing the world oil industry have been so huge that the OPEC nations will make strenuous violent efforts to maintain it. The Iran-Iraq war was a great help in a difficult decade. So is the Iraqi aggression, which has shut down two major producers. If the cartel collapses, it will reappear, perhaps with a partly different membership. Whenever they settle their differences they can cut production, and raise the price." (Adelman, 1990, p. 12)

That the OPEC cartel has exercised and can exercise monopoly power in world oil markets by cooperating to curtail production is widely accepted (see, e.g. Griffen and Vielhaber, 1994; Jones, 1990; Adelman, 1990b; Griffen, 1992; 1995; MacFadyen, 1993). Instances of cheating are literally exceptions that prove the rule. As owner of two-thirds of the world's proven reserves and supplier of half of the world market, OPEC's potential to use market power is rarely disputed. Those who argue that OPEC has not been effective in using its potential monopoly power in the past (e.g., Bohi and Toman, 1993) have been confused by the dynamics of monopoly power in slowly adjusting markets. Recent studies (Suranovic, 1994; Greene, 1991; Wirl, 1985) have shown that extreme price shocks are inevitably followed by the waning of monopoly influence with the loss of market share, and that loss of market share leads to lower prices. But at lower prices lost market share is recaptured in time, and monopoly influence restored.

Basic economic theory applied to the history of world oil prices proves to be very enlightening. Economic theory demonstrates that in a static market a monopolist maximizes profits by charging a price, P, that exceeds the cost of production, C, (including the normal return to capital).

$$\frac{P}{C} = \frac{1}{\left(1 + \frac{1}{\beta(P)}\right)} \qquad (1)$$

In reality, it is very rare for a monopoly to control 100% of a market. For a monopoly controlling a large share, $0 < s < 1$, of a market, things are a bit more complicated. The profit maximizing price depends on the price elasticity of demand, but it also depends on the monopolist's market share, as well as on the ability of competitors to respond to a reduction in supply by the monopolist (Greene, 1991). In equation (2) which defines the profit maximizing price for such a partial monopolist, μ is defined as the change in quantity supplied by competitors for a one unit increase in supply by the monopolist. Here, it is the

negative of the number of barrels supplied by the ROW for a one barrel-per-day reduction in supply by OPEC.

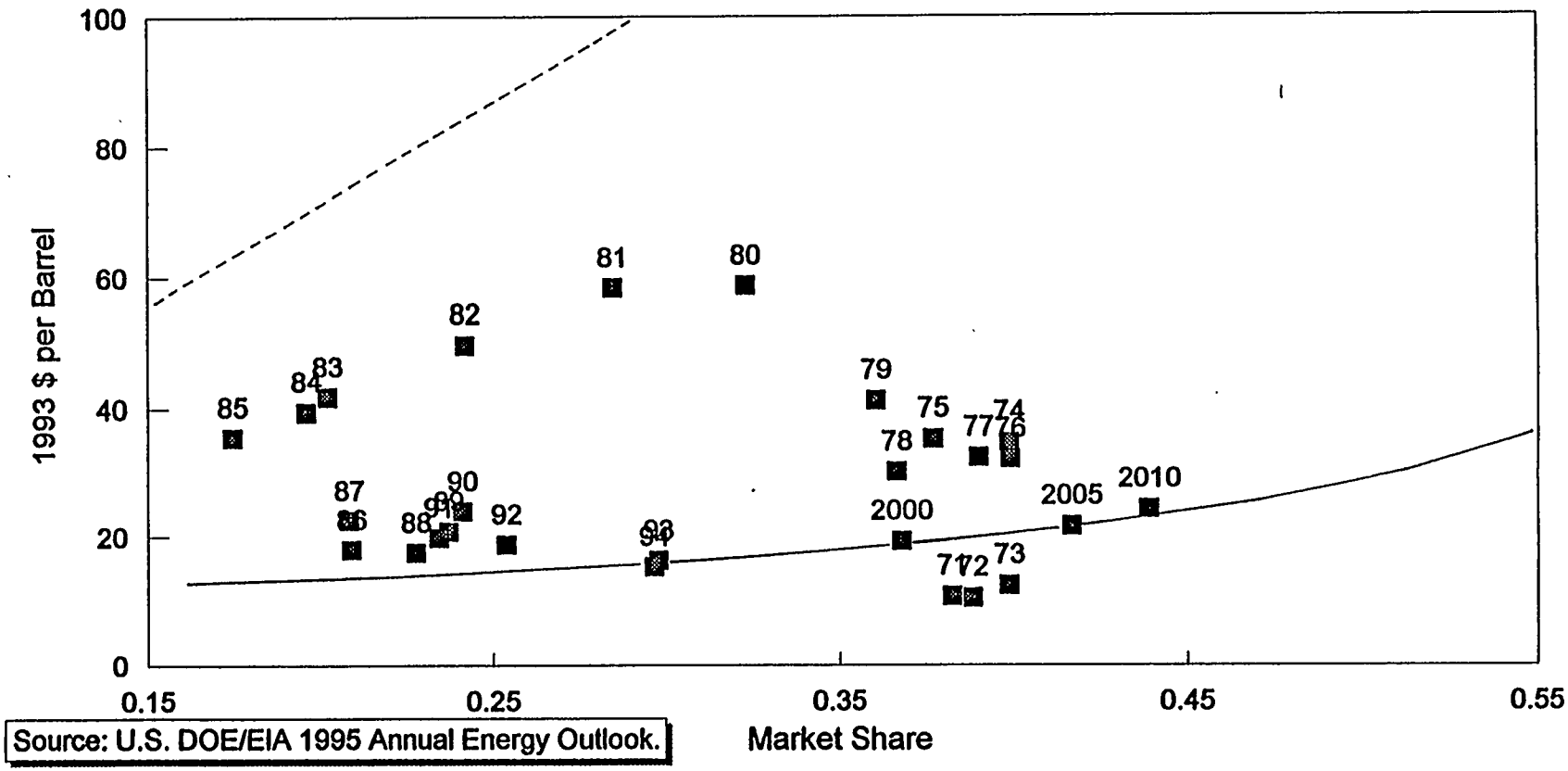
$$\frac{P}{C} = \frac{1}{1 + \left(\frac{1}{\beta(P)} \, s \, (\mu(P)+1) \right)} \tag{2}$$

This equation has several important features. Like equation (1), the larger β is, the smaller the ratio P/C. Also, the smaller the monopolistic share, s, the smaller P/C. This is very important for understanding the recent history of world oil prices. As OPEC loses market share in defending higher prices, its profit maximizing price *must* fall. Put another way, its monopoly power, defined as the ability to raise prices without loss of profit, declines. Finally, the more responsive the ROW oil supply, μ, the smaller P/C. If the ROW can meet OPEC's supply reductions barrel for barrel, *at the same price*, the cartel has no monopoly influence over prices. Supply responsiveness is a direct function of the price elasticity of supply, as one would expect (Greene, 1991).

The large difference between short-run and long-run oil market price elasticities implies that the cartel can force prices much higher in the short-run than can be maintained in the long-run (Greene, 1991; MacFadyen, 1993). In the short-run, P/C ratios may exceed 5. In the long-run they are probably less than 2. Thus, small supply shortfalls on the order of 10% or less can create enormous price shocks in the short-run, but such price levels cannot be maintained in the long-run. To maintain high prices, the cartel must sacrifice market share. But as it gives up market share it gives up the ability to maintain high prices. Ultimately prices must fall to long-run monopoly levels (or somewhat higher in a growing market).

There is no way out. Maintaining prices at short-run profit-maximizing levels requires loss of market share which eventually requires lowering prices. Retaining market share requires lowering prices. This pattern is clearly evident in the history of oil prices and OPEC market share of the 1970s and 1980s. In Figure 4 oil price is plotted against the market share of the

Figure 4. Oil Prices and Core OPEC Market Share
Historical and Projected



Source: U.S. DOE/EIA 1995 Annual Energy Outlook.

OPEC core nations: Saudi Arabia, Kuwait, Iraq, Iran, the United Arab Emirates, and Lybia. Years are identified by their last two digits. Curves representing the long-run and short-run P/C ratios as functions of the core OPEC nations' share of the world market have also been plotted. The curves have been drawn using consensus elasticity estimates based on the energy economics literature.[6] The 1972 world oil price is assumed to be the competitive price (c) for all years.

The 1972 and 1973 oil prices appear to fall below even the long-run monopoly price curve, given OPEC's market share. The price shock of the last quarter of 1973 and 1974 raised prices above the long-run curve but well below OPEC's short-run profit-maximizing price. In a growing world market, prices just above the long-run curve can be maintained indefinitely at a constant market share. This appears to be approximately what was happening from 1974 to 1978. In 1979 and 1980, spurred by the oil supply disruptions due to the Iran-Iraq War, prices rocketed towards short-run profit-maximizing levels. Sustaining these price levels in 1981, 1982, and 1983 cost OPEC dearly in market share. With profits and market share continuing to dwindle in 1984-85, the OPEC resolve cracked. Prices were lowered to approximately the long-run monopoly price level where readjusting economies and economic growth are now building OPEC market share back towards its previous level. Department of Energy forecasts of OPEC market share in 2000, 2005, and 2010 are included to illustrate the expected trends (U.S. DOE/EIA, 1995b).

Studies by Wirl (1990) and Suranovic (1994) have shown that a pricing policy of brief price shocks of two years or so in duration, separated by periods of lower prices may well be a profit maximizing strategy for OPEC. This is bad news for consuming nations since price shocks reduce GNP, tend to increase unemployment and transfer national wealth to oil producing countries.

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[6]Because short-run elasticities are so small, curves cannot be drawn based on the assumption of constant elasticities. Elasticities must be an increasing (in absolute value) function of oil price. We assume linear supply and demand equations, which satisfy this requirement, and the same parameters as Table 1 below.

1.6 IMPACTS OF MONOPOLY BEHAVIOR ON THE U. S. ECONOMY

A sudden increase in the price of oil creates three principal types of economic losses to the U. S. economy:

1. Loss of the potential to produce,
2. Macro-economic adjustment losses, and
3. Transfer of wealth from U. S. oil consumers to foreign oil exporters.

These three effects are separate and additive.

When oil prices rise, they signal the economy that a basic resource has become more scarce. As a result, the economy is able to produce less output with the same resources of capital, labor, materials, and land. The impact of this **loss of potential output or GNP**, will be greater in the short-run than in the long-run because greater substitution for oil is possible in the long-run. The implications for the economy's long-run potential to produce have been described by Tatom (1993) and many others (e,g, Pindyck, 1980; Burgess, 1984; Pakravan, 1984; etc.).

> "Oil and energy price changes affect the economy because energy resources are used to produce most goods and services. As a result, a rise in their price will (1) raise the total cost of an efficient producer's output, (2) alter the most efficient means for producing output, (3) lower the profit-maximizing level of output, (4) raise the long-run equilibrium price of output, and (5) reduce the capacity output of each firm's existing stock of capital."

In the short-run, the technology embodied in energy using capital cannot be adjusted immediately to the new price regime. It is obvious from the short-run inelasticity of oil demand that the economy's ability to quickly substitute away from oil remains very limited. Even in the long-run, oil demand appears to be inelastic. In the short-run, losses are magnified by the fact that it takes time to optimize the economy is energy-using technology

to the new scarcity of oil. How long does it take? Consider the typical life of transportation equipment: 10-15 years for an automobile, much more for a jet aircraft, locomotive, or ship. Additional time is needed to develop designs incorporating more efficient technology and bring these designs to market. Indeed, if prices fall again within a few years, the economy will never fully adjust. This short-run versus long-run potential GNP effect is distinct from macroeconomic adjustment losses.

When prices rise rapidly, additional transitory costs result because wages and prices are not able to adjust sufficiently rapidly to the new oil price regime to permit the economy to operate at full employment. **Macroeconomic adjustment losses** are in addition to the loss of productive capacity that would occur even were the economy at full employment. Because of stickiness in wages and prices, the economy is unable to immediately adjust to a sudden increase in the price of as important a commodity as oil. These cyclical losses are truly transitory, perhaps lasting only about one year (Tatom, 1993, p. 132). Their effect is to temporarily amplify the loss of output capacity.

Third, when prices are increased by monopoly behavior, there is also a **transfer of wealth** from U. S. oil consumers to the owners of foreign oil. This "loss" is a transfer payment. It is not a loss of economic output, which distinguishes it from the two economic losses described above. The wealth still exists, ownership is simply transferred from U. S. citizens to foreign oil producers. A similar transfer of wealth also takes place within the U. S. from oil consumers to owners of U. S. oil resources. Since this is internal to the U. S. we do not count it as a loss to the U. S. economy.[7] The transfer of wealth is exactly equal to the quantity of oil the U. S. imports times the difference between the monopoly price and the competitive market price of oil.

[7]Nonetheless, it is likely to be perceived as a social problem, as the Windfall Profits Tax on oil imposed during the 1970s attests.

All three effects have been recognized by economists for some time. Pindyck (1980, p. 19) estimated a 0.25% loss of U.S. potential GNP for a 10% increase in the price of oil, based on "back-of-the-envelope" calculations, and also asserted that the indirect, or macroeconomic adjustment effects would be of roughly equal magnitude. He also noted that the cost of an energy price shock depends on the energy cost share of GNP and that, in the short-run at least, it would be reasonable to assume no substitution possibilities as an approximation. Thus he assumed that the short-run elasticity of GNP with respect to an energy price shock would equal the negative of the energy cost share of GNP. Tatom (1994, p. 134) also noted the relationship between the impact of oil prices on output and the oil cost share of GNP as well as the fact that the oil cost share today is about what it was in the 1970s.

