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**Oil Price Developments:
Drivers, Economic
Consequences and Policy
Responses**

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Robert Price,
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Niels Westerlund,
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ABSTRACT/RÉSUMÉ

This paper analyses the factors influencing the price of oil and its likely evolution over the next quarter century. It begins by investigating the fundamental forces shaping long-term oil price developments, highlighting the importance of growth-led demand for oil, particularly that emanating from fast-growing, energy-intensive developing countries, and the implications of increasingly geographically concentrated oil reserves. The paper presents oil price projections to 2030 and examines the sensitivity of the projections to the assumptions about growth and non-OPEC supply. While certain combinations of factors could lead to a significantly higher oil price, the projections also suggest that the optimal strategy of resource-rich oil producers would be to prevent it rising too far. The paper then documents short-term influences on the oil price, which peaked at \$50 a barrel in 2004, and notes that they have probably led to a significant departure from the long-run equilibrium price which could persist for some time. Finally, the paper assesses the effects of higher oil prices on OECD-area economic activity and inflation. It argues that these effects have diminished over time, but that monetary policy should remain vigilant in preventing second-round effects on inflation. At the same time, fiscal policy should remain orientated towards long-term goals while structural policies should assist in the development of greater transparency in oil markets.

JEL codes: L13, Q41, Q43, Q48

Keywords: crude oil, energy, market structure

* * * * *

Ce document analyse les facteurs qui influencent le prix du pétrole et son évolution probable au cours du prochain quart de siècle. Il examine d'abord les déterminants fondamentaux de l'évolution des prix du pétrole à long terme, en soulignant l'importance de la demande pétrolière alimentée par la croissance, en particulier celle émanant des pays en développement à forte intensité d'énergie et en expansion rapide, ainsi que les conséquences de la concentration géographique croissante des réserves pétrolières. Le document présente des prévisions des prix du pétrole jusqu'à l'horizon 2030 et évalue leur sensibilité aux hypothèses concernant la croissance et l'offre hors OPEP. Tandis que certaines combinaisons de facteurs pourraient se traduire par un prix du pétrole nettement plus élevé, les prévisions montrent aussi que pour les producteurs pétroliers dotés d'abondantes réserves la stratégie optimale consisterait à empêcher une hausse excessive des cours. L'étude décrit ensuite les influences de court terme sur le prix du pétrole, qui a culminé à 50 dollars le baril en 2004, et constate que ces facteurs ont probablement entraîné une rupture significative par rapport au prix d'équilibre de long terme qui pourrait persister pendant quelque temps. Enfin, le document évalue les effets de la hausse des prix du pétrole sur l'activité économique et l'inflation dans la zone de l'OCDE. Il en ressort que ces effets se sont atténués au fil du temps, mais que la politique monétaire devrait rester vigilante de manière à éviter les répercussions sur l'inflation. Parallèlement, la politique budgétaire devrait rester axée sur des objectifs de long terme, tandis que les politiques structurelles devraient contribuer à une plus grande transparence des marchés pétroliers.

Codes JEL : L13, Q41, Q43, Q48

Mots clés : pétrole brut, énergie, structure de marché

OIL PRICE DEVELOPMENTS: DRIVERS, ECONOMIC CONSEQUENCES AND POLICY RESPONSES

by

Anne-Marie Brook, Robert Price, Douglas Sutherland, Niels Westerlund and Christophe André¹

I. Introduction and summary

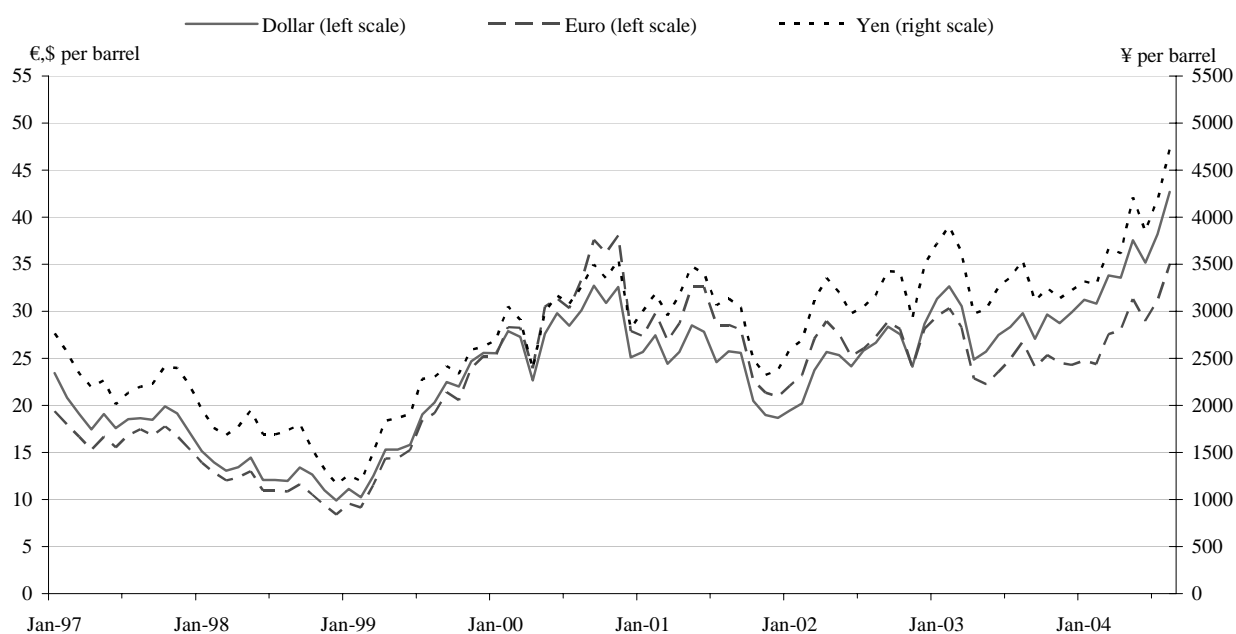
1. This paper analyses the factors driving the significant variation and high levels of oil prices and the economic and policy implications of recent oil-market developments. During October 2004 the oil price had hit a peak of over \$50 per barrel,² at which point the oil price had more than doubled in dollar terms since the late 1990s, while increasing substantially, though somewhat less, in terms of the other major currencies (Figure 1). The paper begins by investigating the fundamentals driving longer-term oil market developments and the implications for the long-run equilibrium price. It then attempts to identify the short-term influences which may have caused risk premia to rise, volatility to increase, and the oil price to diverge from its equilibrium. It concludes with an assessment of the impact of higher oil prices on OECD growth and inflation and the implications for macroeconomic policy stance. The main points to emerge from this analysis are as follows.

2. *Global dependence on oil will continue.* Despite the growing importance of alternative fuels and the more efficient use of oil in production, fossil fuels are still likely to provide almost 90 per cent of OECD primary energy needs in 2030, with oil imports making up almost two-fifths of that. Within the OECD, the largest absolute increase in oil demand is likely to come from North America. More globally, demand from China and elsewhere in Asia will also increase strongly. Rapid economic growth in the more energy-intensive non-OECD countries is likely to entail an upward structural shift in the demand for oil per increment of global GDP compared with recent decades. Transport is expected to remain the principal consumer of oil, accounting for three-quarters of the increment in oil demand between 2000 and 2030.

3. *Dependence on OPEC will increase.* While global oil reserves are probably relatively ample, and will be forthcoming under favourable assumptions about investment in exploration, their distribution is likely to be increasingly concentrated on the Middle Eastern members of OPEC, which already account for around two-thirds of global proved reserves.

1. The research presented in this paper was conducted in the General Economic Assessment Division of the Economics Department. The authors wish to thank Jean-Philippe Cotis, Jørgen Elmeskov, Mike Feiner, Vincent Koen, other members of the Economics Department, the IEA and industry contacts for useful comments and discussions. The authors also wish to thank Anne Eggimann and Sarah Kennedy for secretarial assistance. The views expressed here are those of the authors and do not necessarily represent those of the OECD.

2. All dollar prices of oil refer to Brent crude unless otherwise mentioned. On average, the price of Brent crude is about half a dollar higher than the average OECD import price of crude oil and \$1 to \$1½ lower than West Texas Intermediate, the other Benchmark price.

Figure 1. Oil prices: a historical perspectivePanel A. Brent crude oil price in key currency terms¹Panel B. Real oil price¹

1) Quarterly Brent crude oil price deflated by US consumer price index. Before May 1987, oil prices are OECD estimates for crude oil of the same quality as Brent.

Source: OECD and International Energy Agency.

4. *A gradual rise in the equilibrium price of oil may be expected over the next quarter of a century*, given geological evidence on the extent and location of global oil reserves. Exploration, development, and extraction costs in the Middle East are reported to be less than \$5 per barrel, while short-run marginal costs are generally estimated to be below \$2 per barrel. But elsewhere, newly-discovered resources have tended to become smaller and more expensive to develop, being increasingly offshore, and the costs of exploration, development and production are high and rising relative to those in the reserve-rich Middle East. On the assumptions that initial market shares (38 per cent for OPEC) are maintained over the projection horizon, the baseline scenario generates a trend rise in the oil price to \$35 a barrel by the end of the projection period (2030) from \$27 per barrel in 2003.

5. *Oil price projections depend greatly on the assumptions adopted about economic growth and energy intensity*. Higher GDP growth assumptions, or higher income elasticities of demand, especially in China and the rest of the non-OECD, could require either that prices rise significantly more than in the baseline scenario, or that OPEC be prepared to increase its market share significantly, from 38 per cent to around 55 per cent by 2030).

6. *Oil price increases should be constrained by the long-term price elasticities of non-OPEC supply and of global demand*. Over the longer term, the assumed price elasticities of non-OPEC supply and of global oil demand would imply that OPEC has an interest in raising its market share rather than restricting supply and forcing up the price. This implies that the longer-term price elasticities could act as “softeners” on cartel-like behaviour, particularly given the endogenous but non-reversible nature of technological progress in non-conventional supply and in oil consumption.

7. *Short-term price volatility appears to be an inherent feature of the oil market and adversely affects investment*. In the short run, the low price elasticities of global demand and non-OPEC supply make oil prices highly sensitive to supply and demand shifts. Price volatility, compounded by geopolitical instabilities raises uncertainty about underlying price trends and has tended to depress oil exploration. As a result, OPEC’s excess capacity is currently the lowest in three decades, providing little cushion to raise supply in the event of unexpected oil market disruptions.

8. *Bottlenecks have put upward pressure on prices* Transportation bottlenecks have emerged recently as the changing geographical composition of demand has put pressure on the tanker fleet. In addition, regional mismatches between the grade of oil supplied and demanded have seen premia on low sulphur oil rise.

9. *Part of the current price shock could be persistent*. It is not clear how rapidly short-term factors boosting the oil price will endure, hampering the return to long-term equilibrium prices. The current oil price is significantly greater than the six-month futures price, implying that the “convenience yield” (the premium attaching to physical ownership) has risen. This may be due to an unusually high risk premium. At the same time, in contrast to previous oil shocks, the far futures price of oil, which reflects the price for contracts seven years out, has gone up quite sharply, to around \$35, which signifies a degree of expected persistence in the current price spike.

10. *The link between the oil price and core inflation in OECD countries has weakened*. The pass-through from oil price increases to core inflation has been very limited in recent years, consistent with the increasing focus of monetary authorities on core inflation as the measure to be monitored or targeted, and hence with expectations that monetary policy will respond to offset any pass-through from headline inflation to wages and non-energy prices. Going forward, the established credibility of monetary policies should ensure that oil price rises do not become embedded in inflation expectations to an extent requiring a significant rise in nominal interest rates.

11. *Oil price shocks have moderate effects on output.* Traditional model analysis suggests that the adjustment to OECD output projections following an oil price hike of the magnitude experienced recently is relatively small in the short run. Over the longer run, and on the basis of a permanent oil shock, reduced-form models that attempt to pick up supply-side influences arrive at significantly larger effects. There is also evidence of asymmetry, in that price increases -- particularly large-scale ones -- appear to have a more significant effect on output than do price decreases.

12. *While fiscal policy does not have an active role to play in stabilising the oil price, energy taxes reduce oil dependence and increase the resilience to oil price shocks.* A high tax component of the final price reduces oil intensity and hence the terms-of-trade and inflation impacts of oil price shocks. Using taxes to stabilise end-user prices would run contrary to these long-run goals, while also possibly jeopardising the attainment of budget objectives.

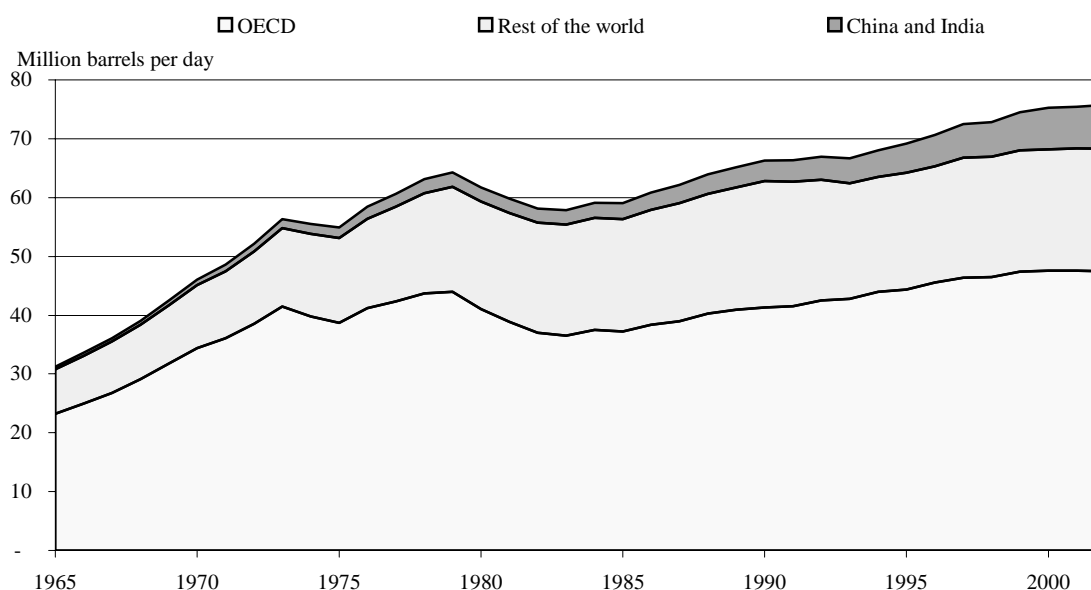
13. *Structural policies that promote the development of markets, such as improving transparency, could serve to reduce uncertainty and remove disincentives to invest.* By ensuring that market participants can make better informed decisions, the match between supply and demand will improve. Greater transparency would help to damp the effects of “news”, while allowing more effective hedging activity reduce exposure to price volatility,

II. Longer-term prospects for the oil market

Global dependence on oil will continue

14. World oil demand (measured as *ex post* supply net of stock movements) has decelerated significantly since the first oil shock, tending to grow about a third as fast as real GDP (Figure 2). This reflects a decline in the oil intensity of production -- total oil consumption per unit of output³ -- in OECD countries (Figure 3). This is largely a result of the more efficient use of oil in production, as ongoing fuel-saving technical change has contributed to continuing reductions of energy intensities, and an increasing utilisation of alternative energy sources, such as natural gas in power generation. In addition, the shift in the composition of output towards services, which are less oil intensive than traditional manufacturing processes, has contributed to declining oil intensity in OECD economies. By contrast, in non-OECD countries oil intensities have generally increased slightly up to the mid 1990s -- partly reflecting a change in production structure towards manufacturing and increasing vehicle ownership -- before starting to fall slightly. China is an exception; its extraordinarily high oil intensity fell back after the mid-1970s as the country increased the use of coal in power generation and switched from being a net oil exporter to importer. Nonetheless, the oil intensity of the Chinese economy remains twice as large as the OECD average.

3. Energy intensity differs from energy efficiency, which is a technical concept referring to the ratio between energy output (light, heat, mobility) and input (fuels). For a single productive process, energy efficiency is the inverse of energy intensity, but that does not necessarily hold on more aggregated levels. For example, due to differences in energy prices, climate, geography and lifestyle, the energy intensity of Japan is roughly half of that of the United States, even though both countries have comparable technical knowledge and technical energy efficiency.

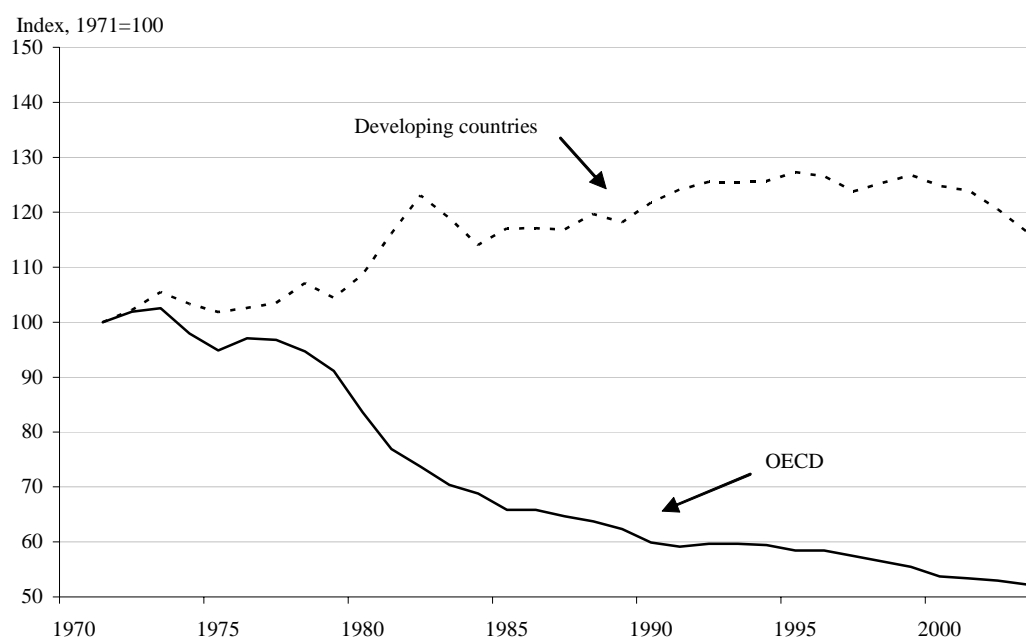
Figure 2. Oil demand growth has slowed since the first oil shock

Source: BP Statistical Review of World Energy, 2004

15. While income growth has been an important determinant of oil demand, relative price shifts have also played a significant part in global energy trends and in promoting the declines in oil intensities seen in OECD economies. In mid-2004, the real oil price was around 40 per cent below its peak following the second oil price shock, but it was nonetheless almost three times above its level prior to the first oil crisis.⁴ While short-run price elasticities are very low, long-run demand is generally estimated to be substantially more elastic. Importantly, there appears to be a significant asymmetry in the response of demand to oil prices, as the negative demand response to high prices is generally not reversed when prices fall. This is to a large extent because rising prices accelerate the development of more energy-efficient technology, as well as the scrapping rate of energy-inefficient capital and its replacement with newer technology. A price fall, on the other hand, does not undo these advances. The longer-term impacts of the comparatively high real oil price between 1974 and 1985 thus contributed to absolute falls of oil consumption for many industrial uses and for space heating.⁵ These trends have, in turn, driven the reductions in the oil intensities experienced in the OECD area.

