CHAPTER IV WILL THE OIL MARKET CONTINUE TO BE TIGHT?

During most of the 1990s, real crude oil prices (expressed in 2003 dollars) fluctuated about $20 a barrel. Moreover, the oil market experienced periods of high volatility only during the Middle East conflict in 1990–91 and during the Asian currency crisis in 1997–98. Crude oil prices started edging up with the economic recovery and production cuts at the end of the decade, but the upward price pressures became pronounced only during 2003–04. Synchronized global growth, high oil demand (especially from China), and a series of supply disruptions eroded spare capacity of producers and pushed the annual real average price of oil close to $40 a barrel in 2004 (Figure 4.1). Average oil prices increased further to about $50 a barrel in March 2005.

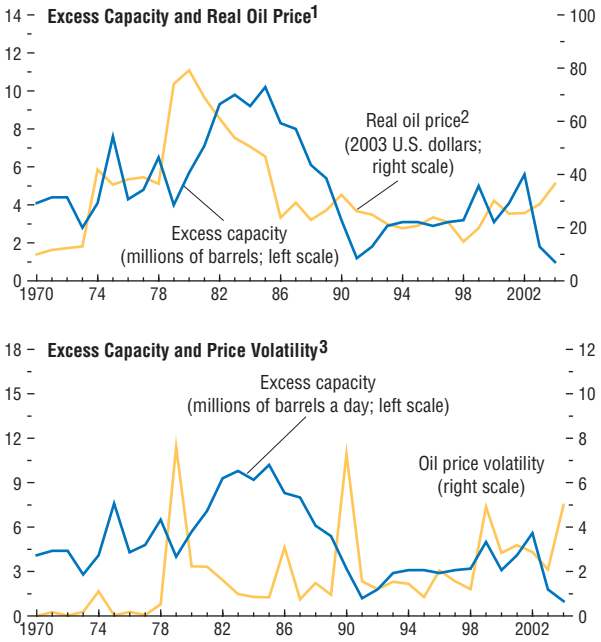
Should policymakers be concerned about developments in the oil market? While the percentage increase in the real oil price has been much smaller than during the 1970s,[1] Chapter I of this *World Economic Outlook* suggests that the recent oil price increases may still have a non-negligible impact on the world economy—GDP growth is expected to slow by 0.7–0.8 percentage points in 2005–06 relative to 2004, with oil prices being one of the contributing factors. The impact could be yet stronger in the developing countries and emerging markets that face external financial constraints. IMF staff analysis suggests that the relationship between oil price and output is nonlinear: particularly high oil prices may trigger a rapid fall in consumer and business confidence with a strong negative impact

Note: The main author of this chapter is Martin Sommer, with support from Dermot Gately. Paul Atang provided research assistance.

[1]The real average oil price rose by 74 percent between June 2003 and March 2005, compared with the 185 percent increase during 1974 and the 158 percent increase between June 1978 and November 1979.

Figure 4.1. Oil Market as a Source of Shocks
(1970–2004)

Periods of low spare capacity tend to be associated with rising and volatile prices.



Sources: International Energy Agency; U.S. Department of Energy; and IMF staff calculations.

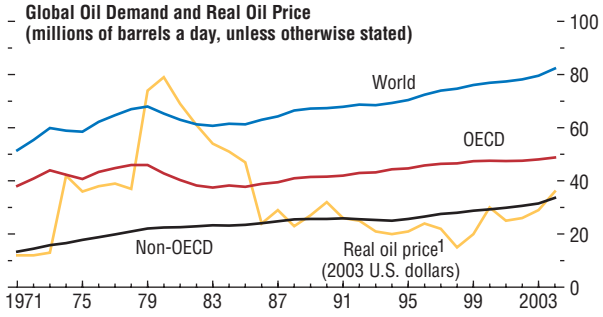
[1]Excess capacity is defined as spare capacity of OPEC producers in millions of barrels a day.

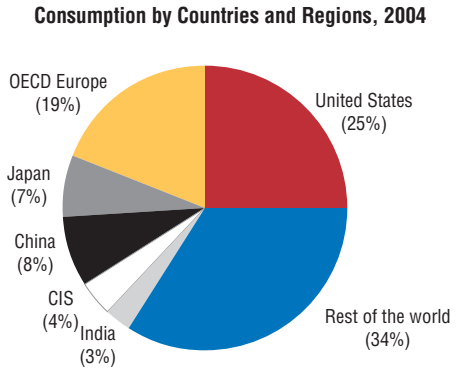
[2]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

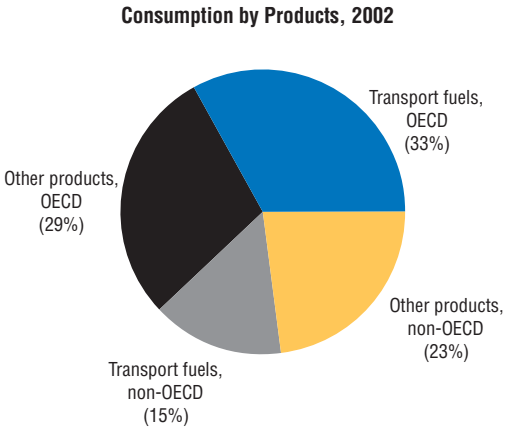
[3]Volatility is defined as the standard deviation of monthly real oil prices.

Figure 4.2. Oil Consumption
(1971–2004)

Oil consumption declined in response to price shocks of the 1970s but has since grown steadily. The United States, European Union, and Japan account for half of total demand. Almost half of oil is used in transport.







Sources: International Energy Agency; and IMF staff calculations.
[1]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

on economic activity. Besides generating price volatility (see Box 4.1), the current lack of spare production capacity also makes oil-importing economies, especially in the non-OECD region, vulnerable to supply disruptions.

Recent developments in the oil market are analyzed in detail in Appendix 1.1 of this *World Economic Outlook* and in the April 2005 edition of the IMF's *Global Financial Stability Report*. The purpose of this chapter is to assess longer-run oil market prospects, focusing on the following questions.

- What is the medium- and long-term outlook for the oil market, and what are the relevant risk factors on the demand and supply sides?
- Will there be enough spare production capacity going forward to satisfy demand in periods of unexpectedly strong growth or supply disruptions?
- In the long run, will the level of oil prices that has been typical until recently ($20–30 a barrel) be sufficient to provide the main producers with incentives to increase capacity and meet growing demand?
- How can policymakers reduce the risks arising from tight market conditions? How much insurance should they take out and in what form?

Basic Stylized Facts

Oil Demand

The main consumers of oil continue to be the advanced economies; the United States, OECD Europe, and Japan together consume about half of annual oil output (Figure 4.2). But consumption in the emerging market and developing countries has been increasing at a faster pace, as these economies grow rapidly and their use of energy including oil in the transport, industry, and residential sector expands. China and India contributed 35 percent to incremental oil consumption between 1990 and 2003, even though the two countries produced only 15 percent of world output over the period. By sectors, demand for transport fuels is the most important,

Box 4.1. Should Countries Worry About Oil Price Fluctuations?

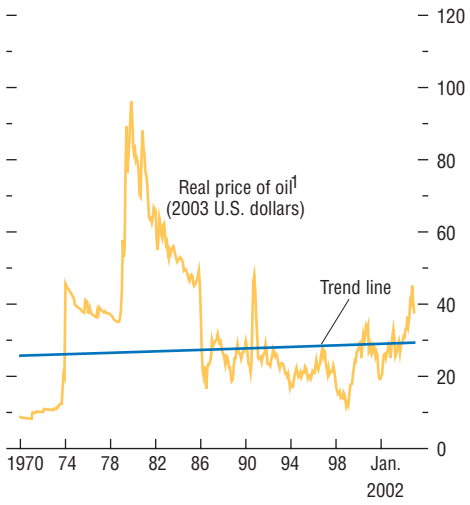
Despite a consistent fall in global oil intensity, crude oil remains an important commodity and events in the oil market continue to play a significant role in shaping global economic and political developments. Oil accounted for 8 percent of global trade in goods and services and about 2.5 percent of world activity in 2004—higher than any other commodity, although well below 1980 levels. Moreover, given the distribution of oil reserves and the structure of supply and demand, geopolitical factors play an important role in the oil market.

Over the past 30 years, oil prices have moved in the range of US$8–96 (in constant 2003 dollars), and have lacked any meaningful trend (see the first figure). After a period of sharp movements in the 1970s and the first half of the 1980s, prices were more stable through 1997—except for the spike during the first Middle East crisis in 1990–91. Since that time, however, volatility has increased markedly, reflecting a combination of declining excess capacity, which is held almost entirely in OPEC countries; lower private stocks; changes in OPEC production levels, including disruptions to Iraq's production; and geopolitical uncertainties. Volatility may well have been exacerbated by persistently low oil prices between the late 1980s and the late 1990s, which encouraged a relatively cautious approach to investment.

How much of a concern is oil price volatility?[1] If it were possible to clearly distinguish a temporary oil shock from a permanent one, and for all economic agents to borrow/lend as necessary to smooth the effects, the economic impact of price volatility should be rather limited. In practice, however, neither of these conditions hold. Of the 2.5 percent volatility (defined as the standard deviation) of the median of GDP growth across the globe over the past 35 years, rough estimates suggest that volatility in oil prices has contributed about 0.3 percentage point. Based on the results in the literature on the impact of volatility on growth[2] reducing such volatility by, say, 50 percent could increase global GDP, on average, by about 0.03 percentage point or $12 billion a year. The impact of volatility is, of course, likely to vary significantly across countries.

- Industrial countries are likely to be best placed to manage oil price volatility, aided by credible monetary policy frameworks—reducing the need for an interest rate response to higher oil prices; well-developed domestic financial markets, allowing consumers to smooth expenditure in response to shocks; and access to international capital markets, so that the balance of payments impact can be more readily financed. Even in this relatively

Real Price of Oil and Trend Line
(Monthly, 1970–2004)



Sources: IMF, *International Financial Statistics;* and IMF staff calculations.
[1]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

Note: The authors of this box are Sam Ouliaris and Hossein Samiei.

[1]Note that the focus of this box is on the impact of volatility and price uncertainty per se, as distinguished from the impact of higher prices.

[2]See, for example, Ramey and Ramey (1995).

Box 4.1 *(concluded)*

benign environment, it remains very difficult to distinguish temporary from permanent shocks; and uncertainties related to large changes in oil prices can have significant effects on consumer confidence, and thereby on growth.[3]

- The impact is likely to be significantly greater in oil-importing developing countries, especially where policy frameworks are weak, foreign exchange reserves are low, and access to international capital markets is limited. This is particularly so for many of the poorest developing countries, where even a temporary period of higher oil prices can force a substantial adjustment in domestic consumption, at a considerable cost to growth and poverty reduction. The fiscal impact can also be significant when domestic petroleum product prices are administered.
- Price volatility can also cause significant problems for oil exporters. For many, volatility and unpredictability of prices are a potential source of fiscal vulnerability, and an impediment to sound expenditure planning—especially as government expenditures tend to increase with the price of oil (see the second figure). This is, in particular, true for countries that do not operate within a longer-term framework.