> "While energy use per unit of output is lower than earlier, economic theory indicates that the responsiveness of prices or output to a change in a resource's price are proportional to the share of the resource's cost in total cost, not to the share of its quantity in output."

Empirical estimation of the impact of oil price shocks on U.S. GNP was carried out by Mork and Hall (1980a, 1980b). In response to the 70% increase in energy prices in 1974 and additional 30% increase in 1975, they estimated that U.S. GNP fell 2.5% in 1974, about 5% in 1975 and 4.5% in 1976. They concluded that,

> "...the energy price shock appears to explain about three quarters of the recession, in terms of decline in real output in 1974 and 1975, and most of its shortfall thereafter." (Mork and Hall, 1980a, p. 45).

Findings by Mork and Hall (1980b) for the 1979-80 price shock were similar: a 1% decrease in GNP in 1979 and a 4% decrease in 1980.

Hickman (1987) used fourteen major macroeconomic models to estimate the impact of a 50% oil price shock, occurring in 1984, on U.S. GNP. He found short-run responses ranging from -0.010 to -0.047, with an average of -0.028. This would imply an average elasticity of

twice that amount, or -0.056, very much in line with both theory and statistical evidence. The oil cost share of U.S. GNP in 1984 was 0.044, which would imply an elasticity for lost output in 1984 of -0.044, leaving -0.012 as the macroeconomic adjustment cost component for that year. Using a small model of the world oil market, Helkie (1991) simulated the impacts of past price disruptions and concluded that an estimate of the elasticity of GNP with respect to oil price of about -0.03 replicated past events well.

Bohi (1989, Ch. 3) claimed to show that a theoretical upper bound on the impact of an energy price shock on potential GNP was so small that the empirical and model-based estimates cited above could not possibly be correct. He obtained a maximum impact of 0.7% in 1974 and 0.36% in 1979-80. Greene and Leiby (1993), however, showed, and Bohi has acknowledged, that these results were due to an error in his calculations, and that the correct answers were 5% for 1974 and 2.5% for 1980. These estimates, of course, are very consistent with all the published estimates from Pindyck (1980) on.

Hamilton (1983; 1985) investigated the historical relationship between oil price shocks and rejected the hypothesis that oil price shocks were statistically uncorrelated with economic recessions. He also rejected the hypothesis that other factors, including monetary policy, could have caused oil prices to rise before recessionary periods. Examining the historical events believed to be responsible for oil price shocks, he concluded that, "...we must give causal interpretation to the correlation between oil prices and output" (Hamilton, 1985, p. 115). More recently, Moosa (1993) concluded that there was a significant relationship in which oil price caused output to decline but not the reverse. He observed,

> "The results are in general hardly surprising: they are in agreement with the basic theory and confirm the conclusion derived from the informal examination of the data." (Moosa, 1993, p. 1151)

Recently, Mork, Olsen and Mysen (1994), estimated macroeconomic responses to oil price increases in seven OECD countries from 1967 to 1992. They found an elasticity of U.S.

GNP with respect to the price of oil of about -0.05 to -0.07, essentially the same as studies using only data from earlier oil price shocks. Only Norway did not show a negative impact of oil price increases on GNP. The authors concluded,

> "Overall, our results seem to leave no doubt that oil-price fluctuations must be reckoned with as a significant force in the shaping of business cycles of the leading market economies. This force must be expected to persist as long as oil remains an important energy source." (Mork, Olsen, and Mysen, 1994, p. 34)

Oil prices doubled from July to October 1990, but declined relatively quickly as Saudi Arabia and the U.A.E. boosted production to eliminate the supply shortfall caused by loss of output from Kuwait and Iraq. Taking into account the shorter length of this price shock, Tatom examined the question of whether its impact on the U.S. economy was disproportionately smaller than previous shocks. He found that it was not.

> "Thus, another lesson from the 1990-91 price changes is that the economy appears to remain exposed to oil price shocks to a nearly equivalent extent as earlier." (Tatom, 1994, p. 148)

The transfer of wealth from oil consumers to owners of foreign oil that occurs when monopoly power is exercised in world oil markets is sometimes neglected because it is not a loss of economic output, but only a transfer of ownership. The output is still produced, it is just a question of who owns what. Oil consumers get poorer, oil producers get richer. If one's concern is with the welfare of the entire world, transfer of wealth is entirely a question of equity, not economic loss. But if one's concern is with the U.S. economy, wealth transfer is a genuine loss. Wealth leaves, and if it comes back, it comes back only in exchange for more U.S. output or property.

> "An international oil shock also reduces the purchasing power of U. S. national income.

> "Even if total U. S. output remains unaltered by the oil shock, the U. S. economy would still be worse off due to the reduction in the purchasing power of its domestic income." (Huntington and Eschbach, 1987, p. 202)

Precisely the same phenomenon has been described by Hogan and Broadman (1988, p. 65). Mork, Olsen, and Mysen (1994, p. 20) also mention the transfer of wealth as a cost of oil price shocks.

That the transfer of wealth is not included in the loss of output (GNP) has been explained by Greene and Leiby (1993) and Huntington and Eschbach (1987, pp. 199-200).

> "In particular, the oil wealth loss that is central to the microeconomic analysis is excluded from real GNP as measured in macroeconomic models. This situation requires a combination of losses estimated from each approach if one wants to measure the full effects of oil price shocks on oil-importing countries."

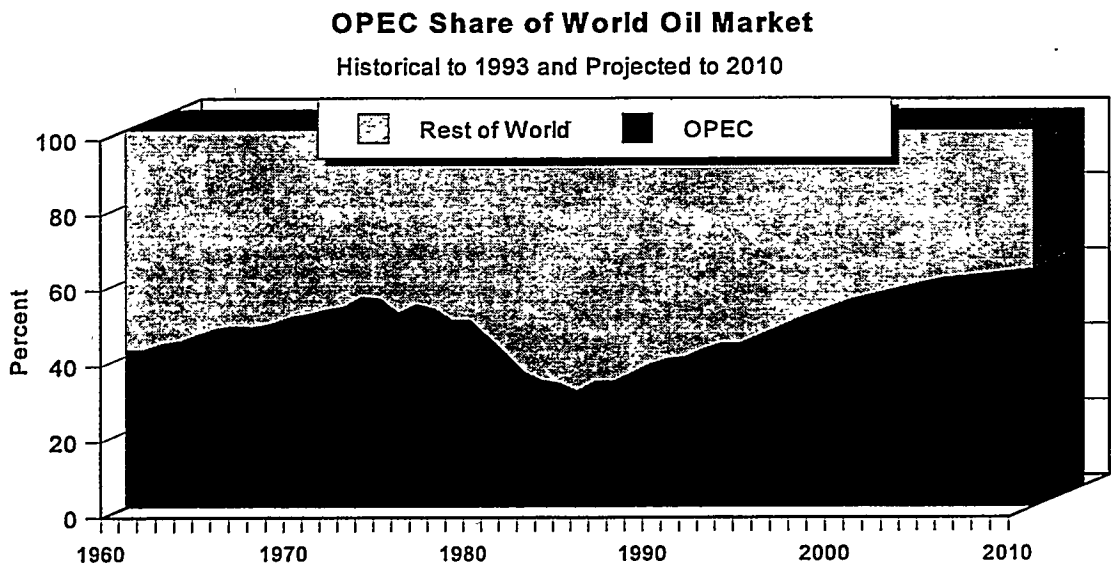
Finally, the transfer of wealth as a cost of oil dependence derives from the fact that it results from the exercise of monopoly power by oil producers. If there were no monopoly behavior in world oil markets, there would still be some transfer of wealth, in the form of rents, to low-cost oil producers. In a competitive market, this would not be counted as a cost of oil dependence to the U.S. Thus, in estimating the transfer of wealth cost in the monopolized oil market, only the cost over and above a competitive market price is counted.

1.7 THE FUNDAMENTALS HAVE CHANGED LITTLE SINCE 1973

Since 1973, the basic determinants of U.S. vulnerability to monopoly behavior in world oil markets have changed less than one might think: 1) OPEC's market share has fallen but is on the rise; 2) oil demand, now more concentrated than ever in the transport sector, remains price inelastic; 3) the oil cost-share of GNP is about what it was before the first oil price

shock; and 4) the level of U.S. imports, key determinant of the transfer of U.S. wealth, is as high as ever. OPEC's monopoly power depends on its share of low-cost world oil resources and its correspondingly large share of the world oil market, as well as from the inelasticity of short- and long-run world oil supply and demand. Market share OPEC lost defending high prices from 1980-85 is being rapidly regained. It appears that reports of OPEC's demise have, in the words of Mark Twain, been greatly exaggerated. Lost market share can and is being regained, and with it comes market power. The Energy Information Administration (U. S. DOE/EIA, 1995b) projects that by 2005, OPEC's market share is likely to exceed the levels of the 1970s (Figure 5).

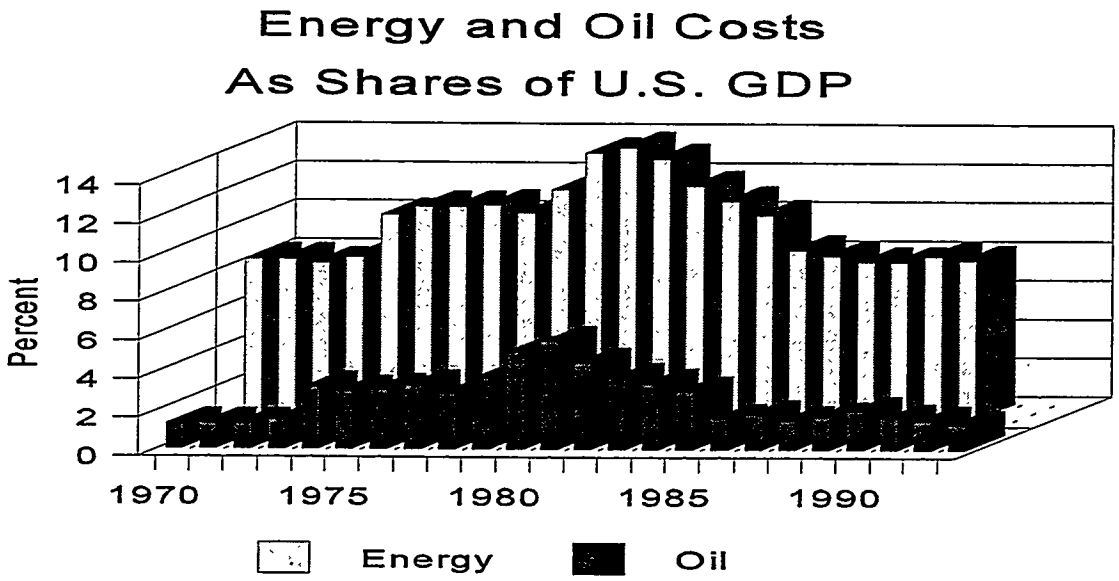
Figure 5.



Source: U. S. DOE/EIA, 1995b, Table C.20, 1994a, Table 11.5

The sensitivity of the economy to oil and energy price shocks depends on the cost shares of oil and energy in GNP. Intuitively, the more one spends on oil, the more a proportional increase in its price will reduce output. Though the economy's dependence on energy and oil since 1981 has been significantly reduced, it is now about the same as it was at the time of the first oil price shock. In 1973 the net cost of oil to the U. S. amounted to 1.5% of GDP. In 1992 oil's cost share was 1.5%, and decreased to 1.3% in 1993 (Figure 6). Energy costs

Figure 6.

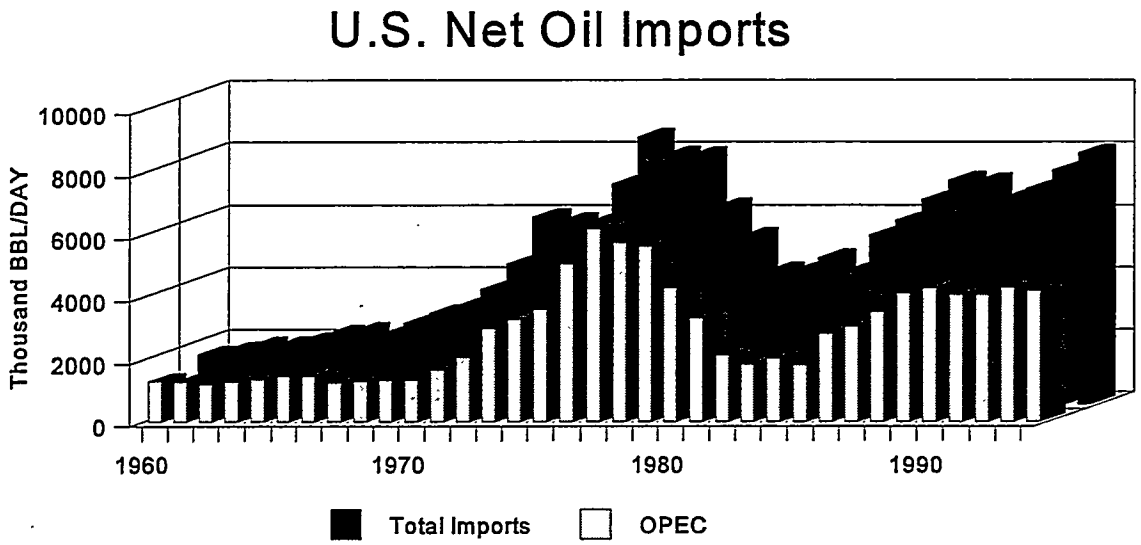


Source: U.S. DOE/EIA, 1994, tables 3.2, 3.5, 3.6.

amounted to 8.3% of GDP in 1973, and in 1992 energy costs comprised 8.2%. To be sure, energy and oil costs rose during the late 1970s and early 1980s with the price of oil. They will rise again with future oil price hikes. The important point is that oil's importance to our economy is about the same as it was twenty years ago, before the Arab OPEC oil embargo of 1973-74. The uses of oil have changed somewhat, increasing the importance of transportation oil use as other sectors moved away from oil.

