Energy security: externalities and policies

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In this paper we review conceptual arguments and empirical evidence related to two potential sources of market failure involving energy security. In doing so we consider several questions involving the distinction between externality and market inefficiency, and the distinction between market failures that are amenable or not amenable to correction given our current understanding of the workings of an economy. Several conclusions follow from our analysis regarding the potential sources of market failure and possible remedies. The problem of excess wealth transfer from exporter market power may be an issue, but current knowledge of oil market behaviour is too weak to support a strong conclusion. Other supposed costs of oil import dependence also are not well grounded, including externalities related to the vulnerability of the economy to energy price shocks.

Keywords: Energy security; Oil price shock

For at least six decades, energy policy in the USA has accorded petroleum a special status in which its value to society is regarded as greater than its market price. On the basis of this view, the US domestic petroleum industry for many years received special tax treatment that was intended to encourage domestic production, while at the same time production restrictions were imposed to prevent a reduction in the market price. When cheaper oil imports began to threaten domestic industry after the Second World War, national security concerns were invoked to impose an import quota that lasted from 1959 to 1973.

The first oil price shock in 1973 heightened fears about the effect of rising oil prices on the US economy, and policy makers began to talk about the hidden costs of oil imports. The economic concept of an externality was used to argue that oil imports imposed costs on the economy that were not reflected in the market price of oil or in private decisions regarding the use of oil instead of other alternatives. The value of domestic oil (or domestic substitutes for foreign oil) was regarded as higher than the market price, thus perpetuating the special status accorded to oil in earlier decades. Concerns also arose about the apparently deleterious effects of energy price shocks on the macroeconomy (employment, capacity utilization, inflation).

Legislative proposals to limit oil imports, encourage substitutes for oil imports, and improve energy efficiency have surfaced regularly since 1973. Energy security figures prominently in the Department of Energy's 1991 National Energy Strategy.[1] The National Energy Security Act of 1992 (S.2166) called for the promotion of alternatives to oil based motor fuels, the development of renewable energy sources, mandated energy efficiency standards and, until it was deleted from the 1991 version of the bill, development of oil and gas reserves in the Alaskan National Wildlife Refuge. The alleged benefits to be gained from these actions result from their contribution to reducing oil imports and limiting exposure to energy price shocks.

Quite apart from the debate over oil imports and energy security, energy production and use create other externalities in the form of environmental costs that do not enter into energy prices and private decisions regarding production and consumption. Consequently, there is growing pressure to internalize those costs in both federal and state policies.[2] In the debate over the accuracy of estimates of the externalities, and over the wisdom of using this concept in regulatory policy, it has been argued that all possible externalities, including energy security externalities, should be taken into account.

While the concept of energy security externalities has been introduced in a variety of energy policy debates, there seems to be considerable confusion about what the concept means, how it should be measured, and how it should be applied. This paper

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critically examines the potential externalities related to energy security, the issues related to the measurement of these externalities, and the problems of incorporating these measures in market prices for energy. We begin by specifying what is meant by an energy security externality for the purposes of this study. We recognize that energy security can be defined in various ways, but our primary focus is on economic issues related to the behaviour of energy markets. We specifically exclude from consideration any military, diplomatic or foreign policy costs and benefits where economics and energy are only a part (sometimes a small part) of the bigger picture. While these non-economic issues may be vital concerns, the scope for addressing them through economic policies in energy markets is limited.[3]

Generally, an externality refers to any characteristic of the economic system that creates costs or benefits not reflected in private production and consumption decisions, so that the resulting allocation of resources is not Pareto efficient.[4] Where an externality is present, private and social costs diverge in production or consumption, and a reallocation of resources among economic agents or across time periods can improve the efficiency of resource use. However, the presence of an externality is not sufficent justification for government intervention. In practice, the reallocation of resources is not costless; it is necessary to identify whether a proposed change imposes more costs than it ameliorates. Related to this point, social institutions or market outcomes that appear inefficient relative to an ideal standard may be the best that society can currently accomplish. Thus, as discussed further below, there is considerable ambiguity in practice as to what constitutes an energy security externality. This ambiguity is compounded by the dependence of welfare levels in one nation on the actions of other nations through links in trade for petroleum and other commodities.

In discussing energy security externalities it is also appropriate to narrow somewhat the scope of potential spill overs considered. In keeping with most of the literature on the subject, we consider two broad sets of sources of potential externalities. The first concerns potential externalities associated with dependence on foreign energy (mainly petroleum) supplies. These issues involve potential excess payments for imports, and indirect consequences of imports for the economy as a whole. The second set of potential externalities concerns the effects on the economy of fluctuations in energy costs. These cost fluctuations may derive from disturbances in the world petroleum market or from other shocks of a local or regional nature, such as component failures in the natural gas or electricity delivery systems.

Another broad area excluded from our definition of energy security externalities is the effects of public utility regulation, although some indirect effects of utility regulation may be broadly similar to the energy security concerns outlined above. For example, utilities may not provide socially preferred levels of service reliability across customers because pricing regulation does not allow for 'unbundled' pricing of different reliability levels. The result may be unnecessary disturbances in the flow of electrical energy and unnecessary fluctuations in costs associated with the use of electricity. In addition, regulatory imperfections could lead to insufficient long-term availability of capacity for gas or electricity delivery and result in unnecessary scarcity. However, while such regulatory shortcomings cause deadweight losses in electricity markets, they are not energy security issues as the term is normally defined.[5] Nevertheless, the consequences of unreliability in energy delivery systems for the whole economy is an energy security issue, similar to the effects of oil price shocks. Similarly, the distortions in the rest of the economy resulting from utility price inflexibility can be thought of as an energy security issue. We return to these points subsequently in the paper.

In the following two sections of the paper we turn to a critical review of potential energy security externalities, examining both conceptual arguments and empirical evidence. The final section discusses problems that arise in using measures of energy security externalities in energy policy.

Potential externalities related to energy imports

As noted above, we distinguish between two sources of potential externalities: those related to changes in the quantity of oil imports,[6] and those related to volatility in the price of energy. The first category, discussed in this section, generally involves adjustments that occur over medium to long periods of time, while the second category, discussed in the next section, refers primarily to short-term adjustment problems. In this section we explain why externalities involving oil imports may be present and assess whether those that do exist may be significant.

Direct cost of oil imports

In a perfectly competitive international market the price of a commodity like oil is a complete measure

of the worth of a transaction for individual actors. The outflow of US$1 of wealth in payments for oil gives rise to an inflow of oil whose value to the buyer (including consumer surplus) is at least US$1, and the wealth outflow at least compensates the seller for the real resource costs (including reserve replacement costs) incurred in supplying the oil.

In a market where sellers exercise some market power the price may lie above the competitive level. This could be the case in the oil market because of the actions of the Organization of Petroleum Exporting Countries (OPEC). We discuss this issue below. Whether or not OPEC controls the price of oil, the price of oil remains a complete measure of the value for an individual purchaser whose actions do not affect the world price: US$1 worth of wealth outflow occurs only if the value of oil purchased is at least US$1.

The situation may be different if a buyer's decision may affect the market price. If the market price is positively related to the total volume of purchases, then an increase in purchases raises the cost of all imports.[7] In a competitive market, the effect on the cost of inframarginal imports is not taken into account in decisions to buy the marginal increment of imports. For this reason, the cost of oil to the country as a whole is larger than the price. The assumption of a positive relationship between price and total purchases is crucial to this argument. This assumption is reasonable if sellers behave competitively, so that there is a well defined aggregate supply schedule. However, it may not be appropriate when sellers possess potential market power.

The discussion to this point spotlights two issues that are relevant in gauging the existence and importance of externalities related to oil imports. The first is the presence of exporter market power. If market power is being exercised then importers would face a market failure and would have a justification for countervailing efforts to recapture rents. Whether such efforts would succeed is another matter, as we shall discuss.

The second issue is the capacity of an importer to exercise monopsony power opportunistically (to 'beggar one's neighbour'), even in the absence of exploitation of market power by exporters. Here there is no market failure in the sense of global efficiency, but the importing nation none the less may be paying more than is necessary for energy imports. This is a more controversial and problematic rationale for policy intervention than a response to non-competitive exporter behaviour. In the subsections that follow we consider exporter and importer market power in turn.

Oil exporter behaviour

The members of OPEC are undoubtedly capable of influencing the market price of oil if they should choose to exercise their market power. It is also easy to show that OPEC has not behaved (so far) as a classic market sharing, price setting cartel. There is, however, disagreement about the degree of market control that OPEC has exerted. MacAvoy takes issue with the conventional wisdom that observed petroleum prices and quantities reflect significant influences by sellers.[8] He expresses the view that the price explosions of the 1970s primarily reflected individual political events and demand-side responses, not concerted OPEC decisions. He also asserts that OPEC was not the prime force behind the sustaining of price increases in the mid-1970s; instead, he attributes the market responses primarily to a burgeoning of world petroleum demand, significant declines in non-OPEC production, and some adjustment of production plans by individual OPEC members. OPEC's inability to control the market effectively is further highlighted, MacAvoy argues, by its inability to offset subsequent stagnation of demand and non-OPEC production increases in the wake of the price jumps during the 1970s.