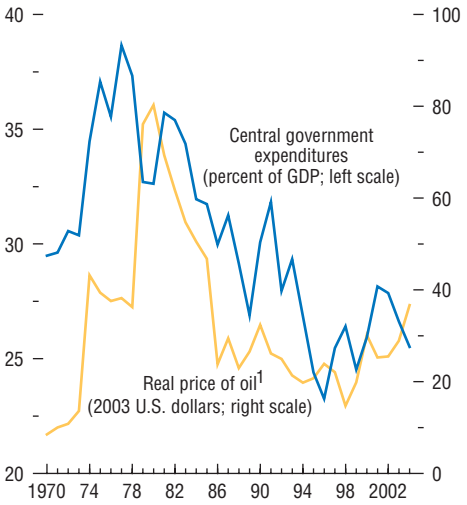
The unpredictability and volatility of oil prices also has deleterious effects on investment in the oil sector. Higher volatility and uncertainty—other things being equal—generally lead to conservative future oil price assumptions and higher required rates of return (to compensate for the higher risk), while the difficulty of distinguishing between transitory and permanent price shifts complicates the task of predicting future cash flows. Given the huge up-front capital outlays involved and the irreversible nature of investment in the oil sector, it could also encourage delays in decision making. The impact of price volatility on investment could generate a vicious circle whereby low or delayed investment activity could in turn add to price volatility.

How can the costs of oil price volatility be reduced? Clearly, one important way—discussed in detail in the main text—is to reduce oil price volatility itself. One key issue is maintenance of adequate spare capacity as a public good. The costs and benefits of doing so are obviously difficult to calculate. Rough calculations, however, suggest that additional spare capacity (relative to current levels) on the order of 5 mbd may reduce price volatility by over 50 percent. Based on IEA estimates of exploration and development costs, the up-front costs of such additional capacity for OPEC countries are about $20 billion, with an average estimated depreciation costs on the order of $2 billion a

[3]In the United States, for example, the loss of consumer confidence accompanying the two shocks of the 1970s was in the range of 30–40 percent, estimated to reduce GDP by 0.5–1 percentage point.

OPEC-10 Central Government Expenditures and Real Oil Price

(Annual, 1970–2004)



Sources: IMF, *International Financial Statistics;* and IMF staff calculations.
[1]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

year. Given the benefits of lower volatility for world activity—as noted above—the world as a whole can clearly benefit from higher spare capacity. Devising mechanisms that would allow the potential benefits of lower volatility to finance the cost of creating spare capacity is, however, not an easy task. There is a role for enhanced consumer-producer dialogue in this regard, although, as noted above, oil producers on their own also have some incentive to increase price stability.

Beyond these steps, efforts could focus on mitigating the impact of volatility. First, given the difficulties of distinguishing temporary from permanent shocks, greater transparency in oil markets and enhanced dialogue between producers and consumers will allow markets to assess developments in fundamentals more clearly (see Box 4.2); this also underscores the importance of allowing changes in world prices to flow through to domestic prices. Second, both importers and exporters can reduce price risks by actively engaging in hedging markets. Finally, oil price shocks—like other shocks—are more easily managed in countries with credible domestic policy frameworks.

accounting for 48 percent of oil products consumption in 2002.

As is apparent from Figure 4.2, demand for oil has grown steadily in the past, only marginally reacting to year-on-year price fluctuations. However, oil consumption responded very strongly to the oil price hikes of the 1970s, especially in the advanced countries that subsequently imposed high taxes on energy consumption. On average, oil intensity, or use of oil per unit of output, halved over the past 30 years in advanced countries and declined by about one-third in developing countries (Figure 4.3). The group of developing countries and emerging markets is less oil efficient than the advanced economies when output is measured at market exchange rates. But oil intensity is similar in the two groups when output is adjusted for differences in national price levels.

Oil Supply

Proven oil reserves (see Figure 4.4) are sufficient to meet world demand at current levels for over 40 years.[2] However, this figure significantly underestimates the volume of oil resources that may be eventually recoverable with improved technology or at higher oil prices. On this basis, the International Energy Agency (2004b) calculates that remaining oil resources could cover 70 years of average annual consumption between 2003 and 2030.

For the purposes of this analysis, oil producers can broadly be divided into two categories.

- *Producers from OPEC* (Organization of the Petroleum Exporting Countries),[3] which own about 70 percent of proven oil reserves. The OPEC countries are highly dependent on oil revenues and try to coordinate their production targets to influence prices on the world oil market.
- *Producers from non-OPEC countries*, which mainly invest and produce based on current and expected market prices, subject to cost, technological, and regulatory constraints.

OPEC members currently produce 40 percent of total world oil output and supply about 55 percent of oil traded internationally. Their output market share used to be higher—about 50 percent in the 1970s. However, the oil shocks of

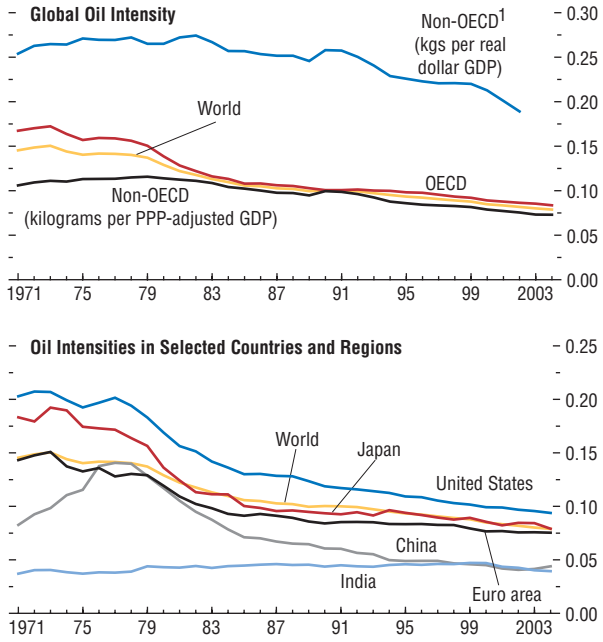
[2]Proven reserves are the oil resources that can be extracted profitably with at least 90 percent probability.

[3]The OPEC member countries are Algeria, Indonesia, I.R. of Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

Figure 4.3. Oil Consumption per Unit of Output

(Kilograms per unit of real PPP-adjusted GDP, unless otherwise stated; 1971–2004)

Over the past three decades, the use of oil per unit of output has fallen by about half in OECD and by one-third in non-OECD countries. Oil intensity is comparable between the two groups in purchasing-power-parity (PPP) terms though the intensity is much higher in the non-OECD countries at market exchange rates.



Sources: International Energy Agency; OECD analytical database; and IMF staff calculations.

[1]Data for this series are available only through 2002.

the 1970s reduced demand and OPEC, in particular Saudi Arabia, responded in the early 1980s by cutting production to stabilize prices. This had the side effect of creating significant spare capacity, with several consequences for the world economy. The financial position of many OPEC members deteriorated. At the same time, the existence of spare capacity provided oil consumers with a buffer against supply disruptions (such as during the Middle East conflict in 1991); but it also deterred some oil extraction projects in the non-OPEC regions. Over the past two years, spare production capacity has been eroded by surging oil demand. OPEC now produces close to its capacity, which, for comparison, is lower than its peak capacity in the 1970s (Figure 4.5).

Proven reserves in the non-OPEC region account for only 30 percent of the world total. Moreover, unit exploration, development, and production costs are much higher than in the OPEC region (Table 4.1). Despite lower and more expensive endowments, non-OPEC supply has grown steadily, though the price collapse of the mid-1980s combined with OPEC excess capacity slowed down growth. Most of the recent increases in non-OPEC production have been from the Commonwealth of Independent States (CIS) (see Figure 4.5). Many fields in the non-OPEC region are now mature and have high decline rates. Canada holds almost one-half of non-OPEC proven reserves in the form of non-conventional oil contained in its oil sands. The production costs of such oil have fallen considerably over the past decades, in many areas to about $10–15 a barrel including producer taxes (National Energy Board, 2004). However, achieving high output from the fields is a complex and time-consuming task since significant investment in extracting and refining infrastructure is needed, together with large quantities of water and natural gas.

Medium- and Long-Term Projections

This section presents projections of oil demand and supply, and identifies the main risk

factors, focusing on medium- and long-term developments. It is important to keep in mind that the projections are sensitive to specific assumptions about economic growth, efficiency gains, use of alternative fuels, and new oil discoveries. But important conclusions about the market dynamics can be drawn even without the benefit of perfect foresight.

The section is organized as follows. First, projections of oil supply and demand are presented assuming that:

- Global growth averages 3.6 percent in purchasing-power-parity-adjusted (PPP-adjusted) terms between 2003 and 2030.[4] Annual growth rates for each country are based on *World Economic Outlook* estimates and forecasts for 2004–09 and the U.S. Department of Energy projections thereafter.
- Oil prices move as projected in futures markets (as of end-February 2005) through 2010, and thereafter stay constant in real terms. This implies that the real average oil price falls from $45 a barrel in 2005 to approximately $34 a barrel in 2010 and beyond.[5] This long-term price level is $3–10 higher than that assumed by other institutions (see Department of Energy, 2004a, for a detailed price comparison).

Second, we make a comparison of the initial demand and supply projections, and assess whether the starting assumption of a long-term $34 a barrel real oil price is realistic. Finally, we use an oil market model to calculate the price that will balance supply and demand over the long run.

Oil Demand

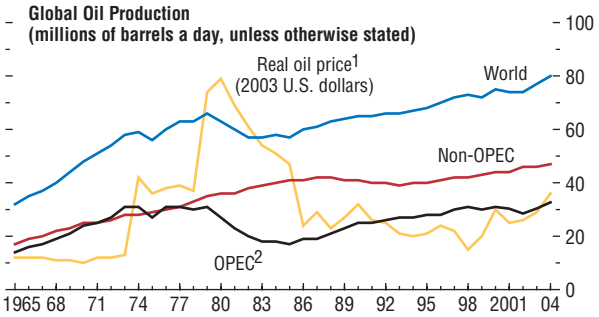
The analysis of oil demand is based on a simple model estimated using disaggregated data for advanced economies and emerging market

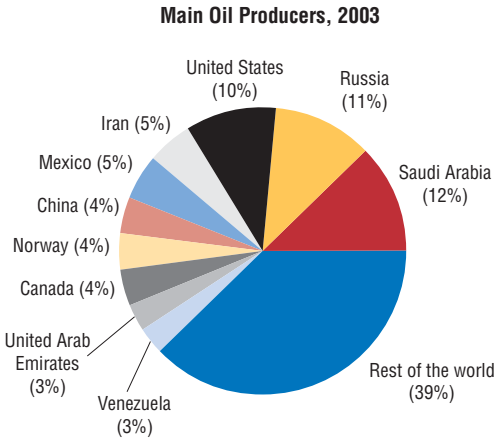
[4]Global GDP growth is assumed to be 3 percent between 2003 and 2030 based on market exchange rates.

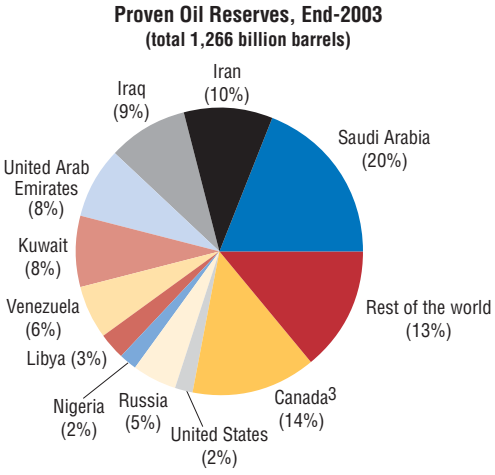
[5]The average oil price is defined as the simple average of West Texas Intermediate, Brent, and Dubai oil prices.

Figure 4.4. Oil Production and Reserves
(1965–2004)

In the 1980s, non-OPEC countries surpassed OPEC as the dominant producers of oil. The proven oil reserves, however, are much higher in the OPEC region, especially in the Middle East.