The transfer of wealth from U. S. consumers to foreign owners of oil depends directly on the level of U. S. imports. Current levels of U. S. oil imports are higher than those preceding the first oil price shock in 1973-74 and almost equal to the highest level on record: 46.5% in 1977. U. S. oil imports have been rising since 1982 and are expected to continue to rise in the future (Figure 7). The EIA predicts that U. S. imports will increase from their current level of 45% of U. S. consumption into the range of 58% to 67% by 2000, and from 58% to 77% by 2010. Greene and Leiby put the transfer of U. S. wealth due to monopolistic oil pricing from 1972-1991 at over $1 trillion. A given OPEC price hike in the future will

Figure 7.



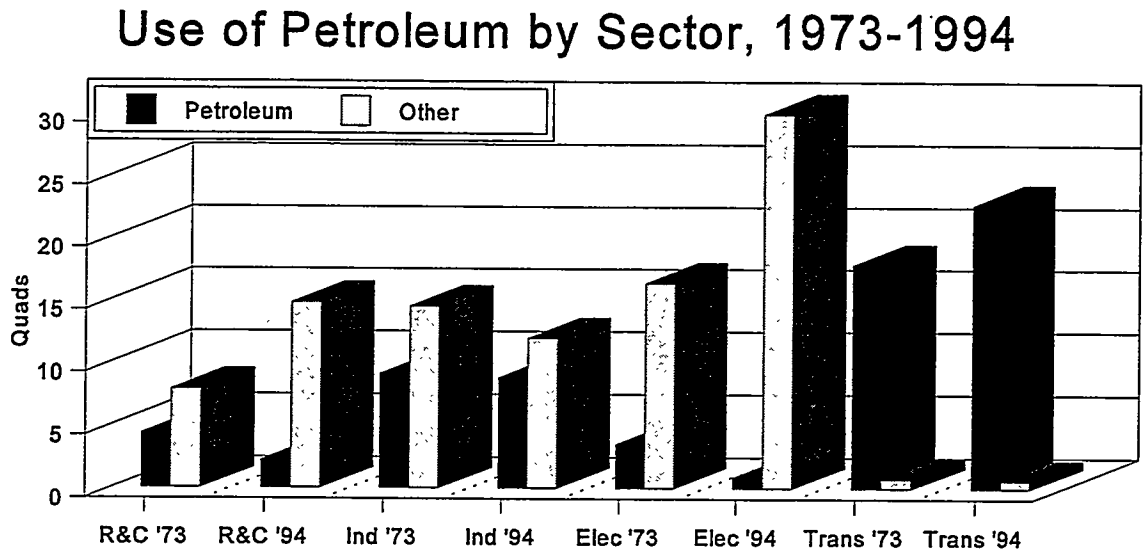
Source : U.S. DOE/EIA, 1994a, table 5.7; 1995a, table 1.8.

almost surely cause a greater loss of U.S. wealth than in the past because the U. S. will be importing more oil.

Oil use is now highly concentrated in the transport sector where fuel demand is known to be price-inelastic. Transportation is at the center of the United States' petroleum problem for three reasons. First, the transportation sector is far and away the dominant consumer of petroleum products, accounting for two-thirds of U. S. oil use in 1993. In terms of the light products that drive the petroleum market, transportation's share is more than three fourths. Second, whereas other sectors over the past twenty years have shown some ability to substitute other energy sources for oil, transportation has not (Figure 8). Third, the transportation sector is all but totally dependent on oil for energy. Pipelines using natural gas or electricity are the only significant nonpetroleum energy users.

Finally, some argue that oil futures markets significantly reduce or even eliminate the costs of monopoly oil pricing and price shocks to the U.S. The purpose of futures markets is to allow oil consumers to hedge, in effect buy insurance, against the possibility of future price

Figure 8.



Source: U.S. DOE/EIA, 1994a, table 2.1; 1995a, table 2.6.

increases (or decreases). Futures markets did not create the possibility of hedging: that always existed in the form of stockpiling, private insurance markets, etc. Futures markets make it easier to hedge, i.e., reduce the transaction costs. Thus, futures markets make it easier for oil consumers to insure themselves against the expected **private** costs of future price shocks. The key word is private.

Futures markets cannot internalize the public costs of oil use. Given that OPEC wields monopoly power in the world oil market, buying an additional barrel of oil makes a tiny increase in demand, resulting in a tiny increase in the price of oil and a tiny increase in the probability and size of a future oil price shock. All oil consumers experience this infinitesimal increase in cost. The fraction of the total cost that is born as private cost by the marginal consumer is a truly tiny fraction (one over the total number of barrels consumed). The private oil consumer will take no account of the benefits that would accrue to the nation if he reduced his oil consumption or if the price elasticities of oil supply and demand could be increased. Thus, the portion of the marginal social cost of oil that could be internalized

by futures markets is negligible in comparison to the total. Futures markets cannot solve problems of public goods and bads. In fact, futures markets do not even try. Nearly all oil futures contracts are very short-term, a few months or less. Clearly this can have nothing to do with oil price shocks that might occur in 2005.

2. THE PRESENT AND FUTURE OIL PROBLEM

2.1 A SIMPLE SIMULATION MODEL

In this section, the likely impact of a future oil price shock on the U. S. economy is simulated. A simple model of world oil supply and demand was constructed in the form of a spreadsheet (see Appendix A for details). World oil demand is represented for two regions: the U. S. and the ROW (including OPEC). World oil supply is represented for three regions: OPEC, the U. S., and the ROW (excluding OPEC). OPEC supply is to be specified (exogenous), while the model solves simultaneously for U. S. and ROW supply and demand. A dynamic adjustment specification is used to represent short- and long-run adjustment to price changes. The EIA's *Annual Energy Outlook 1995*, (AEO) Reference Case provides a "Base Case" forecast. Price shock scenarios are produced by changing OPEC supply and using the model to compute a new market solution for U. S. and ROW oil supply and demand. The cost of monopoly oil pricing to the U. S. economy is then estimated based on techniques developed by Greene and Leiby (1993) to estimate the costs of monopolistic oil pricing from 1972-1991. These are described in detail in Appendix B.

Supply and demand equations are assumed to be linear, which implies that elasticities will be an increasing function of oil price (since both supply and demand are inelastic). Elasticities for the Base Case Simulation Model are shown in Table 1 as a function of world oil price.

Whether and when a future oil price shock will occur will depend on the desire and ability of OPEC nations to cooperate to restrict production. In addition, temporary price shocks can occur even without monopoly behavior if supplies are significantly disrupted by an act of

Table 1. Simulation Model Short-Run Elasticities

	Demand	Supply	
World Oil Price (1993 $/BBL)	U.S. and ROW	U.S.	ROW
$20	-0.037	0.028	0.023
$35	-0.068	0.048	0.032
$50	-0.099	0.067	0.056

war or nature. Because of this, the precise timing and size of a future price shock cannot be predicted. It is conceivable that OPEC nations may be unable to cooperate to restrain production. To say that there is mistrust among OPEC nations today is an understatement. Price shocks, however, are likely to be very profitable for OPEC countries (Suranovic, 1994) and as OPEC's share of the world oil market grows, the economic rewards to restraining production will also grow. If the pay-off is sufficiently large, it is reasonable to expect OPEC countries to search for ways to cooperate and to find a suitable apology for creating yet another oil price shock. Unless meaningful alternatives to petroleum use in transportation are developed, the 2000-2010 period will provide OPEC with both the opportunity and motive to create another oil price shock. The value to OPEC of a brief, two-year supply reduction of 10% the first year and 17% the second is likely to exceed half a trillion dollars.[8]

The consequences for the U. S. economy of another sustained price increase, such as that of 1979-1985, would be grave. The two-year price shock simulated below costs the U. S. economy over half a trillion 1993 dollars, discounted to present value (PV). This single shock nearly doubles the cost of monopoly oil pricing to the U. S. economy through 2010.

[8]The 10% and 17% reductions are relative to the year before the shock. They correspond to 13% and 21% reductions over what OPEC would otherwise have produced under the Base Case projection. Furthermore, OPEC cannot immediately return to previous production levels but must increase slowly from these restricted levels.

2.2 1993-2010 BASELINE FORECAST

The U. S. Department of Energy (DOE), EIA's 1995 *Annual Energy Outlook*, Reference Case Projections are used as the Base Case for analyzing the impacts of future oil supply reductions by OPEC.[9] The Base Case oil price projections call for oil prices to increase from $16.12/bbl in 1993 to $19.13 in 2000, $21.50 in 2005 and $24.12 in 2010. World oil demand grows at the modest rate of 1.7%/year, from 66.18 MMBD in 1993 to 88.32 MMDB by 2010. U. S. demand grows at a much slower pace, 0.7%/year through 2010. U. S. oil supply declines from 9.53 MMBD in 1993 to a low of 8.22 in 2005, but then begins increasing to 8.58 MMBD in 2010 as oil prices increase. The ROW oil supply increases gradually from 29.63 MMBD in 1993 to 33.07 MMBD in 2010, an average annual rate of 0.6%. The 1995 AEO does not present its assumptions about total oil production by China and former Soviet countries, but only shows the net exports from these countries. The Energy Information Administration's 1994 International Energy Outlook (U.S. DOE/EIA, 1994d, Table 3), however, does show production projections for China, the Former Soviet Union and Eastern Europe through 2010 that are generally consistent with the 1995 AEO Reference Case Projections. These project oil output in China growing from 2.84 MMBD in 1992 to 3.4 in 2010, an average growth rate of 1%, and former Soviet plus Eastern European countries increasing from 9.16 MMBD in 1992 to 11.4 MMBD, according to the 1994 IEO projections, an average rate of 1.2%. We use these growth rates in our simulation analysis. Sensitivity analysis indicates that the results of the simulations are not greatly dependent on this assumption.[10]

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[9]"Oil" production here includes crude oil, natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, alcohols, liquids from coal and other sources, and refinery gains. EIA projections do not include production for internal consumption in Eurasia but only Eurasian exports. An estimate of all Eurasian production is included in the simulation below. As a result, OPEC market share exceeds 50% in 2004 and reaches only 53% by 2010. If former Soviet countries and China become full participants in international trade, this would be more correct.

[10]For example, Griffen and Vielhaber (1994) propose an "aggresstive non-OPEC supply scenario" the "Key assumption" of which is that production by former Soviet Republics and China would increase to 19.2 MBD by 2010. This implies a 3.5%/yr. Rate of production growth for these countries.

With oil prices near the long-run monopoly price level and growing world demand, OPEC's share of the world oil market increases continuously throughout the Base Case forecast. Including Eurasian production for domestic consumption in our ROW Base Case reduces OPEC's market share in comparison with that reported in the 1995 AEO forecast, shown in Figure 8 . OPEC's Base Case market share grows from 41% in 1993 to 46% by 2000, 51% in 2005, and reaches 53% by 2010. With growing volume and rising prices OPEC revenues more than double between 1993 and 2010. From $160 billion in 1993, OPEC gross revenues increase to $410 billion by 2010. OPEC grosses a total of $5.0 trillion (1993 $) over the forecast period with a PV of $3.5 trillion discounted at 4%/yr.

2.3 ALTERNATIVE SCENARIOS

Past oil price shocks occurred when wars or the deliberate actions of OPEC nations restricted the supply of OPEC oil to world markets. Following the 1973-74 and 1979-80 price shocks, OPEC nations continued to restrict their supply of oil to world markets in a deliberate effort to maintain high oil prices. As we have seen above, prices following the 1979-80 oil price shock were sufficiently high to result in a continuing erosion of OPEC's market share as oil supply and demand dynamically adjusted to the higher price regime. In 1991, Saudi Arabia and other producers intentionally increased oil production, resulting in a much briefer episode of higher prices. A plausible future oil price shock can be simulated by a similar reduction in OPEC oil supply in the context of an undisrupted, "Base Case" projection. Although it is not clear exactly how a future oil price shock will occur, analysis by Suranovic (1993; 1994) indicates that repeated shocks, each of approximately two years' duration would yield the maximum revenues for OPEC. For our purposes it is sufficient to demonstrate the impacts of a single plausible shock on world oil prices and the U. S. economy.

The price shock scenario assumes that all OPEC nations reduce their supply in the year 2005 by 10% over the previous year, or 13% over what they would have produced in 2005 according to the AEO projections. In the following year, they further reduce supply by 17% versus 2004, or 21% versus what they would have supplied under the Base Case scenario. OPEC is then assumed to begin gradually increasing supplies until in 2010 the supply reduction is 20.4% versus the Base Case. This pattern was chosen because it produces almost exactly the same revenues for OPEC in the years 2007-2010 as OPEC would have received in the Base Case. This diminishes the need to consider revenue gains or losses in years beyond the 1995 AEO forecast horizon of 2010.

