during supply interruptions, the consuming nations' *economic* risk has been reduced.

3. A spot market sale of SPR oil may also affect future price expectations to the extent that some of the oil may be resold in the future. However, it cannot affect price expectations more than a futures sale would, since, with a spot sale, there is uncertainty over which date in the future the oil will be resold. Typically, a fraction of the oil can be expected to be resold three months in the future. By contrast, with a futures sale, agents can expect all the oil to be available at the date the contract is due. Hence, the impact on the expected future price will be greater with a futures sale than with a spot sale.
4. This conclusion holds a fortiori in a multiperiod world, so long as there is no further policy intervention in the subsequent periods.

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11 GOVERNMENT STOCKPILES IN A MULTICOUNTRY WORLD
Coordination versus Competition

R. Glenn Hubbard and Robert J. Weiner

Three times in the past decade, the world has witnessed major disruptions in the supply of crude oil from the Middle East. Twice—in 1973–74 and again in 1979—the result has been havoc in the international oil markets and substantial damage to the Organization for Economic Cooperation and Development (OECD) economies. But the experience was not repeated when the Iran–Iraq War broke out in late 1980. General consensus attributes the relatively high level of stocks at the war's outset with facilitating the ensuing drawdown, thereby making up part of the loss and easing pressure on the spot markets. In contrast, world stock levels were below historical averages in the last quarter of 1978. The ensuing scramble to build up stocks is widely credited with exacerbating the price effects of the relatively small Iranian disruption. In this chapter we undertake an economic analysis of stock behavior and, utilizing an econometric model that links the world oil market and the economy, investigate the effectiveness of so-called "stock policies" in avoiding a repetition of 1979.

The Iranian crisis left in its wake numerous scholarly studies, many of which were variations on the theme "What happened, and how can we avoid similar disasters in the future?" Among the con-

Thanks are due to Albert Danielsen, Shantayanan Devarajan, James Hamilton, and William Hogan. However, the views expressed herein, as well as any errors, are solely ours.

clusions reached was that cooperation among importing countries is highly desirable but damnably difficult.

Several economists have constructed elegant optimizing models in order to quantify the potential benefits of cooperation. Such analyses have been carried out by Chao and Peck (1980), Hogan (1982), Manne (1982), and Rowen and Weyant (1982). The estimated value of cooperation varies due to the different modeling techniques employed as well as the diverse assumptions about OPEC behavior, the structure of oil demand, the size and length of the disruption, the form the cooperation takes, and underlying economic factors. Although these benefits are measured along different dimensions (e.g., cost of protective policies and changes in GNP) and are thus difficult to compare across studies, a consensus exists that the value of joint action is substantial.

These studies are generally silent on the difficulty of designing and implementing a joint program, although Hogan uses his model to demonstrate that the benefits to the United States of reneging are small compared to the risk of having an agreement fall apart altogether. In actuality, the International Energy Agency (IEA), an organization within the OECD, has been charged with the development and refinement of such a program.[1]

It is not our task here to provide a detailed critique of past IEA actions.[2] Suffice to say the consumer cooperation has not always been a resounding success; indeed, it has sometimes proved difficult to detect. It will, however, serve to summarize briefly the manner in which cooperation is to take place within the IEA. The salient points are three. First, member countries are required to hold stocks equal to ninety days of net imports. Second, the agency's oil-sharing mechanism is essentially dormant until such time as its members determine that a severe disruption has occurred. In order for the emergency program to be set in motion (referred to as "triggering"), the disruption must lead to a loss of at least 7 percent of IEA consumption—compared to a base period of the previous four quarters with a one-quarter lag for data collection.[3] Third, when the trigger is pulled, member countries are required to institute demand restraint to reduce consumption by 7 percent, reduce imports by more than 7 percent, and make up the difference by drawing down reserves.[4] These measures are designed to restrict demand in the short run in an effort to prevent oil prices from skyrocketing.

Various technical problems with such a program have been pointed out in the literature; here, we take note of two broader difficulties. First, the 7 percent threshold corresponds to a severe disruption. Assuming free world oil consumption of roughly 50 million barrels per day (mbd), and taking the IEA share of consumption as constant,[5] a loss of 3.5 mbd (net of increased exports by other producers) is necessary to trigger the emergency mechanism. The Iranian crisis, during which oil prices more than doubled, was of considerably lesser magnitude. Second, demand restraint proved to be easier said than done; the March 1979 agreement to reduce consumption by 5 percent was not accompanied by vigorous enforcement.

Among the lessons to come out of the 1979 and 1980 supply shocks was that while high stockpile levels are a sine qua non for the functioning of international sharing agreements, it is the drawdown (or buildup) behavior that is likely to spell the difference between containment and disaster. Another is that actions taken in a "subtrigger disruption" (one falling beneath the threshold) may serve to avert a 1979-style catastrophic price runup. Demand restraint having failed, the economic damage attending a subtrigger disruption has called forth proposals for coordinated drawdown programs.[6] These proposals, often termed "flexible stock policies" have generated only moderate interest in the United States. The Reagan administration officially supports IEA cooperation in the case of a large (trigger) disruption but prefers to rely on the market for anything smaller.[7] We are unaware of any economic analysis of the effectiveness of these programs in mitigating disruption damage; such is our task in this chapter.