Sources: International Energy Agency; *British Petroleum Review; Oil and Gas Journal* (2003); and IMF staff calculations.

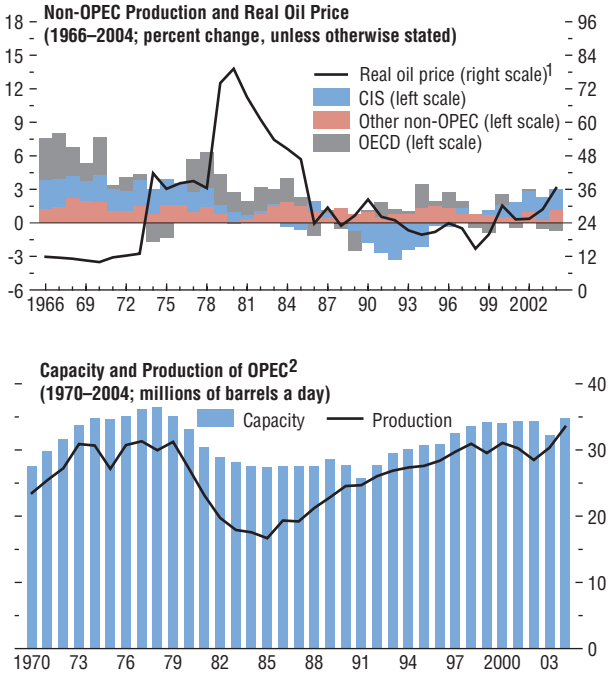
[1]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

[2]Members of OPEC (Organization of the Petroleum Exporting Countries) are Algeria, Indonesia, I.R. of Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela.

[3]Includes nonconventional oil.

Figure 4.5. OPEC and Non-OPEC Oil Supply

In the past several years, Russia and several other CIS members have contributed most to growth in non-OPEC production. OPEC countries now produce very close to their capacity.



Sources: International Energy Agency; *British Petroleum Review;* U.S. Department of Energy; and IMF staff calculations.

[1]Simple average of West Texas Intermediate, Brent, and Dubai oil prices, expressed in 2003 U.S. dollars.

[2]Includes crude oil and other liquids.

and developing countries over the past three decades. The model distinguishes between consumption of different types of oil products: transport fuels, other fuels for industry and residential sectors, and heavy fuel oil (used mainly for electricity generation). The demand for transport fuel is primarily modeled as a function of the number of motor vehicles in each economy; the number of vehicles is in turn estimated as a nonlinear function of income. Consumption of other fuels is directly related to the level of income; and consumption of the heavy fuel oil is assumed to stay constant or grow slowly, depending on each country's historical pattern. Details of the model are discussed in Appendix 4.1.

The model finds that in both groups of countries, consumption of oil products is closely linked to the level of economic activity and vehicle ownership. These two variables in fact explain the bulk of oil consumption growth over time. In contrast, oil demand is fairly unresponsive to price changes as long as the level of real oil prices remains well below its historical peak—a 10 percent a barrel increase in prices reduces demand by only about 1 percent. However, large price changes, such as the ones experienced in the 1970s, have substantial—up to five times stronger—effects, in part because they can trigger a significant adjustment of technology and oil consumption. Both insights are consistent with the intuition built from the aggregated data in Figure 4.2.[6]

Table 4.2 presents the baseline oil demand projections using the estimated coefficients and the above price and growth assumptions. (Figure 4.6 examines the sensitivity of the demand projections to these assumptions, and Table 4.3 summarizes the average income elasticities over the forecasting period.) The baseline scenario

[6]In many advanced economies, taxes make up a large proportion of end-user prices of oil products. Owing to limited availability of comparable cross-country products' price data, the analysis in this chapter mostly focuses on the crude oil prices. In countries with large specific oil consumption taxes (such as in the European Union), the sensitivity of oil demand to price could be lower than assumed in this chapter.

Table 4.1. Unit Costs of Oil Production
(Dollars a barrel)

	Exploration and Development Cost	Production Cost	Implied Tax Cost[1]	Differential to Brent[2]	Total[3]
Non-OPEC[4]					
Africa	2.9	2.2	9.0	2.6	16.8
Asia	2.9	3.3	8.3	2.0	16.5
Asia-Pacific	2.7	2.2	7.8	2.3	15.1
Europe	4.0	2.7	8.0	1.2	15.9
Latin America	3.2	3.1	6.1	3.3	15.8
Middle East	2.6	2.6	9.7	1.7	16.6
North America	3.7	6.0	4.2	—	13.9
OPEC					
Saudi Arabia	1–2	<2	Markup to revenue[5]	. . .	. . .

Sources: Goldman Sachs; and International Energy Agency.
[1]Combined income tax, production tax, and royalty fees. The tax components vary with revenue and profit a barrel. Here they are calibrated for the revenue of about $20 a barrel.
[2]Difference between the average revenue a barrel (oil and gas combined) and the Brent crude oil price.
[3]Total unit cost structure, on a Brent oil equivalent after-tax basis. Excludes any profit (return) from invested capital. According to Goldman Sachs estimates, oil price of $20 a barrel would cover the cost structure of the industry while offering an 8 percent nominal rate of return.
[4]Based on 100 largest recent oil and gas projects.
[5]Most oil revenues are surrendered to the government.

projects oil consumption to grow from an average of 82.4 million barrels a day (mbd) in 2004 to 92.0 mbd in 2010, and 138.5 mbd in 2030. The main contributor to the consumption increase is transport demand, which is expected to account for over 60 percent of the total oil consumption increase. Demand for other oil products will contribute about one-third to demand growth, and heavy fuel oil, less than 5 percent.

Looking across regions, advanced countries will only account for 25 percent of the increase in world oil demand. Most of demand growth will come from developing countries, with transport demand in the non-OECD region almost tripling from 16 mbd to 45 mbd between 2003 and 2030, driven by a six-fold increase in vehicle ownership. Much of this is expected to take place in the rapidly growing Asian economies—particularly in China, where income per capita has reached the level at which vehicle ownership rates rise quickly. Demand for other products will more than double in developing countries, from an estimated 10 mbd in 2003 to 22 mbd in 2030.

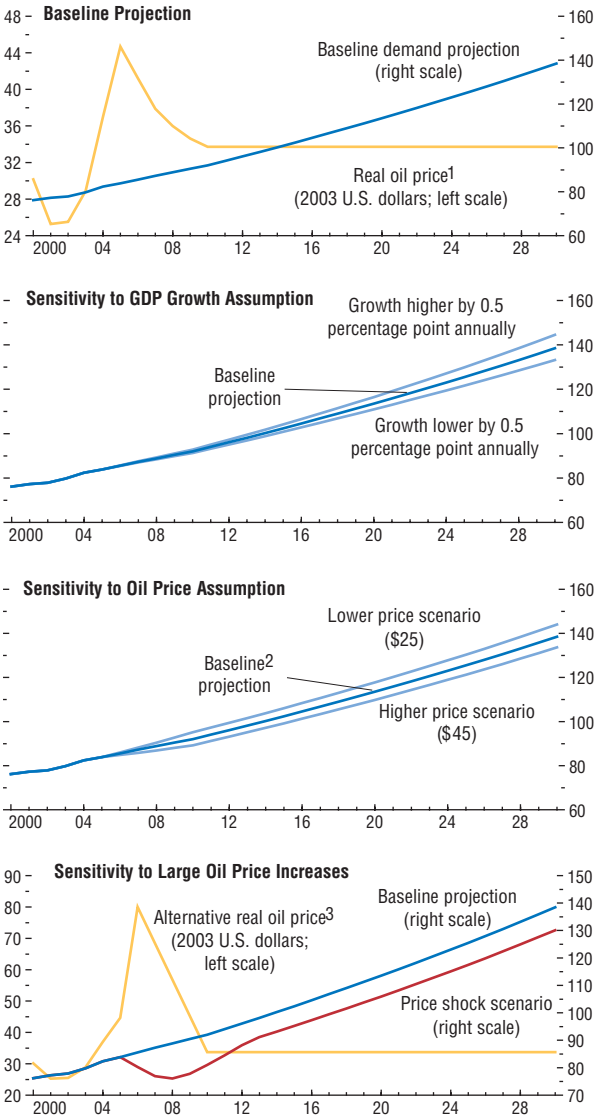
As can be seen from the above, vehicle ownership plays a key role in oil demand growth; transport demand in emerging market and developing countries is projected to contribute almost half of the total oil demand increase over the next three decades. To provide a perspective on the importance of fast transport growth, Figure 4.7 compares the vehicle ownership rates across countries over the past three decades (see Appendix 4.1 for a formal model of vehicle ownership). Both OECD and non-OECD countries started to experience rapid vehicle ownership growth at income levels of about $2,500 per capita in PPP terms. Growth in vehicles continued to be much faster than GDP growth until about $10,000 of per capita income. The projections suggest that China, as a fast-growing developing country, could see its vehicle ownership rates jump from 16 vehicles per 1,000 people in 2002 to 267 vehicles per 1,000 people in 2030. This is actually slightly below the vehicle ownership rates seen in other countries at similar PPP per capita income levels (between 300–600 vehicles per 1,000 people—see Figure 4.7).[7] If

[7]The predicted vehicle ownership rate for China is below the historical range because, for the purposes of vehicles projection, the country is divided into three areas with different initial income levels.

Figure 4.6. Long-Term Projections of Oil Demand

(2000–30; millions of barrels a day, unless otherwise stated)

Oil demand is projected to grow as economies and vehicle ownership expand. Projections are sensitive to underlying assumptions about growth and oil price.



Sources: International Energy Agency; U.S. Department of Energy; and IMF staff calculations.

[1]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

[2]According to the futures markets, the real price of oil expressed in 2003 dollars is expected to fall from $45 a barrel in 2005 to about $34 a barrel in 2010. The real price of oil is assumed by the IMF staff to stay at this level after 2010.

[3]Real oil price is assumed to jump to $80 a barrel in 2006 and then gradually fall to the baseline price of about $34 a barrel in 2010.

Table 4.2. Oil Demand Projection

(Millions of barrels a day unless otherwise stated)

	Estimate		Projection		
	2003	2004	2010	2020	2030
Total demand	**79.8**	**82.4**	**92.0**	**113.5**	**138.5**
OECD and NIEs[1]	48.9	49.5	52.0	57.9	63.7
Other non-OECD	30.9	32.9	40.0	55.6	74.7
Of which: China	5.5	6.4	8.6	13.6	18.7
Transport demand[2]	**46.3**	**. . .**	**54.3**	**67.6**	**82.8**
OECD and NIEs	30.4	. . .	32.5	35.6	38.3
Other non-OECD	15.9	. . .	21.8	31.9	44.5
Other nonresidual demand[3]	**23.0**	**. . .**	**27.1**	**34.3**	**42.9**
OECD and NIEs	13.6	. . .	14.9	17.7	20.8
Other non-OECD	9.5	. . .	12.2	16.6	22.0
Residual demand[4]	**10.5**	**. . .**	**10.6**	**11.6**	**12.8**
OECD and NIEs	4.6	. . .	4.6	4.6	4.6
Other non-OECD	5.9	. . .	6.0	7.0	8.2
Memorandum					
Number of vehicles (millions of units)	**751[5]**	**. . .**	**939**	**1,255**	**1,660**
OECD and NIEs	625[5]	. . .	720	827	920
Other non-OECD	126[5]	. . .	219	429	741
Of which: China	21[5]	. . .	80	209	387

Sources: International Energy Agency; United Nations Yearbook; and IMF staff calculations.