The Energy Information Administration (U.S. DOE/EIA, 1994d, p. 22) recently published the results of the simulation of a shorter supply disruption, assumed to occur earlier, in the year 2000, at a Base Case oil price of $20.70. Three different levels of supply disruption were assumed: 4, 6, and 8 MMBD, corresponding to 11%, 17%, and 23% of OPEC's projected rate of production in 2000. The 4 MMBD disruption was assumed to last for only 6 months, the 8 MMBD for 9 months, and the 6 MMBD disruption was simulated for both 6 and 9 month durations. Because these disruptions last less than a year, their impact on annual prices will be proportionately smaller than our assumed supply cutbacks. In addition, the EIA assumes that 2 MMBD of surge capacity will be available, inside and outside of OPEC, to offset the supply disruption. That is, no monopoly behavior on the part of OPEC is assumed. The EIA simulation also assumes that the U. S. will draw down the SPR at rates of 3.5 MMBD in the first quarter, 1.1 MMDB in the second and 0.5 MMBD in the third (an annual average rate of 1.3 MMBD). Given all of the above, impacts were evaluated for four scenarios defined by use of the SPR, and assumptions about stock inventory responses and price elasticities (Table 2).

Because of the earlier occurrence, shorter duration, and absence of monopoly behavior, the EIA's supply disruption simulations differ from those presented below. On an annual basis, the 8 MMBD supply curtailment with 1 MMBD inventory build-up corresponds to a

Table 2. Oil Prices, EIA Simulation of 8 MMBD, 9-Month Oil Supply Disruption in the Year 2000

Scenario	SPR Not Used	SPR Used
1.0 MMBD inventory build-up + 10% lower elasticity	$54.50	$45.00
1.0 MMBD inventory draw-down + 10% higher elasticity	$37.60	$31.60

5.25 MMBD annual supply shortfall. On this basis, the market response to supply curtailments is comparable to those we present below. Prices rise to $54.50/bbl in EIA's simulation.

Nine additional scenarios are considered (Table 3). Two explore the effect of use of the Strategic Petroleum Reserve (SPR) on this sustained supply curtailment. Three others assess the impact of doubling world price elasticities of supply and demand assuming: 1) Base Case OPEC production, 2) Price shock OPEC production, and 3) OPEC aggressively cuts back on production so as to match OPEC's price shock revenues for as long as possible. These three scenarios are then repeated, assuming that only U.S. oil price elasticities double. Finally, for purpose of comparison, it is assumed that OPEC restricts production to the same levels as in the aggressive scenario with doubled U.S. elasticities, but the lower Base Case elasticities are assumed.

Table 3. OPEC Revenues and U.S. Economic Impacts Under Alternative Scenarios

(Billion 1993 $ Present Value, 1993-2010)

SCENARIO	U.S. GNP IMPACTS				OPEC REVENUES	
	Wealth Transfer	Potential GNP Loss	Macroeconomic Adjustment Costs	TOTAL	1993-2010	2005-2010
Base Case	469	454	51	974	3473	2260
Price Shock	606	710	186	1502	3858	2852
Strategic Petroleum Reserve	592	708	192	1492	3841	2827
Double SPR, Two Years	580	707	162	1449	3833	2814
Double World Elasticities	139	152	43	334	2294	1139
2X World + Price Shock	222	262	108	592	2486	1434
2X World, Aggressive OPEC	374	552	185	1111	2503	785
2X U.S. Elasticities	294	310	15	619	3008	1791
2X U.S. + Price Shock	341	471	109	921	3311	2259
2X U.S., Aggressive OPEC	194	688	234	1116	3337	2045
Base Elasticities, Aggressive	702	1150	413	2265	3870	2580

2.4 SIMULATION RESULTS

2.4.1 A Two-year Price Shock in 2005

The initial supply disruption is about the same size as those that occurred in 1973-74 and 1979-80. In 1980, OPEC crude oil production was 4 MMBD (13%) lower than in 1979. In 1981 OPEC cut output by another 4 MMBD for a 26% reduction over 1979's output level (U.S. DOE/EIA, 1994a). The quantity of oil assumed to be lost in 2005 is somewhat greater, 5.5 MMBD, but the percent reduction is also 13%. As a result of the OPEC cutback, oil prices more than double, from $21/bbl in 2004 to $54/bbl in 2005. To keep prices elevated, OPEC is assumed to cut 2006 output by a total of 21% over what it would otherwise have been. Still, the price of oil declines to $46/bbl as world supply and demand adjust and OPEC's market share falls. After 2006, OPEC is assumed to gradually ease up, allowing prices to drop to $28-30/bbl through 2010. Though past oil price increases lasted longer, this two-year shock is consistent with the types of price shocks Suranovic's (1994) simulation analysis found to be a profit-maximizing strategy for OPEC.

If OPEC were to return to the original Base Case production levels in 2007, prices would fall below the competitive long-run price of $10/bbl and OPEC revenues would plummet. Instead, it is assumed that OPEC expands production just enough to approximate the gross revenues it would have received in the Base Case in the years 2007-2010. The percent cutback is eased to 20.4% in 2010 over the Base Case. Holding revenues in the final years at approximately the same levels as the Base Case minimizes the problem caused by not having forecasts for years beyond 2010.

Responding to the higher prices, world oil supply increases in 2005 by 1.5 MMBD and world demand is 4 MMBD lower than the Base Case scenario. U. S. supply is 0.4 MMBD higher in 2005 and 0.7 MMBD higher in 2006. In comparison with the Base Case, U. S. demand is 1 MMBD lower in 2005 and 1.7 MMBD lower in 2006. Though prices drop

to about $3 above the level of the Base Case, supply increases and demand reductions persist after the price shock due to the dynamic adjustment structure of the simulation model. World supply remains 2 MMBD above the Base Case, demand continues to be almost 6 MMBD below it. OPEC's market share falls from 50% in 2004 to 44% in 2006. From there it begins to recover as the cutback is trimmed (Figure 9).

The effect on OPEC revenues is substantial. In simple 1993 dollars discounted to present value (PV) in 2005 at 4%, the supply shock and subsequent strategy nets OPEC an additional $600 billion in gross revenues. This is a 25% increase over the Base Case revenues for the 2005 to 2010 time period (Figure 10). The general picture is little affected by alternative assumptions about oil supply costs and discount rates. Whether $600 billion over five years is sufficient incentive to OPEC members to cooperate on a supply strategy is an interesting question. Of course, profits might be further increased by an additional price shock, but such issues are beyond the scope of this report (Table 3).

2.4.2 Impact of Releases from Strategic Reserves

Use of the SPR is simulated by assuming a maximum drawdown in the first year of the shock. The SPR presently contains 600 million barrels of oil. If all were used over the period of a year, the average production rate would be 1.64 MMBD. Use of SPR is simulated by adding this to world supply for 2005 before recomputing the market equilibrium price. It is assumed that OPEC will not change its planned pattern of cutbacks in response to the SPR release. Perhaps surprisingly, this turns out to be a reasonable assumption.

The SPR release causes oil prices in 2005 to fall by almost $10/bbl versus the scenario without SPR. Thus, SPR mitigates the price shock of 2005. However, in 2006 there is no more SPR and, by assumption, OPEC goes ahead with its original planned cutback of 21%. Because prices were lower and supplies more plentiful in 2005 with the SPR release than

Figure 9. PRICE V. OPEC MARKET SHARE

SCENARIO: Supply Shock in 2005

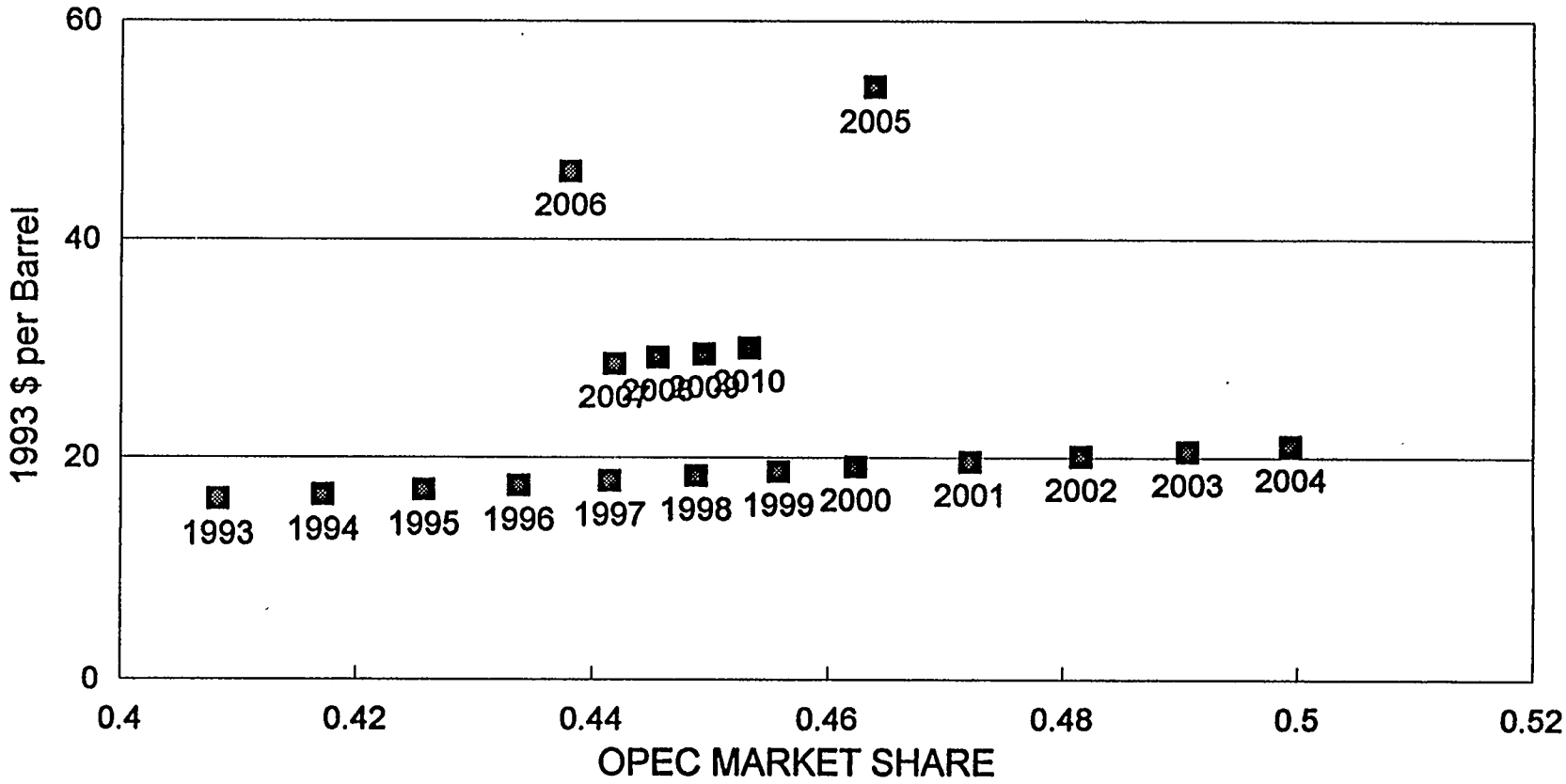
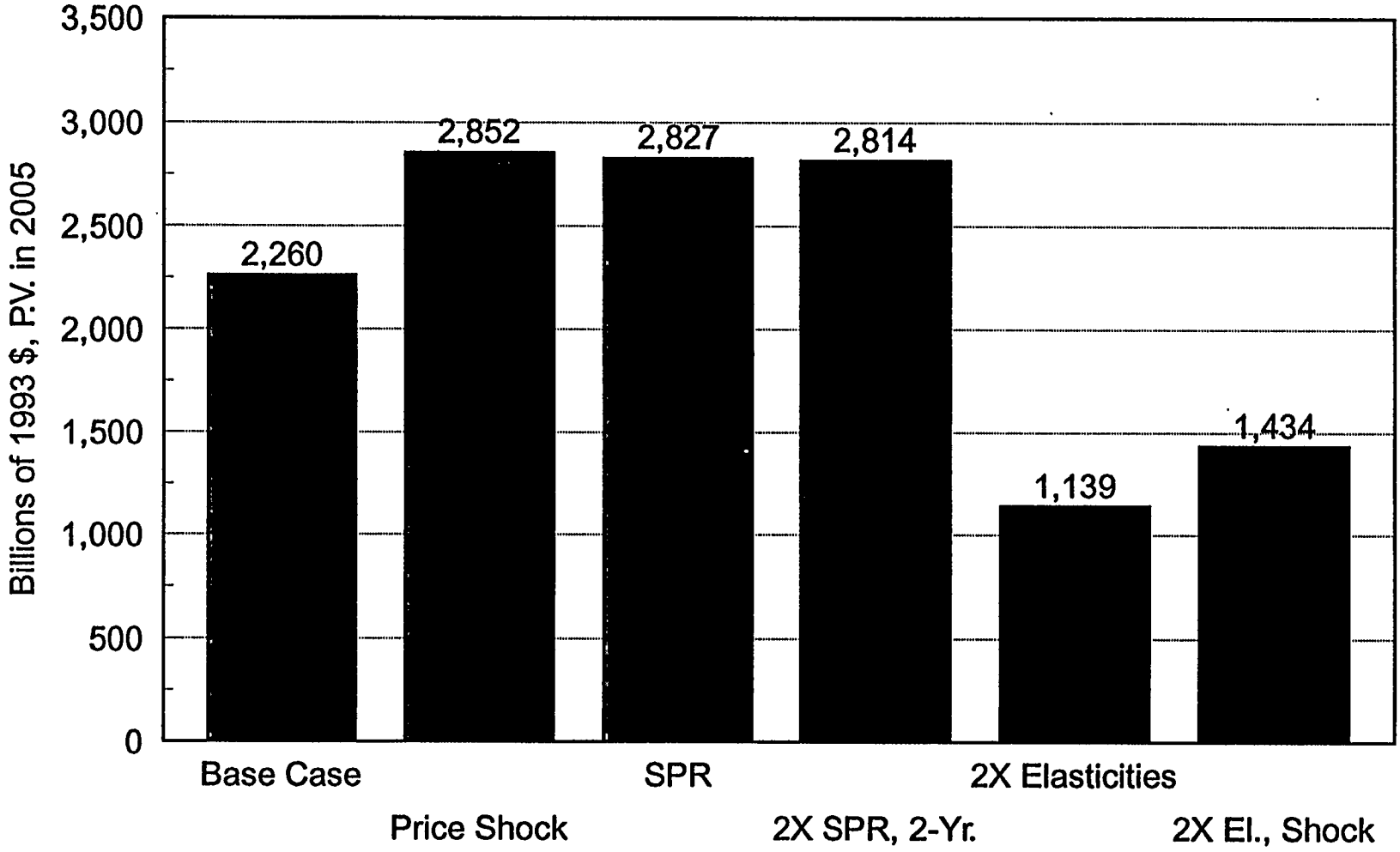