MacAvoy attempts to support his argument about market scarcity with a very simple simulation model showing that price increases much like those observed in the 1970s would have emerged even under an extrapolation of OPEC behaviour from the 1960s, a period of less collusion than that which occurred in the 1970s. Unfortunately, attempts to statistically estimate coefficients in the model fare very poorly, and even with judgementally specified parameters the model is not too successful in tracking actual market outcomes through the 1970s. Thus, while MacAvoy's assertions about market influences may be plausible conjectures, they receive fairly little empirical support in his study.

Teece presents another argument to explain why petroleum prices remain above competitive levels in the absence of concerted exercises of market power[9] – the so-called target revenue theory. According to this view, once petroleum prices rise to the point where further revenues no longer could be comfortably absorbed by the exporting country, further price increases would cause a reduction of supply. Revenue absorption levels, in turn, are complex dynamic functions of national development objectives, the size of national oil reserves, the returns to foreign investment of oil proceeds, and political risks. With a backward bending supply curve, prices which have fortuitously risen above the marginal cost of reserve production and replacement – the

standard for price behaviour in a competitive market[10] – can remain high even without collusive output restrictions because individual suppliers have no incentive to expand output and put downward pressure on the price. Producer rivalry would emerge only as revenues are eroded over time by demand stagnation and growth of non-OPEC supply.

In a series of papers, Adelman presents the more widely accepted view that OPEC has exercised market power, though it has functioned only as a 'clumsy cartel'.[11] The core of Adelman's argument is a set of calculations that attempt to measure the marginal cost of producing and replacing reserves, which is the standard for a competitive price as noted above. From his calculations, Adelman concludes that the gap between the world oil price and the marginal cost of oil supply in OPEC is too large to be explained by market forces. Thus, he concludes that output restrictions must be in place to explain the excessive prices. He makes a similar argument in comparing the spread in marginal costs between OPEC and high- cost producers in the USA.

Adelman views the target revenue argument with disdain, arguing that countries like Saudi Arabia with vast reserves inherently earn a higher return on money in the bank than from leaving the oil in the ground. However, this argument presumes that individual OPEC members can be characterized as seeking to maximize the present value of financial wealth. As Teece suggests, a variety of economic and non-economic factors may explain exporters' propensities to hold petrodollar balances.[12]

In addition, Adelman attributes all of the differences between oil prices and his measures of marginal supply cost to cartel rents. He does not give much weight to the possibility that the gaps could also represent scarcity rents earned by lower cost producers. For example, OPEC countries may not have been in a position to rapidly expand output after the first oil price increase because of deliverability constraints. In addition, Saudi Arabia has attached a high value to its associated natural gas deposits and has limited oil production until productive uses of the gas (eg petrochemical plants) are more fully developed.

In yet another study of OPEC market power, Griffin econometrically tests several categories of hypotheses about the behaviour of individual oil producing countries inside and outside OPEC.[13] These hypotheses include variants of market sharing cartel behaviour; competitive price responsiveness; the target revenue theory; and a 'property rights' hypothesis. According to the last hypothesis, observed price increases in the 1970s resulted from a transfer of oil resource ownership to host countries which collectively had a lower discount rate, and thus a lower proclivity for current output versus future output, than the former oil company owners.

Griffin's principal conclusion is that OPEC seems to most closely resemble a partial market sharing cartel: individual member outputs are sensitive to other countries' shares, but the output responses to changes in price are not strictly proportional. In contrast, output decisions in a group of non-OPEC countries appear to be competitively determined by prices. Griffin rejects the property rights theory, while his findings concerning the target revenue explanation of OPEC behaviour are inclusive but generally unfavourable.[14]

Griffin's results extend only to 1983. A more recent paper by Jones extends Griffin's analysis to include behaviour after the 1986 price drop.[15] His results are basically in agreement with Griffin's regarding OPEC and non-OPEC behaviour before and after the 1986 price drop, although Jones finds slightly less support for the partial market sharing hypothesis and he finds that the explanations for some individual countries vary between the two samples.

While these results are provocative, they have some weaknesses which point to the need for further investigation. As Griffin points out, the partial market sharing cartel cannot be rejected for many non-OPEC oil producing countries, although in these regressions the individual coefficients are frequently insignificant and the overall explanatory power of the cartel model does not substantially exceed the competitive model. It is difficult to draw sharp distinctions on the basis of these models since both the independent variables – price and other countries' output – are likely to move together. The same could be said of the independent variables – price and investment expenditure – in the target revenue model: the revenue target is probably endogenous to oil market conditions. Griffin also tests only an extreme version of the target revenue theory in which price and quantity move in opposite directions, rather than allowing for price and quantity to move together up to the point where the revenue limit is reached. Finally, the fact that the model can be readily extended over such an abrupt change in the market as the 1986 price drop may be cause for concern rather than confidence.

We must conclude at a minimum that the state of knowledge about OPEC and the world oil market is incomplete. This view is bolstered by comparisons of findings from different oil market models.[16] The

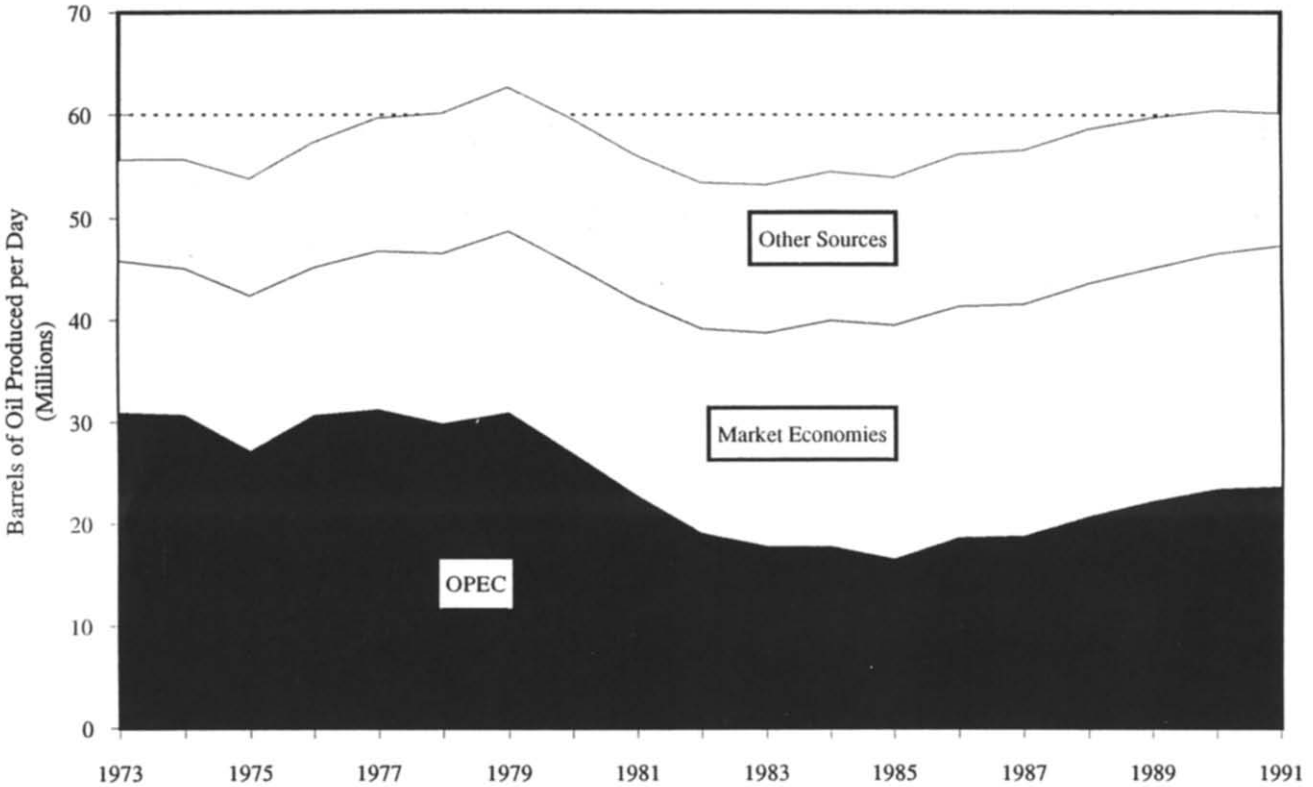

Figure 1. World crude oil production (million barrels per day).[a]

[a]Market economies exclude Albania, Bulgaria, Cambodia, China, Cuba, CSSR, former GDR, Hungary, Laos, Mongolia, North Korea, Poland, Romania, Former USSR, Vietnam and Former Yugoslavia.

Sources: Energy Information Administration, *Historical Monthly Energy Review*; *Monthly Energy Review*, April 1993; *International Energy Annual*, 1991.

comparisons highlight the sensitivity of outcomes to assumptions about oil supply and demand, energy–economy interactions, OPEC incentives, and the level of aggregation. For example, none of the models in the Energy Modeling Forum study was very successful in simulating the market over the period 1980–85.