[1]Newly industrialized Asian economies (NIEs) include Hong Kong SAR, Korea, Singapore, and Taiwan Province of China. Korea is also an OECD member.

[2]Includes gasoline, jet fuel, and gas/diesel (including light heating oil).

[3]Includes liquefied petroleum gas, naphtha, kerosene, and other products except heavy fuel oil.

[4]Heavy fuel oil.

[5]Year 2002.

China's economic growth is sustained, and the cross-country experience is at least a partial guide for its vehicle ownership rates, the country would contribute almost one-fourth of total world incremental oil demand between 2003 and 2030. But even if annual growth rates of vehicle ownership in China were only at one-half of what is predicted based on the past experience of other countries, world oil demand would still be about 132 mbd in 2030—a significant increase over the current 82 mbd.[8] Additional sensitivity tests are reported in Figure 4.6.

[8]Similarly, if we stipulated that vehicle ownership would saturate in all developing countries at levels that are much lower than in the advanced economies (for example, at about one-half), oil demand could be lower by as much as 10 mbd relative to the baseline in 2030. However, the experience of many emerging market economies has not been consistent with this assumption.

Table 4.3. Average Income Semi-Elasticities, 2003–30[1]

	OECD and NIEs[2]	Other Non-OECD
Transport fuel	0.32	0.85
Other products	0.60	0.70
Heavy fuel	—	0.37
Total demand	0.38	0.74

Source: IMF staff calculations.
[1]Semi-elasticity is defined as average growth of oil consumption over average growth of purchasing power parity adjusted income. The semi-elasticity includes the impact of oil price changes on oil consumption.
[2]Newly industrialized Asian economies (NIEs) include Hong Kong SAR, Korea, Singapore, and Taiwan Province of China. Korea is also an OECD member.

Oil Supply

Against this background, we now turn to prospects for oil supply in both OPEC and non-OPEC regions. We start by analyzing the outlook for non-OPEC oil production. Given projections of demand and non-OPEC supply, we will subsequently assess the expected demand for OPEC oil at the baseline real price path.

Non-OPEC Oil Production

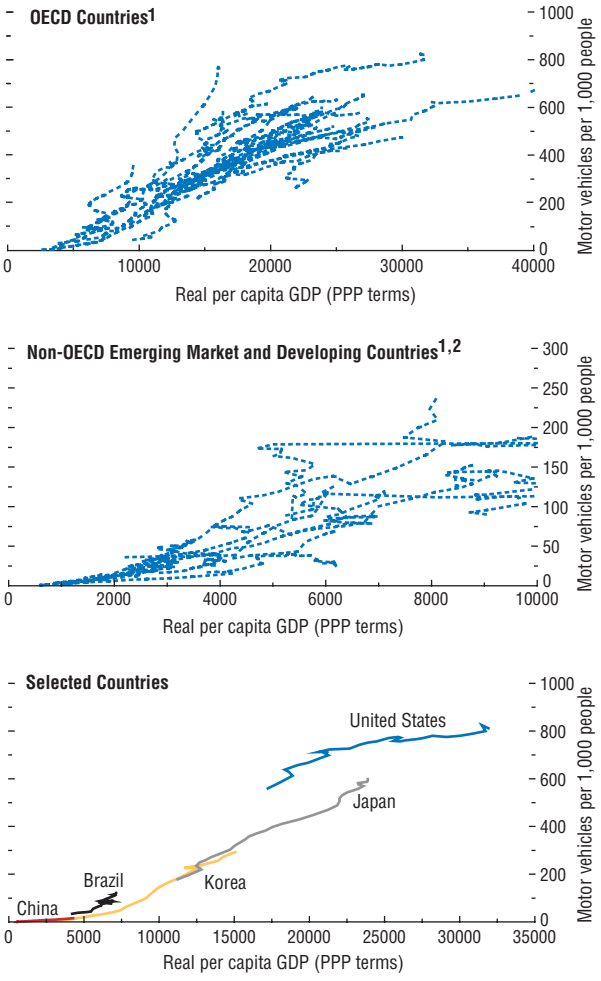
Expansion of non-OPEC production will be constrained by the declining potential of many traditional fields and, relative to OPEC, by limited and high-cost reserves. Capacity additions are planned in Africa, the CIS, and Latin America in the medium term. However, it is not clear whether non-OPEC production growth can be sustained in the long run.

Non-OPEC supply projections in this section rely primarily on estimates by the International Energy Agency (IEA) and the United States Department of Energy (DoE).[9] IEA (2004b) expects non-OPEC oil production to rise from 50 mbd in 2004 to 57 mbd in 2010 (including non-conventional oil and processing gains), and stay broadly constant thereafter as falling production

[9]Oil supply is inherently difficult to estimate using simple regression models owing to long time lags between price signals and investment decisions, technological and reserve constraints, and changes in policy frameworks.

Figure 4.7. Vehicle Ownership and per Capita Income
(1971–2002)

Vehicle ownership starts to grow quickly when countries reach income of about $2,500 per capita in purchasing-power-parity (PPP) terms. Rapid growth continues until income per capita reaches about $10,000. Saturation level is at about 850 vehicles per 1,000 people.



Sources: United Nations Statistical Yearbook; OECD analytical database; and IMF staff calculations.
[1]Only data fitting the scale are shown.
[2]This group of countries includes Argentina, Brazil, Chile, China, Colombia, Dominican Republic, Ecuador, Egypt, Morocco, South Africa, Israel, India, Indonesia, Malaysia, Thailand, Pakistan, and Syrian Arab Republic.

Table 4.4. Projections of Non-OPEC Oil Supply[1]
(Millions of barrels a day)

	International Energy Agency (IEA)					U.S. Department of Energy (DoE)				
	2002	2004	2010	2020	2030	2002	2010	2020	2025	2030[2]
United States and Canada[3]	10.5	. . .	11.0	9.1	7.6	11.1	11.3	10.5	. . .	9.9
Mexico	3.7	. . .	4.4	4.2	3.0	3.7	4.2	4.6	. . .	5.0
OECD Europe	6.9	. . .	5.0	3.2	2.3	6.8	6.4	5.5	. . .	4.6
Russia	8.0	. . .	10.8	11.1	11.4	7.6	10.0	10.9	. . .	11.3
Other transition economies	2.0	. . .	4.4	4.9	5.5	1.8	3.5	5.6	. . .	8.0
China	3.5	. . .	3.4	2.8	2.3	3.3	3.6	3.5	. . .	3.3
Other Asia	2.6	. . .	2.4	1.9	1.2	2.5	2.6	2.7	. . .	2.5
Central and South America	3.8	. . .	4.9	5.8	6.4	3.8	4.5	5.9	. . .	6.9
Africa	3.1	. . .	4.8	5.1	4.6	2.9	3.8	5.4	. . .	8.1
Rest of world	3.0	. . .	2.4	2.0	1.6	2.9	3.3	3.6	. . .	4.0
Nonconventional oil[4]	1.7	. . .	3.9	6.8	10.7	1.5	2.8	5.0	. . .	5.4
Total	48.8	50.4	57.2	56.9	56.6	48.0	56.0	63.2	65.0	69.0

Sources: International Energy Agency (2004a, 2004b); U.S. Department of Energy (2004a); and IMF staff calculations.
[1]Projections of IEA and DoE at their baseline oil prices (including processing gains).
[2]IMF staff estimate based on DoE projections for 2020 and 2025.
[3]Excludes nonconventional oil.
[4]Includes heavy oil from Venezuela (OPEC member).

of conventional oil is offset by rising nonconventional oil production in Canada (Table 4.4). The U.S. Department of Energy (2004a) is more optimistic about non-OPEC prospects and expects production to continue to grow over the projection period, from 50 mbd in 2004 to 56 mbd in 2010, and about 65 mbd in 2025.[10]

The responsiveness of non-OPEC supply to prices is the key unknown in the projection. While most analysts would agree that the high prices of the 1970s stimulated non-OPEC investment (and the price collapse of 1986 dampened it), the range of quantitative estimates is very wide. Gately (2004) constructs a model where the long-term elasticity of non-OPEC supply to prices varies from 0.15 to 0.58.[11] Such a broad range of elasticities captures a complex mix of uncertainties: the speed of declines in traditional regions such as the United States and OECD Europe, the timing and level of the production peak in the CIS, and the output of nonconventional oil in Canada. Canada's oil sands make up about half of non-OPEC's proven reserves and potential for output growth from this source is in principle very high. However, according to IEA estimates it takes five to seven years for investment in oil sands projects to come on-stream, and therefore the speed of price responsiveness may be slow.

OPEC Oil Production

Given the baseline demand and non-OPEC supply projections, we can calculate the residual demand for OPEC oil (the so-called "call on OPEC"). This is the hypothetical amount of oil that OPEC would need to produce to close the gap between total demand and non-OPEC supply, and maintain prices at their assumed path. Initially (by about 2010), the call on OPEC is expected to stay roughly unchanged at current 32 mbd.[12] Over the next decades, however, the

[10]IEA's projections assume that the real price of oil (expressed in 2003 prices) will fall to $23.5 a barrel by 2010 and then rise gradually to $31 in 2030. In the DoE baseline scenario, the real oil price rises from $25 in 2010 to about $28 in 2025. The IEA and DoE long-term price projections (made earlier in a period of slack market) are lower than this chapter's assumption of $33.73 a barrel for 2010–30, though the price differences narrow down in the long term to $3–5 a barrel.

[11]Moroney and Berg (1999) estimate the long-term elasticity of oil supply with respect to real prices at 0.1–0.2, while Dahl and Duggan (1996) estimate it at 0.6 using U.S. data.

[12]Excluding global inventory changes.

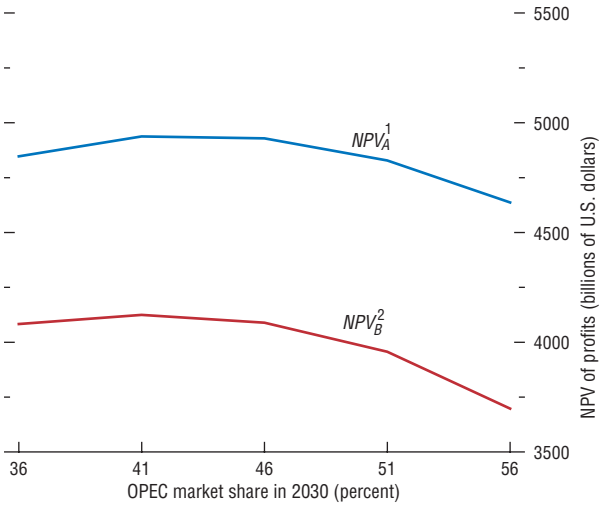
call on OPEC is projected to grow significantly at the baseline price path, to about 61–74 mbd in 2030, implying a more than doubling of OPEC oil production. Such a production increase would require a significant amount of investment spending, both in the form of initial investment (about $5,000 a barrel of daily capacity) and follow-up spending to offset natural declines in fields. The increase in production and capacity would have to be provided mainly by the Middle East OPEC members because these countries have the largest oil reserves.

The actual OPEC response to demand pressures is difficult to predict, but the choices faced by OPEC can be evaluated under the assumption that OPEC, acting as one entity, bases its production decisions on the net present value of future profits. Using parameter values estimated in this chapter, Gately (2005) calculates the OPEC's net present value of profits for different choices of its market share. In the model, OPEC seeks to balance the gains from higher output expansion against the losses from the resulting lower prices, taking into account investment and extraction costs (for details of the model, see Appendix 4.1). The model results suggest that OPEC's optimal market share is between 41 and 46 percent (see Figure 4.8), which corresponds to OPEC output of 52–59 mbd in 2030, well below the initial hypothetical call on OPEC of 61–74 mbd. The simulation model also suggests the market share in the range of 41–46 percent is optimal for OPEC under many different assumptions about income and vehicle elasticities; consequently, OPEC may not have an incentive to significantly increase its current market share of just below 40 percent even if oil demand turns out to be different from the baseline scenario.

