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The role of inventories in oil market stability

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1. Introduction

Generally, in many countries, market forces determine the process of setting up inventories and the determination of their size. Producers, consumers and speculators will arbitrage prices so that it will be profitable for someone to hold inventories to moderate fluctuations in the balance between production and consumption—if indeed it is profitable to do so. Similarly, the extent to which producers maintain excess production capacity is a decision made by individual producers based on the profitability of doing so.

But in the case of energy commodities, it is reasonable to ask whether the management of inventories can be left to market forces. Arguments that energy is different and requires special interventions reflects the fact that oil, and to some extent, natural gas, is a vital input to the overall economy, and that substitutes are not easily available. In the private transportation sector, for example, there are very few, easily available substitutes for fuels derived from oil. The home heating fuel sector has more alternatives but in the short run, there are significant costs to switching from one fuel to another. The industrial and electricity sectors have somewhat more flexibility where burning of coal or use of nuclear power and other alternatives exist but fuel switching still has significant costs and frequently, logistical barriers.

For military vehicles, with the exception of submarines, virtually no substitute is available to oil fuels. It is not an exaggeration to argue that oil is also a strategic resource, essential in time of war.

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In short, oil has important uses and in some areas, limited substitutes, raising the stakes of a shortage. The consequences of such a shortage, as we will argue, elevates the accumulation of oil inventories to a public domain beyond the energy industry. To assert this contention, we survey the academic literature on energy security to clarify the consensus on various market failures that might justify state intervention in setting up energy inventories to protect the social good. We then discuss how deregulation of energy markets has influenced this question. Finally, we investigate some of the mechanisms available to policy makers to lessen or eliminate the negative consequences to consumers of such externalities or other costs associated with insufficient inventory levels or poor inventory management.

Through this process, we hope to raise awareness of the growing importance of energy inventories in the deregulated marketplace, and the social and political stakes involved in their accumulation. By doing so, we hope to foster renewed debate in this area of energy security policy. We believe this is important because the economic and political environment has changed dramatically since the 1980s when much of the literature in this field was developed. Changes have occurred slowly as many markets have adjusted to new deregulation programs over the last fifteen years or so, requiring new approaches and analysis of the optimum practice of inventory accumulation.

2. Market failure in inventory accumulation

Inventories are necessary for most goods since production and consumption are not usually synchronized. Inventories are then held to buffer the difference between the two. Inventories are accumulated whenever production exceeds consumption and then are drawn down whenever consumption is greater than production.

Lack of synchronization could be the result of fluctuations in demand or because the nature of the production process (scale economies) dictates that in order to produce at least cost, firms will produce at volumes that exceed demand, store the excess in inventory and then shut down the production line until inventories are drawn down.

In cases where storage is technically not possible or prohibitively costly, such as electricity or commodities such as oil and gas where the value per unit of the commodity is low relative to the per unit cost of storage, the maintenance of excess production capacity is an alternative to maintaining inventories of product.

Inventories can also be held for speculative purposes when agents expect future prices to be substantially different from current prices.

In investigating the public policy aspects of holding energy inventories, it is first useful to distinguish between commodity price fluctuations that are predictable in the sense that they behave with some regularity, and fluctuations that are uncertain, in that they are infrequent, of significant magnitude and seriously impact the aggregate economy. Markets can reduce the former type of fluctuations at relatively low cost—the analogy here being with insurance markets. Preseasonal build-ups of inventory can be found in various degrees in peak winter natural gas, summer gasoline and winter heating fuel markets in the US.

By contrast, in the case of "once in a decade" demand and supply shocks whose timing, size and duration are unpredictable, maintaining large inventories or excess capacity could be very costly and private agents may not be able to do so profitably. In the cases where private stocks are profitable, the issue is whether private agents will hold the socially optimal levels.

This issue was extensively discussed in the 1960s and 1970s in the context of justifying government intervention in commodity markets in the form of buffer stock programs. The literature on buffer stocks has enumerated several reasons why markets may not optimally allocate commodities over time and in the process fail to moderate large price changes. First, traders do not have perfect "information about the longer-term future which leads to errors in pricing and inadequate markets for pooling risks" (MacBean & Nguyen, 1987). Second, speculators tend to have a short time horizon and demand overly-high risk premiums (Smith, 1978). These problems are aggravated by a third factor, namely the tendency for producers and speculators to over-respond to events through excessive optimism or pessimism. Left to their own devices, commodity markets are unlikely to provide for socially optimal inventories. Investment in spare productive capacity may similarly not result from market signals.