4. In addition, many countries, notably in Europe and Japan, levied higher taxes on petroleum products due to security-of-supply and environmental concerns.

5. For example, between 1971 and 2001 for the OECD area as a whole, fuel oil and gas oil use fell by around two-thirds in industry and by around two-fifths for residential (space heating) uses.

Figure 3. Oil intensity of production has fallen in the OECD area

Note: Oil intensity is defined as total primary oil use per unit of output (GDP).

Source: OECD and International Energy Agency.

16. In contrast to most of its other end uses, consumption of oil by the transport sector has continued to grow strongly over recent decades, reflecting high income elasticities of demand for private transport.⁶ Over the 1990s fuel consumption grew by around one-quarter in the transport sector and largely accounted for the overall increase in oil demand. Though the fuel economy of new vehicles has improved, such as with the introduction of advanced diesel and hybrid engine technologies,⁷ the economising impact on fuel consumption has been limited in the short term by the relatively slow replacement rate of vehicle fleets (around 15 years) as well as by increasing vehicle ownership and greater distances travelled. In addition, shifts in the composition of the vehicle fleet towards heavier vehicles with larger engines and energy-consuming devices -- such as air conditioning -- limits the improvements in fleet-wide fuel economy averages.

17. Looking forward, and on the assumption that global growth will average around 3 per cent per annum over the period from 2000 to 2030, the International Energy Agency (IEA) has projected that global oil demand will increase by around 1½ per cent annually over the same period, leading to a two-thirds rise in the global demand for oil, to 120 million barrels per day (mbd).⁸ This is seen as consistent with an

6. Estimates of the long-run income elasticity of demand for transport fuels is generally estimated to be greater than one, while the long-run price elasticity is estimated to be between -0.6 and -0.8. See Graham and Glaister (2002) for a literature review of estimates, mainly from OECD countries.

7. Such improvements in average vehicle fuel economy have probably been motivated in part by the impact of taxes on transport fuels, particularly in European Union (EU) countries and Japan.

8. International Energy Agency (2002).

\$8 per barrel rise in the real oil price from its then-assumed average 2002-10 level of \$21 per barrel⁹, given certain assumptions about the geographical origin of supply. The projection incorporates steadily lower oil intensities, which are most pronounced in developing and transition economies, where fuel use is currently particularly inefficient.¹⁰ The largest absolute increase in oil demand is expected to continue to come from North America, with demand from China and elsewhere in Asia also increasing strongly (Figure 4). More rapid economic growth in the more energy-intensive non-OECD countries would entail an upward structural shift in the demand for oil per increment of global GDP compared with recent decades, given the large regional differences in oil intensities. Transport is expected to remain the principal consumer of oil, accounting for three-quarters of the increment in oil demand between 2000 and 2030 (its share in oil consumption thereby rising from over one-half to three-fifths). As a result of these geographical and sectoral demand patterns, the share of oil in both global and OECD primary energy supply would remain broadly stable, at almost two-fifths (Figure 5). Moreover, the importance of oil as an energy source is unlikely to be altered substantially even in the case of additional policy changes directed at climate change mitigation.¹¹

Oil reserves should be adequate to ensure supply over the time horizon considered here...

18. At current production rates, existing reserves of 1000 billion barrels would be exhausted in around 40 years. However, this assumes no additions to reserves, whereas the reserves-to-production ratio has changed only marginally over the past two decades due to ongoing additions to reserves. The concept of proved reserves is linked to commercial viability and as such they have increased in response both to oil price shifts and to technological changes, which have both allowed the extraction of new sources and increased the share of oil within a deposit that can be extracted.¹² As it becomes economic to recover

9 . All projected dollar prices of oil are expressed in constant 2000 dollar prices, unless otherwise mentioned.

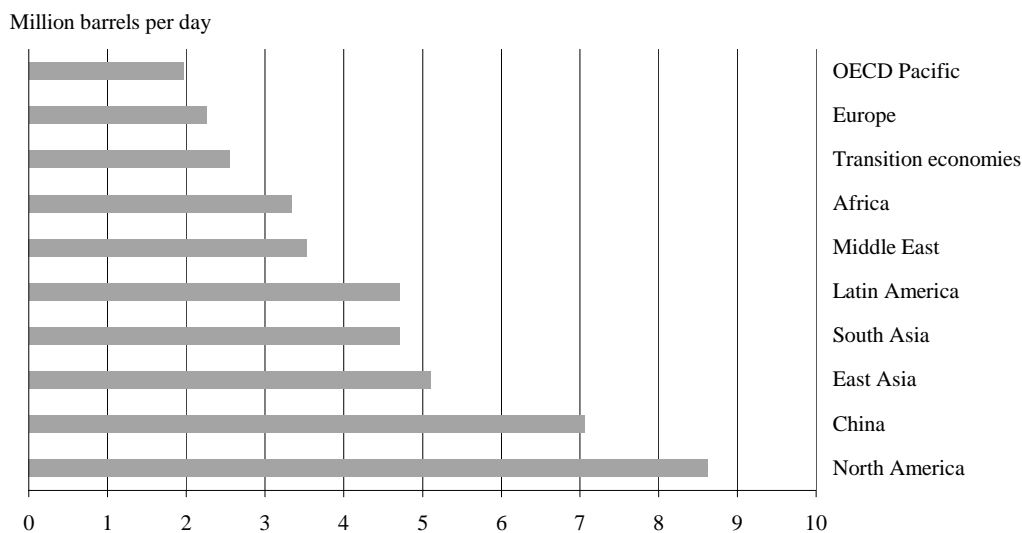
10 . In the longer term, the rate of growth of oil demand may moderate if development follows an environmental Kuznets curve: the empirically-observed phenomenon that environmental problems first increase and then abate as per capita incomes rise. However, while rising per capita incomes, shifts towards less energy-intensive composition of demand and output and the introduction of more efficient technology should reduce oil intensities, a rapid expansion of vehicle ownership would act in the opposite direction. The pace of reduction of oil intensities could thus slow.

11 . The most likely way of achieving climate change targets cost-efficiently would involve changing relative prices such that there is a shift away from coal and towards natural gas in energy supply, leaving the share of oil largely unchanged. Furthermore, oil products in OECD countries typically already attract a substantial tax element, which in many cases is significantly in excess of what could be justified in terms of estimated marginal external costs associated with carbon emissions (see Newbery, 2003).

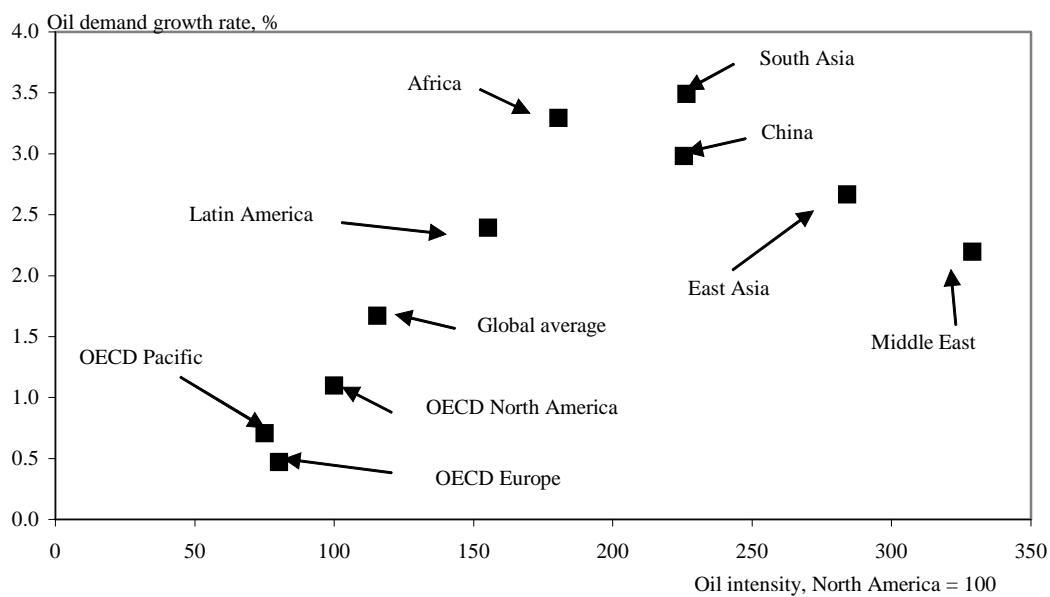
12 . Proved reserves are those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods and government regulations. The “commercially recoverable” caveat can mean that proved reserves could change markedly in response to technological change. For example, until 1950, offshore crude oil production was considered non-conventional and therefore such oil deposits were not recorded as proved reserves.

North America and China

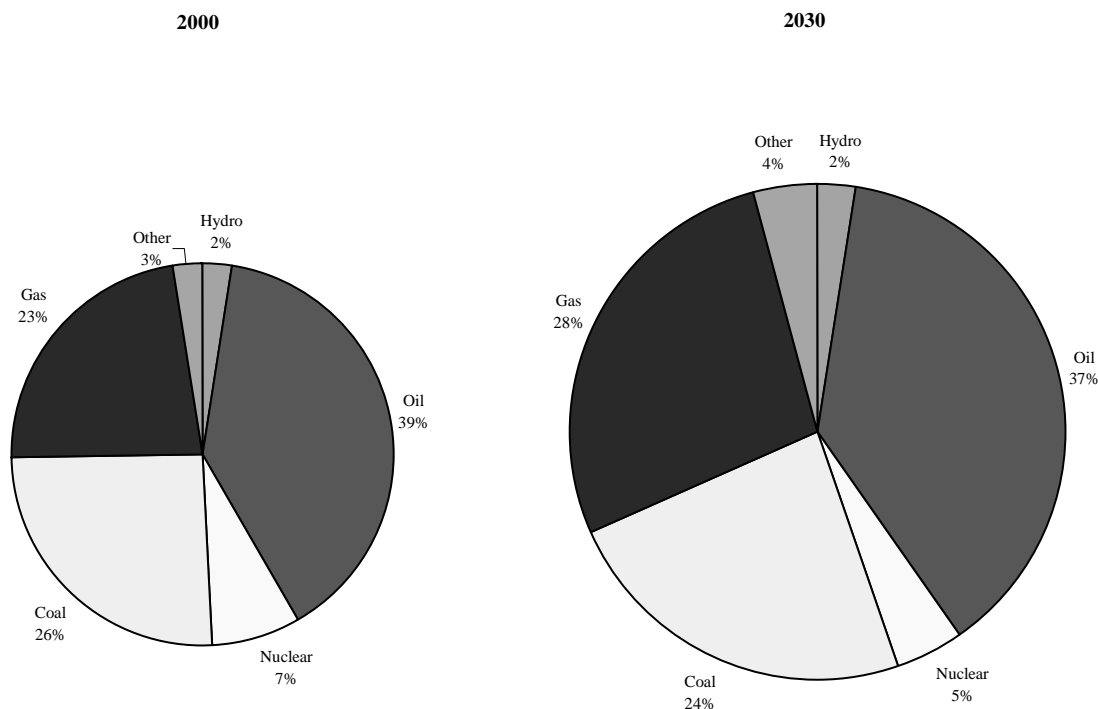
A. Absolute increase in regional oil demand, 2000-30



B. Oil intensities and projected growth of oil demand, 2000-30



Source: International Energy Agency, OECD and World Bank.

Figure 5. The world may remain oil dependent*Per cent of total primary energy supply*

Source: International Energy Agency.

marginal conventional oil supplies, accountancy standards permit companies to restate proved reserves.¹³ Technological advances have slowly pushed up the global average recovery rate -- the share of oil that can be extracted (proved reserves) in relation to the physical volume of oil in a deposit.

19. There is also considerable scope for substantial additions to reserves. For example, probabilistic estimates suggest that undiscovered reserves (combined with growth of existing reserves) could double current proved reserves.¹⁴ However, newly-discovered resources have tended to be smaller and more expensive to develop, being increasingly offshore, and the costs of exploration, development and

13. According to the US Securities and Exchange Commission (SEC) rules, reserves can only be declared proved if they would be developed at current prices and, in this context, the proved reserves of the Royal Dutch/Shell Group of companies were reduced by one-fifth when reporting was brought into line with SEC requirements in 2004. Shell's restatement moved previously identified "proved" reserves into the categories "probable" and "scope for recovery". However, if it becomes economic to start investing in these identified fields, including the two major but as yet undeveloped Australian and Nigerian fields that accounted for one-half of the revision, reserves would re-enter the "proved" category. In contrast to Shell's experience, British Petroleum's SEC filing for the year 2003 showed a modest upward revision in relation to declarations based on UK accountancy standards. This was a result of using the end-of-year market price as required for SEC filings rather than the company's "planning price".

14. US Geological Survey (2000).

production are higher than in the reserve-rich Middle East (see below). Nevertheless, abstracting from the uncertainties and risks involved, the estimated amount of investment needed to ensure supply would be relatively modest in a global context. The IEA estimates that investments in the global oil sector needed to expand supply capacity and to replace existing and future supply facilities that will be exhausted or become obsolete over the 2001 to 2030 horizon come to \$3 trillion, or about 6 per cent of today's world GDP (in constant 2000 purchasing power parities).¹⁵ About three-quarters of this would be for exploration and development. The largest part of global oil investment would be needed in developing countries.

... subject to increasing longer-term dependence on OPEC

20. While oil reserves are probably relatively ample under favourable assumptions about investment, their distribution is likely to be increasingly concentrated on the Middle Eastern members of OPEC, which already account for around two-thirds of global proved reserves. New reserves have continued to be added in OPEC members (and to a lesser extent in the Confederation of Independent States, CIS) (Figure 6). Exploration, development, and extraction costs in the Middle East are reported to be less than \$5 per barrel, while short-run marginal costs are generally estimated to be below \$2 per barrel.¹⁶ However, investment in the energy sector may not necessarily receive the required share of global capital, as global oil supply is likely to be increasingly concentrated in a limited number of OPEC countries where investment is not being allocated according to market forces.¹⁷

21. Global investment, supply and price extrapolations are contingent upon the extent to which OPEC (or a subset of OPEC countries) will exercise its market power. Other suppliers face much higher, and probably more steeply increasing marginal costs than OPEC and the reserve-rich producers in the Middle East have incentives to exploit this cost advantage by trading off market share for a higher price. The less elastic global oil demand and non-OPEC supply are in the long run, the greater are OPEC's incentives to restrict output and thus raise prices in the face of rising world demand.

22. The longer-run supply and demand characteristics of the oil market are thus crucial determinants of future price trends. First, estimates of the long-run non-OPEC price elasticity of supply vary from a low of 0.1 to a relatively high 0.6, depending on the price change is assumed to be permanent or not. Second, the elasticity of non-OPEC supply may be non-linear insofar as at a certain point the oil price would be pushed up sufficiently to encourage investment to promote the production of unconventional oil in other countries. For example, current (comparatively small-scale) extraction of oil from tar sands in Canada is reportedly possible at around \$12-\$16 per barrel and expectations of a sustained high oil price may trigger significant investment in expanding such activity.¹⁸ Third, higher prices induce investment in (non-reversible) energy-saving technology, tending to make the price elasticity of demand for oil

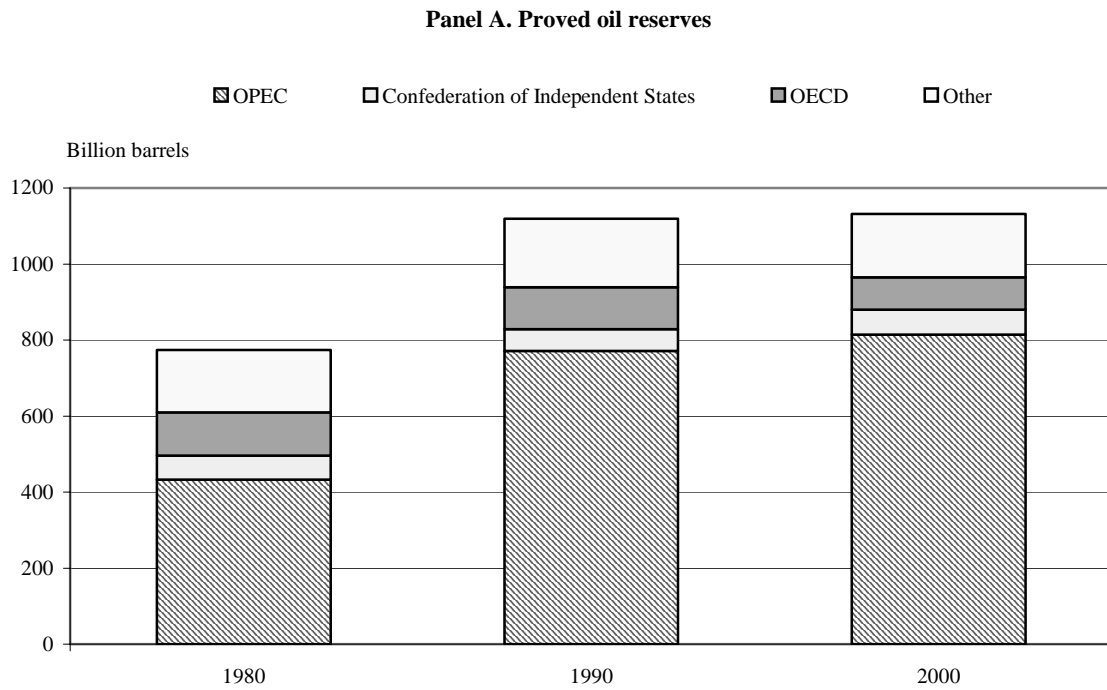
15. International Energy Agency (2003).