All this suggests that once non-OPEC production peaks, there will likely be a strong upward pressure on prices. If OPEC's production decisions were to be broadly along the lines described above, oil prices expressed in 2003

Figure 4.8. Profitability of Various OPEC Market Strategies

According to the model of Gately (2005), the Net Present Value (NPV) of OPEC profits is highest for OPEC market shares between 41 and 46 percent. This is in contrast with the 50–58 percent OPEC market share projected in the baseline scenario in Table 4.5.



Source: Gately (2005).
[1] NPV_A corresponds to the NPV of discounted profits in the baseline scenario, with the International Energy Agency non-OPEC supply path.
[2] NPV_B corresponds to the NPV of discounted profits in the baseline scenario, with the U.S. Department of Energy non-OPEC supply path.

Table 4.5. Projected Oil Demand, Non-OPEC Supply, and Call on OPEC
(Millions of barrels a day)

	2003 Actual	2004 Estimate	2010	2020	2025	2030
Baseline demand projection	79.8	82.4	92.0	113.5	125.5	138.5
Non-OPEC supply[1]						
Lower bound	49.0	50.4	59.3	64.4	64.5	64.1
Upper bound	49.0	50.4	61.4	70.1	73.9	77.2
Call on OPEC[2]						
Lower bound	30.7	32.0	30.6	43.5	51.6	61.3
Upper bound	30.7	32.0	32.7	49.2	61.0	74.4
Memorandum						
Oil demand projection by agency						
IEA (2004b)	79.8	. . .	90.4	106.7	. . .	121.3
DoE (2004a)	79.8	. . .	91.1	110.0	120.6	. . .
OPEC Secretariat (2004)	79.8	. . .	88.7	105.8	114.6	. . .
Call on OPEC by agency:						
IEA (2004b)	30.7	. . .	33.3	49.8	. . .	64.8
DoE (2004a)	30.7	. . .	35.7	47.8	56.0	. . .
OPEC Secretariat (2004)	30.7	. . .	34.1	48.9	58.3	. . .

Sources: International Energy Agency; United States Department of Energy; OPEC Secretariat; and IMF staff calculations.

[1]Non-OPEC supply are projections of the International Energy Agency (IEA, 2004b) and the United States Department of Energy (DoE, 2004a), adjusted for the difference between the IMF's, IEA's, and DoE's baseline price paths. Includes nonconventional oil and processing gains. See Appendix 4.1 for details.

[2]Call on OPEC is the hypothetical amount of oil that OPEC would need to produce to close the gap between total demand and non-OPEC supply at the long-term real oil price of $33.73; excludes global inventory changes.

dollars would range between $39 and $56 a barrel in 2030, with the shortfall in OPEC production of 12.5 mbd relative to the baseline offset by lower oil demand (about 8.5 mbd) and higher non-OPEC supply (roughly 4 mbd). This scenario would still require significant investment in oil extraction capacity by OPEC, about $350 billion until 2030.[13] While the figure is a small fraction of overall OPEC export profits over the period (only about 5 percent, net of domestic consumption), it is important to keep in mind that most of the oil profits accrue to governments who face other competing priorities for spending.[14]

Conclusions and Policy Recommendations

Over the past two decades, oil-importing countries have enjoyed the benefits of double insurance against oil shocks: considerable spare production capacity in OPEC, and sizable emergency stocks held by OECD countries. However, spare capacity is now reduced to historically low levels and there are significant risks that the oil market will continue to be tight going forward. The analysis set out above—which is qualitatively consistent with forecasts of other institutions, including IEA, DoE, and OPEC Secretariat (Table 4.5)[15]—suggests that future

[13]IEA (2004b) estimates global investment needs of the oil sector at $3 trillion between 2003 and 2030. This figure includes investment in refining capacity. Also, unit investment costs in the non-OPEC region are considerably higher that in OPEC countries. Finally, IEA's call on OPEC is higher than suggested by the equilibrium model above.

[14]See Box 1.6 for a detailed discussion.

[15]For 2010, the forecasts of IEA, DoE, and OPEC Secretariat range between 89–91 mbd for total demand, and between 33 and 36 mbd for the call on OPEC. These forecasts are similar to the baseline projection of this chapter. In 2030, the IEA's call on OPEC is within the range of the baseline scenario (65 mbd compared with the 61–74 mbd interval), although it is higher than actual OPEC production suggested by our equilibrium model. Looking at long-term demand projections, IEA and DoE forecasts for 2025–30 are about 5–17 mbd lower than projected by the IMF staff in the baseline scenario, mainly reflecting a lower projection for transportation demand in developing countries, and to some extent also growth of demand for other products.

oil market developments could fall into two main phases.

- During the period through about 2010, the high—though gradually decreasing—oil prices currently predicted by the futures market will keep the oil market broadly in balance, with incremental oil demand being met mostly by higher non-OPEC production. However, since the prospects for higher spare capacity are unfavorable,[16] the market will likely remain tight and vulnerable to shocks. Oil prices will continue to be subject to the risk of large, unexpected price changes.
- From 2010 onward, the call on OPEC may increase significantly as non-OPEC production peaks while global demand continues to rise. With global dependence on oil production from OPEC countries rising, much would depend on OPEC supply response; most likely, however, there would be growing upside risks to prices. While projected increases of the size described above would appear manageable if they took place over a long period,[17] this would add to the risk of volatility looking forward.

As past experience underscores, long-run forecasts for oil supply and demand are subject to substantial uncertainties.[18] Beyond the future pace of global growth—which is clearly critical—two appear to be of particular importance.

- *Technological progress could exceed expectations.* The demand projection assumes a continued reduction in oil intensity measured as oil consumption per unit of output—by 1.6 percent annually in OECD and 1.1 percent annually in non-OECD countries—broadly in line with the average over the past 30 years. It is possible that the spread of new fuel-efficient vehicles, including hybrid cars, or efficiency-enhancing policy measures could produce more rapid reductions, especially if the market went through a period of sustained large price increases. However, the overall efficiency savings incorporated in the projections are already quite large.[19]
- *Non-OPEC production could increase more rapidly than expected.* Output of nonconventional oil might increase more rapidly than assessed above, changing the projected balance between production of OPEC and non-OPEC producers. Output of nonconventional oil would also respond to high prices, although—as noted above—with significant lags. Upward pressures on prices could also be reduced by competition from gas and other fuels, whose endowments are more equally distributed around the world.

Against this background, how should policymakers respond? While the macroeconomic risks from oil price volatility have declined in recent years, they remain a significant concern for both oil importers and exporters (Box 4.1). To reduce these risks, actions in three broad areas could be considered.

Making Oil Markets Work Better

A variety of constraints/rigidities hinder the efficient operation of the oil market, adding to uncertainty and volatility. The priorities include the following.

[16]The non-OPEC producers do not have the incentive to maintain spare capacity as they individually lack the necessary market power to influence oil prices. The OPEC producers have indicated that they plan to maintain some level of spare capacity (about 1.5–2 mbd in the case of Saudi Arabia). However, the historical data in Figure 4.1 suggest that spare capacity in the range of 3–5 mbd would provide much better protection against supply disruptions and demand shocks.

[17]The increase in real oil prices from $34 in 2010 to $56 in 2030 would imply average annual price growth of 2.5 percent.

[18]For example, on April 2, 2004, the oil futures markets expected the nominal price of oil to fall gradually from $32 to $26 by the end of 2006 (see Appendix 1.1, *World Economic Outlook,* April 2004).

[19]The use of oil per vehicle is projected to fall by 0.5 percent annually in OECD and 2.5 percent annually in non-OECD regions by 2030, equivalent to a saving of 50 mbd. Even a complete replacement of the existing and projected global vehicle stock by hybrid cars would reduce world oil demand by at most 20 mbd by 2030 (about 40 percent of the savings already factored into the scenario).

Box 4.2. Data Quality in the Oil Market

Recent developments in the oil market, the most widely traded commodity, have highlighted the need for more timely and accurate oil market data. Limited or incorrect information about oil demand, supply, stocks, and trade can increase perceptions of risk, reduce willingness to invest in new capacity, and increase price volatility. Indeed, price fluctuations in 2004 have likely been exacerbated by data inadequacies. For example, successive upward revisions in estimates of demand by the International Energy Agency (IEA)—in part reflecting limited available information on emerging market countries—added to market uncertainties, when spare capacity in the oil market was approaching historical lows. Underestimation of demand together with overly optimistic assessment of the level of inventory building may have also been responsible for OPEC's decision to cut official quotas in early 2004, thus contributing to higher prices.

The main source of international monthly oil market data is the IEA, which publishes a wide range of oil market indicators for over 130 countries. The data are compiled from questionnaires and market information. Annual questionnaires are sent to OECD and non-OECD countries, whereas monthly questionnaires are sent only to OECD countries. These have recently been supplemented by the Joint Oil Data Initiative (JODI) reporting (see below). Key indicators on demand, supply, trade, stocks, prices, and refining of oil (largely in physical units) are published by area and product. The main publications are the monthly *Oil Market Report* and the *Annual Statistical Supplement*. Annual compendiums on energy balances are also available with a substantial delay.

Within the limits of the data provided by countries, the IEA does a laudable job in providing oil statistics. Yet, a number of weaknesses still exist, with their root in the uneven and inadequate data reporting by individual countries. The problem many countries face is to satisfy reporting requirements with limited resources and shortage of experienced staff. Further, there is room for improved governance to enhance data quality through greater transparency.

Demand data are dominated by information from OECD countries, which are mostly net importers of oil. However, emerging market countries are increasingly significant in the oil market and the quality of data reported by such major consumers as China is of particular concern. Even for OECD countries, there are substantial time lags. Final annual estimates are only available 16–20 months after the reference year, and the initial estimates are not very reliable. The initial monthly estimates (published with a nine-week lag) are based on surveys of OECD countries, market information, and past trends. Monthly data on oil stocks are limited to primary industry and strategic government holdings for OECD countries. Non-OECD stocks held in smaller OECD facilities without reporting requirements are not captured by the data collection system. The average price data for individual petroleum products in OECD countries are adequate for most analyses but are neither defined nor reported consistently for non-OECD countries.

The accuracy and timeliness of data on supply and exports are weaker than those related to demand and prices. This largely reflects the quality of data sources, with current data compiled from a mixture of monthly direct reporting from OECD countries, and market information combined with past trends for non-OECD countries. The latter countries, which account for almost three-fourths of oil supply, have no obligation to report data to the IEA. Production and reserve data from non-OECD countries are particularly lacking, as reporting can be hampered by factors such as the proprietary nature of the data, the existence of production agreements, and sensitivities related to data on the size of oil funds. Hence, these data have to be estimated for a number of countries. Since a dominant share of oil is produced by non-OECD countries, information on global oil production and reserve data are, thus, not as reliable. The limited availability of timely data

Note: The author of this box is Paul Armknecht.

on the breakdown by different types of crude oil—the prices of which have moved differently—is also a concern.

Against this background, the international community has called for additional efforts to improve data quality, including transparency, in the oil market. In October 2004, the G-7 Ministers asked international organizations to strengthen their effort toward transparency, and the International Monetary and Financial Committee stressed the importance of further progress to improve oil market information and transparency. In November 2004, the G-20 Ministers urged cooperation between oil producers and consumers to enhance oil market transparency.