Figure 10. OPEC Gross Revenues: 2005 to 2010
Alternative Scenarios



without it world economies adjust less than in the Price Shock scenario. As a result, the 21% supply reduction in 2006 causes a larger price shock than it would had SPR not been used. Instead of $46/bbl, 2006 prices after the SPR release jump to $55/bbl. After 2006, they are identical to the no-SPR scenario (Figure 11). In effect, the sequence of prices is changed but not the level. As a result, OPEC revenues and profits are little changed by the use of SPR in this way. Estimated gross revenues for the 2005-2010 period are only 1% lower. Used in this way, SPR would have little effect on a determined OPEC strategy to restrain production. On the other hand, during the first year it might have a discouraging effect on a cartel struggling to maintain consensus and discipline.

One could argue that SPR is not the only strategic reserve in the world and that other consuming nations might also release strategic reserves at the same time, magnifying the effect of SPR. Petroleum stocks held by OECD countries increased from 2,588 million barrels in 1973 to 3,665 million barrels in 1993, a net gain of just over 1 billion barrels. Nearly all of the change is accounted for by increased reserves held by the U. S. in the SPR and by Japan in strategic reserves (U. S. DOE/EIA, 1994a, table 11.11). If all of this additional reserve were released in the first year of the shock it would raise supply by an average of 2.95 MMBD. We explore the impact of a larger reserve by assuming that the U.S. has a second 600 million barrel reserve available for use in 2006. The effect of a doubled SPR used over two years is equally disappointing. The price of oil stays at $44/bbl. In 2005, drops to $45/bbl. In 2006, but then jumps to $37/bbl. In 2007 from $29/bbl., without the additional reserve.

2.4.3 Economic Impacts on the United States

Regardless of the assumed use of SPR, the two year supply curtailment costs the U. S. economy in excess of half a trillion dollars PV over the Base Case (Figure 12). Total losses to the U. S. economy in the price shock scenario amount to $1.5 trillion (1993 $) PV (Table 3).

Figure 11. World Oil Prices in Base Case and Price Shock Scenarios

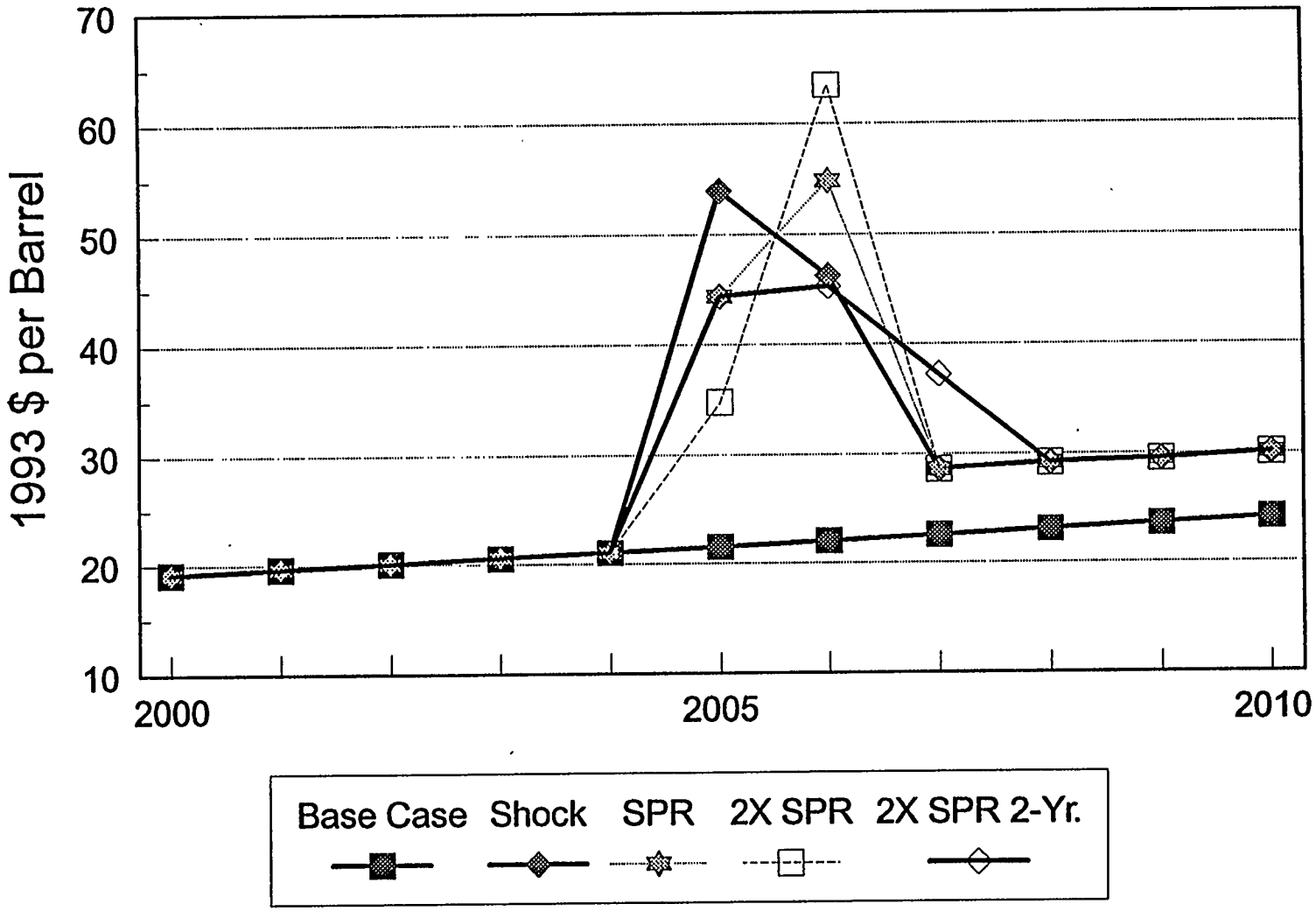
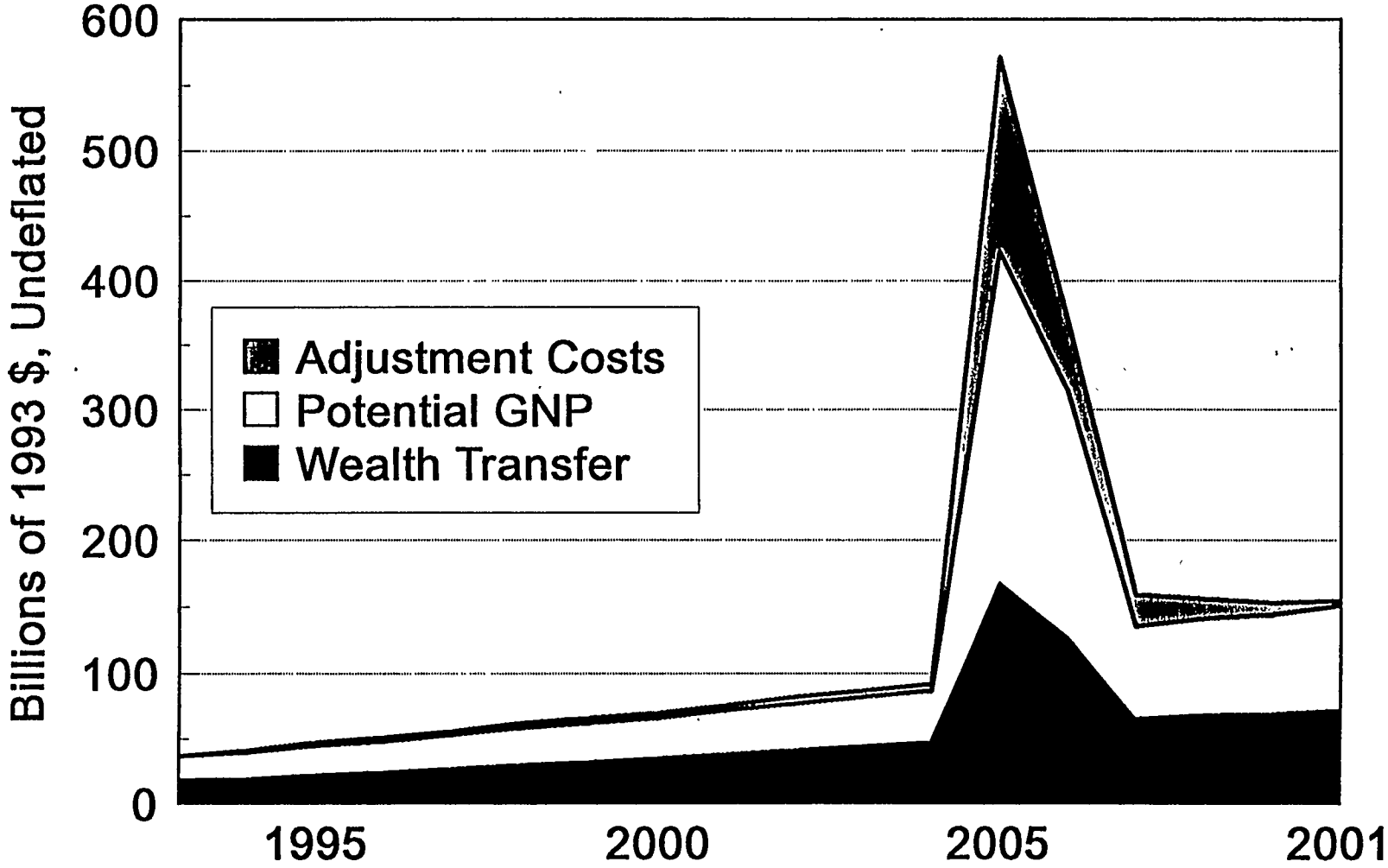


Figure 12. Costs of Oil Dependence to U.S. Economy: Price Shock Scenario



Assuming a hypothetical competitive market price of $10/bbl, the U. S. lost $18 billion in wealth transfer in 1993. By 2010, the U. S. economy would lose $33 billion PV in the form of wealth transfer in the Base Case. Discounted at 4%/yr. the PV of the estimated transfer of wealth in the Base Case through 2010 amounts to $470 billion. The single price shock in 2005-2006 increases this to $610 billion PV. In 2005 alone, $170 billion ($105 billion PV) is lost via wealth transfer. Half of that goes to OPEC, half to other world exporters.

In the Base Case prices increase gradually, but the method used here will always calculate some potential output losses as long as oil prices remain above the assumed competitive market level of $10/bbl. Slow, steady price increases might be accurately anticipated by the market, essentially eliminating all macroeconomic adjustment losses. In the Base Case estimated potential GNP losses amount to $140 billion PV and macroeconomic adjustment losses total $50 billion PV. In the price shock scenario, estimated potential GNP losses hit $160 billion PV in 2005 and $110 billion PV in 2006. Macroeconomic adjustment losses in those two years are $90 billion and $30 billion PV, respectively.

The effect of full use of the SPR in 2005 is estimated to be $10 billion, not counting profit, if any, on the sale of the oil. Estimated wealth transfer declines by $14 billion, potential GNP loss decreases by $2 billion, but macroeconomic adjustment losses increase by $6 billion. The explanation for the SPR's apparently small impact lies primarily in the fact that what is gained in the first year is lost in the second. Without the SPR release, wealth transfer losses are $105 and $75 billion PV in 2005 and 2006 respectively, for a two-year total of $180 billion PV. With the SPR release, estimated transfer losses are $70 and $95 billion PV in the two years for a total of $165 billion PV. If the price shock had lasted only one year, a savings of $35 billion PV would have been realized. As it continued into the second year, an additional $20 billion PV was lost in 2006 due to the use of the SPR in the previous year. The situation is similar for GNP losses. Estimated losses without the SPR total $160 billion PV in 2005 and $115 billion PV in 2006. With the release the estimates

are $120 billion PV in 2005 and $150 billion PV in 2006. The sums of the two years differ by only $5 billion PV (numbers rounded to nearest $5 billion).