The Strategic Petroleum Reserve (SPR) figures prominently in the U.S. government's energy emergency policy, and its fill has been expedited.[8] How and when to use the reserve is currently under study; it is by no means a foregone conclusion that the government considers a repeat of the 1979 debacle to be an acceptable outcome of market processes, or that SPR releases would be held off until mandated by international obligations.[9] Criticism of the IEA trigger often overlooks the fact that some type of threshold is necessary to any contingency plan. The threshold value is a more difficult question and constitutes part of the debate.

In evaluating SPR drawdown strategies, international coordination considerations must be kept in mind. How effective will SPR draw be in relieving pressure in the world oil market if other IEA members do not do likewise? Or, even worse, what if some countries fill while others draw? The existence of this problem is well known but, notwithstanding a few relatively superficial observations, analysis of the magnitudes involved is lacking. It is to this task that we now turn.

THE WORLD OIL MARKET

Be it explicit or implicit, a model of the world oil market is crucial to any discussion of stocks policy. Essential to our analysis is a rigorous notion of market "tightness"; we thus abstract from much of the rich institutional detail of the oil trade in order to focus on this aspect. We employ two prices as proxies for the many prevailing in the market at any given time. Crude oil is sold under term contracts at the contract price. The spot price is paid for oil purchased on a single-cargo basis.[10]

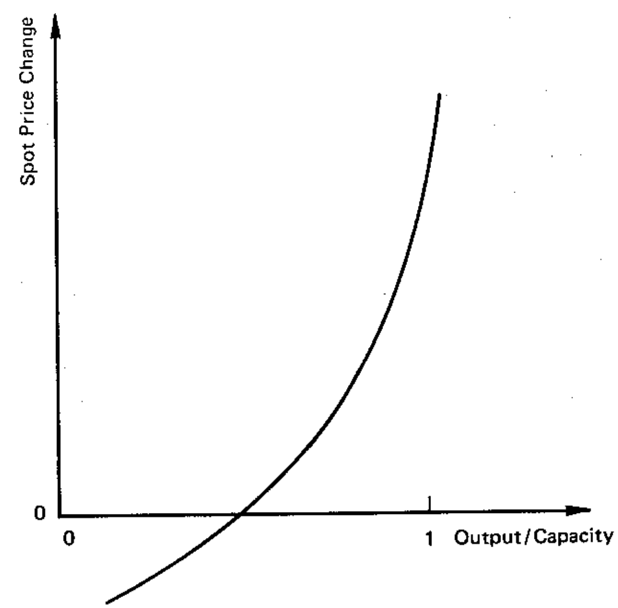
The contract price is set by OPEC in accord with its production decisions and demand estimates.[11] Given the difficulty in forecasting demand and the numerous minor shocks inherent in any market, the contract price will not always equate supply and demand. The spot market serves to satisfy the excess and thus acts as a signal of market disequilibrium to OPEC, which adjusts the contract price. The process is then repeated.

The spot price increases when the market tightens. Two forms of tightening are possible: Demand can increase due to changes in consumption or stock buildup, and supply can decrease due to disruption in a producing country or deliberate production cuts. In order to capture both effects, we employ a form of price reaction function (see Figure 11-1), following Nordhaus (1980), Plummer (1981), and Hubbard and Fry (1982).

When a disruption occurs, capacity is removed from the market, and the output-to-capacity ratio of the nondisrupted producers rises. At higher prices these producers are willing to accelerate output, thereby bumping up against their own capacity constraints. When excess capacity no longer exists, (output/capacity = 1), even large increases in the spot price can elicit little further supply response; hence the nonlinearity of the curve.

Capacity decisions are assumed to be determined by longer term considerations outside the scope of the model and are taken as exog-

Figure 11-1. OPEC Price Reaction Function.



enous. OPEC output is calculated from the condition that supply and demand be equal, where demand comprises U.S. and foreign consumption, SPR fill, U.S. private inventory accumulation, and foreign inventory accumulation. Supply is divided according to source: non-OPEC, disrupted OPEC, and nondisrupted OPEC.

U.S. consumption is assumed to depend on the domestic refiner's acquisition cost, income, and a vector of structural variables, including past prices. Foreign consumption is defined similarly.

The U.S. refiner's acquisition cost is taken to be an average of spot and contract prices (plus transport costs), and to adjust to the spot price. The domestic price abroad is defined similarly.

The objective of stocks policy should be clear: to reduce demand for OPEC output, thus moderating increases in the output-to-capacity ratio and reducing pressure on the spot price. Stock policy yields "more bang for the buck" as a disruption worsens due to the nonlinearity of the price-reaction function.