The JODI, which started in 2001 and is coordinated by the International Energy Forum (IEF), is a monthly exercise to improve the coverage and transparency of oil market data and extend the monthly reporting to non-OECD countries but with less detail than the IEA monthly oil survey. This initiative has led to some improvement in the coverage of data, which increased from about 70 percent at its initiation to about 95 percent now, representing data from 93 countries. However, quality remains weak: only 56 out of the 93 participating countries submit data regularly. In several cases, the data are of questionable accuracy owing, in part, to lack of experience of the respondents with oil market data. A comprehensive review of the data is expected to be undertaken during the first half of 2005.

The Extractive Industries Transparency Initiative (EITI), launched by the United Kingdom in 2003, is a multi-stakeholder initiative involving governments, companies, and NGOs that aims at voluntary disclosure of natural resource–related revenue by governments and payments by companies. The reconciliation and verification of government receipts and company payments is expected to substantially improve the accuracy of these data for participating countries. The initiative has led to increased awareness of the importance of transparency in this area. If major oil-producing countries become convinced that increased fiscal transparency is useful in their own resource management, this could have significant positive implications for the quality of global oil data.

The IMF is exploring ways to support the JODI through technical assistance to member countries on statistical legislation and organization. The IMF is also encouraging its members to embrace and accelerate their participation in the IMF's data-related initiatives. These include the Special Data Dissemination Standard (SDDS), the General Data Dissemination System (GDDS), Reports on the Observance of Standards and Codes on statistical data (data ROSCs), and the Coordinated Portfolio Investment Survey (CPIS). Through their focus on data transparency, the SDDS and GDDS could pave the way for better reporting and monitoring of oil reserves, production, and consumption by individual countries.

Besides the international initiatives, individual countries should take steps to contribute to improved oil data. Many national statistical agencies do not have adequate resources to comply with the increasing requirements on oil data, and new staff need to be trained in energy statistics production. Standard definitions and terminology are critical in obtaining data that are consistent internally and conceptually comparable across countries. Statistical laws need to be reviewed and strengthened to support data reporting, and links between industry and government need to be established to identify data reporting requirements.

- *Strengthening transparency*, particularly by improving the timeliness and reliability of data on oil demand, supply, and inventories, which are now very weak (Box 4.2). Improved data on available excess capacity and planned investment—particularly for OPEC producers—would also be helpful.
- *Participation in the hedging markets.* In principle, oil consumers and producers could protect themselves against increased volatility

by hedging on futures and derivative markets. Daniel (2001) shows that the oil producers (and the oil-rich governments) can use simple hedging techniques to diminish the oil price risk without significantly reducing return, with the added benefits of greater predictability and certainty. The study also finds that companies and governments often do not operate on the hedging markets because of the concerns about the possible political costs of hedging (i.e., failure to benefit from price rises), lack of institutional capacity, and limited market depth. The success story of the state of Texas and the positive experience of Mexico during the episode of market instability in the early 1990s suggest, however, that producers and oil-rich governments should explore possibilities for hedging their own price risk, especially given prospects for increased oil price volatility.[20]

- *Ensuring that taxation and regulatory frameworks are stable, transparent, and do not add to volatility.* Abrupt changes and unexpected raises in taxes and royalty rates should be avoided.[21] Regulatory issues—such as the differences in emissions regulations across U.S. states, as well as tight limitations on refinery investment—should also be reviewed.[22] Moreover, a shift from ad valorem to specific taxation of oil products would tend to reduce price volatility of end products.

Reducing Obstacles to Investment

As can be seen from the discussion above, securing adequate oil supplies and spare capacity would be one possible way of reducing volatility. That said, there are many obstacles to investment in the oil sector. Some of them, such as fluctuating world oil prices and political risks (including embargos) are exogenous to most oil producers. However, in many countries—both inside and outside OPEC—regulatory frameworks are an additional impediment. Some countries limit, or even forbid, participation of foreign investors in oil sector projects. While this may be seen as desirable in part for strategic reasons, it could lead to slower development of fields and reduce access to the latest technological advances, know-how, and financing (though well-defined service contracts can help mitigate these potential drawbacks). Investment by national oil companies is in some countries constrained by surrender requirements for oil revenues and by competing demands for social and infrastructure expenditures. Moreover, the access to external financing is often in such cases limited by a lack of transparency about financial performance. Making policy frameworks more friendly toward investment would be an important step toward creating conditions for further capacity expansion and ensuring orderly developments in the oil market.

Is There an Additional Role for Government?

Since high and volatile oil prices can have significant adverse spillovers for the economy at large, there is in principle an argument for government intervention to reduce volatility. While such arguments have to be assessed very carefully—not least because such measures can be expensive, and because government intervention can in practice have quite the reverse effect—three areas appear worth considering.

- *Both oil exporters and importers could benefit from increasing spare production capacity* (see Box

[20]For a more detailed analysis of hedging on commodities markets, see the April 2005 *Global Financial Stability Report.*

[21]For example, after recent tax changes that included an increase in export duties on crude oil and refined products, most oil companies in Russia make little additional profit when oil prices rise above $25 a barrel (IEA, 2004b).

[22]The lack of refining capacity has increased premia on easy-to-process light crudes with a negative impact on the light-crude oil importers. Moreover, to the extent that most of the incremental OPEC production has been of the heavy kind, bottlenecks in the refinery sector can impede stabilization of the crude oil market.

4.1). Countries highly dependent on oil imports could also consider protecting themselves from the risk of supply disruptions by gradually boosting strategic reserves, especially in the non-OECD region, where reserve ratios are currently low.[23] Enhanced consumer-producer dialogue would be helpful in striking the right balance between building spare capacity (with costs to oil producers) and building stocks (with costs to oil consumers).

- *Energy conservation remains a priority.* As noted above, oil intensity has been falling, partly in response to services-biased growth and price signals, but also reflecting explicit government policies such as energy taxes, efficiency standards, and support of public transport and alternative sources of energy. While faster reduction in oil intensity can require substantial up-front expenditures,[24] countries whose oil import dependency is expected to rise over the projection period should consider oil-saving measures very carefully.
- *Increased multilateral cooperation could also play a role,* both to facilitate understanding of oil market developments, and to move forward a number of the initiatives described above. The Joint Oil Data Initiative is a good example of what can be achieved through cooperation (see Box 4.2). Looking forward, enhanced dialogue between oil consumers and producers could bring benefits to all stakeholders as it would reduce the currently perceived risks of tight oil supplies or unexpected policy actions to curb long-term oil demand.

Appendix 4.1. Oil Market Prospects: Data and Modeling Strategy

The main authors of this appendix are Martin Sommer and Dermot Gately. Paul Atang provided research assistance.

The analysis in the main text of this chapter is based on three integrated models of oil demand, oil supply, and vehicle ownership. This appendix provides a description of each model.

Model of Oil Demand

Oil Demand Data

The model of oil demand is estimated separately for a panel of advanced economies, and for a panel of emerging markets and developing countries over 1971–2002 (a total of 51 countries).

- The first panel consists of the 30 OECD members and the three other newly industrialized economies (NIEs).[25]
- The second panel consists of 18 non-OECD emerging markets and developing countries. This group includes Argentina, Brazil, Chile,

[23]Some major non-OECD countries, including China and India, have been proactive on this front. However, any reserve accumulation would need to be well-timed to avoid additional demand pressures on the market. If all non-OECD countries decided to raise their emergency stocks by five days of annual consumption a year, this would represent additional demand of about 0.5 million barrels a day. According to Downstream B.V. Rotterdam, the necessary infrastructure could cost roughly $1.5 billion annually, or 0.02 percent of non-OECD gross domestic product at market exchange rates. OECD countries already have a significant amount of protection against supply disruptions as their emergency stocks cover over 110 days of net imports and the member governments have well-defined plans for emergency situations under the IEA framework.

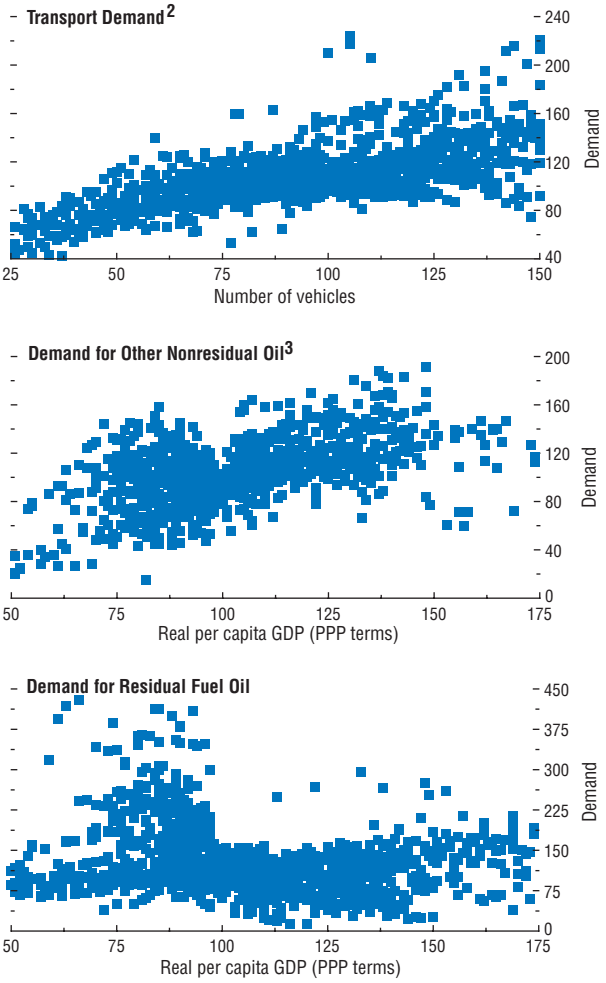
[24]IEA (2004b) estimates that OECD countries would need to invest about $30 billion annually (0.1 percent of GDP), and non-OECD countries would be required to invest about $10 billion annually (above 0.1 percent of GDP) to reduce oil intensity of their transport systems by 10 percent in 2030 beyond the efficiency gains projected by the IEA. The 10 percent efficiency gain would correspond to about 7 mbd world oil demand in the IEA Reference Scenario, currently valued at about $100 billion annually. The initial gains from adopting the more radical policies would be smaller—about one-third in 2010.

[25]The group of NIEs consists of Hong Kong SAR, Korea, Singapore, and Taiwan Province of China. Korea is also an OECD member.

Figure 4.9. Oil Demand in Advanced Economies[1]

(1971–2003; per capita, 1985 = 100)

Transport demand and demand for other nonresidual oil have been increasing in proportion to the number of vehicles and GDP, respectively. Residual fuel demand dropped off in the 1980s and has not on average recovered.



Sources: International Energy Agency; United Nations Statistical Yearbook; OECD analytical database; and IMF staff calculations.

[1]Advanced economies defined here as OECD countries and newly industrialized Asian economies (Hong Kong SAR, Singapore, and Taiwan Province of China). All variables were expressed in per capita terms and indexed for each country at 1985 = 100. Only data fitting the scale are shown.

[2]Transport demand is defined as consumption of gasoline, jet fuel, and gas/diesel oil (including light heating oil).

[3]Other nonresidual demand is defined as consumption of naphtha, liquefied petroleum gas, kerosene, and other products except residual fuel oil.

China, Colombia, the Dominican Republic, Ecuador, Egypt, Morocco, South Africa, Israel, India, Indonesia, Malaysia, the Philippines, Thailand, Pakistan, and the Syrian Arab Republic.