In the 1960s and 1970s, buffer stock programs became fashionable and were initiated in sugar, tin, cocoa, and natural rubber markets. However, there is a general consensus that the programs did not work.[1] As a result, serious consideration of such programs has ceased.

One reason for the failure of these buffer stock programs is that the process of setting prices, especially the floor price at which the buffer stock holder buys the commodity, was subject to many political pressures. Generally speaking, prices were set too high, leading to an excessive accumulation of stocks at too high a cost to the program. Another reason for failure was that the multiple objectives of such programs were mutually inconsistent—aimed to protect both producers and consumers simultaneously. Given elasticities of demand and supply for most commodities and fluctuations in those elasticities, stabilizing prices at the same time as protecting producer income from fluctuations was a near impossible task. Attempts at intervention in tin, sugar and cocoa markets through buffer stock programs have been discontinued.

Within the US, government commodity stockpiles in these materials have either been eliminated or reduced. Those that remain typically are of strategic materials that are essential to any future war effort.

3. Energy markets as a special case

While faith in buffer stock programs to stabilize commodity markets has generally waned, the industrialized energy importing countries adopted a policy of maintaining "strategic reserves" of oil as a response to the energy price shocks in the 1970s. These reserves were not intended to serve as buffer stocks in the usual sense of holding price variations within a predetermined range. Rather, strategic oil reserves were intended to provide oil supplies in periods of "supply disruptions" (Krapels, 1980, 20). While this definition made some sense in the world of the 1970s, characterized by underdeveloped spot and futures markets and long term, fixed price supply contracts between participants, it is inadequate in the current world where oil is traded on a daily basis as any other commodity. Horsnell (2000) points out that compared with the Gulf war, the 1998–1999 actions of OPEC

> "brought a greater net amount of oil off the market for a longer period. In terms of prices, it brought a greater percentage increase, measured from trough to peak, and sustained price increases for far longer. The Gulf War disruption proved to be short lived. The price impact of the Gulf War peaked two months into the crisis, and was in effect completely removed five months into the crisis. By contrast, OPEC's recent market correction measures brought a price peak a full year after the third tranche of output reduction. " (Horsnell, 2000, p. 4)

In this new environment where market freedom and transparency help clear shortages and surpluses, "supply disruptions" will manifest themselves as price increases rather than supply shortages. Krapels (1980) points out that the initial motivation for establishing reserves was to guard against "supply disruptions" emanating from situations as "Political disruptions, deliberate export restrictions imposed to influence foreign events, production disruptions due to internal unrest in OPEC countries, sudden supply reductions for domestic economic reasons (countries reduce production to prolong useful life of their reserves), terrorist acts or sabotage against oil or oil-related installations,—war involving OPEC nations, and shipping disruptions due to superpower conflicts." Situations of large price increases arising from a confluence of events such as occurred recently (rapidly rising demand at a time of low capacity growth and the exploitation of the resulting tight market by OPEC) was not seriously contemplated.[2]

The consequence of all of the above mentioned events contemplated or not—is the same, namely a sharp, unanticipated price increase. This raises the serious question how to decide how large a price increase, regardless of the cause, must occur before strategic government-held reserves are released. However, in a market that will clear at higher prices, the fine line between using stocks to replace disrupted supplies or to keep prices from moving out of a desired range begins to get blurry.

4. Oil market "failures" or social and other costs

The usual market failure arguments, imperfect information and the divergence between private and social discount rates, are probably not as salient today given the development of the market in futures and derivatives. In the present context, the maintenance of strategic reserves is justified in terms of broader definitions of "market failure" as well as truly "strategic" considerations, in the sense of countering *potential* threats to oil market stability by oil exporting countries. Bohi and Toman (1996, p. 14) discuss the justification for importing countries to use their monopsony power when oil exporters exercise monopoly power opportunistically.

