CHAPTER 3

OIL SCARCITY, GROWTH, AND GLOBAL IMBALANCES

The persistent increase in oil prices over the past decade suggests that global oil markets have entered a period of increased scarcity. Given the expected rapid growth in oil demand in emerging market economies and a downshift in the trend growth of oil supply, a return to abundance is unlikely in the near term. This chapter suggests that gradual and moderate increases in oil scarcity may not present a major constraint on global growth in the medium to long term, although the wealth transfer from oil importers to exporters would increase capital flows and widen current account imbalances. Adverse effects could be much larger, depending on the extent and evolution of oil scarcity and the ability of the world economy to cope with increased scarcity. Sudden surges in oil prices could trigger large global output losses, redistribution, and sectoral shifts. There are two broad areas for policy action. First, given the potential for unexpected increases in the scarcity of oil and other resources, policymakers should review whether the current policy frameworks facilitate adjustment to unexpected changes in oil scarcity. Second, consideration should be given to policies aimed at lowering the risk of oil scarcity.

After a year and a half of global recovery, natural resources are again in the headlines. The spot price of a barrel of Brent crude oil crossed the US$100 threshold in January 2011. The prices of many other commodities have risen to meet or surpass their precrisis peaks, and commodity futures markets point to further price increases in the next year or two. Commodity price strength mirrors buoyancy on the demand side. Consumption levels of many natural resources, including crude oil, have already risen above precrisis peaks, largely reflecting robust demand in emerging and developing economies.

At current high levels, commodity price developments and prospects can have important global economic repercussions (see Chapter 1). The possibility that rising energy prices will spill over into core inflation is just one example. But how unusual is the current situation? There are important linkages between global economic conditions and commodity prices, and large fluctuations in commodity prices over the global cycle are nothing new.[1] Cyclical factors and special factors seem to explain much recent commodity price behavior. Nevertheless, persistent commodity price increases in recent years point to a break with the experience of the 1980s and 1990s as well as with the experience of earlier commodity price booms.[2] Concern about resource scarcity is more widespread now than a decade or two ago.

This chapter considers the case of oil scarcity.[3] The main motivation is twofold. On the one hand, oil market prospects are central to the global economic outlook—the oil price assumption is one of the key assumptions underlying the forecasts in the *World Economic Outlook* (WEO). On the other hand, there is considerable uncertainty about how strong the tension will be between rapid growth in oil demand in emerging market economies and the downshift in oil supply trends. The baseline oil market outlook discussed in Chapter 1, which is based on current oil market pricing, assumes that the tension will be resolved with oil prices around current high levels.

Against this backdrop, this chapter analyzes the risks presented by several oil scarcity scenarios for the global outlook and the transition to a more robust and balanced global expansion. As indicated by the emphasis on scarcity, the focus is on the medium to long term, not on short-term risks.

Specifically, this chapter seeks to answer the following questions:

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[1]See Vansteenkiste (2009), Kilian (2009), or Helbling (forthcoming).

[2]See, for example, Radetzki (2006), who notes that earlier commodity price booms in the post–World War II period were short-lived.

[3]Appendix 2 of Chapter 1 provides an overview of recent developments and prospects for other commodities.

- What is oil scarcity? How is it measured? What is its current status?
- Will oil scarcity constrain the global economy in the medium to longer term? What are the risks that it will lower the feasible rate of global growth? Could it widen global imbalances?
- What are the policy implications?

A discussion of oil scarcity faces the challenge of any forward-looking analysis. Experience to date does not allow for strong predictions about the likely evolution of some of the factors that will determine the eventual extent and impact of oil scarcity. For example, technological developments will be crucial. These will affect the cost of extracting oil from reservoirs or deposits so far deemed uneconomical and will define the scope for efficiency and substitution. In the face of such uncertainty, which increases with the time horizon, the key objective of this chapter is to illustrate the potential global economic impact of various oil scarcity scenarios. At the same time, it marks the beginning of renewed efforts to give greater consideration to the role of oil and other natural resources in the IMF's modeling of the global economy, both as the source of shocks and in the transmission of other shocks.

What Are the Main Findings?