Uncertainties and suspicions about OPEC's dominance are enhanced by an informal look at the data. Direct evidence of the exercise of market power by OPEC would be present if there were reductions in supply in 1973–74 and 1979 when the two price shocks occurred. Indirect evidence of market power would be present if the price of oil failed to decline after 1980 when world oil demand was declining. Experience in each of these cases fails to support the view that OPEC has exercised a significant degree of market power. As seen in Figure 1, OPEC output increased substantially in 1973, declined only slightly in 1974, and increased again in 1979. As argued by Bohi, inventory behaviour in these periods appears to have had more influence on oil prices than OPEC actions.[17] OPEC output actually declined after 1980 but not fast enough to stabilize the world price. The real price declined by 40% between 1981 and 1985, and by another 50% in the first two months of 1986. It could be said that the slow pattern of price erosion before 1986 is evidence of market power at work. However, our understanding of world oil price behaviour is too weak to substantiate the extent to which the sluggishness of price is due to supplier behaviour or to other factors. In any case, the fact that the price collapsed indicates that any success in the exercise of market power was temporary at best.

Monopsony power and import policy

The USA as a whole may possess monopsony power in the world oil market, even though individuals buyers in the USA do not. If oil import demand could be coordinated it might be possible to drive down the world price of oil by restricting demand, benefiting all oil users in the USA (and elsewhere).

Monopsony effects are usually thought to be only pecuniary externalities, effects that redistribute rents but do not bear on market efficiency. Indeed, such effects are ubiquitous in efficient markets

where short-term or long-term scarcity (increasing supply cost) causes a bidding up of prices with increasing demand. However, when the rent redistribution involves transfers out of the purchasing country, the size of these wealth transfers may be a concern for policy makers even if the market is efficient from a global perspective.

Notwithstanding such concern, it does not necessarily follow that a potential monopsony position should be exploited. The USA eschews the exercise of monopsony power in a number of international markets out of a belief that this approach is consistent with its long-run interests. In particular, the history of international trade relations suggests that gains from neighbour beggaring policies are usually transitory because the injured parties will retaliate, directly or in other markets, and the result will probably make all parties worse off. To argue for the exploitation of monopsony in the world oil market, it is necessary to conclude that the policy decision has a justification, that it can affect world prices, and that it will not provoke a retaliation by exporters which would leave the USA worse off.

The exercise of market power by oil exporters is a potential justification. However, it remains to be seen whether aggregate oil demand restrictions by the USA could substantially affect world oil prices without retaliation. The ability of the USA to unilaterally affect world oil prices is limited since total US oil demand is only about 30% of world oil use, and imports are only 40–50% of US demand. Any drop in oil prices from a decline in US demand will be partially offset by increases in other countries' demands. Even proponents of an active oil import control policy, such as Broadman and Hogan, conclude that the direct value to the USA of unilateral import restrictions to reduce world oil prices is only a small fraction (4–8%) of the price unless the base price of oil is low and a very substantial import control programme is deployed.[18]

Regarding retaliation, a case can be made for the use of monopsony power if OPEC possesses sufficient market power to make the exploitation of buying power more than marginally profitable. In this case OPEC also possesses the power necessary to retaliate against import restrictions by raising the world price of oil. However, retaliation will not result in higher OPEC profits if a profit maximizing monopoly price has been established already. Retaliation simply reduces revenues and will be contrary to OPEC's interests. In contrast, if OPEC is not already earning monopoly profits, then retaliation can be profitable and OPEC is more likely to undertake such a response. Ironically, efforts to exercise monopsony power may galvanize OPEC into a more cohesive entity and increase its capacity for exercising monopoly power.[19]

An important corollary to this discussion is that import tariffs and quotas are not likely to be wise choices as policies intended to address externalities related to OPEC market power. These policies are highly visible beggar thy neighbour actions. A better way to mitigate export market power, as argued further below, is through energy research and development that expands the range of substitutes for OPEC oil and indirectly reduces OPEC market power.[20]

Indirect costs of oil imports

Even without the presence of monopsony power or the exercise of market power by oil exporters, transfers of wealth for oil imports could have secondary effects on the economy that are not reflected in the price of oil and constitute a potential externality in the oil fuel cycle. The payments for oil imports have an unfavourable effect on the US merchandise trade balance, which could in turn have a negative effect on the international exchange value of the dollar and on the cost of all imported goods. It also has been argued that higher oil prices could aggravate 'structural' inflation that leads to adverse macroeconomic consequences. Broadman and Hogan attribute 8–11% of the total 'import premium' they calculate to these two effects.[21]

The argument that higher oil prices translate into depreciation of the dollar is basically as follows. An increase in the price of oil means (assuming oil demand is price inelastic) that total payments for oil rise and (assuming all other trade is fixed) the current account will move toward deficit. A current account deficit leads to an overall balance of payments deficit (assuming no change in capital flows) which in turn implies an excess supply of dollars in foreign exchange markets. Consequently, it is possible that the international value of the dollar will fall and that all US imports will be more costly; that is, the USA must export more goods to buy the same amount of imports. While this is a pecuniary effect, it could be viewed as relevant to US national welfare in the same way that US interests are related to monopsony power – limits on US oil imports could curb the cost.

While the argument may have some intuitive appeal, the necessary sequence of assumptions is not likely to hold. The conclusion of two complementary approaches to the analysis of the balance of payments effects on prices, and the behaviour of exchange rates after each oil price shock, is that it is

Figure 2. US dollar/SDR exchange rate.[a]

[a]Before July 1974, the SDR was valued relative to the US dollar. Since then its value has been based on a weighted basket of currencies.
Source: *International Financial Statistics*, IMF.

inappropriate to attribute an exchange rate externality to oil imports. One analytical approach is concerned with real terms of trade effects of higher oil prices, as in Marion and Svensson.[22] The terms of trade refers to the amount of imports a given unit of exports will command in the international market; thus, a rise in the price of oil means that the USA must export more goods to buy the same amount of imports. Marion and Svensson demonstrate that the terms of trade effect of higher oil prices can be positive or negative for any individual oil importing country, depending on special circumstances for each country.[23]

The second analytical approach looks at the effect of oil prices on the monetary exchange rate, as in the work of Krugman.[24] Like Marion and Svensson, Krugman shows that the relationship between a country's exchange rate (or, for that matter, its current account position) and the price of oil is ambiguous in general. All oil importing countries will experience an initial current account deficit when the price of oil rises, but the effect on exchange rates among oil importing countries will depend, initially, on the willingness of the oil exporting countries to hold different foreign currencies (that is, on relative capital flows). If oil exporters prefer to hold more dollars than other currencies, for example, the dollar exchange rate will rise. Over time, the exporting countries will spend their foreign currencies on goods or assets, and the countries of preference for these expenditures will experience currency appreciation.

A study of exchange rate behaviour by Trehan finds a little empirical support for the view that higher oil prices lead to an *appreciation* of the dollar, but the evidence is weak.[25] A more defensible conclusion, in view of the weak statistical results, is that the price of oil is a poor predictor of the dollar exchange rate, either positively or negatively. A look at the history of the dollar/SDR exchange rate in Figure 2 corroborates these findings. The SDR is representative of a composite of other currencies. The SDR exchange rate with the dollar shows that the value of the dollar is not obviously harmed by oil price increases nor helped by oil price reductions.

We turn next to the question of the connection between oil prices and inflation. Higher oil prices will no doubt raise all prices somewhat, but unless oil prices continue to rise there is no ongoing inflationary process in the long term, only an increase in the price level (although that increase may be spread over time). Similarly, a rise in oil prices may aggravate