There are a number of additional market "failures" more specific to the energy market that have been discussed in the literature. There is some question as to whether these additional examples truly reflect "externalities" as usually defined, namely, the divergence between private and social marginal costs (Bohi & Toman, 1996, pp. 15–30). However, regardless of the categorization, these are cases where private behavior can be inconsistent with public policy objectives.

One concern is the effect of energy price changes on the macroeconomy. These effects are referred to as aggregate demand externalities. Research on price shocks in the 1970s by

Hickman, Huntington and Sweeney (1987) and Burbidge and Harison (1984) and many others clearly shows a tradeoff between accommodating a price shock, and hence fueling inflation, or counteracting the supply shock with restrictive monetary and fiscal policies and hence inducing a recession and rising unemployment. Lost economic output from the two oil shocks in 1970s was estimated at $1.2 trillion in 1997/98 dollars by the US Department of Energy (1988). These outcomes are real costs, born by the economy but only partially by individual producers or participants in future markets. Hence these industry actors and speculators do not take these costs to the overall economy into account in determining their behavior.

The concept of a distinct aggregate demand externality is somewhat controversial. What this term may refer to is a number of other market failures that prevent the economy from adjusting optimally to a price shock. Examples include labor market institutions (labor unions) which hinder wage adjustments, capital market imperfections, which make capital goods prematurely obsolescent and unusable, or energy market regulations that interfere with the substitution among energy sources. But given that many of these market imperfections are institutionally and politically constrained (for example, the existence of labor unions), a case can be made to address the macroeconomic problems by intervening in oil and energy markets rather than in labor and capital markets (Bohi & Toman, 1996, pp. 15–17).

Not all economists agree that oil shocks must lead to recessions (Bohi, 1989, 1998). For example, Darby (1982) has argued that it was the elimination of price controls, coincident with the 1973 oil shock, that resulted in a decrease in GDP. The oil shock itself had an insignificant effect. Using VAR techniques, Burbidge and Harrison (1984, p. 460) conclude that the oil price increase in the early 1970s served to deepen a recession that was already underway.

The dispute regarding the interpretation of the observed correlation between oil prices and GDP and inflation can only be resolved by constructing a testable model that spells out the mechanism by which oil prices affect the macroeconomy. The controversy then becomes one of differing views about what this mechanism is and how it works (Soligo, Jaffe & Mieszkowski, 1997).

Hamilton (1983) was among one of the first economists to examine and establish the relationship between oil price changes and GDP. However, when Mork (1989) extended the study to include data from the early 1980s he was able to confirm the statistically significant correlation between oil price increases and reductions in GNP but found that oil price decreases were not significantly correlated with GNP increases. More recently, Mork, Mysen and Olsen (1994) have provided further evidence that the effect of oil price changes on GDP is not symmetrical. Price decreases have a much smaller expansionary effect than the negative effect of an oil price increase. Huntington (1998) explains some of the asymmetry. He argues that increases in crude prices are passed through to refined product prices more quickly than crude price decreases and that the relationship between aggregate output and petroleum product and energy prices is symmetric.

Much of the work on the relationship of oil prices on the economy was done using data from the oil price shocks of the 1970s. The world economy today is very different than that which prevailed in the 1970s and 1980s. Not only have oil markets developed in sophistication, but there has been a trend towards deregulation of markets in general—including reductions in tariffs and other barriers to trade. Today's economies are able to adjust to supply shocks much more quickly that in the world of the 1970s and early 1980s.

However, the freer markets of the 1980s and 1990s provide other challenges. Beyond the macroeconomic effects stemming from unexpected but "once and for all" price changes that characterized the 1970s, an additional inefficiency arises from the increasing volatility of oil prices, a phenomenon more characteristic of the last two decades. Lee, Ni and Ratti (1995), using a methodology that is similar to that of Hamilton and Mork, have found that the effect of an oil price shock is greater when prices have been relatively stable, and therefore change is unanticipated, as opposed to situations where prices movements have been frequent and erratic. In the latter case, the price change may contain little new information and hence, does not induce a response. While oil price changes do not correlate well with output growth, particularly since the mid-1980s, a statistically significant relationship is established when the effect of price variability is removed. Oil price increases were found to have a larger impact on output than oil price decreases, a result that is consistent with Mork's.