We are interested in the effect of SPR releases on the spot price. In this model, such effects are three. The "direct effect" is to ease pressure as the SPR release reduces demand for OPEC output. The "feedback effect" occurs because holding down the spot price serves to hold down domestic prices at home and abroad as well, thus reducing the cutbacks in U.S. and foreign consumption. The feedback effect clearly works against the direct effect. Together, these two constitute what we shall call the "domestic effect." The "international interaction effect" depends on the reaction of foreign stock to SPR releases. "Cooperation" implies that the SPR and foreign stockpiles are drawn down simultaneously. Under "competition" foreign stocks may be built up as the U.S. government draws down the SPR. A mathematical expression for these effects can be found in Appendix A.

Cooperation serves to magnify the benefits of the SPR release; competition serves to mitigate them. In the extreme case, when foreign stocks are built barrel-for-barrel as the SPR is released, the net effect on the oil market is nil. It is important to realize that due to the nonlinearity of the price reaction function, the magnification (or mitigation) effect is more than proportional. Thus, as in the analyses referenced above, cooperation provides more than proportional benefits.

Finally, we should note that the benefits of stock draw are likely to be underestimated by the above analysis, which covers only "within-drawdown period" effects. Insofar as current spot prices influence future spot prices, the effect of an SPR drawdown today will be felt in future periods as well.

The Role of Private Stocks

For the sake of exposition, attention thus far has focused on strategic interaction between the SPR and foreign stocks. The SPR, however, constitutes but a small fraction of U.S. inventories. The bulk of the rest is controlled by the petroleum industry, which is free to build or draw as it sees fit. Indeed, folklore has it that private companies were largely responsible for destabilizing the oil market in 1979 through stock building.

Some have suggested that this stocking up represented a panic reaction by those seeking supplies "regardless of price." A related, more sophisticated line of reasoning holds that firms build stocks as prices rise, only to draw them down when the market slackens. The

view of stock change as procyclical implies that inventory behavior necessarily serves to exacerbate the problems associated with disrupted markets (Frankel 1982; Danielsen and Selby 1980). Drawing down the SPR makes little sense in this type of world.

Verleger (1982) has advanced an alternative theory—one that centers on the relationship between stock changes and potential profits. Verleger predicts stock build when the difference between expected future prices and current prices exceeds the cost of storage. As long as prices are expected to rise sufficiently, the predictions of the two theories are identical. These expectations cannot continue indefinitely, however; eventually, stocks act as a stabilizing force.

The empirical investigation presented here takes as inspiration the work of Verleger. As he points out (1982: 120), "[i]t is difficult to model the behavior of oil industry inventories." His examination of the profit motive produced weak (i.e., correctly signed but largely statistically insignificant) results, implying that the "panic theory" could not be rejected. The specification estimated here contains a profit motive but differs from the one employed by Verleger in that: (1) the stock and consumption data have been seasonally adjusted (to account for the normal patterns of alternating build in the second and third quarters and draw in the fourth and first quarters); (2) effects of unanticipated changes in demand ("surprises") are incorporated; (3) we allow for the effects of price controls on stock behavior; and (4) we do not lump the disparate countries of the OECD together.

We take the inventory-to-sales ratio, rather than the raw inventory level, as the variable to be explained. Although not strictly defensible on the grounds of economic theory alone, the use of this ratio is consistent with trade and industry characterization of stocks in terms of "days of consumption."

Our explanatory variables are three. The first attempts to capture the profit motive by comparing expected future prices with today's prices and carrying costs. We expect stock build when the difference is positive. The second reflects the cost of stock adjustment by comparing the inventory-to-sales ratio in the last quarter with a four-quarter moving average. If last quarter's value is high relative to trend, we expect a gradual movement back. Finally, the "demand surprise" term is included because higher than expected demand last quarter (due to, say, unexpected climatic or economic conditions) will result in stock depletion, since contract renegotiation is gradual. We seek to capture this surprise term by comparing the previous quarter's demand with a four-quarter moving average.

The results sketched here summarize a larger effort (Hubbard and Weiner 1983). In the absence of any a priori wisdom concerning the correct structure for the regression, we use logarithms; the effect of changes can thus be readily compared across variables and the results interpreted as elasticities. The regression was estimated using two-stage least squares over the fourth quarter of 1974 (1974: 4) to the second quarter of 1981 (1981: 2) with all variables seasonally adjusted (the adjustment is based on quarterly data extending back to 1960) and in logarithmic form. The results were as follows (absolute values of t statistics in parentheses):

$$(I/S)_t - (I/S)_{t-1} = \underset{(2.0)}{.16}\left[\epsilon P^{US}_{t+1} - (1+r_t)P^{US}_t\right] - \underset{(4.0)}{.54}\left[(I/S)_{t-1} - \overline{(I/S)}_{t-1}\right] - \underset{(5.5)}{1.44}\left[S_t - \overline{S}_t\right]$$

$$\overline{R}^2 = .54, \qquad D.W. = 1.24$$

where t indexes time, I is inventories, S is sales (both seasonally adjusted and in logarithmic form), P^{US} is the U.S. domestic price, r is the three-month Treasury bill rate divided by four, a bar over a variable indicates a four-quarter moving average, and ϵ denotes expectation. A description of expectation formation can be found in Appendix A.