Oil demand is modeled for three different groups of products:

- transport demand, defined as consumption of gasoline, jet fuel, and gas/diesel oil;
- other nonresidual demand, which includes naphtha, liquefied petroleum gas, kerosene, and other products other than residual fuel oil; and
- residual (heavy) fuel oil.

Figures 4.9 and 4.10 illustrate the basic stylized facts about demand for the three product groups. The data for each country is expressed in per capita terms and indexed at 1985 = 100 to distinguish between the periods before and after adjustment of economies to the oil price shocks of the 1970s. Transport demand is in the long run strongly related to the number of vehicles, while the demand for other nonresidual products is correlated with the gross domestic product. Demand for residual fuel has been falling in advanced economies as many oil-based power generation plants switched to alternative fuels in the 1980s. Demand for the residual fuel oil continues to grow in some emerging markets and developing countries.

The measure of transport demand contains gas/diesel oil, whose subcomponents are diesel, light heating oil, and other gas oil. Light heating oil and other gas oil are not, strictly speaking, transport fuels. However, IEA does not provide decomposition of gas/diesel oil into its components for the period prior to 1993. Figure 4.2 in the main text is based on the strict definition of transport demand—that is, excluding light heating oil and other gas oil. All other calculations and projections consider all gas/diesel fuels as transport fuels.

Oil Price Data

The estimation was carried out with two alternative measures of historical oil prices: end-user

prices and the U.S. refineries crude oil acquisition cost. The advantage of using end-user prices is that they capture changes in taxation, transport costs, and refiner's margins over time. However, the series is available on a consistent basis only for a subgroup of 11 OECD countries. The oil prices are expressed in U.S. dollar terms. Estimation results change only marginally when prices are expressed in local currency. Using the U.S. dollar prices simplifies oil demand projections.

Equation Specification

The estimated equation for *transport demand* takes the following form:

$$D_{i,t}^{transport} = k_{1\,i} + \mu V_{i,t} + \beta_{T,m} P_{max,t-1} + \beta_{T,d} P_{decline,t-1} + \beta_{T,r} P_{recovery,t-1} + \varepsilon_{i,t},$$

where $D_{i,t}^{transport}$ is the natural logarithm of transport demand per capita in country i at time t; $V_{i,t}$ denotes the log of number of vehicles per capita in country i at time t; P_{max} denotes the natural logarithm of historical real oil price maximum; $P_{decline}$ denotes cumulative decreases in the natural logarithm of real oil price; and $P_{recovery}$ denotes cumulative increases in the logarithm of real oil price. For simplicity, transport demand is modeled only as a function of vehicles and prices; business cycle fluctuations in utilization are abstracted from in this medium-term model. The decomposition of prices into the three elements follows the approach of Gately and Huntington (2002). This approach helps to distinguish between the impact of large and small price changes on oil demand, and test for any asymmetries between the impact of price increases and price decreases. Figure 4.11 illustrates how the decomposition is made in practice. Formally, the decomposition can be characterized as follows (all variables are expressed in natural logarithms):

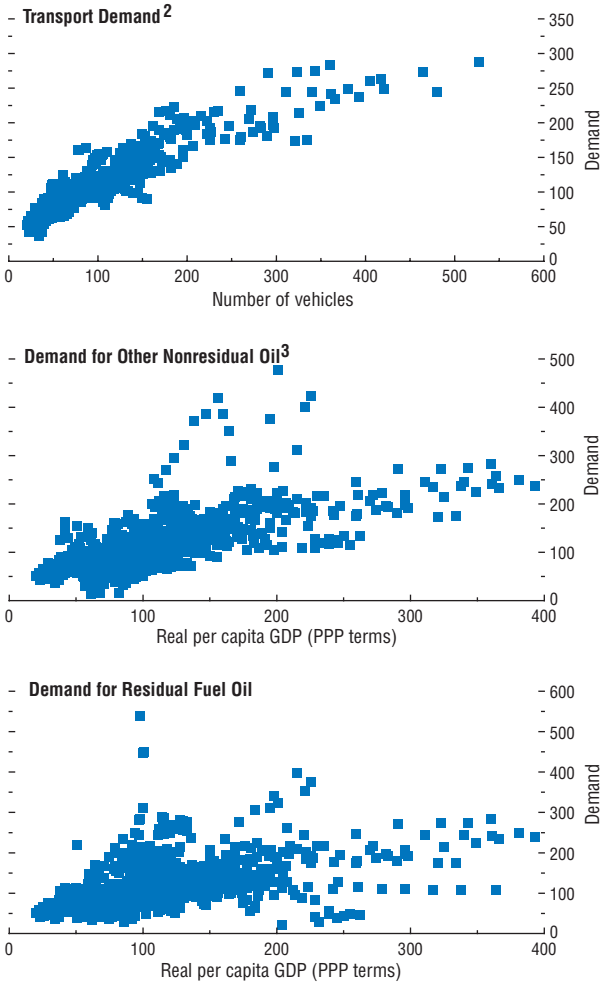
$$P_t = P_{max,t} + P_{decline,t} + P_{recovery,t}$$

$$\text{if } P_t \geq P_{max,t} : P_{max,t} = P_t; \text{ otherwise } P_{max,t} = P_{max,t-1}$$

Figure 4.10. Oil Demand in Emerging Market and Developing Countries[1]

(1971–2002; per capita, 1985 = 100)

As in advanced economies, transport and other nonresidual demand have been increasing steadily. Unlike in OECD countries, demand for residual fuel continues to grow on average.



Sources: International Energy Agency; OECD analytical database; United Nations Statistical Yearbook; and IMF staff calculations.

[1]This group of countries includes Argentina, Brazil, Chile, China, Colombia, Dominican Republic, Ecuador, Egypt, Morocco, South Africa, Israel, India, Indonesia, Malaysia, Philippines, Thailand, Pakistan, and Syrian Arab Republic. All variables were expressed in per capita terms and indexed for each country at 1985 = 100. Only data fitting the scale are shown.

[2]Transport demand is defined as consumption of gasoline, jet fuel, and gas/diesel oil (including light heating oil).

[3]Other nonresidual demand is defined as consumption of naphtha, liquefied petroleum gas, kerosene, and other products except residual fuel oil.

if $P_t < P_{max,t}$ and $P_t < P_{t-1}$: $P_{decline,t} = P_{decline,t-1} + (P_t - P_{t-1})$; otherwise $P_{decline,t} = P_{decline,t-1}$

if $P_t < P_{max,t}$ and $P_t > P_{t-1}$: $P_{recovery,t} = P_{recovery,t-1} + (P_t - P_{t-1})$; otherwise $P_{recovery,t} = P_{recovery,t-1}$.

The equation for *other nonresidual oil* takes the following form:

$$D_{i,t}^{other} = k_{2i} + \gamma Y_{i,t} + \beta_{NT,m} P_{max,t-1} + \beta_{NT,d} P_{decline,t-1} + \beta_{NT,r} P_{recovery,t-1} + \eta_{i,t},$$

where $D_{i,t}^{other}$ is the natural logarithm of other nonresidual oil demand per capita in country i at time t; and $Y_{i,t}$ denotes the log of real purchasing power parity GDP per capita in country i at time t.

No equation for *residual fuel oil* was estimated.

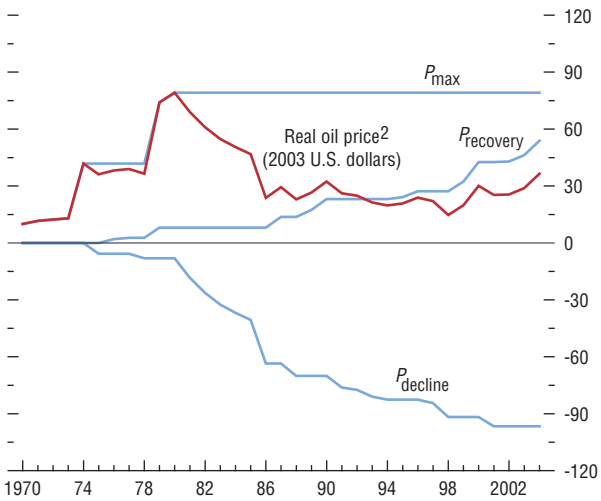
Estimation Results

Table 4.6 presents the estimation results. The coefficients on vehicles and income in the demand equations are all highly statistically significant. Large negative coefficients on the P_{max} price term suggest that oil consumption in OECD countries responded strongly to the price shocks of the 1970s. The estimated elasticities are particularly high when using the end-user prices. By contrast, the oil consumption in developing countries did not seem to respond much since the P_{max} variable was insignificant. Therefore, only results for a specification without the three-way decomposition of prices is reported for the panel of developing countries. The estimation results suggest that price elasticity of oil demand is small for minor price fluctuations. Overall, the econometric estimates are qualitatively similar to the evidence presented in Gately and Huntington (2002).

The estimation results should be interpreted with two caveats: the estimated relationships capture only the long-run dynamics of oil demand; and, as discussed in the main text of this chapter, the parameter values embed historical trends in oil intensity in the form of reduced estimates of income and vehicle elasticities.

Figure 4.11. Decomposition of Oil Price Movements
(1970–2004)

Movements in the real price of oil can be decomposed into three components: historical maximum (P_{max}), cumulative increases ($P_{recovery}$), and cumulative decreases ($P_{decline}$).[1]



Source: IMF staff calculations.
[1]Current oil price P_t equals the sum of $P_{max,t}$, $P_{decline,t}$, and $P_{recovery,t}$.
[2]Simple average of West Texas Intermediate, Brent, and Dubai oil prices.

Table 4.6. Estimated Demand Elasticities

	Transport Demand			Other Nonresidual Demand		
	OECD 11	OECD and NIEs	Other non-OECD	OECD 11	OECD and NIEs	Other non-OECD
GDP				0.63**	1.10**	0.73**
Vehicles	0.70**	0.51**	0.55**			
Crude oil price			−0.07**			−0.10**
Crude oil price (max)		−0.10**			−0.09**	
Crude oil price (decline)		−0.03			−0.01	
Crude oil price (recovery)		—			−0.06*	
End-user price (max)	−0.50**			−0.48**		
End-user price (decline)	−0.03			−0.14**		
End-user price (recovery)	−0.11**			−0.07		

Source: IMF staff estimates.
Note: Oil demand, gross domestic product, and vehicles are expressed in per capita terms. ** and * denote significance at the 1 and 5 percent level, respectively. Crude oil price (max) denotes the maximum historical real price. Price (decline) denotes cumulative decrease, while price (recovery) denotes cumulative increase in real price. Regressions contain country-specific constants.

Calibration of Elasticities in the Oil Demand Model

The choice of elasticities for demand projections was closely linked to the estimated coefficients. The calibrated parameters are reported in Table 4.7. The demand for residual fuel oil was calibrated based on an expert judgment.

Main Assumptions Underlying Oil Demand Projections

Long-term projections of oil demand are sensitive to assumptions about economic growth and efficiency improvements. Sensitivity to price is a less important factor for small price changes.

Economic Growth

The average world growth rate is 3.6 percent in PPP terms over 2003–30, and 3.0 percent at market exchange rates. GDP projections set out in the September 2004 *World Economic Outlook* were used for 2004–09. For 2010–30, we used the U.S. Department of Energy (DoE) *International Energy Outlook April 2004* projections. An adjustment was made to the DoE growth projection for China and India. In both cases, the long-term growth rates were reduced by 1 percentage point. The adjustment was made for two reasons: to build in a conservative bias into the oil demand projections for Asia and to reduce the PPP-weighted world growth rate closer to its historical average.