The conclusion that oil price variability is an important determinant of output growth is also reached by Ferderer (1996). In addition, Gao, Medlock and Sickles (2001) show that price volatility negatively affects innovation and productivity growth. The implication of this literature is that unexpected large swings in oil prices can significantly and adversely affect investment and GDP growth rates.

Bohi and other authors have written about the burden of the domestic resource cost of imported oil. Because the US is a significant part of the world oil market, the world price will be affected by the level of US imports. An increase in the price of oil will increase the foreign exchange cost per barrel of imports. Larger resource transfers to oil producing countries reduce the level of goods and services available to US consumers. However, US consumers do not take this effect into account in determining the amount of oil consumed, giving rise to a divergence between marginal private and social costs of oil. This divergence reflects an externality only in the case where we consider the US economy independently from the rest of the world. From the perspective of the world economy, this simply reflects the redistributive consequences of changes in market conditions.

To illustrate the magnitudes involved, Broadman (1986) gives an example of a situation where the US imports 4MMb/day at a price of $26.00/b. If imports were to increase by 1MMb/day to 5MM/day, the world price, assuming a supply elasticity of 4.0 would increase price to $27.63. But the marginal social cost for each additional barrel would be $34.15, a difference of $6.52.[3] Private markets set price below social marginal cost and lead to overconsumption of oil. The resulting inefficiency has implications for US policy. The upward sloping supply curve for imported oil facing the US gives the US some monopsony power to counter the monopoly power of OPEC. Whether the US should exploit this power is the subject of some controversy but is not directly related to the issue of inventory policy.[4]

The implication of a rising supply curve for imported oil for inventory policy lies in the fact that, given the low short run elasticities of demand and supply for oil, the gap between the average and marginal cost of imported oil will most likely be an increasing function of the level of imports. In other words, if demand were to increase by more than supply, the larger the shortfall of supply at the initial price, the larger the gap between average and marginal cost of oil and the larger the resource transfer to producing countries. But the significant result is that the resource transfer is an increasing function of the additional imports. The impact on domestic consumers rises at an increasing rate as imports rise. But private agents will not take this factor into account in determining inventory behavior.

If price increases are the result of temporary imbalances in the oil market, a country can significantly reduce short run increases in wealth transfers to producing countries by holding sufficient inventories to moderate changes in the supply/demand balance.

Yet another factor that may lead to suboptimal inventories from a social point of view is the uncertainty of governmental response to a supply shock. As Wright and Williams (1982) point out, private agents must take account of the fact that during a major run-up in oil prices there will be enormous pressures brought to bear on governments to impose a price ceiling. Under reasonable assumptions, Wright and Williams show that because of this possibility firms will hold smaller inventories than they would otherwise. Plummer, Chao, Gately and Gilbert (1982, pp. 13–36) point out that in both 1973 and 1979 the government took control of private inventories under the Emergency Petroleum Allocation Act. In deciding how much inventory to hold, firms must take into account the possibility that the government may do so again. Since it is unlikely that government assurances that private inventories will not be appropriated in the future will be fully believed by private agents, an alternative is to use government held inventories for government intervention to counteract sudden and large price movements.

Politicians also worry about the impact of sudden price movements on their constituents. Energy is, in many of its uses, a basic necessity. Large price increases can severely impact consumers, particularly poorer families, even if they are temporary. Part of the problem facing lower income consumers stem from a capital market failure. Low income households are liquidity constrained and unable to borrow to finance large increases in energy prices, possibly resulting in severe economic deprivation.[5]

In addition, of course, permanent increases in energy prices can significantly reduce the real incomes of low-income families. This has prompted politicians to argue in favor of government intervention on wealth distribution or social justice grounds. Given the inelastic nature of short run demand and supply curves for energy, large rents accrue to suppliers when prices increase. These rents represent large transfers of income from consumers to producers.[6] Reduced volatility or smaller price changes that might result from the existence of larger inventories would reduce the occurrence of these situations and moderate the level of income transfer when they do occur. Also, the moderation of price swings will reduce the likelihood that energy policy becomes over politicized.

5. Effects of deregulation of energy markets

As discussed in the introduction to this paper, the increasing trend toward energy industry deregulation has affected the accumulation of oil and natural gas inventories and thereby raises questions anew about the various social costs of related oil price variability.