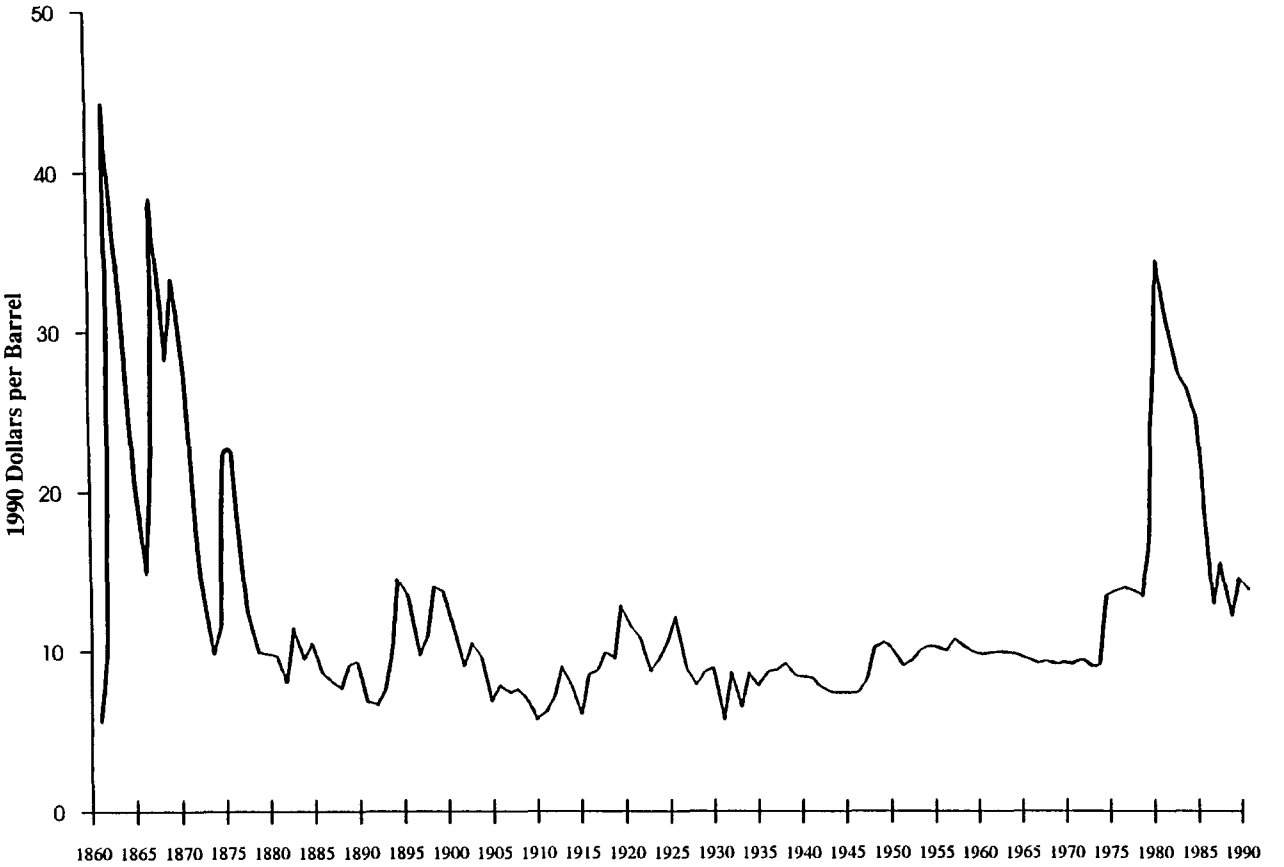

Figure 3. US crude oil prices.

Sources: US Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970*, Part 2, MI38–142, pp 593–594; Energy Information Administration, *Petroleum Marketing Monthly , Domestic Crude Oil First Purchase Price*, April and July 1990; and US Bureau of the Census, *Wholesale Price Indices, Producer Price Index*, converted to 1990=100.

an inflationary process that is already in motion, but higher oil prices are not the cause of that inflationary process. The distinction between inflation and a rise in price, and between cause and effect, is important in establishing whether higher oil prices give rise to a need for a deflationary policy response.

To attribute an inflationary side effect to increases in oil prices, the increase must be in the rate of growth of oil prices, not merely in the level of oil prices. Our understanding of world oil markets is not complete enough to rule out the possibility of a boost in oil price growth rates. However, a rise in growth rates is inconsistent with the predictions of resource supply theory and with the record of actual oil prices. Resource supply theory predicts that increased producer market power will probably result in a rise in the initial price level, and that the price thereafter will probably grow more slowly over time compared to the price in a competitive market.[26] Actual oil prices exhibit surprisingly few trends of any kind, as indicated by the history of crude oil prices in the USA since 1889 shown in Figure 3. The overall trend is flat over the past 100 years and, apart from temporary crises, the price has fluctuated within a fairly narrow band of US$10–15 per barrel.

Another possibility is that an on going bout of inflation can result from an overzealous monetary authority which is seeking to accommodate a rise in oil prices. The monetary authority could err in estimating what is required to adjust to a higher level of oil prices, thereby setting in motion an inflationary spiral that requires a deflationary jolt to stop. However, inflation scenarios that rely on planning errors by the monetary authorities can be triggered by any number of events, and to focus policy on the triggering event rather than the cause of the problem seems misguided at best. Nor is there a reasonable second best argument for attaching an inflationary spillover cost to oil prices, since the first best alternative of educating the monetary authority is feasible

and more likely to avoid further costs than a policy aimed at oil prices or imports. In short, any connection between oil prices and inflation seems dubious and would reflect at most a policy failure, not a market failure.

Military expenditures and oil import costs

It is sometimes argued that military expenditures in the Middle East add a substantial premium to the social cost of oil imports.[27] This is a disturbing myth because the argument rests on several logical flaws. First, military expenditures are a cost of mitigating energy insecurity rather than a cost of insecurity itself. To assume that the level of military expenditures is a good approximation of the externality implies that the size of policy response defines the size of the externality. By way of comparison, a pollution externality refers to the damages that pollution imposes on third parties, not the cost of cleaning up the pollution. The magnitude of the environmental damages tells us something about how much we should be willing to spend to clean up the pollution. Similarly, the magnitude of the potential damages (broadly defined) of insecurity in the Persian Gulf should provide guidance to policy makers about how much to spend on a military response to mitigate the damages.

In addition, military expenditures in the Middle East are made to serve a variety of national security interests other than securing oil flows or stabilizing oil prices. Thus, it is incorrect to interpret all of these expenditures as a cost of pursuing energy security. Indeed, since the expenditures are a common cost for many purposes, any assignment of cost shares among different purposes is arbitrary.

The arithmetic of assigning a premium to oil imports based on military expenditures also suffers from logical shortcomings. Spreading these costs over US imports alone is questionable for at least two reasons. First, to the extent that energy security is a question of adjusting to price shocks, where the damages depend on total oil consumption or even total energy consumption, then the unit cost of seeking to stabilize the market through military activity should reflect this larger denominator. Second, and more importantly, the USA undertakes a military presence in the Middle East on behalf of many allies, not just for its own narrow self- interest. Thus, the benefits are related to energy consumption of many nations in addition to the USA. These considerations, together with the observation that the military expenditures serve multiple purposes, sharply reduce the apparent 'military expenditures premium'.

Finally, the calculation of a per barrel military outlay for energy security is sometimes construed as a marginal, behavioural concept: if the price of oil were higher, then the resulting drop in oil use would shrink the need for military expenditures correspondingly. It seems unlikely, however, that a reduction of US imports by one or two million barrels a day would systematically lower the US military commitment in the Middle East. The military outlay, to the extent that it can be associated with energy protection, is a fixed cost that cannot be altered by marginal changes in energy prices and demands.

Potential externalities related to energy price variability

The issue explored in this section is whether there are externalities associated with the adjustment of the domestic economy to rapid fluctuations in energy prices.[28] Sudden changes in energy prices could result from a variety of causes, including changes in world petroleum supply and demand or fluctuations in local energy delivery capabilities (eg gas well freeze ups, power station breakdowns, transmission system failures). The effects could be local, regional or national. Among the possible causes of sudden increases in energy prices, the most serious from a national perspective will inevitably involve a shift in world oil supply or demand. Disruptions in oil markets represent the only event capable of seriously taxing demand–supply balances in national and world energy markets. Moreover, given substitution possibilities between petroleum and other energy sources, oil price shocks are capable of causing a simultaneous disruption in all energy markets.[29]

Energy price shocks can have both long-term and short-term effects on the economy, although only the short-term effects will likely involve externalities. Long-term adjustments will take place in the amount of energy related investment and in the rate of innovation. These adjustments could have significant effects on the level of productivity on the economy over time.[30] However, these adjustment costs are likely to be fully internalized in private decisions and there is no *a priori* reason to believe the costs could be avoided by correcting a market failure (other than that related to R&D, as mentioned above). Thus the following discussion of price related externalities deals exclusively with the short-term problems of adjusting to a sudden change in energy prices.[31]

The most important short-term adjustment problem concerns the possibility that real wages will not

adjust to maintain employment when energy prices suddenly rise. A rise in energy prices will reduce the use of energy and (when energy and labour services are complementary inputs in production) will lower the marginal productivity of labour. Lower productivity implies an increase in the cost of labour, which employers will seek to reduce. If wages cannot be reduced (for institutional reasons such as periodic labour contracts), employers have no choice but to reduce the amount of employment. The decline in employment thus becomes an indirect effect of higher energy prices which lowers total output of the economy.

A second possible indirect effect of an energy price shock is a reduction in capital services because of premature obsolescence of energy using capital stocks. A sudden increase in energy prices will make some energy-inefficient capital goods superfluous, either because of competition with more efficient capital goods or because the demand for more expensive energy intensive end products declines. A decline in capital services implies a reduction in productive capability throughout the economy, and thus a reduction in potential output.

Employment and output losses after an energy price shock may be further aggravated by difficulties in reallocating factors in response to changes in the mix of final demand brought about by changes in product prices. For example, commodity price rigidities could cause inefficient inventory accumulations in some sectors and unwanted decumulations in others. Another source of commodity price rigidity is public utility regulation in the natural gas and electricity industries. Since prices are set administratively in these industries and will not easily adjust to changes in market conditions, energy supplies will not necessarily flow to their highest valued uses after an energy price shock.