The results imply that companies build stocks in terms of days of consumption (1) when they expect prices to increase by more than the cost of holding them, (2) when their inventory-to-sales ratios are below historical levels, and (3) when consumption is unexpectedly low. The coefficients, which are significant at the 95 percent level, can be interpreted as elasticities. A 1 percent increase in expected profit leads to a 0.16 percent increase in the inventory-to-sales ratio, or roughly 20 thousand barrels per day (inventory-to-sales ratio of 80 days × 0.16 percent × 15.5 mbd sales ≈ 2 mb/quarter ≈ 20 thousand barrels per day). It is too simplistic to characterize inventory accumulation as "procyclical" or "anticyclical" per se. Stock build or stock draw (or both) can accompany the various stages of an oil supply disruption.

POLICY ISSUES

The various issues surrounding stocks policy can be distilled into four questions: the size of the reserve, the fill schedule, the draw schedule, and the institutional framework (e.g., ownership, finance, decision-making). Clearly, the answer to any one of these questions is constrained by the answers given to the other three. However, devising a comprehensive cradle-to-grave program for the reserve is prohibitively complicated, the answer to each of the questions being far from trivial. It is also of limited value to policymakers, who seldom, if ever, have the luxury of creating the world anew.

In this chapter, we concentrate on drawdown decisions and ignore the questions of size, fill schedule, and institutional framework. Our reasons for doing so are two. First, the drawdown issue has received considerably less analysis than the others.[12] Second, while most economists tend to agree, or at least do not disagree strenuously, about the size of the reserve and its institutional setup, considerable controversy exists about its use as an instrument of policy.[13] It should be obvious that a reserve that is never intended to be used is no better than no reserve at all.

In analyzing drawdown alternatives, a firm grasp of the objectives of policy is paramount. The adverse economic effects (losses in GNP, increased unemployment, and inflation) of a supply shock such as a rapid oil price increase are well known; we take the goal of stockpile release as mitigation of this damage through the above-described exertion of downward pressure on oil prices. We regard debates over whether reserves should be used for strategic or tactical purposes as vacuous; we assume that in the event of war, the armed forces will have priority access to oil as well as other goods. We assume that government reserves are instruments of energy emergency policy, not a means for manipulating oil prices in the medium run. As David Stockman (1980) observed "That would be a little like a mouse taking on an elephant; our [proposed OECD reserves of] two billion barrels in salt domes is no match for their 500 billion barrels in the ground."

As noted above, an inherent problem in any contingency program is determining when the emergency has occurred. Below, we devote some attention to this critical question of timing, which lies at the heart of the subtrigger controversy.

Options

What alternatives—short of pulling the trigger—are available to OECD members when confronted with the specter of a disruption? First, they can do nothing. Laissez faire has been a popular option in the past and can serve as a control for "do something" alternatives.

In the "do something" sphere, recent stress appears to be on informality, flexibility, and consultations among governments and between governments and oil companies (see Becker 1982; Keohane 1982; and Chapter 4). Such measures, while admirable as modi operandi, are of little value in the absence of ideas to talk about. Otherwise, they will very likely wind up serving as a fig leaf for a "do nothing" policy.

Second, governments can exhort companies to refrain from making spot market purchases, or at least from doing so at "abnormal" prices. We regard spot prices as being determined by supply and demand. Thus, insofar as spot market abstinence follows from stock draw or demand restraint, price pressure will be eased. Otherwise, such exhortations are foolish. The spot price represents the thermometer, not the illness, and disabling the former can do little for the latter.

Third, due to rigidities in the oil market, a supply shock is likely to affect countries unequally. Informal reallocation can correct these imbalances and, hence, limit recourse to the spot market. This option is thus a version of the last; reallocation can be effective if accompanied by demand restraint or stock draw.

Fourth, as discussed above, demand restraint is effective, but would be terribly difficult to implement. The fifth alternative is that of "flexible stocks"—our focus for analysis in this chapter. Several approaches are possible. One plan of attack is to calculate the optimal draw-cum-fill schedule for the SPR under the various assumptions about the stock behavior of other OECD members. Such a procedure entails a dynamic programming solution and requires that the oil market be characterized by a small number of discrete states, with known probabilities of going from one state to another. Teisberg (1981) took this approach; Hogan (1982) extended it to incorporate international interaction. Neither considered private inventory behavior. Wright and Williams (1982) incorporated private stocks, but their assumptions result in inventory draw in a disruption; the behavior examined here is excluded. Another possibility is to assume away most of the uncertainties associated with the disruption and then optimize by linear programming methods. Such an approach was taken by Kuenne, Blankenship, and McCoy (1979).

Despite its attractive features, we do not employ an optimizing model in this chapter. The data and simplifying assumptions required to do so limit its value in short-term policy applications, Instead, we adopt the less intellectually satisfying but simpler approach of comparing a few proposed strategies designed to be illustrative of a broad range of alternatives.