16. Maurice (2001).

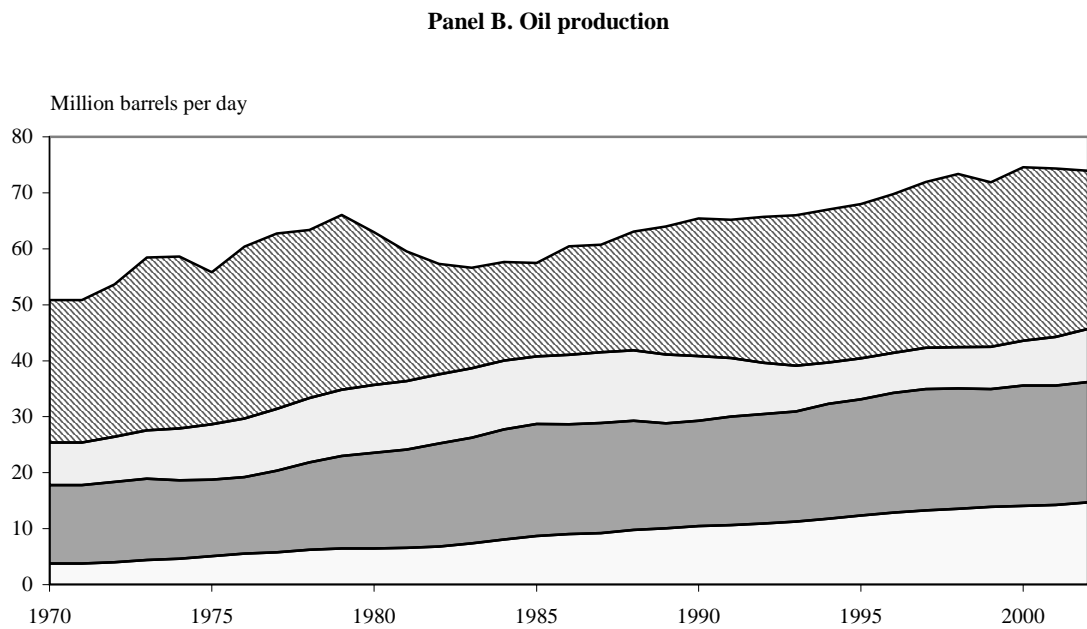
17. International Energy Agency (2003) contains a "restricted investment outlook" that considers the impact of lower investment in the Middle East, resulting in a lower supply and higher price (rising to \$35 from \$29 per barrel in the baseline). Kohl (2002) documents some of the deterioration in public finances in many OPEC countries. In the future, demographic pressures may also place additional strain on the public finances of OPEC members.

18. International Energy Agency (2003). Substantial capital costs and long development times in comparison with conventional oil production and expected rising marginal production costs have so far restrained the expansion of oil extraction from tar sands. As large quantities of natural gas are used in the extraction of oil from tar sands, the development of tar sands depends on price expectations for both oil and natural gas.

Figure 6. Proved oil reserves are stable despite growing production



Source: BP.



Source: International Energy Agency.

asymmetric, or induce substitution to other fuels. Production costs have dropped substantially over the past decades for non-conventional sources, which now account for a modest but not insignificant share (around 5 per cent) of oil production. In total, non-conventional deposits may exceed conventional ones. Indeed, the liquefaction of other fossil fuels, which are in plentiful supply, serves as a backstop technology and as such introduces an implicit upper bound on the price of oil, although it is impossible to put an exact figure to this bound.

Oil price scenarios to 2030

23. To explore possible oil price scenarios over the coming quarter of a century, a number of longer-term oil-price simulations have been undertaken, using a simplified spreadsheet model of the global oil market.¹⁹ The baseline scenario is one in which initial market shares are maintained (38 per cent for OPEC) over the projection horizon and the non-OPEC price elasticity of supply is assumed to be in the middle of the range of estimated elasticities (Box 1).²⁰ To keep market shares constant while demand is steadily growing, non-OPEC producers are assumed to pass into oil prices the expected rise in long-run marginal costs, as new additions to reserves and enhanced recovery techniques are increasingly required to raise their production levels. On the basis of these assumptions, and using the potential growth rates embodied in the OECD's Medium-term Reference Scenario, the baseline generates a rise in the oil price to \$35 by the end of the projection period (2030), from \$27.4 per barrel in 2003.

24. The baseline could be interpreted as an estimate of the equilibrium long-term price (contingent upon the elasticities adopted) only under certain assumptions. First, and most importantly, the starting point for the oil price (in 2003) would itself have to be considered as a long-run equilibrium. Second, an oil market evolution based on a stable OPEC market share would need to be seen as the most likely supply side outcome. With respect to the first assumption, the 2003 price of \$27 per barrel was achieved against the background of an already volatile oil market, so the spot price may already have included a short-term risk premium, but it was one where supply and demand were relatively well matched. With respect to the second assumption, alternative assumptions about OPEC behaviour could greatly affect the overall elasticity of oil supply. Indeed, an OPEC market share exceeding 50 per cent by 2030 would not be unusual historically, in which case the equilibrium price could well differ quite substantially according to the OPEC supply and pricing strategy.

25. The consequences of alternative OPEC supply and pricing strategies for the geographical distribution of oil supply are assessed in Table 1. Keeping unchanged the elasticity of non-OPEC supply and allowing OPEC supply to meet the additional demand, OPEC's share of the oil market would have to rise to over 44 per cent (a rise of more than 6 percentage points compared with the baseline) to limit the rise in the oil price to \$3 and thereby the oil price itself to \$30 in 2030. Conversely, the oil price would have to rise to \$40 in 2030 for OPEC's market share to drop below 32 per cent.

19. The model – which should not be confused with the IEA's World Energy Model which is used to make projections for all fuel types for all regions and sectors – consists of three demand regions (OECD, China, and the rest of the world (ROW)) and two supply regions (OPEC and non-OPEC). It is calibrated using estimated price and income elasticities of demand for OECD and China as a guideline. For more details see Box 1 and the Appendix.

20. The assumption of constant market shares is adopted as being consistent with the maintenance of the existing diversification of supply. The long-term projections of oil demand also assume that there will be no major changes in the structure of energy supply, for example greater use of conventional nuclear power combined with a gradual shift to a "hydrogen economy".

Box 1. Oil demand and supply elasticities

The estimation of oil demand elasticities can be very sensitive to both the equation specification and to the time period. Although there is consensus that long-run elasticities are higher than short-run elasticities, the range of estimates is very wide, as indicated in the table below for long-run elasticities. Differences emerge between OECD countries and developing countries, with the latter typically having lower price elasticities and often higher income elasticities, particularly if they are fast growing economies. In addition, there is evidence that oil demand may have become less sensitive to measures of income, with income elasticities estimated over the post-1986 period being considerably lower than those estimated over a longer time period. In light of this trend, the estimates presented in the tables stress more recent studies. Given the variability of these estimates, the elasticities used in the spreadsheet model (see table below) were calibrated on the basis of Gately and Huntington (2002), but adjusted downwards slightly to adjust for the fact that the elasticities have probably fallen slightly over recent decades.¹ Gately and Huntington's estimates were chosen as a guideline since they are based on differentiated models of oil demand for both the OECD and non-OECD regions.² The sensitivity of the model results to these assumptions is explored in Table 2.

Selected estimates of price and income elasticities of oil (or energy) demand

	Long-run elasticities with respect to:		Comments
	Price	Income	
Hunt, Judge and Ninomya (2003)	-0.23	0.56	Model of sectoral demand for total energy in the United Kingdom, 1971-1997
Gately and Huntington (2002)	-0.64	0.56	Pooled estimates, 1971-97
	-0.18	0.53	- for OECD oil demand
	-0.12	0.95	- for non-OECD oil demand - for fast-growing non-OECD oil demand
Pesaran, Smith and Akiyama (1998)	-0.1 to -0.3	1.0 to 1.2	Pooled estimates for Asian countries total energy demand, 1974-1990
Assumptions used in OECD spreadsheet model			Estimated for 1986-2004 period
OECD	-0.6	0.4	
China	-0.2	0.7	
Rest of World	-0.2	0.6	

Similarly, there is also a relatively wide range of estimated elasticities of non-OPEC oil supply with respect to price. Again, the OECD assumption has been calibrated to represent a central estimate.

Selected estimates of price elasticities of non-OPEC oil supply

	Elasticities of non-OPEC oil supply with respect to price		Comments
	Short-run	Long-run	
Gately (2004)		0.1 - 0.6	
Alhajji and Huettner (2000a)		0.29	
Dahl and Duggan (1996)		0.58	
OECD model assumptions	0.04	0.35	Based on central estimate of Gately (2004)

1. Most estimates in the economic literature are based on a time period beginning in the early 1970s. However, OECD estimates, which remain preliminary, suggest significantly lower estimates over the post-1986 period.

2. Note that the other two sets of results in the upper table are for total energy demand. However, Gately and Huntington (2002) find that their estimates of the long-run income elasticities are very similar regardless of whether the model is for oil or total energy. On the other hand long-run price elasticities tend to be slightly lower (in absolute value terms) for total energy demand than for oil demand.

Table 1. OPEC's market share under different assumptions

Oil price ^a	OPEC supply (Mbd)	OPEC market share (%)	Per cent change in OPEC supply
<i>Baseline value in 2030</i>			
\$35	53.3	38.4	..
<i>Deviations from baseline in 2030</i>			
\$25	23.8	11.6	45
\$30	11.9	6.1	22
\$40	-11.9	-6.8	-22

a) Constant 2000 dollars.

Source: OECD.

26. The results summarised in Table 2 explore the sensitivity of the oil price extrapolations to different assumptions about GDP growth, income and price elasticities of oil demand, and non-OPEC supply elasticities. In part A of the table (the first four columns), the scenarios are based on the assumption that OPEC targets a constant market share (38 per cent) regardless of the price implications.

27. The first two scenarios suggest that oil price projections may be particularly sensitive to assumptions about the demand for oil. Moderate variations in global growth ($\frac{1}{2}$ per cent per annum stronger except in China, where the variation is 1 per cent) could push the oil price up by an additional \$4½ by 2030 (scenario group 1), while an increase of 0.2 in the income elasticity of oil demand could lead to an oil price some \$13 higher (scenario group 2). In both cases, the magnitude of the shock imposed is plausible; any GDP growth projections over a 25-year horizon will have significant error bounds associated with them, and the range of estimates for long-run elasticities of demand with respect to income is sufficiently wide to suggest that a 0.2 percentage point change relative to the baseline assumption is possible (Box 1). Although the scenarios presented in Table 2 are for positive shocks to growth and the income elasticity, negative shocks are equally plausible.²¹ The model already assumes that the income elasticity of demand has declined relative to the 1970s and 1980s, consistent with falling oil intensity and on-going technological change. But this process could continue over the next 25 years, resulting in even lower income elasticities.

28. The next two scenarios suggest that oil price projections are sensitive to assumptions about the price elasticity of demand (scenario group 3) and the non-OPEC supply elasticity (scenario group 4). In the baseline scenario, the price path is relatively flat and the effect of changed elasticity assumptions on the oil price relatively small. In both cases the magnitude of shock assumed (0.2) seems reasonably significant relative to the range of estimates in the economic literature (Box 1), and this magnitude of shock affects the oil price by around \$1 by 2030. However, the non-OPEC supply elasticity becomes much more important in scenarios where the price increases significantly and remains at the new level.

29. In terms of the global composition of oil demand, there is significant uncertainty about the likely path of oil demand from non-OECD countries. The risk of exceptionally strong demand from the non-OECD region is addressed in the final two scenarios, which combine the high growth scenario with higher income elasticities of demand in China and the rest of the world (scenario group 5), and with the additional effect of lower long-run price elasticities (scenario group 6). These results suggest that stronger

21. Since the spreadsheet model is linear, the approximate impact of a negative shock can be obtained simply by reversing the sign on the results presented in Table 2.

Table 2. Oil price extrapolations under selected demand and supply scenarios

Deviations from baseline^a

	A. Oil price in constant 2000 dollars (fixed OPEC market share target - 38%)				B. OPEC target price band +/- 10% from baseline 2030	
	2004	2010	2020	2030	OPEC Supply (Mbd)	OPEC Market share (percentage points)
1. Higher growth						
OECD (+1/2%)	0.2	0.6	1.0	1.4	0.6	0.0
China (+1%)	0.1	0.3	0.7	1.3	0.5	0.0
Rest of the world (+1/2%)	0.2	0.5	1.1	1.9	0.8	0.0
World	0.4	1.5	3.0	4.6	4.5	1.5
2. Higher income elasticities						
OECD (+0.2)	0.7	1.9	3.1	4.1	2.6	0.6
OECD and China (+0.2)	0.9	2.6	4.5	6.5	9.6	3.9
World (+0.2 for ROW)	1.4	4.6	8.7	13.2	29.0	11.7
3. Lower price elasticities of demand						
OECD (+0.2)	0.0	0.0	0.2	0.4	0.2	0.0
China (+0.2)	0.0	0.0	0.0	0.1	0.0	0.0
Rest of the world (+0.2)	0.0	0.0	0.1	0.4	0.2	0.0
World	0.0	0.0	0.5	1.2	0.5	0.0
4. Different non-OPEC price elasticities of supply						
Higher (+0.2)	0.0	-0.1	-0.3	-0.6	0.3	0.0
Lower (-0.2)	0.0	-0.1	0.4	0.9	-0.5	0.0
5. Higher growth and income elasticities in non-OECD countries^b						
China	0.3	1.1	2.6	4.8	5.0	1.8
World excluding OECD	1.1	4.0	8.7	14.9	34.4	13.6
6. Higher growth and income elasticities and lower price elasticities of demand^b						
China	0.3	1.1	2.8	5.3	6.3	2.5
Rest of the world	0.8	3.1	7.3	13.2	24.9	10.3
World excluding OECD	1.2	4.5	10.9	20.1	38.9	15.1

a) Assumptions in the left column are also shown as deviations from baseline. Since price elasticities are negative a positive change implies a lower elasticity (in absolute terms).

b) Scenarios 5 and 6 are simulated as combinations of scenarios 1, 2 and 3 where relevant, for the country or region concerned.

Note : Rest of the World is defined as the total world less China and the OECD.

Source : OECD.

demand and a higher income elasticity in China alone would be sufficient to push prices up by an additional \$5 per barrel by 2030, with the rest of the world pushing prices up by a further \$10. In the most extreme case, the final scenario in the table suggests that the oil price could rise by around \$20 relative to the baseline price of \$35 per barrel.²²

30. The consequences of an alternative OPEC reaction function have been investigated in the last two columns of Table 2 (Part B). Instead of aiming at a fixed market share, OPEC is assumed to behave in a way that mimics OPEC's declared policy of attempting to maintain oil prices within a band. In particular, OPEC is assumed to adjust supply in order to prevent the price from moving by more than 10 per cent from the baseline price. In this context, some events, such as a ½ per cent per annum increase in OECD growth or a change to the price elasticity of demand, could be accommodated without an increase in OPEC share. But more significant shocks such as slower reductions in oil intensities, or combination scenarios, could require OPEC to adjust supply substantially. In order to restrict price rises to no more than 10 per cent, the scenarios that incorporate robust, oil intensive and price-inelastic growth in non-OECD countries (scenario groups 5 and 6) would require OPEC to increase output significantly. The most extreme scenario suggests that OPEC would need to increase supply by 39 million barrels per day (relative to 51 million bpd in the baseline). In turn this would imply that global dependence on OPEC would increase from around 38 per cent to 53 per cent.