Doubling the SPR and releasing over two years produces a small additional benefit to the U. S. economy. The implication is that use of strategic reserves in this way against a determined multi-year supply reduction is neither an effective deterrent nor an effective protection for the economy.[11] These discouraging results corroborate the conclusions of an earlier analysis by Suranovic (1994), who found that reserves on the order of 30 billion barrels would be necessary to defeat a strategy of determined supply curtailment.

2.4.4 Increasing Price Elasticities

Given the dependence of OPEC market power on supply and demand elasticities, a logical strategy would be to enhance the ability of oil supply and demand to respond to higher oil prices. Increasing the short- and long-run price elasticities of supply and demand would reduce the impact of the price shock caused by a given supply shortfall, thereby cutting OPEC revenues and reducing the impact on the U. S. economy. Improving price responsiveness should therefore act simultaneously to deter OPEC from initiating a supply cutback and protect the U. S. economy in the event one occurs.

The impact of increasing the oil market's price responsiveness is illustrated by doubling the price elasticities of supply and demand and resimulating the effect of the two-year price shock and its impacts on the U. S. economy. Doubling price elasticites implies that the elasticity of demand at $28/bbl would increase from -0.053 to -0.106. The elasticities of

[11]Of course, in a simulation such as this the model's equations determine the results. We note, for example, that the value of an SPR would probably be greater if constant elasticity supply and demand equations were used instead of linear equations in which elasticities increase with increasing price.

supply at the same price for the U. S. would increase from 0.038 to 0.076.[12] Two scenarios are considered, one in which only U. S. price elasticities are increased and another in which ROW supply and demand elasticities are doubled, as well. The increase in elasticities is assumed to begin in 1996 and increase linearly over a decade until a doubling is achieved in 2005. As a result prices and oil quantities change for all years after 1995, not only those in which supply shortages occur.

Unlike the effect of strategic reserves, the effect of substantially increasing the price-responsiveness of the market is dramatic. Doubling the elasticities of supply and demand for the entire world cuts post 2005 OPEC revenues in half assuming the Base Case OPEC production levels (Figure 10). U. S. economic losses drop to $335 billion PV when world elasticities double, for an estimated benefit to the U. S. economy of $640 billion PV. If the strategy of supply curtailment is tried, OPEC still gets a $300 billion windfall versus no price shock, half the size of the price shock windfall at Base Case elasticities. Total economic losses for the price shock scenario are $1.5 trillion PV at base elasticities and $0.6 trillion PV if elasticities are doubled for a savings of nearly $1 trillion (Figure 13).

But what if OPEC aggressively tries to maintain its Base Case revenues in the face of increasing world elasticity of supply and demand? The answer is that it runs head on into the discipline of the marketplace. With world oil price elasticities at twice their present values, OPEC can maintain its Base Case revenues by cutting back on production only through 2002. By 2003 its market share has dwindled to 23% and it is not capable of raising prices, by cutting production, to a level sufficient to maintain its Base Case revenues (Figure 14). We assume that OPEC ceases cutbacks at this point, and maintains prices at $21/bbl through 2010. This strategy produces only $785 billion PV in revenues,

[12]Of course, this exercise also makes it clear that accurate short-run price elasticity estimates are the most critical element of this analysis. While the estimates used here are consistent with those used by others and produce a pattern of market behavior consistent with past experience, there remains uncertainty both with respect to their values at particular prices and the rate at which they change as price increases.

Figure 13. Costs of Oil Dependence to U.S. Economy: Price Shock & Doubled Elasticities

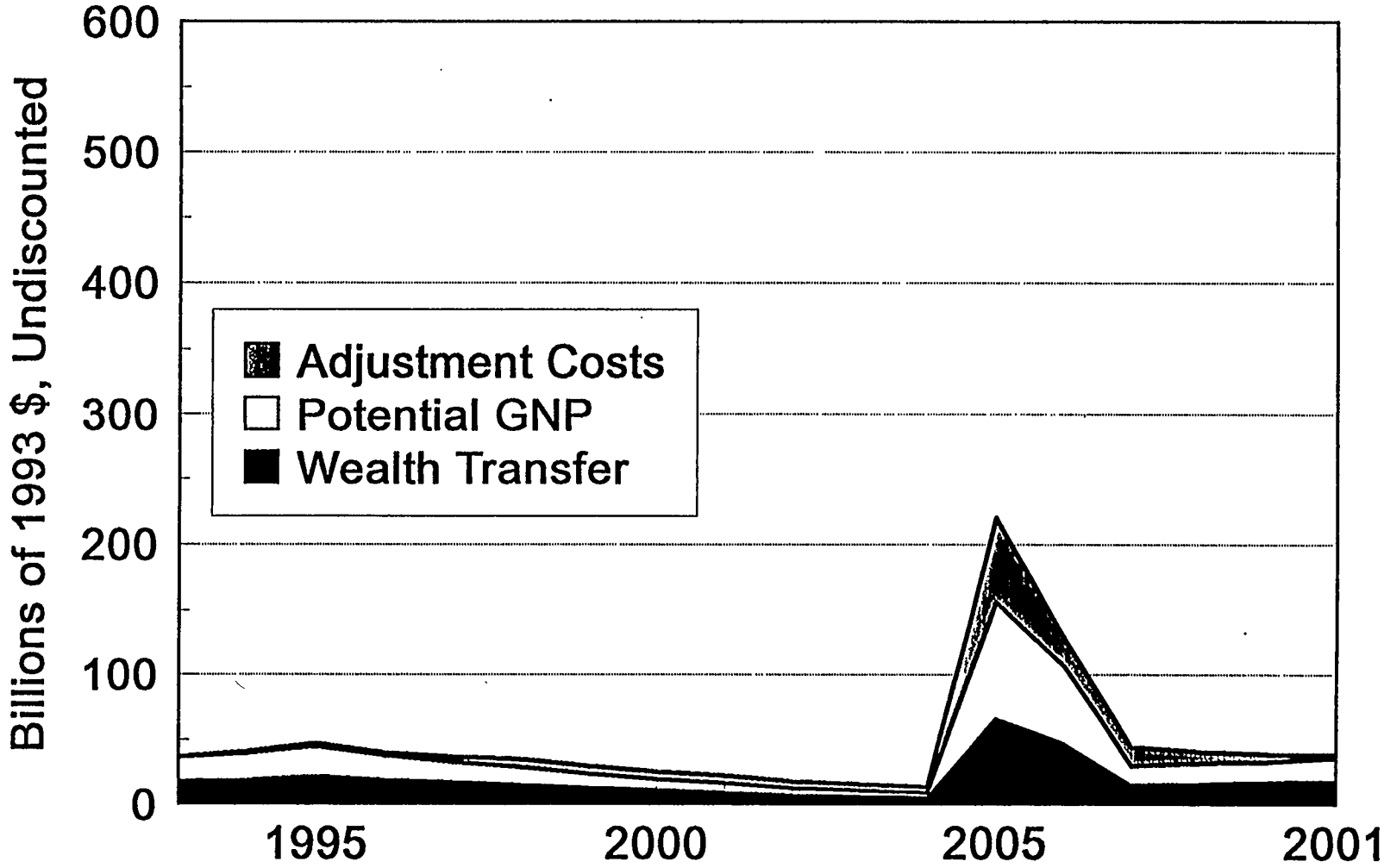
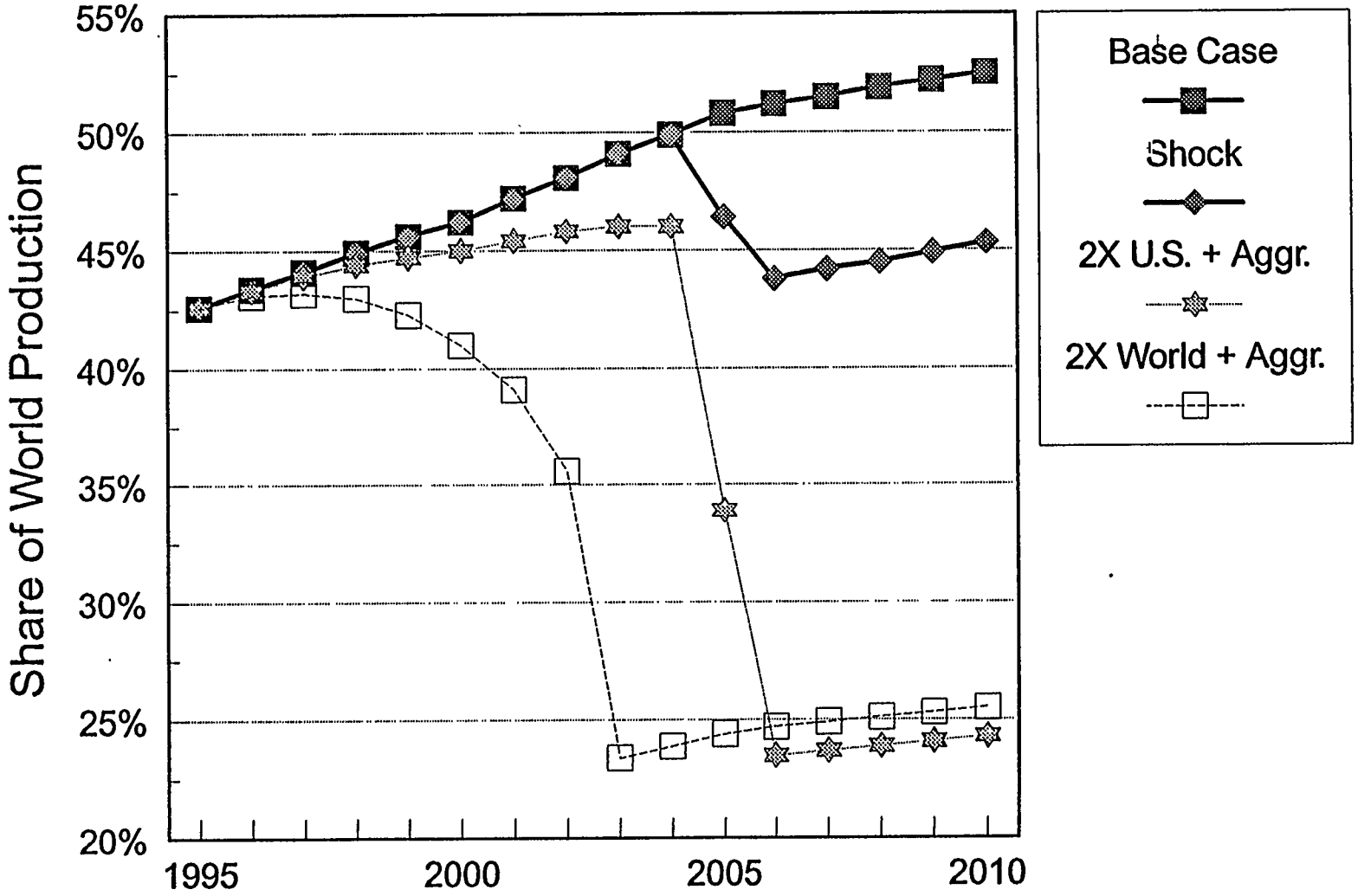


Figure 14. OPEC Market Share, 1995-2010
Alternative Scenarios



$340 billion PV less than the scenario in which Base Case production levels are maintained (Table 3). Costs to the U.S. are significantly higher, but this type of "retaliatory" behavior doesn't pay. The single price shock still works better, raising almost twice as much revenue. Harm to the U.S. economy is also much smaller.

If only U.S. oil price elasticities double, benefits are reduced but are still substantial. At Base Case OPEC production levels, the costs of U.S. oil dependence are reduced 35% or $350 billion PV (Table 3). Assuming the OPEC output levels of the Price Shock scenario raises U.S. costs from $0.6 trillion to $0.9 trillion, but this is still much lower than the $1.5 trillion in Price Shock scenario costs at Base Case Elasticities. If OPEC aggressively cut production, trying to achieve the same revenues as in the Price Shock case at Base Case elasticities, costs to the U.S. economy would increase to $1.1 trillion, slightly higher than the original Base Case with no production cut-backs. However, OPEC revenues are lower than in the Base Case and also lower than in the Price Shock case with doubled U.S. elasticities. If the same aggressive production cuts are made at the lower Base Case elasticities, estimated costs to the U.S. economy double to $2.2 trillion.

Increasing the oil market's price responsiveness is effective against the sustained supply disruption strategy because it simultaneously reduces the incentive for OPEC to create a supply disruption, diminishes the impact of that disruption on world oil prices, and increases the U.S. economy's ability to reduce oil use and oil imports. Increasing the U. S. elasticity of demand is almost equivalent to increasing the price elasticity of transportation oil use. Doubling this elasticity is obviously more easily said than done. Use of alternative fuels, substitute fuels, technology for rapidly increasing energy efficiency, and techniques for quickly improving the operating efficiency of transportation systems would probably all be required.

3. CONCLUSIONS

The United States' oil dependence problem is not one of running out of oil. It is a problem of the use of monopoly power in world oil markets by a few nations that hold the majority of the world's oil resources. In the past, the OPEC cartel has created or capitalized on disruptions in the world oil market, reaping hundreds of billions of dollars in monopoly rents from oil consuming countries. During the past decade, however, the cartel has been less effective. This has led some to conclude that conditions in the world oil market have materially changed and that oil dependence no longer poses the threat it once did (Bohi and Toman, 1993). Unfortunately, the majority of the evidence points to the opposite conclusion. It appears that the only important objective factor that has changed significantly is the market share of the OPEC cartel, a key determinant of OPEC's power in world oil markets. The geographical concentration of world oil reserves, together with trends in world production and consumption, indicate that lost market share will soon be regained. This is corroborated by recent trends and consistent with the best efforts to project the future. The potential for monopoly power in the world oil market remains because oil resources are still concentrated under the control of a few sovereign states.