We examine five stock policies:

1. Laissez faire. In this "base case," countries rely on the market to allocate supplies. The IEA mechanism is not triggered, even in a severe disruption.
2. The United States relies on the market, other countries release five days of stocks in the notation used above, $(I/S)_{t+1} - (I/S)_t = -5)$ held compulsorily. A plan of this type has been advanced by the Commission of the European Communities (1981).
3. As in 2., but other countries increase stockpiles by five days (i.e., $(I/S)_{t+1} - (I/S)_t = 5$).
4. Unilateral U.S. SPR drawdown of five days of consumption (other countries rely on the market).
5. All countries participate in an agreement to release from stocks the equivalent of five days of consumption.

The players involved are three: the U.S. SPR authorities, the U.S. oil industry (whose behavior is described above), and the foreign authorities. Diverse forms of regulation make separation of public and private stock behavior abroad a formidable task and prevent our treating foreign stock behavior endogenously. This is equivalent to assuming either that foreign governments are able to dictate stock behavior to their domestic oil companies or that foreign stock changes reflect decisions made in both the public and private sectors. Neither is particularly palatable, but modeling foreign stock behavior must await future work.

Economic Analysis of Stock Policy Alternatives

The economic effects to be considered are two. First, we seek to quantify the above-described effects of stock adjustments on the world oil market. Second, we examine the resulting macroeconomic impact, which is presumably the raison d'être of stocks policy. The effects of unilateral American action (e.g., the infamous 1979 middle distillate entitlement) on other buyers in the world oil market are well appreciated. In this chapter, we turn the question around by investigating the impacts of OECD policies on the U.S. economy, utilizing a short-run macroeconomic model linked to a model of the world oil market. Unlike most large macroeconomic models (wherein the oil price is a datum), the linkage here runs in both directions. The world oil market model and the macroeconomic model are solved simultaneously; income effects of oil price changes feed back into oil demand, which affects the price of oil, and so forth. A brief description of the macroeconomic model can be found in Appendix A; consult Hubbard and Fry (1982) for more detail and documentation.

How can policies designed to influence oil prices affect the economy? Through which channels do oil shocks have economic impacts? First, the increased oil price diverts spending from home-produced goods to imports, increasing the transfer of resources to oil-producing countries and reducing aggregate demand for U.S. output (net exports fall since oil exporters don't spend all their increased wealth immediately). Second, the rise in the relative price of oil, an important input, reduces the profit-maximizing level of output for firms that use oil, necessitating a fall in real GNP from the supply side. This reduction in output reduces the demand—at least in the short run—for other inputs, such as labor, thus lowering the real wage at which the supply of and demand for labor would be equalized.

These direct aggregate demand and supply effects are magnified because the economic system is not perfectly flexible. Because of rigidities in the economy, particularly sticky real wages, unemployment results, and the economy will fail to attain its (already diminished) consumption and production possibilities. The failure of wages and prices to adjust downward aggravates the rise in the price level caused by an oil price increase. The ultimate consequences for inflation and real income will depend on the size and timing of the disruption (and oil price increases), on the effect of the consequent price level increase on wage settlements and on the fiscal, monetary, and regulatory responses of the government.

In principle, two types of policy responses could be advanced to reduce the economic costs of a large oil price increase attendant

to a supply disruption: income stabilization policies and oil market policies. The former include such devices as temporary tax rebate schemes, accommodating monetary policy, or investment incentives—tools for mitigating the short-run drain on aggregate demand for a given oil price increase. Oil market policies encompass oil taxes and tariffs, price controls, and stockpile drawdown programs—interventions designed specifically to alter oil prices directly. Clearly, the two categories are not mutually exclusive.

There are two basic difficulties with relying solely on stabilization policies to address the problems of oil shocks. First, precisely to the extent to which they are successful (in maintaining real income), oil demand remains high, keeping upward pressure on prices.[14] Second, the imprecision with which stabilization policies achieve their goals is well known. The lags inherent in implementing policy, and phasing it out—not to mention correctly diagnosing the problem—may well nullify the intended result. Temporary tax changes may be ineffective. An accommodating monetary policy runs the risk of raising inflationary expectations.

Analyses of oil market policies have produced similarly ambiguous conclusions. Oil taxes and tariffs put downward pressure on world oil prices, but in the process, they may exacerbate the price shock at home and generate a substantial fiscal drag problem. Oil price controls reduce the domestic price, but they may reduce incentives for domestic production and increase the demand for imported oil, thereby raising world oil prices. In contrast, stockpile releases can serve to reduce world oil prices without the unpleasant economic side effects.

SIMULATION RESULTS

Our simulations cover the five-year period 1982 through 1986; results for 1986 are omitted for brevity. We first present a control scenario, wherein no further disruption takes place. Combined Iranian and Iraqi production recovers throughout the interval. U.S. oil production is projected to drop slowly throughout the interval, although it is more than offset by increases outside OPEC. We expect a relatively loose market (i.e., low output-to-capacity ratio) in the absence of further deliberate restrictive actions by OPEC, with oil prices first falling and then rising as the OECD economies recover from the recession. In the control scenario, the United States fills the SPR at 200 thousand barrels per day.