These macroeconomic adjustment problems are fundamentally different in character from the problems associated with oil imports discussed above. The problem of excess wealth transfer for imports depends on the *level* of energy prices and the volume of energy *imports*, whereas the macroeconomic adjustment problems depend on the size of the *change* in energy prices and the volume of energy *consumption*. In addition, the wealth transfer problem operates at a fundamentally national scale, whereas the oil price adjustment problems could vary significantly from region to region depending on the causes of the disturbance, the flexibility of local energy production and consumption, and the effects of energy prices on local labour markets and capital utilization.

We first examine the extent to which these macroeconomic effects may be thought of as externalities. The conclusion is that some market failures may be present, but it is difficult to distinguish between externalities and frictional adjustment problems that are accounted for in private market decision making. The empirical section that comes next looks at *gross* macroeconomic effects of energy price shocks, since costs attributable to externalities are difficult to distinguish from those that are internalized, and concludes that even at a national level there is also considerable ambiguity in ascertaining the gross effect of energy price shocks on the economy. Consequently, little can be said in practice about the subset of gross macroeconomic costs that are attributable to market failures.

Identifying the externality

To what extent can macroeconomic effects of energy price shocks as described above be thought of as externalities? To address this question we must distinguish two types of reductions in economic activity that might result from an energy price increase. The first type of reduction, which is not an externality, occurs because more resources are required to pay for energy. Part of this direct resource cost is the income transfer abroad to pay for energy imports and part is the diversion of resources away from other economic activities and into domestic production of energy. These effects occur because of private sector responses to changes in energy prices, so they represent costs that are internalized in private decisions.[32]

As noted previously, national income may drop below the level that would obtain in a perfectly frictionless economy if the energy price shock results in unemployment of labour and capital.[33] Some of these effects represent relatively clear cases of imperfection in factor market adjustment that would be lessened with reduced exposure to energy price volatility. In other cases factor markets may be operating as well as possible given real world institutional constraints, but adjustment problems still can be ameliorated by some outside policy action. In either case we can say that an externality exists to the extent that the parties to the labour and capital transactions themselves cannot fully avail themselves of means to anticipate and respond to the energy price shocks. Conversely, to the extent that the costs are anticipated and coped with, the effects of energy price instability are internalized.

To illustrate the various distinctions among effects of energy price volatility, an increase in labour unemployment after an energy price shock may at

least partly reflect the existence of institutions like union contracts that encompass a degree of wage rigidity not suited to an environment of energy price variability. Individual workers as well as employers might prefer more flexible arrangements but are unable to achieve them in practice. In this case an energy price shock triggers a failure in the market for labour services that induces unemployment.[34]

Some rigidities may reflect labour contracting practices that are efficient *ex ante*, given real world informational and institutional constraints. In particular, downward real wage adjustments after an energy price shock may reduce labour productivity, because lower wages cause the average quality of the workforce to decline. This can happen because the best workers quit and the cost of being caught shirking declines.[35] In this case, wage rigidity reflects institutional arrangements in the labour market that represent the best choice among currently available methods for structuring labour services transactions. Nevertheless, reliance on energy sources with less volatile costs could reduce adjustment burdens due to wage rigidity, so the issue is a relevant consideration for energy policy.

Problems of identifying externalities also arise in analysing a decrease in capital services from accelerated obsolescence of energy intensive capital after an energy price jump. Private agents who anticipate the risk of future energy price shocks will have an economic incentive to hedge by adopting less energy intensive technologies, or technologies which allow greater short-term flexibility in substituting away from energy inputs.[36] Hedging also can be accomplished by expanding energy storage capability so that energy can be purchased at lower cost for use during a disturbance.

Even with these private hedging activities, society may experience adjustment costs from decreased capital utilization after an energy price shock. Hedging opportunities will not work perfectly, even under the best of circumstances. Private agents will not have perfect foresight of energy changes. Nor will capital be perfectly malleable across sectors and uses, even with investments in flexibility. Again, energy sources with less volatile costs might reduce the difficulties. At issue here is the extent of the market failures which impede the hedging process.

One possibility is the existence of systematic price forecasting errors that bias private actors away from efficient investments. No doubt there have been episodes of forecasting error in the past, notably in the response of US refiners to price signals in late 1978 and early 1979 during the Iranian Revolution.[37] As detailed by Lynch, forecasters have consistently overestimated the growth of oil prices since the second oil price shock in 1979–80.[38] Forecasts by government and academic experts are no better than those from private industry. However, the degree to which prices embody relevant information about market conditions seems to have increased in recent years.[39] The literature does not provide strong support for the existence of a systematic *ex ante* bias in forecasting energy prices, despite the obvious *ex post* bias.[40] Even if such errors could be identified, it is problematic whether government intervention (other than its current activities in publishing energy statistics) could improve upon the situation.[41]

Another possibility is the existence of scale economies in energy storage which result in less than the socially efficient amount of storage being undertaken. This is one of the justifications for government investment in the Strategic Petroleum Reserve. An additional justification stems from the notion that the private rate of discount exceeds the social rate because of tax distortions, barriers to risk pooling, and other factors.[42] A high private discount rate will lead to less oil storage and will discriminate against more capital intensive, less energy intensive production technologies if capital and energy are substitutes, or against capital expenditures that promote energy flexibility. Unfortunately, however, the degree of capital–energy substitutability remains a matter of dispute.

Our definition of externalities also includes adjustment costs in the rest of the economy resulting from the pricing of services provided by public utilities, where regulation generally impedes adjustment of commodity prices to changing market conditions. Because of regulation, an increase in oil prices will not lead to efficient adjustments in natural gas and electricity prices. These price rigidities in turn may cause adjustment problems throughout the economy.[43] While distortions in gas and electricity markets from economic regulation may be endemic, society has not yet developed practical alternatives to current forms of regulation that will simultaneously constrain market power and allow regulated prices to adjust the changes in market conditions. Nevertheless, energy policies *may* be able to ameliorate the *consequences* of output price rigidities in utility markets, and the spill over effects of these rigidities to labour and capital employment, by helping to reduce input price variability or enhance adaptability. Thus, from the standpoint of energy security we would view spill over effects of commodity price rigidity in utility markets no differently from other commodity price rigidities.

To summarize, there are plausible theoretical

arguments for the existence of externalities from energy price volatility. However, there are major conceptual ambiguities in calculating the costs of volatility based on the causes of rigid adjustment and the degree to which volatility of energy prices is accommodated *ex ante*. These ambiguities are compounded in empirical analyses of volatility costs, to which we turn next.

Empirical information

Empirical studies of the macroeconomic effects of energy price shocks do not try to distinguish between internalized and externalized costs. The best that we can do, therefore, is to try to assess the importance of the gross macroeconomic costs of energy price shocks and draw inferences about the potential empirical significance of the externality component.

Perhaps surprisingly, the evidence about the gross costs at the national level is mixed. The coincidence of timing of the two oil price increases and two recessions during the 1970s leads many observers to believe that the effects of energy price shocks on the economy are large.[44] This view is best represented by an extensive simulation analysis conducted by the Energy Modeling Forum (EMF).[45] The study compares estimates of the effects of various oil shock scenarios on US GNP calculated by 14 macroeconometric models, including standard large-scale models used by forecasting and consulting companies. While there is considerable variation among the findings of individual models, there is a consensus that the calculated GNP losses are substantial.[46]

The authors of the EMF study take pains to enumerate caveats which must be considered when interpreting their results. They indicate that the individual model results vary significantly because of differences among the models with respect to the relationship between GNP and the overall price level, and with respect to the link between oil prices and the general price level. Nevertheless, most of the models have the same basic mechanism for the transmission of energy shocks. Increased energy costs cause firms to increase their price mark ups, and higher prices depress aggregate spending. The reduction in aggregate spending reduces the demand for labour, but wages cannot fall fast enough to trim labour costs in line with reduced demand. Consequently, employment declines.

The main source of scepticism about the results of these models is that the equations of the models employ parameters estimated from limited experience with price shocks over the 1950 to 1980 period. During this period real oil prices were stable or falling except for the two brief explosions during the 1970s. Thus, the conclusions of the models regarding the relationship between oil price increases and GNP will be determined by the experience with the two recessions that followed the 1970s price shocks, although this experience may not be representative of the true energy–economy relationship. As noted below, the recessions experienced in some countries could be explained by factors other than energy prices, such as differences in macroeconomic stabilization policies. It is possible, in other words, that the econometric models are confusing the effects of deflationary macroeconomic policies with those of changes in oil prices.

Another reason for scepticism in blaming energy prices for the recessions of the 1970s is that the price collapse of 1986 did not cause an economic boom in the USA and other industrial countries (see Figure 4). The absence of a positive boost to GNP in the major industrial countries suggests again that the experience of the 1970s gives a misleading impression of the energy–economy relationship. Additional corroboration is provided by comparing the conclusions of Hamilton with Mork.[47] Hamilton looks at correlations between energy prices and GNP before 1981 and concludes that higher energy prices cause recessions, while Mork finds that the same statistical methods applied to data extended through 1986 give a different impression.