Since the 1970s, governments around the world have to varying degrees reduced heavy government regulation and intervention in domestic energy sectors. Prior to the 1970s, many governments in the industrial and developing worlds directly administered the prices of key energy components, both at the primary level (crude oil, natural gas) and at the consumer level (petroleum product prices, residential natural gas, and electric power). In the 1970s, consuming country governments were also involved in major purchase contracts for internationally traded energy commodities (oil and natural gas primarily), and often tied these contracts to other trade and national security issues (barter of oil for construction projects, soft loans, arms). Today, private parties dominate the international marketplace for contracting in internationally traded energy commodities, with transactions set at flexible, floating market related pricing.

For the most part, in the OECD, Latin America and increasingly in Asia, governments are exiting the energy sector. There is a widespread global consensus that administered prices and overbearing regulations that are not consistent with market fundamentals create economic inefficiencies, impede smooth adjustment of prices to rapidly changing circumstances, and infuse energy issues with other political issues, thwarting adequate resource development and deliverability (Running on Empty, 2000).

In many countries, government oil and gas companies have been privatized. Even in countries where governments still own significant energy assets, state-owned enterprises are increasingly run in a commercial manner and preferential considerations for state industry have been reduced.

Generally speaking, market liberalization has facilitated efficiency and the smooth allocation of resources to users who most value them.[7] But they have also brought unintended consequences. Some critics (Strategic Energy Policy, 2001, pp. 4, 13–19) have argued that deregulated markets have failed to provide incentives either for the timely and adequate construction of surplus infrastructure capacity or for the accumulation of sufficient inventories of fuels that are needed to smooth out market dislocations or unexpected, sudden rises in demand. On the other hand, defenders of deregulation have argued that the unintended consequences are the result of insufficient deregulation (Vaitheeswaran, 2001) or are simply the short run consequences of a change in the regulatory environment and that these problems will disappear in the long run.

The fact is that deregulation has brought about a more competitive environment that has prompted companies to work to lower operating costs. One tool has been to reduce inventories and excess capacities. Mergers have also allowed firms to reduce inventories by exploiting economies of scale.

In other words, the optimal private level of inventories and/or excess capacity under a deregulated environment is lower than in the regulated, protected one. Companies have begun to trim back inventories and simply pass on higher supply costs that come during market dislocations to consumers. This strategy reduces the capital that is tied up in maintaining larger inventories and excess capacity on a continual basis. The result of this movement to reduce inventories has been greater price volatility. And, as discussed above, greater price volatility can have negative consequences for productivity growth as well as serious distributional consequences as low-income households struggle to meet increases in the cost of electricity, home heating and transport.

6. Accumulation and release rules

Given that there is some justification for government intervention in energy markets, questions are now emerging about how extensive and/or intrusive this intervention should be.

The maintenance of reserves is costly and must be weighed against the benefits of their effect on severe oil price volatility. It is reasonable to assume that futures/derivatives markets can handle day-to-day shifts in demand and supply. To the extent there should be any role for government, presumably (given the poor record of buffer stock programs in the 1970s), it should be confined to dealing with (and moderating) those major price changes that give rise to the costs and inequities discussed above.

Verleger (2000) has argued that the conditions which create the environment where OPEC can exercise monopoly power are clear and can be easily foreseen, improving the chances of effectiveness for a strategic stockpiling program. These conditions preceded the large price increases in the 1970s and the current rise. According to Verleger, these indicators are: an expanding world economy, declining excess production capacity worldwide and declining investment in oil and gas exploration. A policy of increasing reserves when these indicators are present could be prudent.[8]

7. Alternative policies

Today, many governments, including the US, maintain publicly owned and financed "strategic" petroleum reserves. In fact, the number of countries organizing such reserves is rising. Such reserves can only address strategic requirements for a relatively short duration. Green, Jones and Leiby (1998) simulate the effects of a two year supply shock and conclude that the use of strategic reserves to deal with "a persistent OPEC strategy to restrain production" will not be effective either as a deterrent or as a means of protecting the economy. Maintaining an even larger stock may help in the sense of allowing importing countries to "hold out" for a longer period of time. But, as discussed above, strategic stocks are not designed to be used as buffer stocks and therefore, may not be an ideal means to promote orderly markets except in the most extreme circumstances of a war or major accident or natural disaster. Impediments to using these stocks to moderate price swings is primarily political. However, the experience with other buffer stock programs is also important. Once governments are in the position to influence the price of oil, there will be pressure from both consumers and producers to nudge prices in the direction that favors the specific interests of these groups. Perhaps, Central Bank efforts to smooth foreign exchange rates provide a useful analogy. In that case, knowing the difference between a temporary swing in the price of foreign exchange and a fundamental change in its value is not easy to discern.