Monopoly power in world oil markets is limited by the abilities of consumers and other oil suppliers to respond to higher prices and by the OPEC states' own ability to cooperate with one another. Consumers and suppliers have a much greater ability to respond to prices given sufficient time. As a result, a cartel's monopoly power is far greater in the short-run than in the long-run, a fact which has led to considerable confusion about the effects of monopoly behavior in world oil markets. It is very difficult within a single year to discover, develop, and produce new oil supplies or change the fuel economy of an entire fleet of cars. Given a decade or two, however, an entire motor vehicle fleet can be

replaced, new technology can be developed, and new energy supplies brought to market. Very high short-run monopoly prices can therefore only be maintained by sacrificing market share and thereby market power.

It is useful to consider what has changed since the oil price shocks of the 1970s and 1980s since some claim that we are not likely to repeat the experience. The key factors are: 1) OPEC share of world oil production, 2) world short- and long-run price elasticities of demand and supply, 3) importance of oil and energy in the U. S. economy, 4) the level of U. S. oil imports, and 5) OPEC's ability and desire to cooperate. OPEC's share of the world oil market is lower today than it was in the 1970s. It is growing steadily, however, and is expected to reach 1970 levels sometime between 2000 and 2005. The current values of elastiticities of supply and demand, because they are usually inferred from historical data, are more difficult to determine. However, the most recent studies do not indicate that elasticities have increased over historical levels (e.g., Dargay and Gately, 1994). In the U. S., the concentration of oil use in the transportation sector as other, more "switchable" sectors have substituted other forms of energy for oil, suggests that demand elasticity has not increased. Finally, oil's cost-share of U. S. GNP, the key determinant of the impact an oil price shock will have on the U. S. economy, is about the same as it was before the first oil price shock in 1973. Recent estimates of the impact on the U. S. of the brief 1990-91 oil price shock indicate that the economy is as vulnerable as ever. As Tatom (1993, p. 148) concluded, "Thus, another lesson from the 1990-91 price changes is that the economy appears to remain exposed to oil price shocks to a nearly equivalent extent as earlier." Today, U. S. oil imports are within 1 percentage point of their highest level ever, and climbing. OPEC's resolve is more difficult to evaluate, especially for a period ten years in the future. The simulations presented here, however, suggest that there will be at least opportunity and motive for collusion.

The SPR does not appear to provide an effective defense against a sustained supply curtailment. For a multi-year episode, the effect of the SPR is to postpone the full impact

of a sustained cutback in production, to reduce its benefit to OPEC by about 5% and to mitigate its impact on the U. S. economy possibly by even less. If OPEC is determined to cut production, it can apparently wait out the SPR releases and then reap the benefits of higher oil prices. Although SPR may be very effective against a temporary supply interruption, against a multi-year supply restriction it appears to offer neither a major disincentive to OPEC nor significant protection to the U. S. economy.

Both the benefit to OPEC and the cost to the U. S. of a sustained oil price increase, however, are quite sensitive to the **short- and long-run** price elasticities of petroleum demand and supply. If world price elasticities of supply and demand could be doubled, the estimated value of a two-year oil price shock to OPEC would be significantly reduced. The estimated cost to the U. S. economy of an OPEC supply curtailment would be cut by almost half. Doubling only the United States' ability to substitute away from petroleum in the event of a price increase, cuts the estimated impact of a price shock on the U. S. economy by one third. Moreover, when price elasticities are increased, benefits accrue continuously. With doubled price elasticities and Base Case production levels, OPEC revenues after 2005 are cut in half, and U. S. economic costs by two-thirds. Attempts by OPEC to maintain revenues in the face of growing price elasticity are likely to be counterproductive for their gross revenues.

Transportation accounts for two-thirds of petroleum use and 80% of high-valued light product use in the U. S., since transportation is 97% dependent on oil. Accordingly, increasing the elasticity of oil demand and supply amounts to increasing the transportation sector's price elasticity of oil demand, and increasing the price elasticity of supply of alternative transportation fuels and domestic petroleum. Increasing transportation's ability to substitute non-petroleum fuels, as well as improve vehicular and system operating efficiencies in the short-run, should be a very effective strategy against the economic costs of oil dependence. How to accomplish this end is beyond the scope of this paper.

If present trends continue, future price shocks appear likely. Price shocks can be very profitable to oil producers and consuming nations appear to have developed no adequate defense against them. It does not appear that strategic oil reserves could be maintained at levels sufficient to defeat a determined supply curtailment. Instead, the ability of the economy, especially the transportation sector, to respond to higher prices must be increased. The ability to substitute nonpetroleum fuels for oil, and the ability to increase vehicle and systems efficiency in the short- and long-run must be enhanced. Even if the U. S. pursues these goals on its own, the benefits are likely to be substantial. If the technology can be diffused to the rest of the world, the benefits will be multiplied.

The challenge for consuming nations is to find an effective strategy for countering monopoly behavior by OPEC, one that can be sustained during periods of low as well as high oil prices. This is not an easy task. When prices are low, there appears to be no oil problem. When price shocks occur, there appears to be a crisis. In fact, the same oil problem in different phases was there all along. There may now be time, while OPEC's market share is growing and while OPEC members are feuding, to prepare for the next oil price shock. If the U. S. can successfully prepare, the benefits may be counted in the hundreds of billions, if not trillions of dollars.

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APPENDIX A

The method for simulating oil supply impacts begins with an assumed state of the world oil market that is perturbed by a reduction of the supply of oil by OPEC countries. This means the model must be able to represent the world oil supply and demand response to an arbitrary reduction in OPEC supply. The world is divided into two demand regions, the U. S. and the ROW, and three supply regions, the U. S., OPEC, and ROW. To create a price shock, OPEC supply is reduced. At this point, demand exceeds supply at the Base Case market price. To achieve a market balance, price must be increased to depress demand and increase U. S. and ROW supply. Critical to this process is specifying the response of supply and demand to a change in oil price.

A.1 PRICE ELASTICITIES OF OIL SUPPLY AND DEMAND

Both oil demand and supply are known to be highly inelastic over a period as short as one year, but much more responsive over a longer period of time. A very commonly used mathematical formulation for representing an increasing response over time is the simple lagged or dynamic adjustment model. This model assumes that the change in demand, ${}_dQ$ (or supply ${}_sQ$), from period t-1 to period t is a fraction (λ) of the difference between the desired, or long-run, demand, ${}_dq_t$ (supply), that would prevail at the current price, P_t, and last year's demand (supply). Because the equations for supply and demand are structurally identical, the supply and demand subscripts are omitted, below.

$$\begin{aligned} Q_t - Q_{t-1} &= \lambda\,(q_t - Q_{t-1}) \\ q_t &= A_t + b\,P_t \end{aligned} \qquad \textbf{(A.1)}$$

The constant A_t indicates factors other than price that determine demand (or supply) in year t, and b is the price slope of the supply or demand equation. Equation (A.1) can be readily solved for current demand (or supply) Q_t, as a function of price by substituing for q_t.

$$Q_t = \lambda A_t + \lambda b P_t + (1-\lambda) Q_{t-1} \qquad \textbf{(A.2)}$$

From equation (A.2) it is clear that for each of four equations (supply and demand for both the U. S. and the ROW) two parameters are required: b and $0 < \lambda < 1$. The constants, A_t, can be directly computed from the Base Case quantities and prices, given b and λ.[13]

The literature is quite consistent on the point that the adjustment rate for oil demand and supply is very slow. Values of λ on the order of 0.1 are most common. There is also agreement that the short-run price elasticities of supply and demand are quite small, on the order of +0.03 and -0.06, respectively. Values found in the recent literature are shown in Table A.1. Most values given in the literature are specified in terms of price elasticities rather than price slopes, and constant elasticity formulations are common. In the linear dynamic adjustment model (A.2), the short-run and long-run price elasticities (β) depend on price and quantity consumed, as follows.

$$\beta_{SR} = b\lambda \frac{P_t}{Q_t} \quad ; \quad \beta_{LR} = b \frac{P_t}{Q_t} \qquad \textbf{(A.3)}$$

The implication of equation (A.3) is that if price doubles, short-run price responsiveness will approximately double. It is virtually certain that the price elasticity of oil demand, if not oil supply, increases with increasing price in the short-run. Suranovic (1994, p. 126)

[13]This procedure does not explicitly represent the effect of oil prices on demand via the other variables that determine the constant terms. As long as the price responses are reasonably accurate, this should not be an important concern.

Table A.1 Recent Estimated Short- and Long-Run Price Elasticities of Oil Demand

Model/Source	S.R. Price	L.R. Price	λ	Midpoint Price (1993$)
BP America - OECD	-0.048	-0.548	0.09	$30.30
IPE - OECD	-0.027	-0.772	0.03	$30.30
CERI - OECD	-0.099	-0.425	0.23	$30.30
OMS - OECD	-0.062	-0.448	0.14	$30.30
Gately - OECD	-0.067	-0.157	0.42	$30.30
WOMS - OECD	-0.029	-2.544	0.01	$30.30
Penn-BU -OECD	-0.056	-0.247	0.23	$30.30
FRB - OECD	-0.115	-0.538	0.21	$30.30
HOMS - OECD	-0.083	-0.319	0.26	$32.28
HOMS1 - OECD	-0.116	-0.769	0.15	$30.30
OMS92 - U.S. / Suranovic (1994)	-0.090	-0.700	0.13	- -
OMS92 - Europe	-0.060	-0.380	0.16	- -
WOM-World/Huntington (1994)	-0.060	-0.60	0.10	$35.20

Sources: Huntington (1994), (1993) and (1991), Suranovic (1994).

model in which price elasticity increases but at a slower rate than it would if the oil demand equation were linear. In Suranovic's model, for example, an increase in oil price from $24 to $48 (1990 dollars), would increase the price elasticity of demand by only about 30%. Compared to those studies, the linear formulation will predict smaller price shocks for a given reduction in OPEC demand, and thus a greater loss of OPEC market share over time for any given monopolistic supply strategy.

uses a formula based on the Energy Information Administration's Oil Market Simulation (1983) Huntington (1991) calculated price elasticities of demand based on a comparison of eleven world oil market models for a scenario of world oil prices increasing from $21.50 to $43.00 (1993 $) per barrel from 1989 to 2010. He found that short-run price elasticities clustered near -0.1 and long-run elasticities were in the vicinity of -0.4. In a more recent study, Huntington (1993) used more rigorous econometric methods to estimate short-and long-run price elasticities of demand for nine of the world oil models. The range of world oil prices was similar to his previous study. The average short-run elasticity was -0.075 and the average long-run elasticity -0.562, implying an adjustment parameter of 0.13. In a recent article Huntington chose representative values of -0.6 for the long-run price elasticity of world demand and used an adjustment factor of 0.1, implying a short-run elasticity of -0.06 associated with an oil price level of $35.20 (1993 $/bbl).

For supply outside of OPEC, Huntington's (1991) study found that short-run price elasticities were well below +0.1, averaging +0.03 for total non-OPEC supply and about +0.05 for the U. S. and other OECD countries (Table A.2). In his 1994 analysis, Huntington used parameters of +0.4 for the long-run price elasticity of supply and and adjustment parameter of 0.1, implying a short-run elasticity of +0.04.

Translating the point or constant elasticity estimates found in the literature into equivalent parameters for linear supply and demand equations requires associating an oil price with each estimate because in the linear model elasticity is a function of fuel price. At the 1995 AEO forecast price for 1993 of $16.12 (1993 $/bbl) and quantities consumed (17.24 MMBD for the U. S., 48.94 MMBD for ROW), the short-run price elasticities of demand for both the U. S. and ROW are assumed to be -0.03, with an adjustment parameter of 0.1. At $28/bbl, roughly the average price of oil since 1967, the short- and long-run price elasticities of demand would be -0.053 and -0.53, respectively. At $35/bbl, the short-run price elasticity becomes -0.068. Short-run supply elasticities at 1993 prices and quantities are assumed to be 0.0225 for the U. S. and 0.0187 for the ROW. These imply U. S. and

Table A.2 Price Elasticities of World Oil Supply

Model/Source	S.R. Price	L.R.Price
United States		
OMS (EIA)	0.117	0.340
Gately	0.045	0.577
IPE	0.000	
ETA-MACRO		0.215
Penn-BU	0.000	0.162
CERI	0.137	0.195
HOMS	0.012	0.522
FRB Dallas	0.013	0.475
DFI-CEC		0.500
HOMS-I	0.0859	0.662
Average	0.052	0.394
Rest of the World		
OMS (EIA)	0.000	0.170
Gately	0.052	0.553
IPE	0.000	
Penn-BU	0.000	0.200
CERI:WOMM	0.000	0.144
HOMS	0.000	0.510
FRB Dallas	0.013	0.480
DFI-CEC		0.980
HOMS-I	0.076	0.633
Average	0.018	0.384

Source: Huntington (1991), table A.3

ROW supply elasticities of 0.038 and 0.032 at $28/bbl, and 0.048 and 0.04 at $35/bbl. An adjustment rate parameter of 0.1 is again assumed so that long-run elasticities are ten times as large.

Although there can be no exact correspondence between parameters of constant and variable elasticity models, these parameters are generally consistent with other models over

the range of prices mentioned above. Most importantly, as prices rise during a supply curtailment, elasticities in the linear model will increase, mitigating against very large price shocks. Thus, relative to constant elasticity models, the simulation model used here will tend to predict smaller price increases for a significant oil supply reduction.