The Disruption

We simulate a disruption of moderate size. Available capacity is reduced by 7 mbd for one year, starting in 1983:1. Much of the loss is made up (albeit at higher prices) because of the substantial excess capacity at that time. (In the absence of a disruption, capacity would be utilized at about 75 percent.) With no policy intervention—we actually assume that the U.S. government intervenes to the extent of halting SPR fill during 1983—(endogenous) OPEC production falls relative to the base case roughly by 100 thousand barrels per day in 1983:1, 400 thousand barrels per day in 1983:2, 800 thousand barrels per day in 1983:3, 1.4 mbd in 1983:4, 2.2 mbd in 1984:1, 2.4 mbd in 1984:2, 2.9 mbd in 1984:3 and 3.6 mbd in 1984:4.

Table 11-1 and Figure 11-2 present quarterly spot and U.S. refiners' acquisition cost data and changes in private inventories. Although capacity is restored by 1984:1, the spot price does not descend to its predisruption level until 1985:1. U.S. private inventories are built relative to the control, rapidly at first (roughly 90 million barrels in 1983), more slowly thereafter. Starting in 1984:4, private inventories are decumulated relative to the control.

Policy

Borrowing from the European Communities Commission proposal, we examine a policy of releasing from inventory five days worth of consumption. U.S. and rest-of-OECD consumption are taken as roughly 16 mbd and 20 mbd, respectively, which translates into releases of 80 and 100 million barrels.[15] We assume these releases are initiated in the second quarter of the disruption (1983:2) and are repeated in the third quarter, amounting to a 900 thousand barrels per day SPR draw and a 1.1 mbd draw of foreign stocks. The 160 million barrels released from the SPR represent about half of its current contents. Obviously, other configurations are possible. Table 11-2 presents the effects on spot prices. Table 11-3 presents the effects on U.S. real GNP.

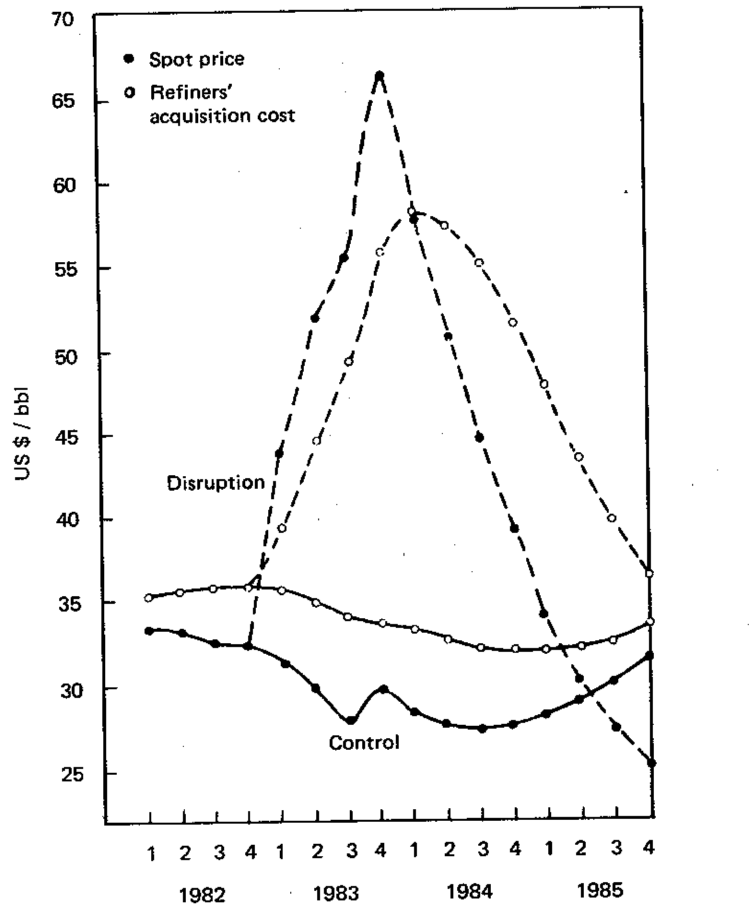
Table 11-1. Comparison of Control and Base Case Disruption.

Quarter	Spot Price (U.S. $/barrel)		Refiners' Acquisition Cost (U.S. $/barrel)		U.S. Private Stock Change (thousands of barrels per day)	
	C[a]	D[b]	C	D	C	D
1982: 1	33.15		35.20		-840	
2	33.05		35.70		620	
3	32.30		35.85		550	
4	32.25		35.90		-410	
1983: 1	31.05	43.90	35.65	39.55	-1050	-750
2	29.70	51.85	35.00	44.60	370	580
3	27.80	55.70	34.00	49.40	500	730
4	29.80	66.50	33.90	56.10	-290	- 40
1984: 1	28.20	57.95	33.40	58.25	-1110	-1110
2	27.45	50.80	32.80	57.60	230	350
3	27.30	44.65	32.30	55.25	450	520
4	27.80	39.20	32.15	51.85	-330	-410
1985: 1	28.20	34.15	32.15	47.90	-1030	-1210
2	29.00	30.30	32.40	43.90	250	150
3	30.10	27.35	32.90	40.20	480	370
4	31.90	25.25	33.85	36.90	-240	-420

a. C = control.
b. D = disruption.