There are several alternative or supplemental ways in which public policy can address the issue of severe price volatility for vital energy supplies. These policies can be divided into three categories according to their function. Some policies like holding strategic inventories are designed to moderate, and/or prevent, large movements in the price of oil. Some policies work to prevent large price changes that might be introduced by political factors or by the monopoly power of suppliers. Finally, there are policies that aim to reduce the vulnerability of the economy to large oil price movements by reducing the dependence of the economy on oil or any other vulnerable form of energy supply.

For the purposes of this paper, four practical alternatives will be discussed. This list is by no means exhaustive but represents options that are either being taken or could be taken utilizing existing infrastructure and programs that could be expanded.

One option, mainly aimed to correct for the social costs imposed by deregulation, is to require or subsidize private firms to hold additional inventories at levels above what they would normally hold. Alternatively, governments could subsidize the holding of excess production capacity by foreign or domestic producers. Throughout the 1980s and during the Gulf crisis, excess capacity in oil producing countries that were allies of the US and the West served as a stabilizing factor in oil markets. Both of these policies serve the function of moderating the impact of events that, minus such inventories, could lead to large price increases.

A third area of policy concerns the development of alternative technologies. Governments can subsidize the development of backstop technologies to prevent producer cartels from exacting monopoly profits or promote alternative energy sources that can serve to reduce the need for fossil fuel. In this practice, back stop technologies create an incentive for oil producers to avoid oil price shocks and supply disruptions for fear that the new technologies would be implemented, permanently eliminating previously lucrative markets. Alternative energy supplies provide ready substitutes if the price of oil rises sharply and, with some time lag, can shield the economy from the negative impact from disruption of any single fuel source. Green, Jones and Leiby (1998) favor this approach of increasing the elasticity of demand (and the elasticity of supply of non-OPEC oil) not only as a strategy for dealing with oil price shocks but also as a way to reduce the monopoly power of OPEC at all times.

Finally, governments can undertake policies that reduce oil use, such as encouraging the use of nuclear power or fuel cell technology or to deploy technologies that increase energy efficiency. Reducing energy dependence (increasing energy efficiency) will reduce the overall vulnerability of the economy to energy price spikes but will not moderate them when they occur.

Each of these four policy options has its benefits and drawbacks. On the face of it, the less than comprehensive policy of maintaining strategic oil reserves financed by government out of general revenue does not appear in itself to meet all of the goals to a sound energy policy that research in the field has identified. A policy that limits itself to government stockpiling fails to provide incentives for consumers of energy to take into account the consequences of high energy output ratios and hence does not serve to reduce energy consumption by increasing energy efficiency.

Requiring oil refiners to hold some minimum level of inventories, either as a substitute for government stocks or in addition to them, is also problematic. This practice is enforced in some European countries where oil refiners are required by law to hold minimum inventories equivalent to 90 days of forward demand coverage. In the US, the Energy Policy and Conservation Act (EPCA) of 1975 authorized the creation of an Industrial Petroleum Reserve (IPR) that would require every importer of crude and every refiner to store an additional quantity equal to three percentage of the previous years' throughput.[9] This provision was never implemented in part because of industry opposition. One argument against mandated inventories was that they would raise costs, thereby serving as a "tax" on oil and inducing inefficiencies in oil company market behavior. Krapels (1980, pp. 84–86), for example, argues that if firms are required to hold excess inventories, then they may economize on distribution costs by switching to larger storage tanks, making infrequent deliveries rather than say, using smaller tanks and making more frequent deliveries. In other words, firms will adjust their business practices to lower costs by substituting inventories with other factors. Excess inventories are thereby likely to become working inventories. But Krapels misses the point. The additional "inefficiencies" are really costs that must be balanced against the benefits of having larger inventories. Such a policy is only inefficient if these costs exceed those benefits or if there were some alternative policy that would generate those benefits at a lower cost. Making such comparisons would be difficult in practice.