Doubts about the meaningfulness of statistical results based on aggregate economic variables led Bohi to examine disaggregated industry data for the USA, Germany, Japan and the UK for explanations of the experiences of these countries during the 1973–74 and 1979–80 shocks.[48] The results of this analysis suggest that energy prices may have had little to do with the macroeconomic problems of the 1970s. To begin with, we might expect more similarity in the way different sectors of the economy were affected, both across the two recessions and across the four countries, if the common cause was energy prices. Within each country, the industries hit hardest are quite dissimilar from one recession to the next and, and for each recession, the industries hit hardest are dissimilar across the four countries.

Another set of statistical tests examined the relative economic performance of different sectors to see if the effects of the shocks are more pronounced among the more energy intensive sectors. The tests reveal no significant negative correlations between energy intensity and changes in output, employment or capital formation for any of the four countries. Nor does the evidence suggest that adjustment costs caused by changes in the composition of final demand are more severe in energy intensive sectors.

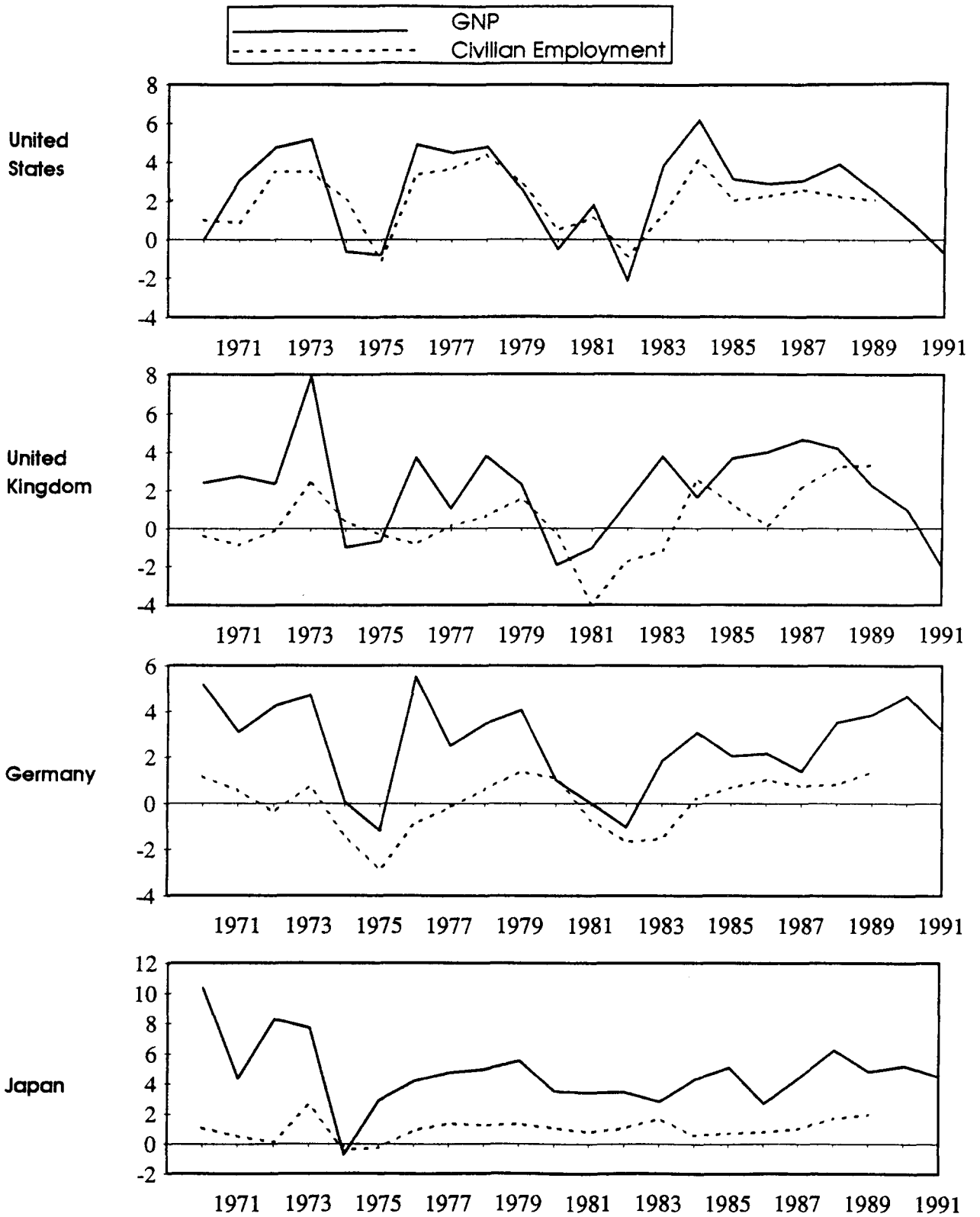

Figure 4. Annual percentage changes in output and employment.[a]

[a]Output is measured in GNP for Germany and Japan and in GDP for the USA and the UK. Figures on Germany refer to FRG.

Sources: OECD Department of Economics and Statistics, *Labour Force Statistics*, 1989, 1990; IMF, *International Financial Statistics Yearbook*, 1992.

Finally, in contrast with the rigid wages argument, changes in real wages appear to vary negatively with energy intensity in the two shock periods, suggesting that wages were more responsive in labour markets where unemployment has been more serious.

These and other findings suggest that we should look to factors other than energy prices to explain the macroeconomic failures during the 1970s. The alternative hypothesis suggested by Bohi[49] is that the industrialized countries were already combating inflation when the oil price shocks hit and, except for Japan in 1979, further deflated their respective economies to mitigate increases in their general price levels. Given that Japan was the only industrial country to avoid a recession after the 1979 oil shock, it is plausible that the monetary authorities rather than energy prices were to blame for the recessions.

In empirical analyses of the recessions it is, of course, difficult to separate the influences of the monetary authorities from those of oil prices, and research to date fails to make a credible distinction.[50] A great deal more study is required before we can begin to understand the nature of energy–economy interactions at the national and regional levels. If nothing definitive can be said about the gross economic costs of energy price shocks, it follows that even less can be said about the magnitude of any embedded externalities.

Preserving the domestic petroleum industry

Variants of the arguments about adjustment problems in labour and capital markets also have been applied to argue for protection of the US domestic petroleum industry in the wake of negative price shocks, like the 1986 oil price drop. Assistance is warranted, it is argued, because specialized human capital and physical assets that are costly to replace or reconstitute may be lost to the market from a temporary bout of underutilization.

The core of these arguments is that there are failures in risk and insurance markets that prevent effective adaptation by the petroleum industry and suppliers of labour and capital inputs to fluctuations in the marginal value of factors as a consequence of energy price variability. However, we believe that proponents of this view have not yet made an effective case for the existence of such market failures, or that industry protection is the best remedy. Many industries are capital intensive, utilize specialized factors and face cyclic market conditions. If there is a market failure in this context, and that is not assured, it is not a failure specific to petroleum.[51]

Moreover, if such evidence could be adduced, it would not follow that protection of the industry is the appropriate response. Unlike the difficulty of correcting general problems of inflexibility in labour and capital markets, here remedies for shortcomings in hedging are feasible. Long-term employment and capital service contracts for specialized resources could be written with flexible terms but long durations to accommodate market conditions and with premiums as needed to compensate factor owners for episodic income fluctuations. Such measures, combined with general income hedging by factor owners and petroleum producers, presumably could take much of the sting out of oil price drops.[52]

Conclusions and policy implications

We have examined potential externalities associated with the volume of oil imports and with variability in the price of energy. Only the potential consequences of OPEC market power appear to be significant in assessing oil import externalities. Indirect externalities operating through exchange rates and inflation are neither conceptually nor empirically credible. With regard to variability in the price of energy, there exists a plausible externality associated with institutional and technological constraints on wage and price flexibility, but it is difficult to identify the extent of any externality and to separate the associated cost from gross adjustment costs. The empirical literature provides no information on the magnitude of the externality and even wide disagreement about the magnitude of the gross adjustment costs.

Our discussion of the market power issue indicates that because of threats of retaliation, direct import controls would not be a wise policy choice to address this externality.[53] In principle, a combination of taxes on energy consumption and subsidies for energy production could be devised to achieve the same effect as import controls, but with less visibility as a 'beggar thy neighbour' strategy and therefore with less risk of retaliation. However, such alternatives have their own drawbacks. Consumption taxes raise domestic prices to force conservation, which may be inconsistent with concerns about macroeconomic adjustment costs. Subsidies to domestic oil production would have to be very high to overcome the high marginal cost of replacing reserves in the USA. It may be more cost-effective to direct those subsidies to production in other parts of the non-OPEC world where marginal costs are significantly lower. In either case, it is difficult in practice to set taxes or subsidies which balance the clear deadweight losses of resource misallocation against a reduction in market power whose magnitude and timing is uncertain.

The only policy recommendation that will reduce OPEC market power without a serious drawback is government support of energy R&D that will lead to an increase in the price elasticity of either world oil supply or demand. This support for R&D does not extend to mandates or subsidies for promoting alternate fuels that otherwise would be non-economic. Such measures have the same drawback as energy taxes in requiring up front social costs for uncertain future benefits. The goal of policy in this area should be confined to developing technological options unless more serious problems of market power emerge in world energy markets.