The tables reveal that given a U.S. laissez faire policy (no SPR draw or fill) during the disruption, it makes a noticeable, although not enormous, difference whether the rest of the OECD follows a cooperative (draw) or noncooperative (build) path. Even under the moderate assumptions employed—the 200 million barrel stock increase or decrease is roughly equal to the rest-of-OECD build in 1979 (U.S. Department of Energy 1983:100)—the difference in the spot price is substantial: about $7 per barrel in the first "policy" quarter (1983:2), $11.75 in the second (recall that the policy lasts only two quarters), $8.60 in the third, and about $7 in the fourth. By 1985 the effect on the spot price is insignificant, but U.S. domestic prices (not shown) remain higher (by about $4 per barrel in 1984:4).

Figure 11-2. Oil Prices: Control versus Disruption.



Source: Table 11-1.

The loss in U.S. GNP is on the order of 30 to 40 percent greater in the noncooperative case in the first two quarters, 15 to 20 percent greater in the next two quarters.

The effects of using the SPR are two. First, the decreased demand for OPEC output exerts downward pressure on spot prices. It can be seen from Table 11-3 that this beneficial effect is only about three-fourths as large as when foreign stocks are decumulated, due to the

Table 11-2. Effects of Stock Policies on Spot Prices *(in U.S. $/barrel)*.

		Difference in Spot Price Relative to Base Case			
Quarter	*Spot Price Base Case Disruption*	*U.S.-Market Rest-Build*	*U.S.-Market Rest-Draw*	*U.S.-Draw Rest-Market*	*All Draw*
1983: 1	43.90	0	0	0	0
2	51.85	3.70	-3.25	-2.55	-5.45
3	55.70	6.25	-5.50	-4.25	-9.20
4	66.50	4.60	-4.00	-2.95	-6.55
1984: 1	57.95	3.80	-3.30	-2.40	-5.30
2	50.80	3.00	-2.60	-1.85	-4.15
3	44.65	2.30	-1.95	-1.40	-3.15
4	39.20	1.65	-1.35	- .95	-2.15
1985: 1	34.15	1.05	- .85	- .70	-1.25
2	30.30	.50	- .35	- .20	- .50
3	27.35	.05	.05	.10	.20
4	25.25	-.40	.45	.35	.85

Table 11-3. Losses in U.S. Real GNP (in billions of 1982: 1 $/year relative to control) under Various Stock Policies.[a]

Quarter	*Base Case Disruption*	*U.S.-Market Rest-Build*	*U.S.-Market Rest-Draw*	*U.S.-Draw Rest-Market*	*All Draw*
1983: 1	1.6				
2	5.6	6.6	4.8	-5.0	-5.6
3	11.8	13.6	10.2	-1.4	-2.8
4	20.0	21.8	18.2	17.0	15.4
1984: 1	24.2	26.0	22.4	22.4	20.6
2	30.4	32.2	28.4	28.0	26.2
3	34.6	36.4	32.8	32.2	30.4
4	36.4	38.0	34.8	34.2	32.8
1985: 1	36.6	37.6	35.2	35.2	34.0
2	39.0	40.8	37.2	37.8	35.8
3	40.8	43.0	38.6	39.2	37.2
4	38.8	41.2	36.6	37.2	35.0

a. Negative numbers indicate GNP is higher than in the control.

smaller size of the SPR draw (900 thousand barrels per day vs. 1.1 mbd). Second, SPR draw substitutes for imported oil almost entirely; U.S. oil imports fall by 900 thousand barrels per day in 1983: 2 and 850 thousand barrels per day in 1983: 3. This import reduction improves the U.S. trade balance and hence the U.S. GNP. Given that market policies are followed by the other OECD members, SPR drawdown in 1983: 2 and 1983: 3 reduces the loss in real GNP by $7.2 billion (all GNP figures are in 1982: 1 dollars) over the year starting in 1983: 2. Since the disruption costs the economy $21.5 billion during this period, use of the SPR recoups about one-third of the loss. A rough estimate of the value of SPR oil can be obtained by dividing the $7.2 billion by the 160 million barrels released, yielding $45 per barrel. This figure measures economic benefits over and above the revenues accrued from SPR sales. In an intertemporal optimization calculation, these revenues must be compared with the costs (which we also ignore) of buying and storing the oil for the reserve.

Finally, we compare the cooperative (all draw) case with laissez faire: The 2 mbd decumulation shaves about $5.50 off the spot price in 1983: 2 and just over $9 in 1983: 3. In the following two quarters, spot prices are $6.55 and $5.30 lower, respectively. U.S. GNP is increased over the year starting in 1983: 2 by $8.2 billion—about 20 percent more than in the unilateral drawdown case.

CONCLUSION

Flexible stock policies, including "don't build," can play a significant role in moderating spot price fluctuations and reducing disruption-induced losses in real income, even in a moderate (subtrigger) disruption, wherein the U.S. refiners' acquisition cost rises by about 60 percent (50% in real terms). Inflation and unemployment (not shown) are also reduced. Cooperation provides noticeable tangible benefits in addition to the widely claimed spiritual advantages. Benefits are understated insofar as GNP is an imperfect measure of economic welfare because it ignores wealth transfers abroad. The "terms-of-trade adjusted" figure would be larger. Still, we should note that while the gains from stockpile coordination are significant, they are hardly overwhelming. Whereas macroeconomic policy responses are partly responsible for damage associated with past oil shocks, we have held them constant throughout. In this respect, international coordination of stabilization policies can play a role.