It has been proposed in Congress and suggested by experts in the US that, rather than mandate oil refiners to hold minimum inventories, tax policy be utilized to neutralize any negative commercial penalty of holding such stocks (Strategic Energy Policy, 2001). Tax breaks or write-offs could be used to offset the real costs of holding such inventory, in effect subsidizing industry for performing this social function. This policy option may be more acceptable to industry and less market intrusive. Still, to assess whether it would have a distorting effect such as described by Krapels, the marginal social costs and benefits of large inventories would have to be looked at along with measurement of what level of inventories (and hence subsidies) are efficient.

Another alternative to requiring private firms to hold inventories of petroleum and natural gas is to subsidize producing countries to maintain excess production capacity. OPEC members Saudi Arabia, Venezuela and Nigeria provided this function in the past and were able to increase production to offset the decline that occurred in Iraqi and Kuwaiti production during the Gulf crisis. Unfortunately, questions remain whether consuming countries can rely on oil producers such as Saudi Arabia and Venezuela to continue to fulfil that role. The present oil market tightness and accompanying rise in oil prices stem, in part, from the failure of many key OPEC countries to make sufficient investments in capacity to maintain a surplus in the face of rising world demand.[10] Excess capacity could be held by domestic oil companies or by those operating in regions considered more "reliable" or "politically stable." But private firms are not likely to voluntarily maintain excess capacity without being subsidized to do so. This would be especially true in regions where capital requirements per barrel of exploration and development costs are high and where private firms are required by shareholders to provide an attractive return on investment. In the case of these private firms, they will be very reluctant not to produce at optimal rates determined by economic and geologic considerations and to recover their investments as quickly as possible.

Providing incentives to oil producers to carry excess capacity is not as attractive an option as domestically held stocks because the latter can be put into the market more quickly than increased production from oil fields, especially if those stocks include petroleum products as well as refinable oil. It takes four to six weeks to refine crude oil domestically and ship petroleum products to end users. Moreover, crude oil production from surplus capacity in countries located far from consumer markets will be delayed by the additional time it takes to transport that oil to market, in the case of the Middle East, this delay could be as much as 30 to 50 days.

The development of alternative (or backstop) technologies is different from other policies discussed in that this policy cannot deal with short run price shocks that occur as a result of running out of excess capacity or from unexpected political events or accidental disruptions.

It is a policy that can be effective in preventing price shocks that occur for political reasons or from producer cartel behavior. The threat of new technologies which will reduce the demand for oil will give producing countries an incentive to prevent price shocks, either by maintaining excess capacity or avoiding setting oil prices too high. In their paper "Oil and Strategic Development of Substitute Technology" Kaz Miyagiwa and Yuka Ohno (2000) argue that the development activities of a new substitute energy technology can in itself lower the oil price and reduce OPEC's cartel behavior before such technology is actually utilized. "OPEC, if rational, will want to sell as much oil as possible before a substitute technology is invented," note the authors. However, even if oil producers realize that it is in their collective interest to maintain excess production capacity in order to stabilize prices, there is a question as to which country will bear the cost of doing so when all other producers can free ride and enjoy the benefits of continued high levels of oil use.

8. Energy security as a public good

While oil is a private good, *security* is a public good in the sense that the price effect of any release of stocks will accrue to all whether or not they have contributed to the cost of maintaining those stocks. That is, all countries benefit from the increased security provided by oil stocks and cannot be excluded from this benefit—so long as oil continues to be traded in an open and free market.

As in the case of all public goods, the situation in which each country acts according to the benefits and costs that it faces, will lead to an underinvestment in such stocks. Each country must bear the full cost of acquiring and maintaining the stock but will have to share the benefits of their stocks with all countries. The IEA acts to co-ordinate stocks for the industrial countries and to prevent free riding. Countries that do not belong to the IEA can, and do, free ride. Any one country which increases stocks unilaterally or (and more significantly) undertakes other policies to reduce its exposure to price shocks will bear the costs of that action but the benefits it derives will be diluted because the benefits accrue to all.