There are no feasible policy options for directly addressing the causes of adjustment rigidities.[54] For example, it is not feasible to replace collective bargaining or other established labour contract arrangements with an option that allows for greater wage flexibility. Similarly, efforts to make natural gas and electricity prices more responsive to market forces are limited by the recognized need to control the market power of legal monopolies. Thus our attention turns to possible second best policies.

Taxes may be employed to reduce energy consumption, or to shift consumption away from the most volatile forms of energy, in order to reduce the impact of an energy price shock when it occurs. However, the logic of this option is strained because taxes force the economy to make the same adjustments as external oil price shocks. While self-inflicted pain may be imposed in more manageable doses, the costs are certain and permanent, while the costs of energy market disruptions are uncertain and temporary. Consequently, circumstances are unlikely to weigh in favour of energy consumption taxes unless and until a stronger case can be made regarding the seriousness of energy market shocks and their macroeconomic consequences.

If it is not possible to mitigate the effects of energy price changes, we must turn to policy options that work to dampen fluctuations in energy prices. With respect to oil, two options are available, a Strategic Petroleum Reserve (SPR) and development of new technology, both of which have been undertaken in the USA. Investment in the USA SPR has been substantial – in excess of US$20 billion has been spent to store close to 600 million barrels of oil. Despite the large investment, the effectiveness of the reserve is questionable because the maximum contribution of the SPR is small relative to the potential increase in private oil storage demand (several hundred million barrels during the early months of the 1979 crisis, for example). According to this line of reasoning, it would be too costly for the USA to build a SPR that is large enough to dampen oil prices in a crisis without the help of other countries. International cooperation, in the form of coordinated stock drawdown or restrictions on imports, is therefore a necessary complement to the SPR to achieve effective control of oil prices.[55]

The second option, investing in R&D, will reduce oil price volatility if it results in new technologies that increase energy demand and supply elasticities. This option is the only one that addresses both the problem of OPEC market power and the problem of oil price volatility.

Our discussion of policy options for addressing energy security externalities suggests a hierarchy of potential responses, although the uncertainties surrounding the magnitudes of externalities obviate a recommendation on how intensively these measures should be applied. At the top of the hierarchy is support for R&D, which has the capability of addressing numerous market failures simultaneously with fewer downside risks. Further down is the SPR, which can be a useful tool for stabilizing energy prices but only in the context of international cooperation. Reform of public utility regulation to enhance the responsiveness of the gas and electric markets to changes in economic conditions is also desirable, but regulatory reform generates consequences well beyond energy security and cannot be lightly tossed into a pot of measures for addressing security concerns. Further down in the hierarchy is the use of taxes to curb energy consumption, because of their unattractive side effects on the economy.[56] Uniform energy taxation is especially inefficient in achieving security goals, since different energy types have differing degrees of price volatility and substitution possibilities. Finally, oil import controls have the least to commend them given the uncertainties about market power by suppliers and the prospects for retaliation.

We gratefully acknowledge the research assistance of Gerwin Bell and Gayle Killam, and helpful discussions with Dallas Burtraw and Alan Krupnick.

[1]US Department of Energy (DOE), *National Energy Strategy*, 1st edn, DOE, Washington, DC, 1991.

[2]For example, the Clean Air Act Amendments of 1990 require electric utilities to cut sulphur dioxide emissions by half by the year 2000. In addition, several states have begun to integrate estimates of the cost environmental externalities into decisions regarding the choice of electric generating technologies for new plants, or, indeed, whether to encourage conservation rather than produce more electricity.

[3]A somewhat more direct connection is sometimes drawn in energy policy debates about military preparedness and access to petroleum supplies. However, military aspects of the security issue have been heavily discounted relative to the economic aspects since the analysis in *The Oil Import Question: A Report on*

the Relationship of Oil Imports to National Security, prepared by the Cabinet Task Force on Oil Import Control (1970). As discussed further below, disturbances in energy markets ultimately are issues of price rather than of physical availability.

[4]See R. Cornes and T. Sandler, *The Theory of Externalities, Public Goods, and Club Goods*, Chapter 3, Cambridge University Press, Cambridge, 1986.

[5]Moreover, they may well be endemic problems that require non-marginal (and difficult) changes in the whole structure of utility regulation to be rectified.

[6]Our discussion focuses on oil imports, since oil is by far the most widely traded energy type. However, the scope of this issue could expand to other energy sources, as with an increase in world gas trade through LNG or ethanol fuel.

[7]See D.R. Bohi and W.D. Montgomery, *Oil Prices, Energy Security, and Import Policy*, Washington, DC, Resources for the Future, 1982, for further exposition. The phenomenon can be simply illustrated in mathematical terms. Let Z denote the volume of imports and let P denote the price. The effect of an increase in imports on the total cost is given by $d(PZ)/dZ = P + Z\,dp/dZ$. The second term measures the effect of the price increase on inframarginal imports.

[8]P. MacAvoy, *Crude Oil Prices as Determined by OPEC and Market Fundamentals*, Ballinger, Cambridge, MA, 1982.

[9]D.J. Teece, 'OPEC behavior: an alternative view', in J.M. Griffin and D.J. Teece, eds, *OPEC Behavior and World Oil Prices*, George Allen and Unwin, London, 1982.

[10]See D.R. Bohi and M.A. Toman, *Analyzing Nonrenewable Resource Supply*, Resources for the Future, Washington, DC, 1984, Chapter 2.

[11]M.A. Adelman, 'The clumsy cartel', *Energy Journal*, Vol 1, No 1, January, 1980, pp 43–52; M.A. Adelman, 'Scarcity and world oil prices', *Review of Economics and Statistics*, Vol 68, No 3, August 1986, pp 387–397; and M.A. Adelman, 'Mineral depletion, with special reference to petroleum', *Review of Economics and Statistics*, Vol 72, No 1, February 1990, pp 1–10.

[12]Constraints on absorptive capacities could affect not just income streams but also the propensity to hold wealth, whether as liquid balances or *in situ* oil reserves. This could at least partly explain Saudi unwillingness even to delineate areas where oil reserves are likely to be found.

[13]J.M. Griffin, 'OPEC behavior: a test of alternative hypotheses', *American Economic Review*, Vol 75, No 5, December 1985, pp 954–963.

[14]The individual explanatory variables often are statistically insignificant, but the combined significance of the variables cannot be rejected in most cases.

[15]C.T. Jones, 'OPEC behavior under falling prices: implications for cartel stability', *Energy Journal*, Vol 11, No 3, July 1990, pp 117–130.

[16]See Energy Modeling Forum (EMF), *World Oil*, Summary Report, Stanford University, Stanford, CA, 1982 and D. Gately, 'Lessons from the 1986 oil price collapse', *Brookings Papers on Economic Activity*, Vol 2, 1986, pp 237–284.

[17]D.R. Bohi, *What Causes Oil Price Shocks?*, Discussion paper D-82S, Resources for the Future, Washington, DC, 1983.

[18]H.G. Broadman and W.W. Hogan, *Oil Tariff Policy in an Uncertain Market*, Energy and Environmental Policy Center Discussion paper E-86-11, Harvard University, Cambridge, MA, 1986 and H.G. Broadman and W.W. Hogan, 'The numbers say yes' (part of a special feature, *Is an Oil Tariff Justified? An American Debate*), *Energy Journal*, Vol 9, No 3, July 1988, pp 7–30. M.A. Walls, 'Welfare cost of an oil import fee', *Contemporary Policy Issues*, Vol 8, No 2, April 1990, pp 176–189, also concludes that the direct value of import controls is low.

[19]This issue aside, US oil import restrictions will complicate trading relationships with non-OPEC trading partners such as Canada, Norway, and the UK. This complication, and the overlay of political interests on economic interests (eg US support for Saudi Arabia) makes it very difficult to separate friend from foe in designing oil import policy.

[20]Most economists would agree that market signals alone do not generate a socially efficient level of investment in research for acquiring basic knowledge for the development of new technologies. The basic problem is that information has attributes of a public good, with benefits to many other agents beyond those who bear the costs of information acquisition (notwithstanding institutions such as patents and copyrights). Since those who bear the costs of information acquisition generally cannot appropriate all the benefits, too little information acquisition is undertaken (see *op cit*, Ref 4). While this argument applies to research generally, the intersection of energy security concerns with R&D externalities suggests that research support should be targeted in particular toward the development of cost-effective alternative energy sources and less energy intensive technologies.

[21]Broadman and Hogan's (*op cit*, Ref 18) figures derive in turn from earlier estimates and judgements in W.D. Nordhaus, 'Oil and economic performance in industrial countries', *Brookings Papers on Economic Activity*, Vol 2, 1980, pp 341–397 and W.W. Hogan, 'Import management and oil emergencies', in D.A. Deese and J.S. Nye, eds, *Energy and Security*, Ballinger, Cambridge, MA, 1981.

[22]N.P. Marion and L.E.O. Svensson, 'The terms of trade between oil importers', *Journal of International Economics*, Vol 20, Nos 1/2, February 1986, pp 99–113.