31. The OPEC reaction function -- and in particular the question of whether OPEC responds to demand shifts by allowing the price to rise or by a matching supply shift -- is obviously crucial to any long-term oil price projection. In this context, it may be interesting to note that, comparing the revenue outcomes of the two strategies, the illustrative scenarios tentatively suggest that stabilising the price while expanding output (as in scenario 6 of part B of the simulations), might result in significantly higher revenues than would accrue if OPEC's share were fixed.²³ This implies that the longer-term price elasticities of non-OPEC supply and of global oil demand could act as "softeners" on cartel-like behaviour. This would apply all the more if the demand elasticity is asymmetric, as it appears to have been in the past, being higher when prices move up than down. Such a response is not built into the spreadsheet model. However, any conclusion about the relative benefits of stabilising market share or price would seem to be heavily contingent on the choice of supply and demand elasticities, which remains unavoidably somewhat arbitrary.²⁴

32. In the short term both the global demand and non-OPEC supply elasticities are very low, leading to considerable price volatility, and this may hold back the investment in exploration and development needed to ensure that supply is elastic in the longer term. Higher oil prices do indeed appear to induce greater investment activity by non-OPEC producers in identifying and developing new reserves. Exploration and development activity (proxied by the active rig count) is positively correlated with the oil price with a lag (Figure 7). However, price volatility increases long-term price uncertainty, prompting oil companies to require a greater rate of return on their investment. Having trended downwards since the

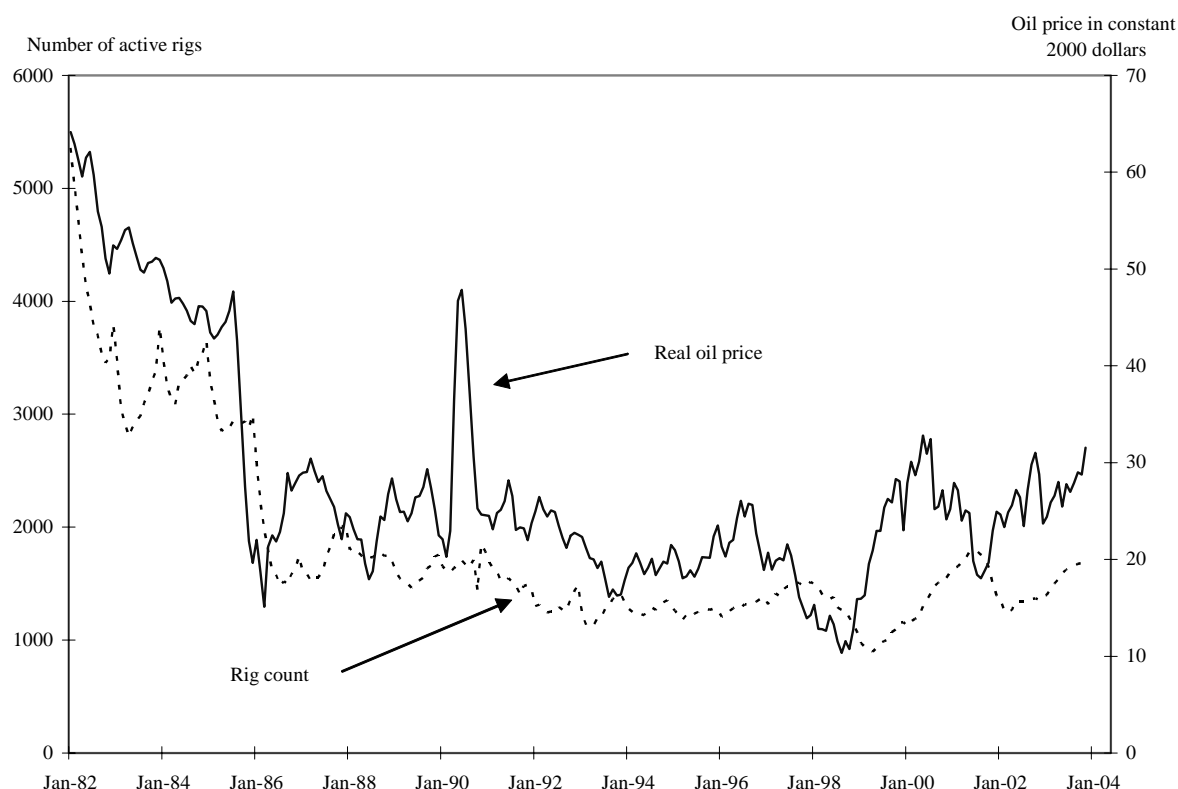
22. In interpreting this result it should be kept in mind that the model does not embody the availability of considerable backstop supplies at a particular price level.

23. In scenario A6 OPEC achieves a 56 per cent increase in the oil price while supply rises by 15 per cent; in scenario B6 the oil price rises by 10 per cent while supply increases by 82 per cent. The incremental revenue calculations which result from these shifts would need to be evaluated with respect to costs and option values to determine which strategy was optimal.

24. Gately (2004), in an investigation of possible OPEC strategies, finds that a competitive market strategy, which would see OPEC's market share rising constantly over time, would be inferior for its members to one that restricts output. An optimal OPEC strategy in one of Gately's central scenarios would result in an OPEC market share of 37 per cent.

early 1980s, and having fallen further in response to the collapse of the oil price in 1998, the number of rigs in use has been slow to recover as oil prices have risen. In this respect, current uncertainties about oil prices may be acting to depress investment activity by non-OPEC oil producers. And one consequence of the reduced investment over the 1990s could be limited flexibility in the supply response to higher prices over the near-term horizon. The next section considers the role of supply and demand shocks and associated volatility in driving the oil price away from its trend level and how long such price spikes might last.

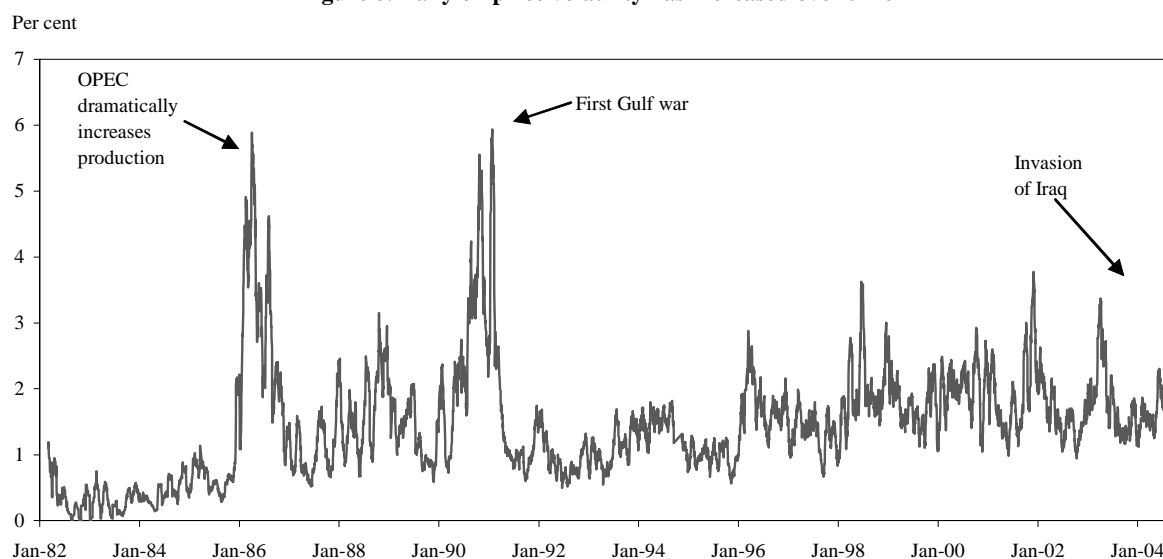
Figure 7. Non-OPEC exploration activity follows the oil price with a lag



Source: Baker Hughes (www.bakerhughes.com) and OECD.

III. Short-term influences on oil price movements

33. So far in 2004, oil prices have increased significantly more than would be implied by longer-term fundamentals, reaching levels similar (in real terms) to those attained in the mid-to-late 1970s following the first oil shock, while being still much below the real oil price of the early 1980s. Spikes in oil prices are not unusual and are, to some extent, symptomatic of a gradual upward trend in daily oil price volatility since the early 1980s (Figure 8). In this regard, it is noteworthy that crude oil prices have been more volatile than the prices of other commodities since 1987, most of which have been less volatile than over the 1974 to 1986 period (Table 3).

Figure 8. Daily oil price volatility has increased over time

Note: Volatility is calculated as the smoothed (one-month moving average) absolute daily percentage change in the price of West Texas Intermediate. Includes data up to 27 September 2004.
Source: Datastream and OECD.

34. Despite relatively high daily volatility, the *ex post* medium-term price trend has been relatively flat since 1986, at least until recently. This implies that volatility does not rule out a relatively stable *ex post* longer-run oil price trend. However, there have been no dramatic shifts in the supply of oil in recent years to compare with the supply disruptions relating to OPEC decisions in the 1970s and 1980s (Table 4), and this may have been a conditioning factor making for the flatter price profile. Indeed, while time series analysis can provide some guidance about the persistence of oil price shocks, the wide variation in shocks and their causes suggest that the recent (post-1986) historical behaviour of oil prices is not necessarily a good predictor of how *future* oil price cycles will evolve (Box 2). The analysis needs to differentiate as to the events and factors involved.

Table 3. Crude oil prices have become more volatile than the prices of other commodities

Standard deviation of monthly percentage changes

	1974-1986	1987-2004	Difference
Agricultural raw materials	3.1	2.5	-0.6
Food and beverages	5.5	3.1	-2.3
Food	6.0	3.5	-2.5
Tropical beverages	6.1	6.5	0.4
Vegetable oil	6.8	4.8	-2.0
Minerals and metals	3.3	3.7	0.4
Gold bullion	6.0	3.7	-2.3
Crude oil (Brent)	4.4	9.2	4.8

Source: Datastream, OECD.

Table 4. A chronology of key events that prompted large oil price changes

Date	Event prompting initial shock	Magnitude of supply change (bpd millions)	Follow-up events	Other comments
1973/74	<p>In 1973, several Arab nations, angered at US support of Israel in the 1973 Arab-Israeli War, instituted an oil embargo against the United States and Holland. The embargo was accompanied by a cut in production, and coincided with declining US crude oil production, rising demand and increasing levels of US imports.</p> <p>Iran expanded sales to the US and these imports served to offset losses from Kuwait and Libya until Libyan crude oil imports resumed in early 1975.</p> <p>As a result of offsetting increases, total oil supply increased slightly in 1974.</p>	<p>1974: OPEC: 0.2 OECD: -0.5 Other: +0.8</p>	<p>The embargo was lifted and production restored six months later. But by then the price had already almost tripled from the 1973 average. Given the limited supply disruptions, it seems likely that the price rise of 1974 was due primarily to a demand shock, together with the absence of additional supply that might have occurred otherwise.</p>	<p>In response to this shock, the IEA was set up to plan for future supply disruptions and to establish secure stable supplies. A number of countries developed plans to establish Strategic Reserves for use in any future supply disruptions.</p>
1979/80	<p>The Iranian revolution, which began in late 1978, resulted in Iranian supply dropping by almost 4 million bpd by 1981. Much of this was <i>initially</i> offset by increases in output from other OPEC members, particularly from Iran's Persian Gulf neighbours.</p> <p>However, in 1980 the Iran-Iraq war began, and many Persian Gulf countries reduced output as well. OPEC's goal was to cut output in order to keep the price high in the face of declining world oil demand and increasing non-OPEC production. However, most of the production cuts were borne by Saudi Arabia.</p> <p>After peaking in early 1980, prices gradually fell back.</p>	<p>1979-1981: OPEC: -8.1 OECD: +1.1 Other: +0.5</p> <p>1979-1985: OPEC: -14.5 OECD: +3.5 Other: +2.4</p>	<p>At the same time that OPEC was cutting output, companies and governments began to stockpile oil and build reserve supplies. This exacerbated the price increases.</p>	<p>The very high level that oil prices reached stimulated significant exploration and production operations in non-OPEC countries.</p> <p>It also depressed petroleum consumption and encouraged fuel-switching and energy conservation. World petroleum demand slid from 63.1 mbdp in 1980 to 60.1 mbdp in 1985 (a drop of 5 per cent).</p>

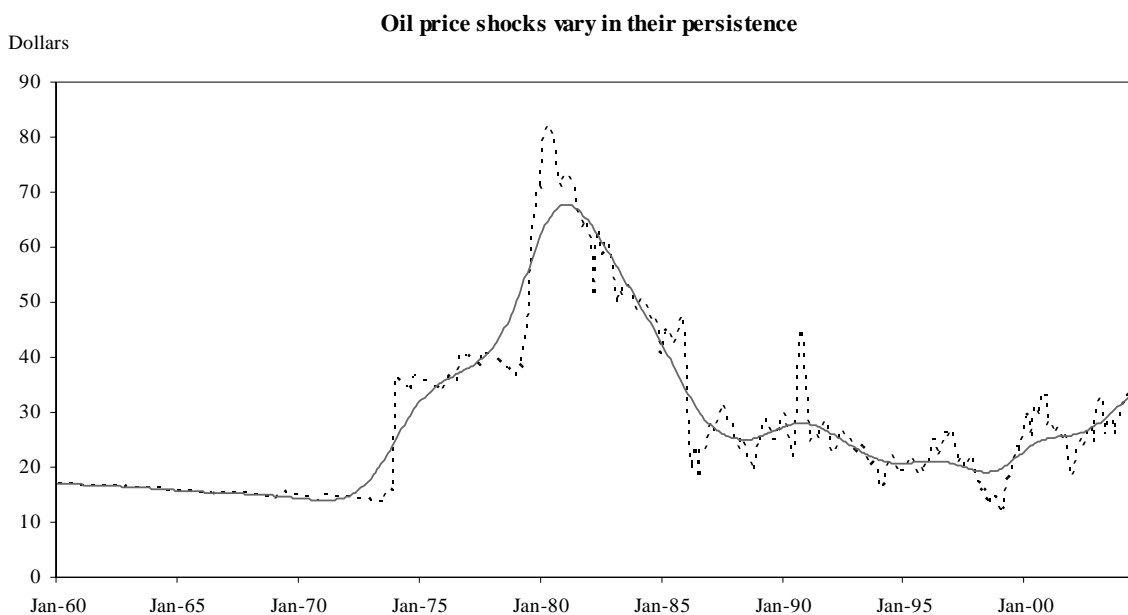
Table 4. A chronology of key events that prompted large oil price changes (continued)

Date	Event prompting initial shock	Magnitude of supply change (bpd millions)	Follow-up events	Other comments
1986	After peaking at over 10 mbpd for the period October 1980 through August 1981, Saudi Arabia's production had fallen to just 2.3 mbpd by August 1985. Thus, in late 1985, Saudi Arabia abandoned its swing-producer role within OPEC, increasing production and aggressively moving to increase market share by implementing a new pricing technique. In response, other OPEC members followed suit, leading to a glut in crude oil in world markets and a sharp fall in prices.	1985-1986: OPEC: +2.7 OECD: -0.4 Other: +0.8	After 1986, total OPEC supply continued to expand every year until 1999.	Many high-cost wells in the US and elsewhere became unprofitable in 1986 and were shut down. Drilling plummeted after March 1986.
1990/91	Iraq invaded Kuwait on 2 August 1990. The United Nations approved an embargo on all crude oil and products originating from either country, leading to a reduction of about 4.3 mbd. Both OPEC and non-OPEC countries increased production to offset this reduction in supply. Overall, total OPEC supply was held at close to 1990 levels. The dissolution of the Soviet Union in 1991 led to a fall in supply from that part of the world, contributing to an overall reduction in world supply that year. However, at the same time this shortfall was more than compensated for by a run-down in global official government oil stocks. Given only limited supply disruptions it seems likely that the rise in crude oil and petroleum product prices occurred largely because of significant uncertainties regarding the outcome of the Kuwait invasion.	1990-1991: OPEC: +0.1 OECD: +0.6 Other: -0.9 Government stocks were run down at the rate of: 1.1 mbd (US), 0.4 mbd (Japan) and 0.3 mbd (Europe).	When the United Nations approved the use of force against Iraq in October 1990, prices began falling. Most of the falls occurred prior to the start of the war, which lasted from January to March 1991. But the record one-day drop in oil prices followed the success of the Allied air strike on 16 January 1991. This took prices back to around \$20 pb by mid-January	Compared to the earlier oil price shocks: - There was more rapid adjustment to disruptions due to refinery upgrades and efficiency improvements over the 1980s (e.g. the development of multi-fuel boilers). - There was less concern about building up stocks due to an expectation that Special Petroleum Reserves could be used, and from the utilisation of the futures market to hedge against large swings in prices.

Source: US Energy Information Administration (2004).

Box 2. The life expectancy of oil price shocks

Ex ante it is not always easy to determine whether a sudden change in the oil price reflects permanent or transitory factors, and, if the latter, how long the adjustment back to trend will take. To illustrate, the figure below shows monthly West Texas Intermediate (WTI) oil prices since 1960 together with a Hodrick-Prescott (HP) filtered trend. Whereas the sharp price increases in 1974 and 1979 and the sudden fall in prices in early 1986 persisted for a number of years, most price shocks since 1986 have been relatively transient, such as during the Iraqi invasion of Kuwait and the subsequent Gulf war in 1991. This wide variation between the persistence of shocks suggests that the guidance provided by time series analysis will be limited when it comes to predicting the durability of any particular spike.



Note: Monthly West Texas Intermediate (WTI) crude oil price, expressed in January 2000 dollar prices, deflated by the consumer price index. Includes oil price data up to 17 September 2004. September CPI is projected. Trend is calculated using the Hodrick-Prescott filter.

Source: Datastream and OECD.

Empirical analysis of monthly crude petroleum prices supports this conclusion. By estimating the autoregressive parameter in oil price data that spans the period since the 1950s, Cashin *et al.* (1999) show that oil price shocks can be very persistent. The half life of a shock to the price of oil is more than six years using a least squares estimator (LS) and up to infinity when the median-unbiased estimator (MU) is used. Even in the case of the lower estimate, these results would seem to suggest that price shocks to crude oil prices are highly persistent.¹ However, consistent with the discussion above, the evidence suggests that oil price shocks have become less persistent since the mid 1980s. Using the same methodology as above, but for the post-1986 time period, it is estimated that the half life of oil price shocks has dropped significantly, to around one to two years.²

The persistence of crude oil prices does not necessarily extend to the prices of refined products. Even over the full time period, the half life of a shock to heating oil may be only 5 to 8 months.³ The relatively greater persistence of crude oil prices probably stems from the greater role of OPEC in the determination of prices, particularly prior to 1987. Fluctuations in the price of heating oil are driven more by weather-related shocks. In addition, the entry of new producers into the crude oil market requires much longer lead times (and all the uncertainties of oil exploration) than is the case in the heating oil market.