Given the short-run price elasticity estimates at 1993 prices and quantities, slope coefficients (b in equation A.3 above) are calculated. These are assumed to remain constant throughout the 1995 AEO forecast, and to apply at the Base Case prices and quantities supplied and demanded. Next, for each forecast year and for each supply and demand equation, a constant term (A_t, in equation A.2 above) is computed. With the year-specific constant terms and the price slopes, we have demand and supply equations for each year. Given a reduction in supply from the Base Case, these can be used to solve for a new world price that equates oil supply and demand.[14]

In some scenarios, we assume that price elasticities increse over the Base Case levels. This is simulated by multiplying the initial elasticity estimates by a constant factor (say, 2, to double price elasticity) and recomputing new price slopes (using equation A.3) at the same initial price and quantities. The Base Case calendar year constant terms (A_t) are not changed. It is assumed that price slopes begin to increase in 1996 and increase linearly to reach the new higher value in the year 2005, remaining constant thereafter. This is intended to reflect the fact that price elasticities cannot be changed immediately.

[14]A very simple algorithm, implemented as a macro in the market simulation spreadsheet, is used to equate supply and demand. Given an initial supply shortfall, the change in price that would equate demand to the lower level of supply is computed. One fourth of the difference between the "hypothetical" price and the initial price is then added to the initial price to create a new price estimate. World supply and demand are recomputed at the new price and a new supply shortfall estimate is calculated. The process is repeated until the supply shortfall becomes sufficiently small to be negligible. The dynamic adjustment specification of demand equations causes the previous year's demand to affect the current year's, and so on. Still, the process ususally converges in less than 20 iterations.

APPENDIX B

B.1 METHODS OF ESTIMATING ECONOMIC IMPACTS

Each of the three principal types of economic losses to the U. S. economy is estimated:

1. Loss of the potential to produce,
2. Macro-economic adjustment losses, and
3. Transfer of wealth from U. S. oil consumers to foreign oil exporters.

The **loss of potential GNP** is related to oil's cost share of GNP, as the following demonstrates (Bohi, 1989). Let Q be the gross output of the economy, including final consumption of goods and services **plus** the intermediate consumption of oil used to produce them. Net output, or true GNP, is therefore,

$$GNP = Q - P_{oil} X \qquad \textbf{(B.1)}$$

where P_{oil} and X are the price and quantity of oil consumed by the economy, respectively. Q is a function of capital (K), labor (L), other energy (E), and oil X, Q(K,L,E,X). If we assume that marginal products (dQ/dK, etc.) are equal to factor prices, as they would be at equilibrium in a full employment economy, then a change in GNP can be related to changes in factor inputs as follows.

$$dGNP = P_k dK + P_L dL + P_E dE - X dP_O \qquad \textbf{(B.2)}$$

If we divide equation (B.2) through by dP_O, then multiply through by (P_O /GNP) and rearrange terms, we derive the following expression in terms of the cost shares of GNP of each factor,

$$\eta_{GNP,P_O} = \sigma_K \eta_{K,P_O} + \sigma_L \eta_{L,P_O} + \sigma_E \eta_{E,P_O} - \sigma_O \qquad \textbf{(B.3)}$$

where σ_i is the cost share of GNP for factor i (price of i times quantity of i divided by GNP), and η_i is the elasticity of substitution of i with respect to the price of oil (percent change in the use of i with a percent change in the price of oil). If the elasticities of substitution were all zero, then the elasticity of GNP with respect to the price of oil would equal the negative of oil's cost share of GNP.

While capital, labor, and other energy sources can certainly be substituted for oil in the long-run, the short-run substitution possibilities are more limited. For the period of a year or two, it seems quite reasonable to assert that the products of the substitution elasticities for capital and labor and their respective cost shares are essentially zero. Also in the short-run, experience indicates that the effect of an oil price shock on nonpetroleum energy use may even be negative. Thus, the negative value of the oil cost share of GNP should be a reasonable, if very approximate, estimate of the short-run elasticity of GNP with respect to the price of oil. The long-run elasticity of GNP with respect to the price of oil should be smaller. It is assumed to be zero in this analysis.

Macroeconomic adjustment losses occur due to the inability to maintain full employment of the factors of production throughout the adjustment to the new price regime. Fortunately there have been numerous assessments of the impact of oil price changes on the U. S. economy, some based on model simulations, others using econometric methods to analyze historical data. Unfortunately, these studies generally do not distinguish between the two causes of loss of GNP.

In terms of the size of the impacts, all the estimates of which we are aware are of the same general magnitude as the oil cost share of GNP. The earliest estimates by Mork and Hall (1980) and Pindyck (1980) based on the 1973-74 price shock were -0.03 and -0.02,

respectively. In 1973 the oil cost share of GNP was 0.015 and in 1974 it jumped to 0.032. More recently, Mork, Olsen and Mysen (1994) estimated oil price elasticities for U. S. GNP of -0.054 and -0.068, depending on model formulation, using data covering the period 1967-1992. In the most extensive simulation of the impacts of oil price shocks, the Energy Modeling Forum (Hickman, 1987) tested fourteen macroeconomic models with a simulated 50% oil price increase beginning in 1983 (Table B.1). They tracked the impact on GNP for four consecutive years, ending in 1986. If one takes the simple average of all four years and all fourteen models, an estimate of -0.047 is obtained. Elasticities for individual models ranged from -0.02 to -0.095.

> "Thus the average finding is that real output is reduced by about 0.5 percent and the price level increased by about the same amount for each permanent increase in the price of oil, with a range for each response of about 0.2 to 1.0." (Hickman, 1987, p. 164)

In the years 1982 and 1983, the oil cost share of GNP was .045 and .037, respectively, having been as high as 0.056 in 1981. Helkie (1991) cites an elasticity of GNP with respect to oil price of -0.03, based on simulations of the Federal Reserve Board staff's MCM model, which he uses in his analysis of the impact of supply shortfalls on oil prices. The apparent correlation of GNP impact and the oil cost share of GNP is to be expected based on the simple theoretical discussion above, and has been previously pointed out by Tatom (1993, p. 131) and earlier by Pindyck (1980, p. 19).

> "The percentage decline in capacity output and the rise in the price level associated with each one percent rise in the relative price of energy generally are equal and proportional to the share of energy in the cost of output." (Tatom, 1993, p. 131)

We assume that in the short-run, the elasticity of potential GNP with respect to oil price is equal to the oil cost share of GNP. We further assume that in the long-run, substitution

Table B.1 Estimates of the Impact of Oil Price Shocks on GNP

Elasticities of GNP with Respect to Oil Price			
Source	Potential GNP Loss	Adjustment Costs	Total Effect
Pindyck (1980)	-0.01	-0.009	-0.02
Helkie (1991)			
Federal Reserve MCM			-0.03
Federal Reserve MPS			-0.04
Mork and Hall (1980)[a]			-0.03
Hickman (1987) EMF 7 Study			
LINK			-0.05
Wharton			-0.059
MACE			-0.043
Hubbard-Fry			-0.022
Chase			-0.051
Claremont			-0.072
MPS			-0.063
FRB MCM			-0.02
BEA			-0.069
DRI			-0.046
Hickman-Coen			-0.044
St. Louis			-0.057
Mork			-0.095
Michigan			-0.067
Average			-0.055
U. S. DOE Interagency Working Group (1990)			
LOW		-0.020	
MID		-0.025	
HIGH		-0.040	
Mork, Olsen and Mysen (1994)			-0.054
			-0.068

[a]Based on a predicted -2.8% decline in 1980 GNP for a 93% increase in oil prices in 1980 over 1978.

effects will offset half of the short-run loss of output potential. Since we are measuring costs relative to a competitive oil price level, and since that competitive price is much lower than the forecasted oil prices, we do not use the instantaneous oil cost share. Instead we use the midpoint between the oil cost share at the competitive price and that at the current price. Thus, if the current oil cost share is 3% and the competitive price oil cost share is 1%, the short-run potential GNP elasticity would be -0.02 and the long-run elasticity would be -0.01, for that year. The mechanism of adjustment is described below.

There is little in the literature concerning the relative sizes of the macroeconomic and potential GNP effects, however, Pindyck (1980) suggests a 50/50 split. In the calculations done here, it is assumed that the macroeconomic adjustment effect is 75% as large as the short-run potential GNP effect.

In the case of both the potential GNP and macroeconomic adjustment losses, one may expect the economy to adjust over time to the higher price of oil, reducing its impact on GNP. This is represented here by estimating a hypothetical price to which the economy has adjusted in any given year, and computing GNP losses as a function of the difference between the actual market price and the hypothetical price to which the economy has already adjusted. This method is motivated as follows. Consider the lagged adjustment model of oil demand and supply presented in the Appendix in equations (A.1) and (A.2). At any particular time, t, the quantity demanded (supplied) will be the long-run equilibrium quantity for some price of oil, P^*_t. Substituting this price into equation (A.1) and letting the equilibrium quantity, $q_t = Q_t$, and then setting equation (A.2) equal to the resulting expression, we get the following intuitive formula for the hypothetical price.

$$P^*_t = \lambda P_t + (1-\lambda) P_{t-1} \qquad \textbf{(B.4)}$$

For macroeconomic adjustment costs, the rate used is (λ=0.33). This rate implies near complete adjustment within three years. This is faster than the adjustment rats for most of

the models studied by Hickman (1987). Macroeconomic losses occur whether prices rise or fall.

The elasticity of potential output with respect to oil price is defined as

$$\eta_{GNP,P_o} = \frac{\frac{\Delta GNP}{GNP}}{\frac{\Delta P_o}{P_o}} = -\sigma_o \quad short\ run, \quad \frac{-\sigma_o}{k} \quad long\ run. \tag{B.5}$$

Where σ_o is the oil cost share of output (GNP) and P_o is the price of oil. As noted above, we assume k=2. The GNP loss is computed relative to the assumed competitive market price, P_c. Thus in the short run,

$$-\sigma_o \frac{\Delta P}{P} = -\sigma_o \frac{P_t - P_c}{P_c} \tag{B.6}$$

and in the long run,

$$\frac{-\sigma_o}{k} \frac{P_t - P_c}{P_c} = -\sigma_o \frac{P_t - p_t}{P_c} \tag{B.7}$$

The price variable p_t is a weighted average of the current and competitive price that depends on k.

$$p_t = \left(1 - \frac{1}{k}\right) P_t + \frac{1}{k} P_c \tag{B.8}$$

Equation (B.8) is defined so that equation (B.7) is always satisfied. We now assume that the economy gradually adjusts towards the long-run potential GNP elasticity by substituting an adjusted price, $\mathbf{p}_t$, for p_t in equation (B.7).

$$p_t = \lambda p_t + (1-\lambda) p_{t-1} \tag{B.9}$$

In the event that the current price of oil is less than the competitive price, we estimate the potential GNP *gain* by assuming that the short-run elasticity applies. When the current price is above the competitive market price, the GNP loss is estimated by two different formulas, depending on whether the adjusted price is converging on the weighted average price from below ($\mathbf{p}_t < p_t$) or from above. If $\mathbf{p}_t < p_t$, then the elasticity is given by,

$$\eta_{GNP,P_o} = -\sigma_o \left(\frac{P_t - p_t}{P_c} \right) \tag{B.10}$$

When $\mathbf{p}_t > p_t$, the adjusted price is converging on the long-run price from above, so the long-run elasticity is used.

$$\eta_{GNP,P_o} = -\sigma_o \left(\frac{P_t - P_c}{P_c} \right) \tag{B.11}$$

Because P_t is often many times as large as P_c, a better approximation for the denominator than P_c is the midpoint of the competitive and current price of oil. Thus, we substitute $P_{mid} = (P_t - P_c)/2$. in the denomenator of (B.10) and (B.11) in calculating the oil price elasticities of potential GNP.

When oil prices rise due to the exercise of monopoly power by OPEC, there is also a **transfer of wealth** from U. S. oil consumers to the owners of foreign oil. Not all exporters are monopoly producers who will receive the transfer of wealth in the form of pure monopoly rents. Some will have to spend money on exploration and development to produce oil. These costs will be deadweight losses to the world economy, resulting from the monopoly pricing of oil. Thus, they are true economic losses. However, since they occur outside the U. S., they are not included in the loss of U. S. GNP due to higher oil

prices. Therefore, it is not double counting to consider the entire amount that the U. S. pays for imports over and above the competitive market price as a loss of wealth to the United States, and count this as an economic cost in addition to the deadweight losses that make up the loss of potential GNP within the U. S. economy. Whether oil exporters waste the additional money we pay them or put it to productive use does not change the fact that it is lost to us.

A key problem, of course, is determining what the price of oil would be in a competitive world oil market without monopoly influence. In 1972, the year before the Arab OPEC oil embargo, the average cost of imported oil to U. S. refiners, which had been declining for two decades, was $10.30/bbl in 1993 dollars. In this analysis, we assume a competitive market price of $10/bbl in 1993 dollars. Costs may be computed either holding this price constant through 2010, or increasing it at an assumed real discount rate. The latter is consistent with the theory that oil is treated by markets as a finite exhaustible resource, a view that is rejected by several renowned energy economists because of the historically demonstrated ability of technology to discover new reserves, increase recovery from known reserves, and generally expand the definition of economically exploitable resources (e.g., Gordon, 1994; Adelman, 1990; Mabro, 1992).

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