[23]Their analysis includes the counterintuitive result that those countries least able to adjust to higher oil prices (because of rigidities in the way oil is used in their economy) will tend to experience the greatest reductions in domestic output and, assuming other factors constant, will experience an *improvement* in their terms of trade. This outcome is reached because a decline in home output relative to that of other countries means that there is now a relative shortage of home country goods in world markets. The relative shortage will cause an improvement in the home country's terms of trade. This is one way in which the terms of trade may be inversely related to economic performance (the improvement in the terms of trade presumably is of cold comfort to the country experiencing the deeper recession).

[24]P. Krugman, 'Oil shocks and exchange rate dynamics', in J. Frenkel, ed, *Exchange Rates and International Macroeconomics*, University of Chicago Press, Chicago, IL, 1983.

[25]B. Trehan, 'Oil prices, exchange rates and the US economy: an empirical investigation', *Federal Reserve Bank of San Francisco Economic Review*, No 4, Autumn 1986, pp 25–43.

[26]*Op cit*, Ref 10, Chapter 5.

[27]D.C. Hall, 'Oil and national security', *Energy Policy*, Vol 20, No 11, November 1992, pp 1089–1108; and H.M. Hubbard, 'The real cost of energy', *Scientific American*, Vol 264, No 4, April 1991, pp 36–42.

[28]As discussed below, gradual changes in energy prices are unlikely to generate externalities because private markets have the capability to adjust over time without serious efficiency problems.

[29]For a discussion of how shocks in one energy market propagate to other energy markets, see K.A. Monk, 'Flexibility in intercommodity substitution may sharpen price fluctuation', *Quarterly Journal of Economics*, Vol 100, No 2, May 1985, pp 447–463.

[30]See D.W. Jorgenson, F.M. Gollop and B.M. Fraumeni, *Productivity and US Economic Growth*, Harvard Economic Studies, Vol 159, Harvard University Press, Cambridge, MA, 1987; D.W. Jorgenson, 'Productivity and postwar US economic growth', *Journal of Economic Perspectives*, Vol 2, No 4, Autumn 1988, pp 23–41; and W.W. Hogan and D.W. Jorgenson, 'Productivity trends and the cost of reducing CO_2 emissions', *Energy Journal*, Vol 12, No 1, 1991, pp 67–85.

[31]See D.R. Bohi, *Energy Price Shocks and Macroeconomic Performance*, Resources for the Future, Washington, DC, 1989, and references therein for further discussion of these issues.

[32]The income transfer abroad could include monopoly profits if OPEC exercises its market power, in which case these excessive profits constitute an external cost. However, these external costs, to the extent they occur and can be identified, are already included above in connection with the quantity of imports and should not be counted again here.

[33]In addition to effects reflecting relative factor prices, some authors would include short-term Keynesian contractionary effects resulting from the failure of energy exporters to respend their proceeds (see eg R.S. Pindyck, 'Energy price increases and macroeconomic policy', *Energy Journal*, Vol 1, No 4, 1980, pp 1–20 and R.W. Solow, 'What to do (macroeconomically) when OPEC comes', in S. Fischer, ed, *Rational Expectations and Economic Policy*, University of Chicago Press for the National Bureau of Economic Research, Chicago, IL, 1980). However, we view these effects as far more debatable and do not include them here.

[34]Unemployment shock also can result from sticky commodity prices in monopolistically competitive product markets. Sticky commodity prices magnify the burden of adjustment on output quantities and thus on employment when energy price shocks change relative costs of production.

[35]For an excellent survey of alternative explanations of wage and price rigidity and unemployment, along with copious references see N.G. Mankiw, 'A quick refresher course in macroeconomics', *Journal of Economic Literature*, Vol 28, No 4, December 1990, pp 1645–1660; and A.S. Blinder, *Why are Prices Sticky? Preliminary Results from an Interview Study*, Working Paper 3646, National Bureau of Economic Research, Cambridge, MA, March 1991, on price rigidity.

[36]See eg *op cit*, Ref 7, Chapter 4 and references therein.

[37]*Op cit*, Ref 17.

[38]M.C. Lynch, *The Fog of Commerce: The Failure of Long-term Oil Forecasting*, CIS Working Paper No 2598, Massachusetts Institute of Technology, Cambridge, MA, September 1992.

[39]S.L. Green and K.A. Mork, 'Toward efficiency in the crude-oil market', *Journal of Applied Econometrics*, Vol 6, 1991, pp 45–55.

[40]These forecasting errors will encourage less energy intensive investments than necessary *ex post* but our concern is with an *ex ante* bias.

[41]Since gas and electricity prices are subject to federal and state regulation, one source of price unpredictability is changes in regulation. While stability of the regulatory environment is useful for holding down adjustment costs, there often are compelling arguments for regulatory change to mitigate current inefficiencies.

[42]R.C. Lind, ed, *Discounting for Time and Risk in Energy Policy*, Resources for the Future, Washington, DC, 1982.

[43]Note that automatic fuel adjustment clauses avoid this problem, but they also give rise to moral hazard problems in cost minimization by utilities: see D. Baron and R. DeBondt, 'Fuel adjustment mechanisms and economic efficiency', *Journal of Industrial Economics*, Vol 27, No 3, March 1979, pp 243–261; and M. Isaac, 'Fuel cost adjustment mechanisms and the regulated utility facing uncertain fuel prices', *Bell Journal of Economics*, Vol 13, No 1, Spring 1982, pp 158–169.

[44]This view is taken as a fact in US Department of Energy (DOE), *Energy Security: A Report to the President*, DOE, Washington, DC, 1987; and US Department of Energy (DOE), *United States Energy Policy: 1980–1988*, DOE, Washington, DC, 1988. References to this view in the literature are given in *op cit*, Ref 27.

[45]B.G. Hickman, H.G. Huntington and J.L. Sweeney, eds, *Macroeconomic Impacts of Energy Shocks*, North-Holland, Amsterdam, 1987. *Op cit*, Ref 44, 1988, also estimates large macroeconomic costs due to energy price shocks.

[46]*Op cit*, Ref 18, also calculate a macroeconomic disturbance premium equal to 10–12% of the normal market oil price, although the basis for their calculation is different and they mistakenly attribute the premium to the volume of oil imports rather than to total oil consumption.

[47]J.D. Hamilton, 'Oil and the macroeconomy since World War II', *Journal of Political Economy*, Vol 91, No 2, April 1983, pp 228–248; K.A. Mork, 'Oil and the macroeconomy when prices go up and down: an extension of Hamilton's results', *Journal of Political Economy*, Vol 97, No 3, June 1989, pp 740–744.

[48]*Op cit*, Ref 31, and D.R. Bohi, 'On the macroeconomic effects of energy price shocks', *Resources and Energy*, Vol 13, No 2, June 1991, pp 145–162.

[49]*Op cit*, Ref 31.

[50]For example, compare *op cit*, Ref 45; J. Sachs, 'Stabilization policies in the world economy: scope and skepticism', *American Economic Review*, Vol 72, No 2, May 1982, pp 56–61; M. Bruno, 'Aggregate supply and demand factors in OECD unemployment', *Economica*, Vol 53, supplement, 1986, pp 535–552; and J.F. Helliwell, 'Comparative macroeconomics of stagflation', *Journal of Economic Literature*, Vol 26, No 1, March 1988, pp 1–28.

[51]Despite the long concern with the US domestic petroleum industry alluded to at the beginning of the paper, providing the maximum degree of domestic supply capacity should not be a compelling national goal.

[52]These hedging and flexibility measures will be more difficult to implement in economies where the petroleum industry is a large share of total economic activity (eg in Norway). The challenge is particularly acute when the industry is state owned and not always operated according to the dictates of economic efficiency. Nevertheless, the appropriate responses are rationalizing the industry and diversifying the economy, not just protecting the industry.

[53]It is worth emphasizing again that the issue of oil import costs and exporter market power is relevant only at the national scale. Fuel supply and demand decisions made at the local level – for example, the choices of generating technology and fuel in a particular locality – are too small to materially affect world oil prices. For this reason, efforts that penalize oil use in local utility (or transport) systems are misguided simply because the fuel may be imported.

[54]See M. Bruno and J. Sachs, *Economics of Worldwide Stagflation*, Harvard University Press, Cambridge, MA, 1985, with regard to wage rigidities and A.M. Okum, *Prices and Quantities: A Macroeconomic Analysis*, Brookings Institution, Washington, DC, 1981 with regard to commodity price rigidities.

[55]D.R. Bohi and M.A. Toman, 'International cooperation for energy security', *Annual Review of Energy*, Vol 11, 1986, pp 187–208; M.A. Toman, 'The economics of energy security: theory, evidence, policy', in A.V. Kneese and J.L. Sweeney, eds, *Handbook of Natural Resource and Energy Economics*, Vol 3; *Economics of Energy and Minerals*, Elsevier, Amsterdam, 1993.

[56]This is not to deny that energy taxation could serve other useful purposes, such as the internalization of environmental spill overs.