We find the claim that government stock drawdown is impotent due to countervailing actions taken in the private sector to be unfounded. Government releases dampen spot price increases, serving to reduce private inventory accumulation, not increase it. Unless the structural forces behind company decisions are different from in the past, private stockpiling will tend to exacerbate the disruption effects in the early stages and mitigate them thereafter.

Our simulations are designed to be illustrative, and they clearly depend on our policy assumptions. We are also constrained by the well-known limitations of econometric models, but we nevertheless believe that until policy is truly conducted on an optimizing basis, this type of analysis will continue to be a useful input to policy discussions.

NOTES TO CHAPTER 11

1. The Agreement on an International Energy Program, which set up the IEA, was signed by sixteen of the twenty-four OECD countries in November 1974. At this writing, twenty-one countries are members, including all of the major countries but France.
2. For detailed description and analysis, see Keohane (1982), Krapels (1980), U.S. General Accounting Office (1981), and Weiner (1981). For an official view, see Lantzke (1978) and Chapter 4.
3. The agreement can also be triggered when one member country loses 7 percent of its base period consumption but the IEA as a whole does not. Given the rigidities present in the oil market, this "specific trigger" situation is far more likely to occur than the "general trigger" described above, wherein countries are assumed to be affected equally. Given, however, that more oil is always available to those willing to pay, it is difficult to assign a meaningful interpretation to this case, and it will not be discussed further.
4. A 12 percent shortfall requires members to cut consumption by 10 percent. In either case, stockpile draw is pro rata on the basis of imports; thus, more self-sufficient countries have smaller drawdown obligations.
5. This will be strictly true only if the elasticities of IEA and free world demand are equal.
6. For a discussion of the subtrigger crisis and speculation on why demand restraint was inadequate in 1979, see Lantzke (1982).
7. For details, see U.S. Department of Energy (1981b: 29), wherein the door is left open: "The Administration continues to support close consultation with IEA members and would not rule out future actions in the event of [a small] interruption, depending on circumstances."

8. U.S. Department of Energy (1981b) sets out the official emergency policy of primary reliance on the market and substitution of SPR releases for government intervention to allocate supplies.
9. Authority to draw down the SPR stems from the Energy Policy and Conservation Act of 1975. The president must find that "a severe energy supply interruption or obligations of the United States under the International Energy Program" necessitates SPR release, where "severe" is defined as "of significant scope and duration, and of an emergency nature" and causing "major adverse impact on national safety or the national economy." This information is taken from Allen (1982). The definitions of "significant scope and duration" and "major adverse impact" are left open.
10. We use data on Mideast Light, since it makes up the largest fraction of crude oil traded internationally. Our results will thus be biased to the extent that the behavior of spot-contract price differentials varies systematically across grades of crude oil. For further discussion, see Verleger (1982).
11. This description of the short run is consistent with several views of medium- to long-term behavior, and we are thus agnostic on the question of OPEC internal structure, whether it be a cartel, a dominant-country oligopoly, or something else.
12. The size question has been addressed by Balas (1980), Teisberg (1981), Hogan (1982), and Chao and Manne (1982). Institutional issues are treated by Krapels (1980, 1982), and Plummer (1982). Kuenne, Blankenship, and McCoy (1979) examine drawdown decisions. Chapter 9 reviews the present status of U.S. stockpile policy.
13. Neither do we address the questions of how the SPR oil should be sold or to whom it should be sold. For a discussion of these issues, see Allen (1982). For a specific proposal to sell SPR oil through a futures market, see Chapter 10.
14. As mentioned above, there are certain "necessary" costs of an oil supply shock. If stabilization policies attempt to completely insulate the economy, inflation will be higher than it need be in the short run, and the economy's long-run growth path may be adversely affected.
15. These consumption figures are for stock release illustration only. In the model, consumption is endogenous.

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APPENDIX A

MODELING THE WORLD OIL MARKET

This appendix provides some of the technical background of the economic model described in Chapters 10 and 11, emphasizing its applications to analysis of international strategic stockpile coordination and private oil inventory behavior.

The price-reaction function in the text for the spot market price of oil can be expressed in equation form as:

$$P_t = \psi P_{t-1} + \beta f\,(S_t / S_t^*) \quad , \tag{A-1}$$

where P is the spot price, t indexes the time period, f represents the function discussed in the text ($f' > 0$), ψ and β are parameters to be estimated, and S and S^* refer to OPEC output and capacity output, respectively.

Capacity decisions are assumed to be determined by longer term considerations outside the scope of the model and are taken as exogenous. S is obtained from the condition that world supply of and demand for oil must be equal:

$$DUS + DF + USS + FS = S + S^D + S^{NO} \quad , \tag{A-2}$$

where the variables are as defined in the following table.