For example, greenfield nuclear power can be more expensive than power generated by oil and gas. Countries subsidize nuclear power in order to reduce exposure to oil and gas prices. In essence, countries are trading off higher average power costs for less variability in power prices. In addition, by substituting nuclear for oil and gas as a fuel source, the country is lowering the prices of these petroleum inputs below what they would otherwise be. The magnitude of this effect will depend on how much oil and gas use is reduced and could be very small or alternatively, quite significant. In either case, the reduction in price is shared by all oil users.

An interesting difference between maintaining stocks and undertaking policies that reduce oil use, such as encouraging the use of nuclear, is that stocks will always be effective in reducing price variability for all countries (including free riders) whereas reducing domestic use of oil will only have a temporary effect on oil price level and variability. The country which diversifies its energy inputs will experience less overall energy price variability. Countries that do not diversify fuel sources may experience a temporary fall in the price of oil (resulting from the reduction of oil use in the former country) but as any excess capacity is absorbed, these noninvestors diversifying into alternative energy sources will be subject to price fluctuations to the same degree as prior to the diversified country's investment. In this sense, policies such as alternative energy will be less of a "public good" than oil stocks.

This discussion suggests that the IEA be expanded to include all consuming countries and co-ordination extend beyond managing strategic reserves to include issues of increasing energy efficiency so as to reduce sensitivity of consumer economies to oil price variability.

9. Conclusion

A survey of the energy security literature demonstrates that there are substantial reasons to argue that government should be involved in energy markets. We present the case that on the grounds of economic efficiency, growth, stability and equity, unfettered energy markets will not likely produce desirable outcomes, particularly with respect to inventory behavior and stockholding levels. Yet no one of the policies discussed here addresses, by itself, all policy concerns. Hence, an optimal policy might be a combination of several of these policy alternatives. We suggest that future study of these alternatives is merited. Any sound approach will need to involve interventions that promote energy efficiency while also allowing for the creation of mechanisms to dampen unpredictable large price shocks when they occur. Finally, there is a need to find a means to deter oil producers from trying to exercise monopoly power over price or attempting to extract other concessions from consuming countries. Introduction of backstop technologies, expansion of strategic stocks and diversification of fuel sources away from oil are among the options that could be combined into a successful comprehensive strategy.

Notes

1. See, for example, MacBean and Nguyen (1987).
2. Horsnell notes that over one billion barrels of oil was lost to markets from OPEC's 1998 agreement, more than three times as much as was lost in the 1973 oil crisis and the 1990 Iraqi invasion of Kuwait. He rightly questions the logic behind responding to the smaller losses in times of war and not the huge losses as a result of OPEC policy.
3. The result is sensitive to the assumption of the supply elasticity. If the elasticity of supply of imports is only 0.5, rather than 4, the effect of an increase of 1Mb/day would be to increase price by $13.00/b to $39.00/b. The marginal social cost of oil would jump to $91.00/b. See also Bohi and Toman (1993).
4. See Bohi and Toman (1996) for an extensive discussion of this issue.
5. Some public utilities offer limited forms of installment credit to the poor to alleviate this problem. Federal programs to subsidize energy consumption of the poor also exist in the US.
6. Recent transfers of billions of dollars of wealth from California consumers and utility

companies to producers of electricity and natural gas is a good example of the phenomenon.

7. Bacon, Robert (1999), The score card for energy reform in developing countries. *Public Policy for the Private Sector,* Note 175, World Bank, April.
8. For further discussion of options see the task force report "Strategic Energy Policy: Challenges for the 21st Century" Baker Institute/Council on Foreign Relations, 2001. It argues that there is political benefit to filling the reserve during periods of low prices with oil from allied oil producers and discusses the economic benefits of more professional management of stocks.
9. See Plummer (1980), pp. 126–127. The 3% figure is equivalent to 10.95 days of a company's average imports or throughput. See Krapels (1980), p. 84.
10. One can only speculate as to why Saudi Arabia and other countries did not undertake investments to maintain spare capacity. One explanation is that they decided not to provide this benefit to consuming countries and to let excess capacity fall so that OPEC could reassert its market power. Another plausible explanation is that when prices were low, the Saudis and others could ill afford to divert resources from the needs of their rapidly growing populations to maintaining spare capacity.

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