The sensitivity analysis in the middle panel of Figure 4.6 is based on a model where growth rates for each country are higher or lower by 0.5 percentage point annually over 2004–30. The projected demand is 91.3–92.9 mbd in 2010 (compared with the baseline of 92.0 mbd), and 133.2–144.6 mbd (compared with the baseline of 138.5 mbd).

Table 4.7. Demand Elasticities Used for Projections

	Transport Demand		Other Nonresidual Demand		Residual Fuel Demand	
	OECD and NIEs[1]	Other non-OECD	OECD and NIEs[1]	Other non-OECD	OECD and NIEs[1]	Other non-OECD
GDP	. . .	. . .	0.6	0.7	—	0.3
Vehicles	0.6	0.55	. . .	. . .	. . .	. . .
World oil price	−0.1	−0.1	−0.3	−0.1	−0.1	−0.1

Source: IMF staff calculations.
[1]Newly industrialized Asian economies (NIEs) include Hong Kong SAR, Korea, Singapore, and Taiwan Province of China. Korea is also an OECD member.

Baseline Price Path

The baseline price path is the *World Economic Outlook* forecast of the simple average of West Texas Intermediate, Brent, and Dubai oil prices. The average is expected to fall in nominal terms from $46.5 in 2005 to $38.8 a barrel in 2010. The series is converted into constant 2003 prices assuming annual inflation of 2 percent. The real price of oil therefore falls from estimated $44.7 in 2005 to $33.7 a barrel in 2010, and is assumed to stay constant at this level until 2030.

The sensitivity analysis in the bottom panel of Figure 4.6 is based on a model where real prices are assumed constant at either $25 or $45 a barrel over 2005–30. The projected demand is 89.3–95.2 mbd in 2010 (compared with the baseline of 92.0 mbd), and 133.7–144.0 mbd (compared with the baseline of 138.5 mbd).

Efficiency Gains

The demand model was estimated over a period of significant declines in oil intensity, in both advanced and developing countries. The estimated coefficients, therefore, carry over the historical trend in efficiency gains into the projection.

The actual future improvements in oil intensity could be different from the ones estimated from the historical data. Services-biased growth in the advanced countries, graduation of some developing countries and emerging markets into the group of advanced countries, and government policies to promote energy efficiency could all reduce oil intensity beyond the projected gains (1.6 percent annually for advanced countries and 1.1 percent for the other economies). By contrast, the baseline oil price remains in real terms well below the historical maximum in the 1970s, which was one of the main triggers of the past technological adjustment. A detailed assessment of efficiency gains taking into account forward-looking trends and policies would be beyond the scope of this study.

Oil Demand Projection

Oil demand is projected for each of 51 countries in the sample. The projections were converted from per capita terms to overall levels using population data from the United Nations. Various simplifying assumptions are taken for countries that are not in the estimation sample.

The first projection year of the model is 2004. The actual growth in 2004 demand was unexpectedly strong and overperforms the model. Moreover, most industry analysts expect demand growth to be strong again in 2005. In reconciling the model's forecasts with actual data, it is assumed that 2004–05 is a period of unusually strong oil demand and that, by 2010, oil demand will gradually converge to the path predicted by the model. In all figures in the main text, the oil demand data for 2004 and 2005 are the *IEA Oil Market Report* estimates from January 2005.

Model of Oil Supply

Non-OPEC Supply

Non-OPEC oil supply is defined as total non-OPEC output plus world output of nonconventional oil and processing gains. The lower bound projection corresponds to the forecast of non-OPEC output path from the IEA *World Energy Outlook 2004*. The upper bound projection is a forecast of the DoE from *International Energy Outlook April 2004*. Since the baseline IMF, IEA, and DoE price paths are different, the methodology of Gately (2004) is used to adjust the IEA and DoE paths:

$$S_t^{non\text{-}OPEC,adj.} = S_t^{non\text{-}OPEC,IEA}\left(\frac{S_{t-1}^{non\text{-}OPEC,adj.}}{S_{t-1}^{non\text{-}OPEC,IEA}}\right)^{1-\alpha}\left(\frac{P_t^{IMF}}{P_t^{IEA}}\right)^{\alpha},$$

where α captures elasticity of non-OPEC supply. Following Gately (2004), the parameter is calibrated at 0.03, which for permanent price changes implies the long-run elasticity of supply of about 0.5 (by 2030). For comparison, Moroney and Berg (1999) estimate the long-

term elasticity of oil with respect to real price at 0.1–0.2, while Dahl and Duggan (1996) estimate it at 0.6 using the U.S. data. At baseline prices, the IMF upper- and lower-bound projections of non-OPEC supply in Table 4.5 are higher by about 8 mbd than DoE and IEA projections in Table 4.4.

OPEC's Incentives to Increase Output

This section evaluates OPEC capacity expansion strategies in a profit-maximization framework. The methodology follows Gately (2004, 2005). Gately's model calculates OPEC profits for various target market shares, and solves for the associated market-clearing prices together with oil demand and non-OPEC supply. The different market shares are then ranked based on the discounted net present value of profits (the required real rate of return is assumed at 5 percent).

The baseline version of the model was calibrated using parameter values estimated in this chapter but the actual simulation was carried out over 50 alternative parameter sets. In the model, OPEC's decision to increase output is mainly based on the price elasticity of demand, elasticity of non-OPEC supply, and investment costs. The higher the elasticities of demand and non-OPEC supply, the higher the incentive of OPEC to avoid high oil prices. When the real oil price exceeds $63 a barrel (this is the historical maximum of the real U.S. refineries crude oil acquisition cost), oil demand of OECD is assumed to become highly responsive to price with elasticity of –0.5. The investment costs are twofold: the capacity expansion cost is assumed at about $4,000–6,000 a barrel of incremental daily capacity; and the investment to offset natural declines in fields is approximated at 5 percent of total capacity, evaluated also at $4,000–6,000 a barrel, depending on the country. The latter assumption is important because the costs of maintaining capacity can over time be much larger than current investment.

The results presented in Figure 4.8 suggest that the optimal strategy for OPEC is to let its market share grow slowly, to about 41–46 percent by 2030. This is well below the share implied by the baseline projection in Table 4.5. In the baseline scenario, the call on OPEC was predicted at 61.3–74.4 mbd and oil demand at 138.5 mbd in 2030. The implied long-term OPEC market share was therefore up to 54 percent. But the simulation results suggest that OPEC may lack incentives to increase its market share from the current 39 percent to as much as implied by the baseline scenario.

The model solves for the price path associated with the profit-maximizing solution. In 2030, the price range is $39–56 a barrel expressed in 2003 dollars (compared with the baseline of $33.7). Total oil demand is in the range of about 126–134 mbd in 2030 and the OPEC supply is between 52 and 59 mbd, depending on the parameter set.

Model of Vehicle Ownership

For the purposes of this chapter, vehicles are defined according to the UN methodology; the main components are motor cars seating less than eight persons, trucks, buses, and tractors.

The relationship between vehicle ownership and income in Figure 4.7 suggests that income per capita is the main determinant of vehicle ownership across time and across countries. The relationship is highly nonlinear: vehicle ownership grows very slowly at low and high income levels; but grows at much faster rates than income when countries reach per capita income of about $2,500 dollars in PPP terms.

The estimation methodology follows closely Dargay and Gately (1999) except that the PPP-adjusted GDP is used as a measure of income. The model is also estimated over a broader set of countries and contains 10 most recent annual observations for each country (the actual sample is 1971–2002).

The estimated equation is

$$V_{i,t} = (1 - \theta)\, V_{i,t-1} + \theta(\gamma e^{\alpha e^{\beta_i Y_{i,t}}}) + \upsilon_{i,t},$$

where $V_{i,t}$ is the number of vehicles per 1,000 people; $Y_{i,t}$ denotes the real PPP-adjusted

Table 4.8. Vehicle Ownership and Income

Estimated equation: $V_{i,t} = (1 - \theta)V_{i,t-1} + \theta\,(\gamma e^{\alpha e^{\beta_i Y_{i,t}}}) + \upsilon_{i,t}$

Parameter	Value	Country Group
γ	850	Calibrated parameter
θ	0.062**	All
α	−5.513**	All
β_1	−0.221**	United States, Canada, Australia, New Zealand, Taiwan Province of China
β_2	−0.153**	Austria, Belgium, Denmark, France, Finland, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, United Kingdom
β_3	−0.188**	Chile, Czech Republic, Hungary, Poland, Portugal, Slovakia, South Africa, Spain
β_4	−0.158**	Argentina, Brazil, China, Colombia, Dominican Republic, Ecuador, Egypt, India, Indonesia, Malaysia, Mexico, Morocco, Pakistan, Syria, Thailand
β_5	−0.174**	Japan, Korea
β_6	−0.045	Hong Kong SAR, Singapore

Source: IMF staff estimates.
Note: **denotes significance at the 1 percent level.

income per capita; γ represents the saturation level for vehicle ownership (calibrated at 850 vehicles per 1,000 people in line with Dargay and Gately, 1999); θ is the speed of adjustment to the desired vehicle level; α is related to the speed of vehicle ownership growth at high incomes; and β is related to the speed of vehicle ownership growth at low income levels (β is allowed to vary across countries to allow for different speed of vehicles penetration).

The coefficient estimates together with the country groupings are reported in Table 4.8. All coefficients are highly statistically significant with the exception of β for Hong Kong SAR and Singapore, where vehicle ownership grows very slowly owing to geographical factors and restrictive regulatory frameworks.

Urbanization and population density were not significant in the estimated equation as income per capita already explains a large fraction of vehicle ownership variability. The example of Hong Kong SAR and Singapore illustrates that the geographical and institutional factors can to some extent be captured by allowing β to vary across countries.

Table 4.9 presents vehicle projections in absolute as well as per capita terms. China was for the purposes of vehicle projections split into three regions according to their current level of per capita income (high-, middle-, and low-

Table 4.9. Vehicle Ownership Projections

	Millions of Vehicles				Per 1,000 People			
	2002	2010	2020	2030	2002	2010	2020	2030
World	751	939	1,255	1,660	. . .	. . .	. . .	. . .
OECD	625	720	827	920	. . .	. . .	. . .	. . .
United States	234	260	288	312	812	826	837	843
Germany	48	54	60	63	586	655	725	774
France	35	40	46	50	576	650	725	777
Italy	37	39	41	41	656	697	752	793
United Kingdom	31	37	44	50	515	616	711	771
Japan	76	87	95	96	599	682	753	796
Korea	14	22	31	36	293	442	610	718
Australia	12	15	18	19	632	715	778	812
Other OECD	137	164	205	252	. . .	. . .	. . .	. . .
Non-OECD	126	219	429	741	. . .	. . .	. . .	. . .
Africa	11	15	23	33	. . .	. . .	. . .	. . .
Brazil	21	27	42	71	121	139	200	320
Other Latin America	12	19	33	54	. . .	. . .	. . .	. . .
China	21	80	209	387	16	59	146	267
Other Asia	58	72	113	184	. . .	. . .	. . .	. . .
Rest of world	4	6	8	11	. . .	. . .	. . .	. . .

Sources: United Nations Yearbook; and IMF staff calculations.
Note: Vehicles are defined according to the United Nations methodology; the main components are motor cars seating less than eight persons, trucks, buses, and tractors.

income regions). Income growth rate was assumed to be the same in all three regions. Given the current data on vehicle stock by provinces, a separate vehicle forecast was prepared for each region, and then aggregated into the total for China.

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