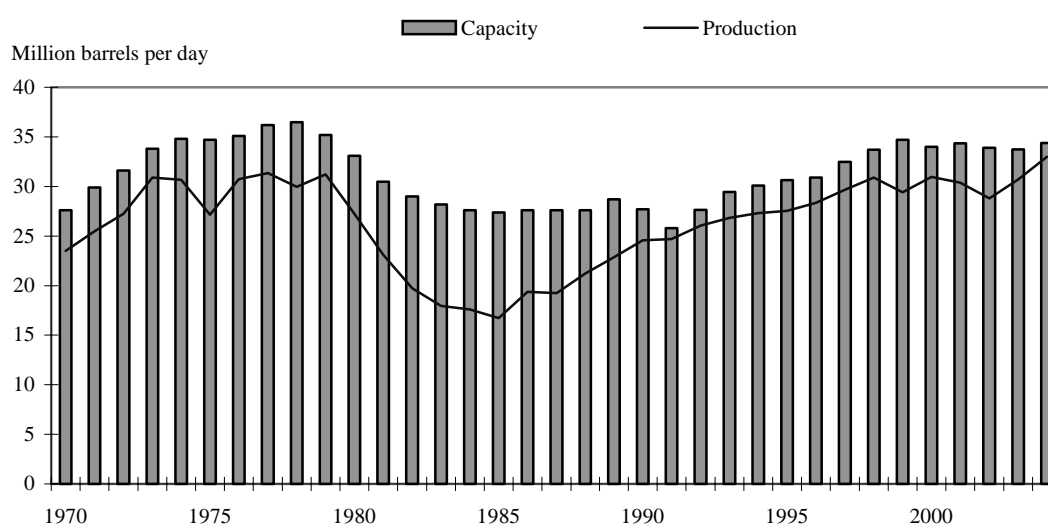
1. Since the standard least squares-based estimator of an AR model is biased toward zero and has low power against plausible trend-stationary alternatives, the median-unbiased estimator (proposed by Andrews, 1993) achieves a more accurate estimate of the persistence of shocks to economic time series.
2. The least squares estimator suggests a half life of around one year and the median-unbiased estimator suggests a half life of around two years.
3. See Cashin *et al.*, *op. cit.*

35. Looking ahead, whether current oil price volatility will be associated with a persistently higher oil price will thus depend on the factors to which it can be attributed. These include: OPEC supply responses and security-of-supply concerns related to geopolitical factors; unexpected shifts in demand; inherent features of the oil market which may be affecting inventory behaviour; and short-term production and distribution bottlenecks. Since the price elasticities of demand and non-OPEC supply are very low in the short run, any of these factors can have quite large impacts on the price of oil. Speculative investment funds may also contribute to price volatility. Each of these drivers is discussed in more detail below.

OPEC supply responses and geopolitical concerns

36. OPEC's excess capacity, currently estimated to be just over 1 million barrels per day, is at its lowest level since the early 1990's, providing little cushion in the event of unexpected oil market disruptions (Figure 9). Although OPEC's official policy since early 2001 has been to adjust output with the view to keeping prices within a band of \$22 and \$28 per barrel, target pricing efforts were effectively abandoned in late 2003, as the significant swing producers (Saudi Arabia and the United Arab Emirates) failed to respond to significantly stronger-than-expected demand with a rapid increase in production. This state of affairs has been largely attributed to insufficient investment in new extraction capacity over recent years and may result from mistaken expectations together with the long gestation lags applying to capital investment. Restraints on foreign direct investment and on the role of the enterprise sector in financing energy projects may also be playing a role. In addition, if OPEC behaviour contributes to greater uncertainty about longer-term price trends, it may also discourage the development of both new non-OPEC supply, and investment in energy-saving technology (Box 3). Some of the price volatility noted above could be associated with a lack of transparency that deprives the market of reliable up-to-date information on global supply. As a result, OPEC "news" can move oil prices sharply, exacerbating oil price volatility and contributing to greater uncertainty about longer-term price trends.

Figure 9. OPEC spare capacity has diminished



Source: International Energy Agency and OECD.

Box 3. Challenges within OPEC and implications for non-OPEC investment

OPEC often encounters difficulties in reconciling diverse interests...

Since Saudi Arabia, Kuwait and the United Arab Emirates all have significant proved reserves that will take many decades to be exhausted, these countries tend to have relatively long time horizons and are often prepared to forego revenue in the short run, in order to prevent the oil price from rising too far. In other words, these countries have incentives to use "entry-limit pricing", which is the practice of targeting a price that is high enough to earn significant profits, but not high enough to trigger investment in energy-saving technology and new oil extraction or to encourage the development of alternative sources of energy supply. In contrast, other OPEC countries, with much smaller oil reserves and/or with larger natural gas reserves, are more likely to prefer higher prices in the short run, particularly if their oil reserves are expected to be exhausted comparatively quickly.¹

... with Saudi Arabia playing a key role

Since Saudi Arabia is the country with the greatest production capacity and flexibility, it has sometimes played the role of the "swing producer" in order to ensure that the oil price remains within acceptable limits.² However, playing this role in the past has sometimes resulted in it losing market share (or export revenues).³ Members with relatively short horizons may try to exploit the inelastic short-term demand for oil by voting against adjusting OPEC production quotas upwards in response to a positive demand shock. At the same time, each individual producer (country) has incentives to defect, particularly as the price rises. Indeed, since OPEC has no explicit compensation or sanction mechanism to enforce adherence, quota cheating is a perennial problem. In addition, in some OPEC member states, the heavy reliance on oil revenues coupled with the poor state of public finances and foreign debt-servicing requirements may increase the likelihood of quota cheating. The Saudi authorities have tried to retain some discipline by occasionally threatening unilateral increases in supply, but the frequent price fluctuations suggest that they have not always been successful.⁴

Investment in oil extraction and energy-saving technology may be discouraged

If OPEC succeeds much of the time at implementing an entry-limit pricing strategy, then private-sector investors will be (intentionally) discouraged from committing to the large initial sunk costs associated with "backstop" investment (*i.e.* investment in new oil extraction, or the research associated with the development of energy-efficient technologies).

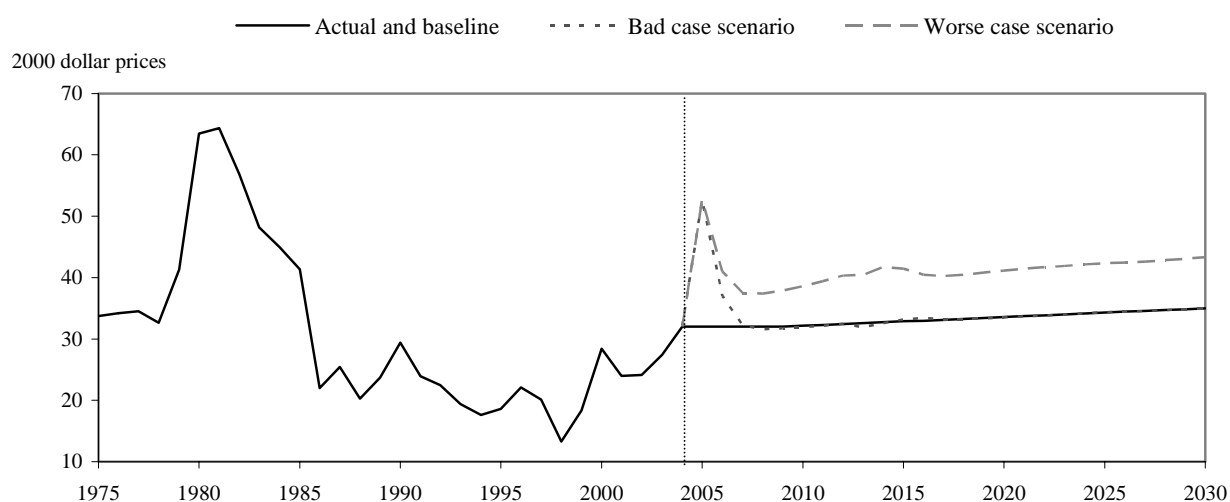
However, backstop investment may also be discouraged *unintentionally*, if coordination and compliance problems are accompanied by significant price volatility, leading to uncertainty about the longer-term price path. The reluctance of investors to commit to new expenditures when prices are high and volatile may be reinforced by repeated "reassurances" from the Saudi authorities that they intend to increase production. Thus, it is possible that even a very poorly-functioning cartel might, at times, serve OPEC's interests.

-
1. With global demand for natural gas growing strongly and gas-to-liquid fuels able to act as a substitute for oil (Green, 1999), Iran and Qatar, which have significant natural gas reserves, may be somewhat less concerned by the potential impact of higher oil prices.
 2. For example, Saudi Arabia increased output and thereby minimised supply disruptions after Iraq's invasion of Kuwait in 1990. However, restoring the oil price in 1998 also required the intervention of the non-OPEC countries Norway, Russia and Mexico.
 3. Prior to the significant increase in Saudi Arabian production in 1986, its market share had fallen from 17 per cent at the beginning of the decade to just 6 per cent.
 4. See Alhajji and Huettner (2000b).

37. Geopolitical tensions and uncertainty stemming from acts of sabotage on oil facilities in the Middle East and fears of disruption in other oil producing countries have added an additional “risk premium” to the oil price, related to the possibility of a significant disruption to supply capabilities.²⁵ To investigate the possible consequences of a serious supply disruption, the model described in Section II was used to simulate the impact of a severe disruption of global oil supply by 7 per cent, which is of a magnitude experienced in the major oil shocks of the past.²⁶ In the first simulation (the “bad case” scenario), post-crisis output is assumed to recover linearly to baseline levels over the following decade. In this case, using the baseline parameter assumptions described in the Annex, the results suggest that the oil price would need to rise by around \$20 per barrel in the first year in order to equilibrate demand and supply. Prices would then fall back to their baseline level relatively quickly.

38. In the second simulation (the “worse case” scenario) the recovery is assumed to be slower, with production remaining at its initial post-disturbance level for ten years before recovering linearly to the pre-crisis production level over the following decade.²⁷ In this case the short-term spike in prices would be the same as in the bad case scenario. However, since production remains permanently below baseline, the price would remain around 20–25 per cent above the baseline price throughout the projection horizon (Figure 10).

Figure 10. An oil supply crisis could push prices up significantly



Source:OECD.

25. Estimates of the “risk premium” are typically derived from a subjective analysis of what the oil price would be in the absence of geopolitical tensions.

26. Hamilton (2003)

27. Although Saudi Arabia is heavily dependent on oil revenues, a persistently lower level of production could potentially be seen as economically feasible in the short-term (since prices would be likely to increase by more than the output reduction thus potentially increasing oil revenues).

39. Finally, it is worth noting that these simulations capture only the increase in the price that would be required to equilibrate demand and supply given the reduction in supply, and as such they probably underestimate the total short-term price shock. This is because the uncertainty and risks that would accompany such a supply shock may also provoke a significant increase in the risk premium.

Contribution of demand factors

40. Another important contributor to the recent spike in oil prices has been unexpectedly strong demand for oil.²⁸ The difficulties of forecasting global economic activity are well known, and misjudgements can, at times, have an important impact on oil prices. An earlier episode that stands out was the slump in oil prices between 1997 and 1999. In 1997, the sharp and unexpected slowdown in the Asian economies coincided with an increase in the OPEC production target, and the oil price fell by more than half between early 1997 and early 1999 (from almost \$25 to just below \$10). While OPEC output cuts eventually allowed prices to return to their previous levels, the unwieldy nature of OPEC meant that the adjustment process took three years.²⁹

41. During 2004, the IEA has revised its estimate of global oil demand for 2004 upwards by the largest margin for decades, by just over 3 million bpd since mid-2003. Oil demand has been surprisingly strong in China, where economic activity has been particularly buoyant, and remained robust in the United States (where the economic recovery has been among the strongest).³⁰ These two countries have accounted for over 40 per cent of the incremental increase in global oil demand over the past decade (Table 5).

Table 5. **The United States and China have been major sources of incremental oil demand since 1995**

	Oil demand (level)			Share of incremental demand
	(million barrels per day)			(per cent)
	1995	2000	2004	1995-2004
United States	18.0	20.0	20.5	19.9
China	3.3	4.6	6.3	24.3
India	1.7	2.3	2.5	6.5
Dynamic Asia ^{a)}	3.7	4.3	5.0	9.8
OECD (excl. US)	26.9	27.8	28.8	15.7
Rest of the world	16.2	17.3	19.1	23.7
Total	69.8	76.2	82.2	100

a) Includes Chinese Taipei; Hong-Kong, China; Indonesia; Malaysia; the Philippines; Singapore and Thailand.

Source: International Energy Agency.

42. In China, strong demand for oil has been related to the vigorous investment cycle over the past year and has been exacerbated by an inadequate electricity distribution network, which has prompted significant investment in diesel generators. While growth in oil demand may not continue at its recent

28. Although the model simulation results discussed in Section II suggest that different long-term growth assumptions have only a relatively small short-term effect on prices, the short-term price sensitivities (to cyclical demand fluctuations) are probably much larger.

29. As discussed by Adelman (2002).

30. This has been reflected in unusually large revisions to the 2004 estimates of global oil demand by the IEA over the past year. The increase in demand in 2004 is now estimated to be the strongest annual increase for a quarter of a century.

pace, China will undoubtedly continue to claim an increasing share of global oil supplies. An additional drain on available supplies stems from the Chinese government's policy to increase its strategic oil reserves from 30 days cover to 90 days by 2015.

43. In the most recent episode, rapidly rising oil demand in the United States may have been affected by factors other than stronger economic activity. For example, rapid growth in gasoline consumption also reflects a shift in consumers' preferences towards relatively fuel-inefficient vehicles. In addition, oil consumption expanded strongly in 2003 following a sharp increase in the price of natural gas. Until recently, crude oil prices were often used as a reference in long-term natural gas contracts and the two prices moved closely together. As the market for trading natural gas contracts has developed and this practice has declined, the two prices have diverged more frequently, while still following similar trends.

44. In addition, the US government has been building up its strategic petroleum reserves from a little less than 600 million barrels in late 2001 to over 660 million today, accounting for about three-quarters of the increase in total OECD government reserves over that period. Although this build-up in the SPR is relatively small in the context of total demand, it contrasts with the situation in 1991 when these reserves were run down in response to the oil price spike during the run-up to the Gulf war. It can be argued that the SPR has the potential to impact oil markets, at least in the short term, even in the case of small adjustments, *via* its effect on market psychology, depending on perceptions about whether the aim is to ensure security of supply or to use the reserves as a buffer stock to damp large shocks.³¹

The role of inventories and differences between spot and futures prices

45. The number of days of forward cover provided by OECD industry stocks has picked up in recent months, but it is not yet clear whether the increase will be sufficient to halt the longer-term downward trend in inventories (Figure 11). In the United States, the increase seems to have acted to reverse an earlier squeeze in oil stocks which had led to a temporary bulge in refinery and marketing margins. Globally, by historical standards, the industry margin to meet unexpected demand increases remains relatively low. However, the particular dynamics of the oil market make it difficult to assess whether low stocks mean that the market is more exposed than normal to potential disruptions and regional supply imbalances, and hence to persisting volatility that may be pushing the oil price up or whether they are a normal function of expectations that the spot price will fall towards the lower futures price.

46. Volatility affects the level of oil prices and inventories in two main ways. First, when the market is volatile, refiners and consumers will usually have a higher desired level of inventories,³² which, *ceteris paribus*, raises prices in the short run. Second, volatility *per se* raises the value of the call option held by oil producers of being able to extract oil from the ground.³³ This increases the opportunity cost of current production and can result in decreased oil supply, unless the spot price increases sufficiently relatively to the futures price to make continuing production and running down inventories worthwhile. Higher demand

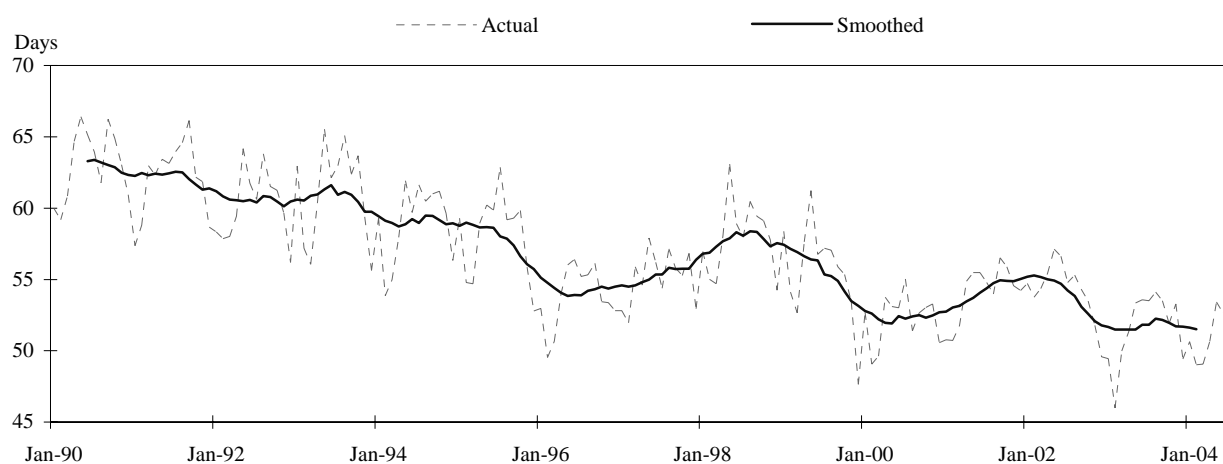
31 . If security is the primary objective, then there may be questions around the timing of the current build-up, given unusually high spot prices. If the primary objective is to damp future large shocks, then there are questions about what method should be used for deciding how large a price increase should be tolerated before strategic government reserves are released. See, for instance, Jaffe and Soligo (2002) for further discussion

32 . For oil producers, inventories serve as a buffer against the costs of adjusting production over time and also facilitate delivery scheduling; the higher the volatility, the greater the need for this buffer. Likewise, inventories facilitate the production processes of refiners and industrial consumers of oil.

33 . The "exercise" price of the option is the extraction cost and the "payoff" is equal to the spot price.

for inventories and reduced supply will thus push prices up. Although the impact of the first channel will be temporary, as inventories adjust to their new higher level, the higher price that results from the second channel will persist as long as the higher level of volatility persists.

Figure 11. Days of forward cover of oil industry stocks have been trending down



Note: Days of forward cover are calculated as the ratio of total stocks in millions of barrels to total oil demand in million of barrels. Data are smoothed using a centered 11-month moving average.

Source: International Energy Agency and OECD.

47. Compared with other markets for traded assets (such as bonds), the oil market is distinguished by the existence of a “convenience yield”, which refers to the services that accrue to the owner of the physical stock of oil, but not to the owner of a contract for future delivery of the oil. Intuitively the convenience yield can be thought of as the premium that purchasers of the physical commodity are prepared to pay to avoid counterparty risk. The size of this convenience yield determines whether the futures price is greater or smaller than the spot price. When the convenience yield is sufficiently high that the spot price exceeds the futures price, the market is described as being in strong backwardation. While some degree of backwardation of normal, a very strong degree of backwardation may be encountered when price volatility is high.³⁴ The futures market is said to be in contango when the spot price is lower than the futures price.³⁵ For an extractive resource commodity like crude oil, the futures market would be expected to normally exhibit weak or strong backwardation most of the time, in order to provide producers with an incentive to extract now, rather than to wait.

34 . See Pindyck (2001) for further discussion.

35 . In the absence of any convenience yield, the spot price would normally be lower than the forward price. This is because arbitrage would ensure that the future price of oil would be the same as the cost of borrowing funds, buying oil in the spot market and storing it over the same period. However, the role of the convenience yield complicates the picture. If it is positive but not large, the spot price will be less than the futures price, but greater than the discounted future price. In that case the futures market is described as exhibiting weak backwardation. The term contango thus includes weak backwardation as well as zero backwardation.

48. However, the recent period has been one of strong backwardation, which has persisted for longer than earlier episodes in 1990 and 1996 (Figure 12, panel A). Under normal circumstances, such strong backwardation would provide important incentives for refineries and consumers to run down their inventory levels, since it would suggest that the future spot price of oil should be lower than the current spot price. However, when the risk premium is large and volatility persistent futures prices often provide poor forecasts of subsequent spot prices, as in present circumstances. Market participants may not interpret strong backwardation in the six-month futures price as a sign that the spot price of oil will necessarily fall. In conjunction with geopolitical uncertainties and capacity constraints, low stocks and the price volatility noted above could imply only a partial and slow return to long-term equilibrium prices. This may be accompanied by unstable dynamics, which exacerbate fluctuations, as when a high spot price leads to strong backwardation and a run-down in inventories, such as has been seen recently. If lower inventories were interpreted as a signal of excess demand, this could cause spot prices to rise, exacerbating the strong backwardation and further discouraging inventory accumulation. Hence, spot and short-term futures prices can rise very dramatically when supply disruptions occur and inventories are low.³⁶

49. The degree of persistence will most likely depend on whether fears about future oil shortages prove to be valid. If, for example, a lasting solution were to be found for current geopolitical concerns, it is likely that the current spot price would fall back significantly. The speed of the price fall would depend on the gap between actual and desired inventories.³⁷ If, on the other hand, the current state of uncertainty turns out to be prolonged, a relatively high spot price (and high volatility) may well persist. In this case, there would be a new equilibrium in which the spot price, the convenience yield, and the desired level of inventories would all be higher than before uncertainty intensified. Indeed, the probability that there is a degree of expected persistence in the current price spike is supported by the fact that the far futures price of oil, which reflects the price for contracts six to seven years out has also increased quite sharply (Figure 12, panel B). Moreover, rising oil company share prices reflect a revaluation of their oil assets over the past few years which is consistent with an increase in longer-term oil price projections of around \$5 per barrel.³⁸

Distributional bottlenecks

50. Even when the global supply of oil is sufficient to meet global demand, there are often regional mismatches between the grade of oil supplied and that demanded. For example, much of the recent volatility in the prices of final oil products has been due to constraints on the level of capacity available to refine specific high-grade petroleum products in the short run, in particular in the United States. Thus,

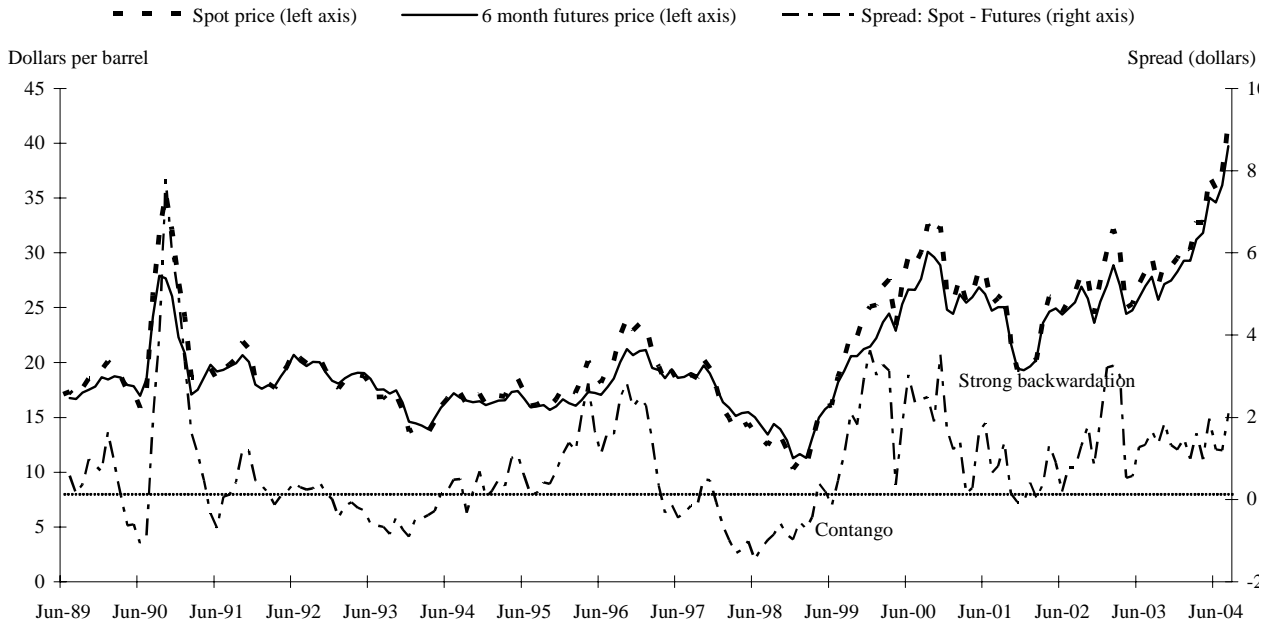
36. The reverse could occur during periods of contango, although in practice this may be less likely. It may be easier for market participants to ease a contango by purchasing oil on the spot market and building up inventories than it is to borrow significant volumes of supply from the future to sell on the spot market in order to ease a situation of strong backwardation. See Farrell *et al.*, (2001).

37. If actual inventories had fallen below desired levels, the spot price would remain above its new "equilibrium" price until inventories had been re-accumulated. Alternatively, if the lessening in geopolitical tensions caused desired reserves to fall below their actual level, then the process of running down the inventories would cause the spot price to undershoot its new level temporarily.

38. For example, see the evolution of price expectations and asset valuations in Randall & Dewey's Acquisition's Review: <http://www.randew.com/gar/backissues.htm>.

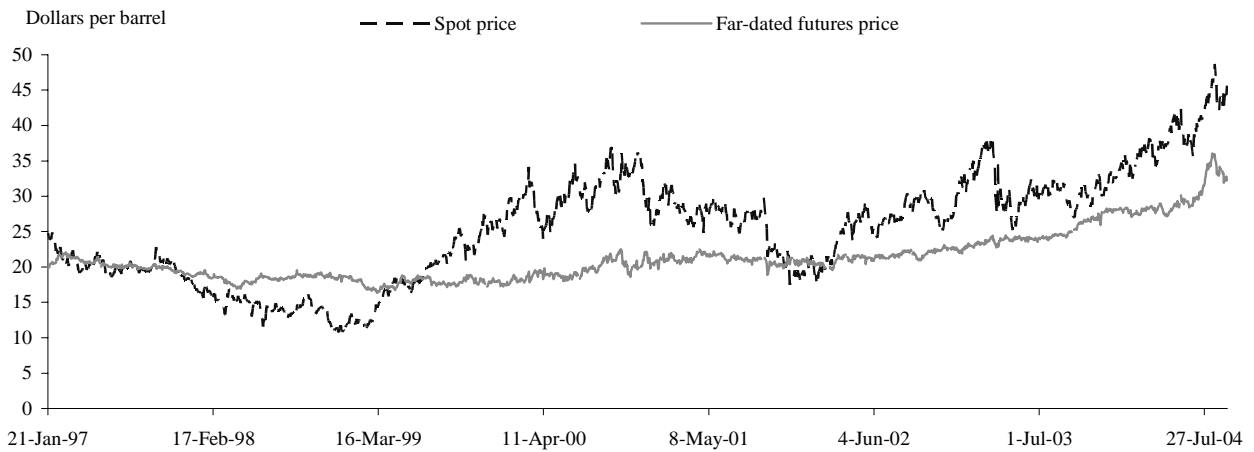
Figure 12. The six-month futures market and the far futures price

A. The futures market has been in strong backwardation since 1999



Note: Chart shows futures and spot prices for Brent crude oil. Includes data up to August 2004.

B. WTI far-dated futures are close to \$35



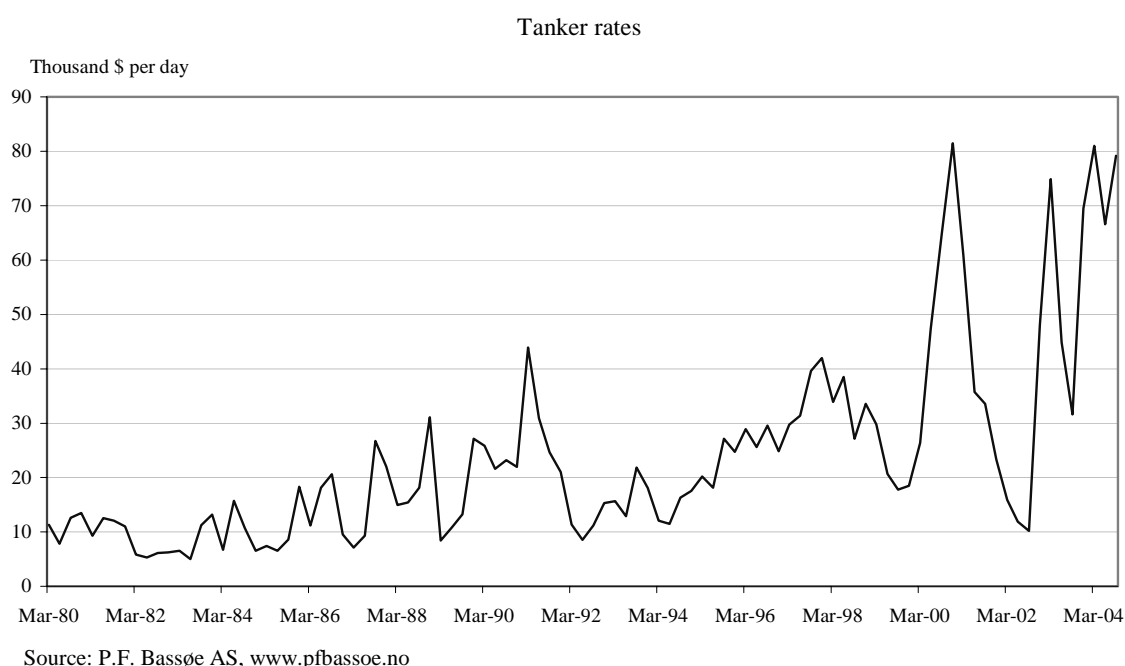
Note: Chart shows spot and far-dated futures prices for West Texas Intermediate crude oil. The time to maturity for the futures contracts varies between 6 and 7 years. Includes data up to 17 September 2004.

Source: Datastream, US Federal Reserve and OECD.

product shortages may go hand in hand with excess crude supply. To some extent this was the case in the United States earlier this year, as heavy, high-sulphur oil was of relatively little use to refiners in need of light, low-sulphur oil to maximise gasoline production over the summer driving season.³⁹

51. Transportation bottlenecks for both crude and refined oil products also seem to be putting upward pressure on oil tanker rates at present (Figure 13), with likely consequences for crude oil prices. Tight capacity is partly a result of unexpectedly high demand, and partly due to changes in the global composition of demand and supply, with more tankers now being required to meet longer supply lines from the Middle East to the dynamic Asian economies and to the Atlantic basin. More rigorous environmental standards have also been influencing prices. According to the IEA, the annual investment in the tanker fleet will need to increase by around one third of its current level over the next two decades.⁴⁰ Industry contacts have noted that new orders of tankers are currently high, although there is a significant time delay (three to four years) to bring new capacity on line. Finally, new pipeline capacity will also be needed to allow the export of extra Russian and Caspian oil, and there are physical bottlenecks at the Suez and Panama canals, which are now too small for the new generation of tankers.

Figure 13. Transportation bottlenecks may be pushing up prices
Quarterly average very large crude carrier (VLCC) rates for key routes



39 . US regulation of the sulphur content in gasoline is being progressively tightened, with an additional step scheduled for 2005. At times there has been evidence of bottlenecks in the gasoline market, with refining capacity shrinking, in part due to unwieldy official requirements for new refineries. While, in theory, there should be no need for new refinery capacity to be located close to final consumers, in practice the fragmentation of regulatory policy across US states has contributed to logistical bottlenecks with different states requiring slightly different grades of gasoline. Partly as a result, the normal spread between the wholesale price of gasoline and the price of crude oil roughly doubled in mid-2004 compared with a year earlier, although it has since returned to more normal levels.

40 . International Energy Agency (2003).

The possible impact of speculation

52. Concerns have surfaced⁴¹ repeatedly about the possibly destabilising role of speculative hedge funds, or commodity pools, which may shift large sums of “hot money” between different markets at the first sign of a possible higher rate of return elsewhere.⁴² In this sense, the term “speculators” usually refers to investors who trade oil futures with a view to profiting from the rise or fall of prices; they have no exposure to the physical oil commodity.⁴³ In contrast, hedgers generally have sizable spot or forward market commitments and trade futures contracts in order to minimise their exposure to price fluctuations. One often-quoted gauge of speculative pressure is the volume of oil futures and options contracts traded on the New York Merchandise Exchange, where registration of all traders with large positions allows the data to be broadly separated into commercial and non-commercial categories. On this basis, Figure 14 shows that there was a significant increase in the net long positions of non-commercial traders in late 2003, supporting the view that there was a pick-up in speculative activity.⁴⁴ More recently, the extent of speculative demand seems to have fallen back somewhat, consistent with prices having risen and speculators taking profits.

53. Although the positions held by non-commercial traders make up only a relatively small proportion of total futures and options contracts traded (Figure 15), their net positions can be very significant and any sudden changes in these net positions could have an important influence on prices from time to time. Thus, speculation may exacerbate price *volatility*, particularly when news about the fundamentals is itself changing rapidly.⁴⁵ At the same time, if speculators are successful, then the amplitude of the price cycle may be reduced. This would be the case if speculators correctly anticipate a turning point in prices and clip the peaks and troughs by selling or buying just prior to the turning point.

41 . A number of commentators have pointed to the possible impact of speculation during the recent run-up in the oil price. However, such concerns are not new. For example, during the 1990/91 Iraqi invasion of Kuwait, and the following United Nations sanctioned attack on Iraq, the US Congress had numerous questions about the role that futures market speculators might have played in driving up crude oil prices on that occasion (Dale and Zyren, 1996).

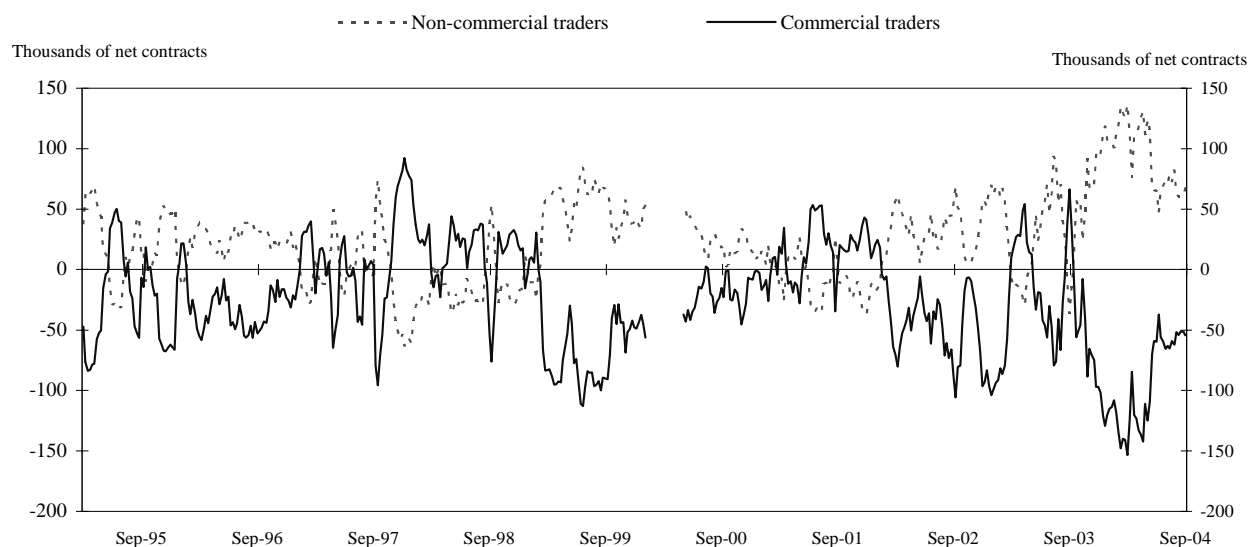
42 . Taking this argument a step further, it has also been argued that the recent period of low real interest rates and high liquidity may have been fuelling a commodity price boom, by encouraging speculators to borrow in US dollars in order to go long in other assets, in this case commodities.

43 . The types of traders who make up this group are, however, diverse. One type is floor traders, who tend to hold spread positions, suggesting that they are largely speculating on price relationships. If, for instance, such traders thought the December futures price was too high relative to the November and January prices, they would short the December futures and long the other two. This group of traders tends to add liquidity to the market. A second broad category of speculators is commodity pools (which includes hedge funds). Rather than taking spread positions, commodity pools tend to take directional positions: either all short or all long. These results were obtained by Ederington and Lee (2000), who analysed the trading activities over the period June 1993 to March 1997 of the 223 largest traders of heating oil futures. It is likely that these results would also be applicable to the crude oil market.

44 . Note, however, that the separation of traders into the commercial and non-commercial category is only a rough approximation of the distinction between hedgers and speculators. While the non-commercial category probably does consist almost entirely of speculators, Ederington and Lee *op.cit* show that the commercial category probably also includes some speculators.

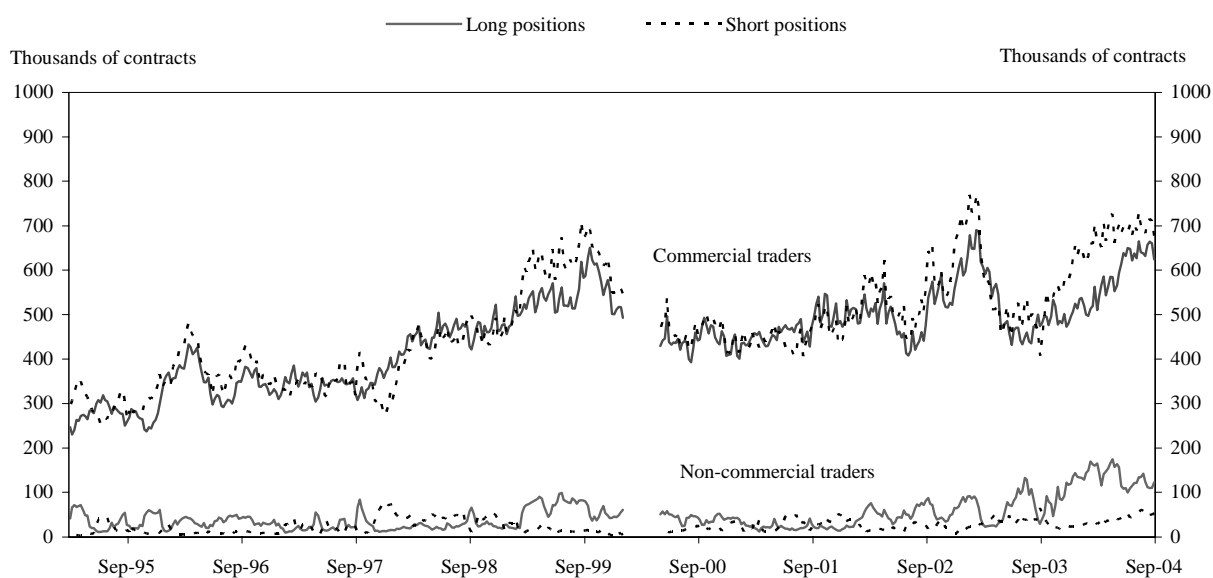
45 . The lack of accurate and up-to-date information on global production, stocks and demand significantly limits the extent to which the market price will bring world demand and supply into balance. In this environment it is inevitable that the oil price will often move sharply as new information comes to light, and in the short term the actions of speculators may contribute to these movements.

Figure 14. Net long positions of non-commercial traders have picked up



Note: Data include futures and options contracts. Each contract is for one thousand barrels. Data from February 1st to mid-May 2000 are unavailable.
 Source: US Securities and Exchange Commission, Commodity Futures Trading Commission.

Figure 15. Non-commercial traders remain in the minority



Note: Data include futures and options contracts. Each contract is for one thousand barrels. Data from February 1st to mid-May 2000 are unavailable.
 Source: US Securities and Exchange Commission, Commodity Futures Trading Commission.

54. It is very difficult to judge whether speculators have any impact on the average *level* of prices. There are two reasons for this. First, it is not easy to distinguish between a situation in which hedgers move market prices (and speculators merely take the other side of the market) and the opposite one, where speculators are behind price movements. Second, changes in market fundamentals should affect both oil prices and the desired futures positions of hedgers and speculators. Thus, any correlation between prices and changes in speculators positions does not necessarily imply that that speculation has caused the price movements. As a result, most robust empirical studies have found little evidence that speculation plays a role in price determination in the oil futures market.⁴⁶ Even if speculators can temporarily raise prices by buying futures contracts, they cannot unload these positions at the higher price without a change in market fundamentals. In fact, the very action of unwinding their large positions would cause prices to fall.

IV. The economic effects of oil price movements

Oil price shocks have become less inflationary...

55. The quantitative relationship between oil price changes and economic activity and inflation is complex (see Box 4), but any negative correlation seems to have substantially weakened over time, for several reasons. First, the weight of oil and oil products in domestic production has dropped, so that terms of trade shifts are less important. Second, the wage formation process has become less responsive to fluctuations in oil prices.⁴⁷ Third, heightened competition has helped to reduce the secondary impact on core inflation from changes in oil prices.

56. The energy price-inflation relationship weakened so much that the correlation between changes in the energy price component of the consumer price index and core inflation has even been negative in many economies so far this decade (Figure 16, panel A). The impact of oil prices on headline inflation expectations also appears to have become smaller over time, indicating that these tend to be formed from extrapolations of core rather than headline inflation (panel B).

57. Nevertheless, in the current context of a relatively large oil price movement, most indicators, both those based on inflation forecasts and those derived from the difference between indexed and conventional bond yields show some increase in inflation expectations from the very low levels observed in the early years of the 2000s. This has been most significant in the United States, Canada and the United Kingdom, which have experienced the largest local currency oil price increases. In the euro area at large, there has been little movement in proxies for expected inflation.

58. Taking account of the weight of oil and oil products and the impact of the tax structure, and assessing the impact of a 10 per cent oil price hike, Table 6 suggests that the mechanical impact would be greatest for the United States and least on Japan, with the euro area impact being intermediate. The weight of transport fuel and lubricants in the consumer price inflation is 4.2 per cent in the euro area, but two-thirds of the price is made up of taxation, so the effect of a 10 per cent energy price hike is to raise the

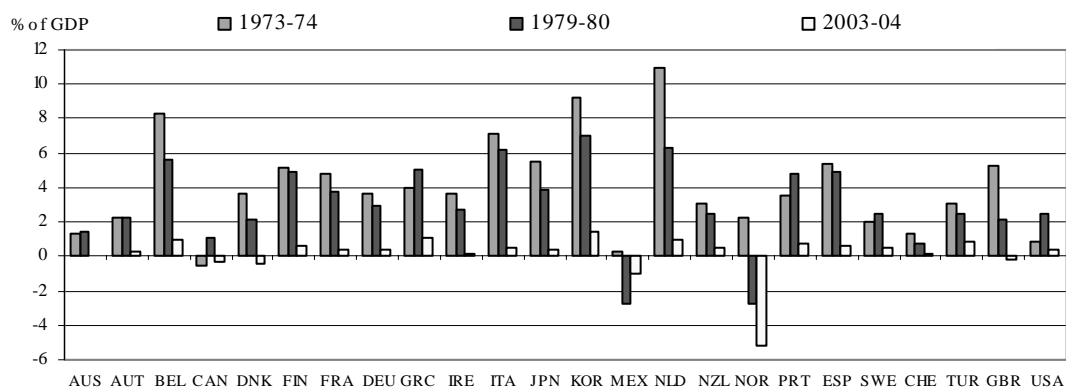
46. See Weiner (2002) for a survey of the literature.

47. See OECD (2000), page 16 *et seq.*

Box 4. Channels of oil price effects on the economy

Terms of trade effects. The first, and principal, impact of oil price shifts on activity arises from changes in purchasing power between oil-importing and oil-exporting nations. The extent to which oil-importing countries will suffer a reduction in purchasing power will depend on the oil-intensity of production and the degree to which the demand for oil is price inelastic. The income of oil-producers would increase correspondingly. The global demand impact would depend on how much of the extra revenue accruing to oil exporters is respent; typically, such revenues are not fully respent in the short term. Terms-of-trade changes have been quite large in the past but have generally been quite moderate in the current episode, with some OECD economies experiencing an improvement.

Terms of trade losses due to oil price increases in OECD countries



Source: International Energy Agency and OECD.

Effect on domestic prices and inflation. Inflation effects mirror terms-of-trade changes in their impact on producer prices. As far as headline consumer price inflation is concerned, taxes on oil products help to insulate the price level from oil price changes, fundamentally by helping to reduce oil intensity in the longer run, but also statistically in the short term, since the proportional impact of an oil price rise is inversely related to the tax content of the retail price. Whether the increase in the price level translates into a shift in core inflation depends on the "second round" effects -- *i.e.* whether workers and/or enterprises are able to compensate for the income loss through higher wages and prices -- which, in turn, depends on the monetary policy regime in place.

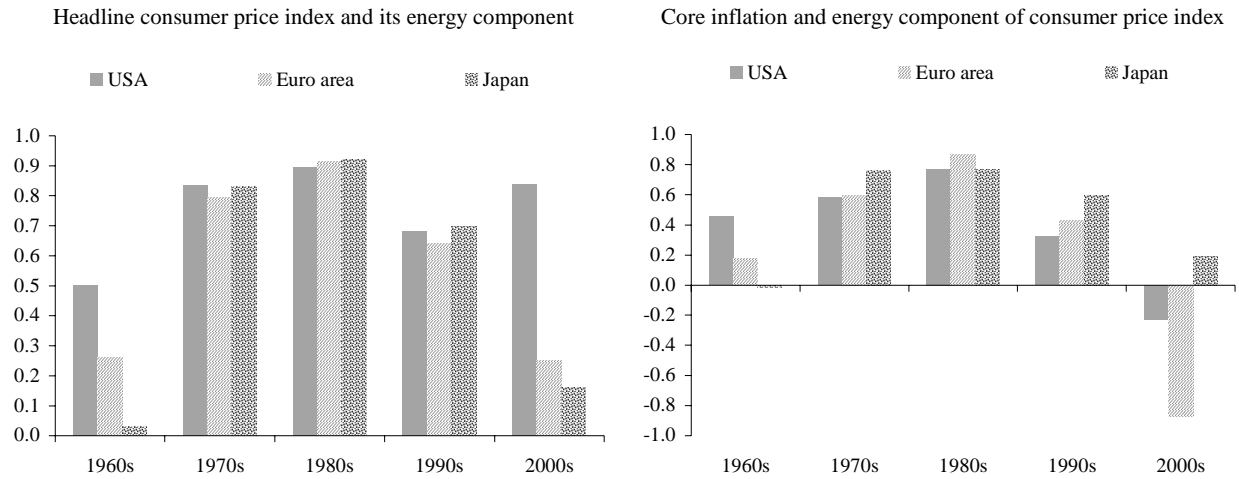
Domestic demand effects: who bears the income loss? Domestically, the income loss arising from the price increase would be borne by consumers to the extent that the demand for oil and oil price products is inelastic in the short run. This would be the case for final consumption products such as gasoline. However, where oil is an input into price-elastic final goods, the negative revenue effects would initially be borne by producers in a competitive market, since they would be unable to pass on the higher costs. More generally, since oil is an input into many goods both consumers and producers would bear losses. To the extent that producers are affected, profit margins and returns on capital will fall, with effects on the allocation of capital. While capital is the most flexible and footloose of the factors of production in the longer run, and would move from energy-intensive areas to areas with higher rates of return, in the short term capital in energy-intensive sectors is relatively inflexible, which makes it bear an income loss.

Supply-side implications: impact on output and employment; The impact on output and employment is determined by the relative supply responses of labour and capital. To the extent that labour market institutions inhibit the adjustment of real wages to shocks -- *i.e.* higher oil prices imply higher input prices which reduce profitability -- the deterioration in the terms of trade following an oil shock can affect equilibrium employment, since it creates a wedge between value-added and consumer prices. In general, the short-term economic impact of an oil shock on output and employment would be smaller, the higher the proportion of the price rise that can be passed on to consumers and/or the more flexible are wages if the price rise cannot be passed on.

Longer-term outcomes. The negative impact of an oil price rise on domestic demand and income will diminish over time as consumers and producers modify their behaviour (as discussed in Section II, the longer-run price elasticity of demand is higher than the short-run elasticity). However, research seems to indicate that there is an asymmetric effect, insofar as oil demand does not revert to its initial level as oil prices fall. In that case, the income losses experienced by energy importers may eventually be partly reversed. Where fluctuations in oil prices create uncertainty, there may be a reduction in trend investment activity, but it is less clear that the effects on profitability or capacity utilisation are asymmetric.

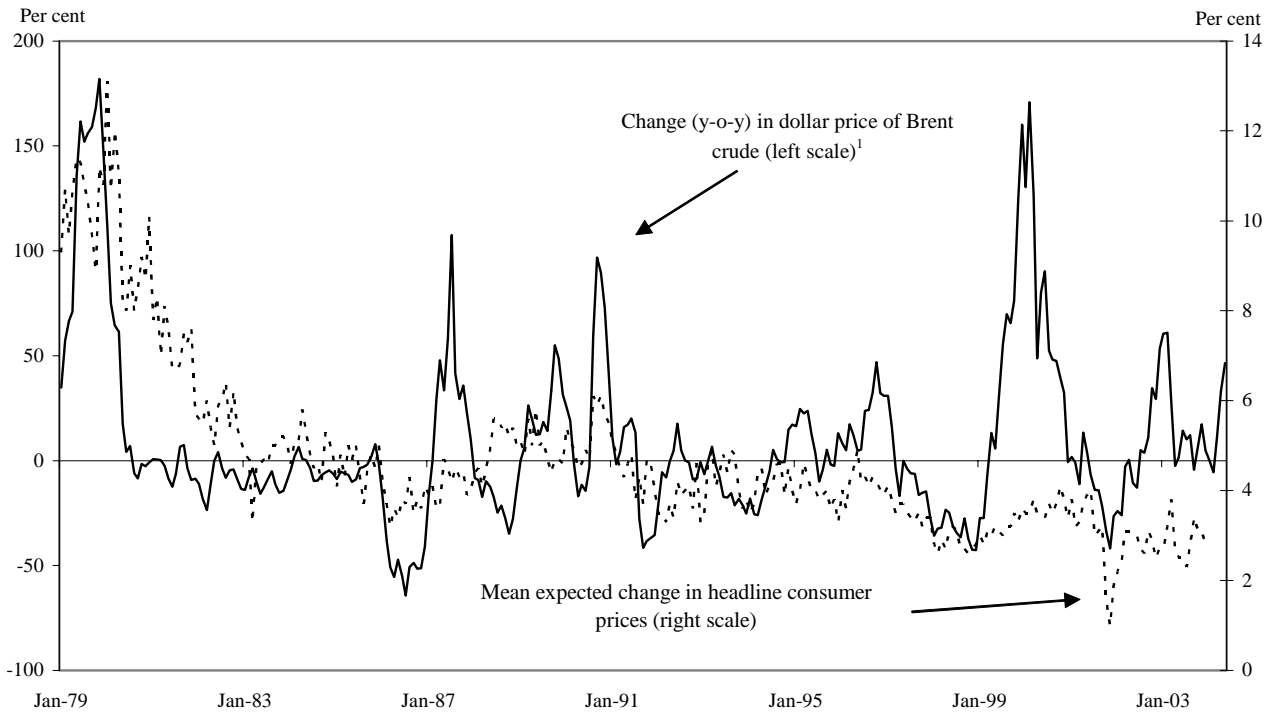
Figure 16. The energy price impact on core inflation has been modest so far

A. Correlations between year-on-year price changes



Source: OECD.

B. Change in oil prices and inflation expectations in the US



1. Before May 1987, oil prices are OECD estimates for crude oil of the same quality as Brent.
Source: University of Michigan Survey and Datastream.

price level by 0.14 per cent (Table 6). In the United States, with its lower tax component, the mechanical impact would be a somewhat larger 0.23 per cent and in Japan somewhat smaller. The actual effect on inflation in different regions will, however, depend on exchange rate movements, the grade of crude oil being imported, pricing behaviour, the price response of other energy sources to oil price rises, and the impact of lower activity on prices.⁴⁸

Table 6. **The mechanical impact of a 10 per cent oil price change on consumer price inflation**

	Weight of transport, fuel and lubricants in CPI, per cent	Share of excise taxes in final transport fuel price, per cent	Change in CPI inflation as a result of a 10 per cent change in oil price, percentage points
United States	3.1	25	0.23
Japan	1.8	53	0.08
Euro area	4.2	67	0.14

Source: OECD calculations.

... and the oil-price/output relationship has weakened

59. Simulation results from large-scale macroeconomic models suggest that the impact of higher oil prices on inflation and output is quite small in the short term. Table 7 summarises the results from a sustained \$15 increase in the price of oil (from \$32 to \$47 per barrel) over the short-term, using the OECD's INTERLINK model.⁴⁹ The effects on inflation are close to those expected from the rules-of-thumb above. However, apart from the size and duration of the shock, the eventual impact on inflation and output depends crucially on the extent to which the country/area is an oil-producer, the assumed nature of the wage-price formation process, the reaction function of the monetary authorities and the degree to which higher oil revenues are respent by oil-exporting countries:⁵⁰

48. Price developments during 2004 are broadly consistent with the rules of thumbs, bearing in mind the lags between oil price and consumer price movements. However, the impact on consumer prices in Japan is more muted. This is mainly due to the different price dynamics of the main oil imported by Japan, Dubai crude, which trades at a discount to low sulphur oils such as Brent. The spread between Brent and Dubai widened to \$14 per barrel during 2004 from an average of \$2 per barrel over the previous 5 years.

49. The rise in the oil price has been chosen to represent the scale of the oil price shock embodied in the projections in this *Outlook*. For these simulations, the country weights of energy in export prices have been updated to their 2002 levels. Due to the model structure this mechanically updates the energy content of import prices and consequently the response of domestic inflation.

50. The simulations reported here assume that two-thirds of oil revenues are respent within two years, leaving the remainder to be recycled through capital markets. Fiscal policy is assumed to be neutral, maintaining public expenditure constant in real terms.

Table 7. **Impacts of a sustained \$15 increase in the price of oil***Deviation from baseline levels, per cent, unless otherwise stated*

	2004	2005
A. Assuming constant real interest rates		
United States		
GDP level	-0.45	-0.55
Inflation (percentage points)	0.70	0.40
Total domestic demand	-0.65	-0.75
Current account (% of GDP)	-0.15	-0.15
Japan		
GDP level	-0.60	-0.60
Inflation (percentage points)	0.40	0.10
Total domestic demand	-0.55	-0.50
Current account (% of GDP)	-0.35	-0.45
Euro area		
GDP level	-0.50	-0.35
Inflation (percentage points)	0.60	0.20
Total domestic demand	-0.50	-0.60
Current account (% of GDP)	-0.45	-0.30
OECD		
GDP level	-0.45	-0.45
Inflation (percentage points)	0.65	0.25
Total domestic demand	-0.50	-0.60
Current account (% of GDP)	-0.10	-0.10
B. Assuming constant nominal interest rates		
United States		
GDP level	-0.15	-0.30
Inflation (percentage points)	0.70	0.45
Total domestic demand	-0.20	-0.40
Current account (% of GDP)	-0.30	-0.25
Japan		
GDP level	-0.35	-0.35
Inflation (percentage points)	0.40	0.15
Total domestic demand	-0.40	-0.40
Current account (% of GDP)	-0.30	-0.40
Euro area		
GDP level	-0.20	-0.20
Inflation (percentage points)	0.65	0.30
Total domestic demand	-0.25	-0.40
Current account (% of GDP)	-0.40	-0.30
OECD		
GDP level	-0.20	-0.25
Inflation (percentage points)	0.65	0.35
Total domestic demand	-0.20	-0.35
Current account (% of GDP)	-0.15	-0.15

Source: OECD calculations (INTERLINK model simulation).

- If real interest rates, measured in terms of headline inflation, were to be held constant, as in panel A, the price shock leads to a negative impact on OECD GDP of -0.4 per cent in the first year, with a slightly larger impact in Japan and the euro area than in the United States. The impact on

output is felt longer in the United States, partly as a result of benefiting less from the respending of oil-exporting countries. The impact on headline inflation is significant in the first year at 0.6 percentage point for the OECD area, but this fades in the following year.

- The negative short-term impact on output of an oil price shock would be reduced if nominal interest rates remain unchanged (panel B), since real interest rates (nominal rates less headline inflation) would fall, with a slight cost in terms of higher inflation in the subsequent year.

60. These impacts would tend to be amplified if supply-side channels were to be taken into account and would not necessarily apply where the oil price were to fall.⁵¹ Indeed, there is a body of reduced-form econometric evidence, which points to more powerful links between oil prices and economic activity.⁵² For example, recent empirical work using multivariate vector auto-regression analysis finds that a \$10 oil price *increase* has a significant negative impact on GDP in all oil-importing countries, with the US output loss being between 1 and 1½ per cent after three years (Table 8).⁵³ The analysis points to non-linear reactions being conditional on the recent history of oil price shocks; with price shocks having a larger impact in an environment of relatively limited oil price volatility. The relatively high estimated impact from reduced-form macroeconomic models may be due to the inclusion of supply-side channels that can have slower-acting effects on potential output. Taking account of these could explain why the relationship between the oil price shock and GDP may be non-linear, with price increases having a larger impact on activity than oil price declines.⁵⁴ This is also supported by US firm-level employment data which show that the response to oil price increases is ten times higher than the response to oil price falls.⁵⁵

61. While orthodox models may not capture the asymmetric, longer-run supply-side effects of oil price shocks, they probably still represent an accurate short-term view of the impact of moderate oil shocks. Reduced form models, being time-series based, may fail fully to identify the heuristic component of responses to oil shocks, based, for example, on the enhanced ability of monetary authorities to condition wage and price inflation expectations.

51 . Reduced-form econometric evidence points to more powerful links between oil prices and economic activity and to non-linear reactions which are conditional on the recent history of oil price shocks. Price increases appear to have a larger impact on activity than oil price declines. The relatively high estimated impact from reduced-form macroeconomic models may be due to the inclusion of supply-side channels that can have slower-acting effects on potential output.

52 . In this context, see ECO/CPE/WP1(2004)10, which presents results from structural vector autoregression (QVAR) analysis based on a sample period that excludes the oil price shocks in the 1970s. The results indicate that a doubling of the oil price reduces output by between 0.8 and 3.3 per cent over the medium term.

53 . Jimenez-Rodriguez and Sanchez (2004). The standardisation for variability allows both for an asymmetric response of GDP to an oil price shock (positive changes have a larger effect) and for a large shock to have a greater effect if there has been little price volatility in the period leading up to the shock. Conversely, a price hike will have a smaller effect if the preceding period was subject to substantial oil price volatility.

54 . See Hamilton (2003).

55 . See Davis and Haltiwanger (2001). Using quarterly, plant-level Census data from 1972 to 1988 on employment, capital per employee, energy use, size and age of plant, and product durability, they examine job creation and job destruction responses to positive and negative oil price shocks. This allows a distinction between aggregate and allocative effects. Their finding is that both monetary and oil price shocks cause larger job destruction than creation in nearly every industrial sector. The magnitude of the oil price shocks is about twice that of monetary shocks, while the response of employment is sharply asymmetric.

— Table 8. **Reduced form estimates of the impact of oil prices on real GDP** —
The per cent decline in real GDP following a 10\$ increase in the price of oil^a
(deviations from baseline)

	Model Specification		
	Linear	Asymmetric ^b	Adjusted for normal variance ^c
United States	-1.0	-1.3	-1.6
Euro area	-0.2	-0.4	-0.6
Germany	-0.5	-1.0	-1.7
France	-0.4	-0.7	-0.9
Italy	-0.5	-0.8	-1.3
United Kingdom	-0.6	-0.4	-0.7
Canada	-0.1	-0.3	-0.4
Norway	0.4	0.5	0.8

a) Effects after 12 quarters.

b) This specification allows for an oil price rise to have a different impact than an oil price fall.

c) This specification allows for an asymmetric relationship between oil prices and GDP and the conditional variance to change over time.

Source: Jimenez-Rodriguez and Sanchez (2004).

The role of monetary policy

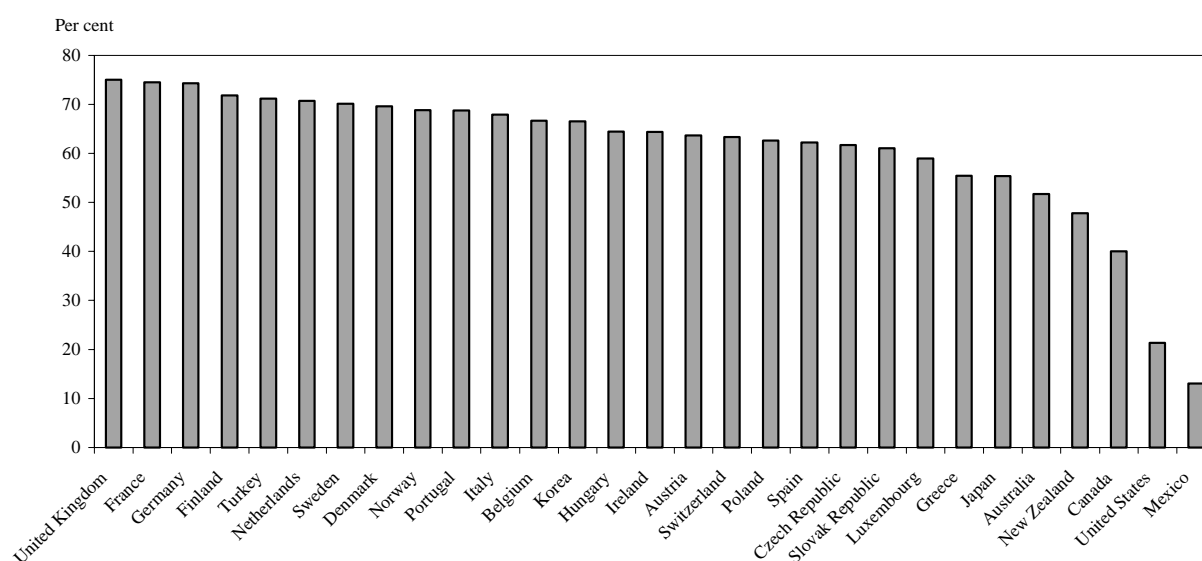
62. It is likely that the increasing independence of central banks and the growing adoption of price stability objectives, often based on inflation targeting, have helped to improve the response of monetary policy, and price-setting behaviour more generally, to oil price shocks. In particular, inflation targeting, or its approximation in practice, has helped to anchor inflation expectations among economic agents, preventing temporary inflationary shocks from becoming embedded into a more generalised and enduring increase in the inflation rate. It is partly as a result of this that the pass-through from higher imported oil prices to core inflation has fallen: the effects of the 1999-2000 oil price shock on core inflation were minor, while only temporary and modest increases in headline inflation were observed. As a result, it is now generally accepted that transitory spikes in headline inflation caused by movements in international oil prices can be ignored, or “looked through”. This is likely to remain the case, making it unnecessary for nominal interest rates to respond to headline inflation, although monetary policy needs to remain vigilant towards any second-round inflationary effects that show up in core inflation.

The role of fiscal policy

63. Energy tax policies should be determined by long-term considerations. The simulation results discussed in Section II suggest that long-term projections of oil prices are very sensitive to assumptions about the elasticity of oil demand with respect to income. Thus, policies that reduce oil intensity will also reduce the risk of significantly higher oil prices in the future. Indeed, many countries have, over the last few decades, raised specific taxes on gasoline, which has acted to reduce oil dependence, and in that respect such taxes may help to buffer the impact of a per-barrel rise in the oil price (Figure 17).⁵⁶

56. At the same time, taxes on energy have the effect of raising the price level, so that a given increment to the oil price will have a smaller impact on measured inflation.

Figure 17. The share of taxes in retail gasoline prices varies across OECD countries



Source: International Energy Agency.

64. While it might be theoretically possible to smooth final prices by adjust energy taxes downwards when crude oil prices rise -- as several European countries did in response to the oil price hike in 1999/2000⁵⁷ -- there are a number of reasons why such a policy may be problematic. First, as discussed above, it is very difficult *ex ante* to determine whether a change in the oil price is a temporary shock or a more permanent response to changes in market fundamentals. If it turns out to be a prolonged shock, then lower taxes would simply impede the beneficial medium-term adjustment of demand and supply to price changes, thus raising long-term oil dependence. More specifically, lowering taxes might impede the effect that higher prices have on incentives to switch to alternative energy sources and increase the efficiency of the capital stock. Second, if many countries adopt such a practice, then the “global” effect would be to reduce the price elasticity of the demand faced by OPEC -- inviting them to cut supply or raise prices further. Third, even if the smoothing of adjustment costs (and therefore slowing adjustment) is a legitimate policy aim, the effectiveness of tax policy as a means of smoothing oil price movements effectively may be compromised by political economy considerations, thus adversely affecting the achievement of budget goals.

The role of structural policies

65. Given that the uncertainty associated with the oil market has a potential to depress investment activity, ensuring that markets are more transparent would allow a better match between supply and demand, by ensuring that market participants can make better informed decisions. This would help to damp the effects of “news”, while allowing more effective hedging activity reduce exposure to price volatility, for example. In addition, governments should examine whether they can remove regulatory or other obstacles to the development of new oil resources, refining capacity, energy substitutes and energy saving technology.

57. See OECD (2000) for details. The European Commission required these concessions to be eliminated within two years.

Appendix:

The oil spreadsheet model: Behavioural equations, parameters and baseline results

1. The impact on oil prices of different assumptions about economic growth or supply and demand elasticities is assessed using a “calibrated” spreadsheet model of global oil demand and supply. World oil demand is comprised of three main regions: the OECD area (which is split into the three largest economies -- the United States, the euro area and Japan -- and other OECD countries); China, which is among the most dynamic and oil intensive developing economies; and the rest of the world (ROW). On the supply-side, two groups of producer countries are distinguished: OPEC and non-OPEC. Non-OPEC producers are assumed to be “price takers” *i.e.* to produce until marginal costs equal the world price of oil. In contrast, the OPEC cartel may adjust production to influence prices.

I. Model equations

2. The model equations are set out here in a simple static framework, whereas the implemented spreadsheet model is dynamic, specifying how the adjustment process takes place over time.

3. *Oil demand* in each country or region i (i = United States, euro area, Japan, rest of the OECD, China, and ROW) is a function of economic growth and oil prices:

$$\text{Log}D^i = \alpha_0^i + \alpha_1^i \text{Log}Y^i + \alpha_2^i \text{Log}P \quad (1)$$

where D^i and Y^i are respectively the demand for oil and real GDP; P_t is the oil price (in real dollar terms); α_1^i and α_2^i are output and price elasticities of oil demand, respectively. World demand for oil is derived by summing over all regions:

$$D^w = \sum_i D^i \quad (2)$$

Non-OPEC oil supply, $S_t^{\text{Non-OPEC}}$ is positively related to oil prices:

$$\text{Log}S^{\text{Non-OPEC}} = \beta_0 + \beta_1 \text{Log}P \quad (3)$$

where P is the oil price and β_1 is the price elasticity of non-OPEC supply.

4. There are two possibilities for OPEC oil supply behaviour. One possibility (used in Scenarios A in the results reported in Table 2) assumes that OPEC targets a constant market share. In this context, the OPEC supply function becomes:

$$S^{\text{OPEC}} = \lambda_0 D^w \quad (4)$$

where λ_0 is OPEC’s “optimal” market share.

5. The second possibility (used in Scenarios B) is that OPEC attempts to stabilise the price. The results, discussed in paragraph 15 of the main text, suggest that stabilising the price by increasing market share may be optimal long-run behaviour for OPEC.⁵⁸

World oil supply is the sum of the two groups of producer countries,

$$S^w = S^{OPEC} + S^{Non-OPEC} \quad (5)$$

6. The equilibrium condition is given by

$$S^w = D^w \quad (6)$$

In the case of a fixed market share strategy, the equilibrium solution -- marked with a bar --- imply that total equilibrium supply \bar{S}^w is a multiple of Non-OPEC equilibrium supply:

$$\begin{aligned} \bar{S}^w &= \bar{S}^{Non-OPEC} + \lambda_0 \bar{D}^w \\ &= \bar{S}^{Non-OPEC} + \lambda_0 \bar{S}^w \\ &= \bar{S}^{Non-OPEC} / (1 - \lambda_0) \end{aligned} \quad (7)$$

II. Exogenous variables, parameters and the speed of adjustment

7. The only exogenous variable is real GDP in each of the main oil consumer countries or regions (the United States, the Euro area, Japan, China and ROW).

- *Parameter assumptions:* The assumptions for most of the key parameters in the baseline are summarised in Box 1. In addition, assumptions are made for the short-term price elasticity of demand. In line with findings in academic empirical research⁵⁹ these are assumed to be very low (-0.02 for the United States and Japan, -0.04 for the Euro area and -0.01 for China and ROW).

- *The speed of adjustment:*

In calibrating the model, it has been assumed that the structural adjustment of demand and supply to prices takes place over ten years⁶⁰.

58 . In the short-term, OPEC has (some) spare capacity and therefore the ability to respond rapidly to increasing demand. This suggests a high short-term elasticity. But to the extent that OPEC behaves as a cartel, it is in their interests to limit production in order to maintain high prices. Hence, the short-term elasticity is highly dependant on the strategy of OPEC. In the longer term, OPEC has huge reserves and low marginal extraction costs. As demand and prices go up OPEC countries should be induced to increase production and the long-term elasticity should be higher than for non-OPEC producers.

59 . See for example Gately (2004).

60 . This is obtained by introducing in each equation a term, P_t^* , which is a weighted average of real oil prices in the last ten years, scaled by the difference between the assumed long and short term price elasticities. The weights decline linearly, implying that the impact of past prices on demand is slowly declining over time.

III. Baseline scenario

9. The baseline scenario (“equilibrium solution”) has been constructed using data from the International Energy Agency and the OECD Economic Outlook database. The main assumptions are as follow:

- Real GDP growth in OECD countries up to 2009 is derived from the OECD’s Medium Term Baseline projections (3.3 per cent in the United States, 1.9 per cent in the euro area and 1.3 per cent in Japan).⁶¹ From 2010 to 2030, GDP is assumed to be driven by trend labour productivity growth, as defined at the end of the Medium Term Baseline, and potential employment growth based on United Nations projections of population growth. Labour force participation rates are based on those contained in earlier OECD research into long term labour supply trends.⁶² This results in potential GDP growth rates slowing after 2010 to around 3 per cent in the United States, 1.4 per cent in the Euro area and 1 per cent in Japan
- China’s GDP growth, projected at 8.5 per cent in 2004, is assumed to decline progressively to 5 per cent in 2020-2030.⁶³
- In the rest of the world, real GDP is assumed to grow at 5.4 per cent from 2004 to 2009.⁶⁴ From 2010 to 2030, average growth is assumed to be 5 per cent.
- OPEC share of supply remains constant at its 2003 level (38.4 per cent). This implies that both OPEC and non-OPEC supply are growing at the same rate as oil demand.

On this basis, the “equilibrium” path which assumes that excess demand is equal to zero in all periods gives the following solution:

- Oil demand is estimated to be around 134 million barrels per day in 2030.⁶⁵
- Brent crude price rises to \$35 in 2030 in constant 2000 dollars, reflecting rising marginal costs of oil extraction, to equilibrate demand and supply.⁶⁶

61 . See OECD (2004).

62 . Burniaux, Duval and Jaumotte (2003).

63 . Using purchasing power parity estimates, GDP *per capita* in China is estimated in 2003 at around 13 per cent of that of the United States. According to the projections embodied in the baseline scenario and to United Nations population projections, this figure would rise to 27 per cent in 2030.

64 . Based on data in International Monetary Fund (2004).

65 . This compares with 120 million barrels per day in the IEA projection, which is based on the lower level of oil demand in 2000. See International Energy Agency (2002).

66 . This is on the high side of publicly available long term projections See Energy Information Administration (2004).

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