- The increases in the trend component of oil prices suggest that the global oil market has entered a period of increased scarcity. The analysis of demand and supply prospects for crude oil suggests that the increased scarcity arises from continued tension between rapid growth in oil demand in emerging market economies and the downshift in oil supply trend growth. If the tension intensifies, whether from stronger demand, traditional supply disruptions, or setbacks to capacity growth, market clearing could force price spikes, as in 2007–08.
- As for the effects on the global economy, the simulation analysis suggests that the impact of increased oil scarcity on global growth could be relatively minor if it involves primarily a gradual downshift in oil supply growth rather than an absolute decline. In particular, a sizable downshift in oil supply trend growth of 1 percentage point appears to slow annual global growth by less than ¼ percent in the medium and longer term. On the other hand, a persistent decline in oil supply levels could have sizable negative effects on output even if there is greater substitutability between oil and other primary energy sources. At the same time, in the medium term, the oil-induced wealth transfer from oil importers to exporters can increase capital flows, reduce the real interest rate, and widen current account imbalances.
- The analysis in this chapter suggests that oil scarcity will not inevitably be a strong constraint on the global economy. However, the risks it poses should not be underestimated either. Much will ultimately depend on the extent and evolution of oil scarcity, which remain uncertain. There is a potential for abrupt shifts, which would have much larger effects than more gradual shifts.
- The chapter concludes that policymakers should strengthen measures to reduce the risks from oil scarcity as a precautionary step and to facilitate adjustment if such shifts are larger than expected or materialize in an abrupt manner. Policies need to be complemented with efforts to strengthen social safety nets, because higher oil prices could lead to shifts in income distribution and to increased poverty.

This chapter is organized as follows. The first section defines oil scarcity, considers the extent of scarcity in the oil sector, and discusses the implications for the oil market outlook. The second section examines the effects of oil scarcity on global growth and global imbalances to determine whether it will constrain the global economy. The last section outlines some policy implications.

Has Oil Become a Scarce Resource?

The implications of oil scarcity could be important and far-reaching. Oil is a key factor of production, including in the production of other commodities and in transportation, and is also a widely used consumption good. Oil is the most traded commodity, with world exports averaging US$1.8 trillion annually during 2007–09, which amounted to about 10 percent of total world exports in that period. This means that changes in oil market conditions have direct and indirect effects on the global economy, including on growth, inflation, external balances, and poverty. Since the late 1990s, oil prices have generally risen—notwithstanding cyclical fluctuations—and supply constraints are widely perceived to have contributed to this trend. This has raised concerns that the oil market is entering a period of increased scarcity.

What Is Oil Scarcity?

Oil is considered scarce when its supply falls short of a specified level of demand. If supply cannot meet demand at the prevailing price, prices must rise to encourage more supply and to ration demand. In this sense, oil scarcity is reflected in the market price.

The price should reflect the opportunity cost of bringing an additional barrel of oil to market. It compensates the reserve owner for the cost of extraction and for the loss of one barrel of reserves that could have been sold in the future. In general, a high price level relative to the prices of other goods and services indicates scarcity, a low price indicates abundance, and changes in price over long periods signal changes in scarcity. Well-known models of commodity extraction also imply that the market price generally serves as a reliable guide to the opportunity cost, including the cost relative to expected future scarcity.[4]

In practice, it is important to distinguish between scarcity and other reasons for high oil prices. Scarcity usually refers to the declining availability of oil or other exhaustible natural resources in the long term. However, oil scarcity in the sense of high and increasing oil prices can also arise for other reasons over shorter horizons. Temporary supply shocks, for example, can lead to short-lived price spikes, as during the 1990–91 Gulf War. There can also be large cyclical fluctuations in oil prices, which largely reflect the interaction between cyclical—including some financial—factors and low short-term price elasticities of demand and supply.

[4]Hotelling (1931) shows that the price increases for a nonrenewable resource should track the interest rate (possibly including a risk premium) if marginal extraction costs remain constant. When the market learns gradually that a resource is becoming more scarce (or abundant), its price may rise at a faster pace (or remain flat or even decline).

Declining oil availability typically reflects technological and geological constraints or a shortfall in the required investment in capacity. Oil scarcity can be exacerbated by its low substitutability. Oil has unique physical properties that make rapid substitution difficult, meaning that the price may be determined largely by supply capacity. In contrast, if other, more abundant natural or synthetic resources can eventually replace oil in the production process, then relatively small increases in prices may redirect demand toward these substitutes.

How Do We Measure Scarcity?

The following analysis focuses on long-term oil price developments as an indicator of scarcity and ignores short-term or periodic fluctuations such as the business cycle. Oil prices may also be subject to "super cycles" caused by long implementation lags for discovery, exploration, and capital investment in minerals industries (Cuddington and Jerrett, 2008). Sluggish supply responses to shifts in demand can then give rise to price cycles with a longer duration than the typical two- to eight-year business cycle (Slade, 1982).

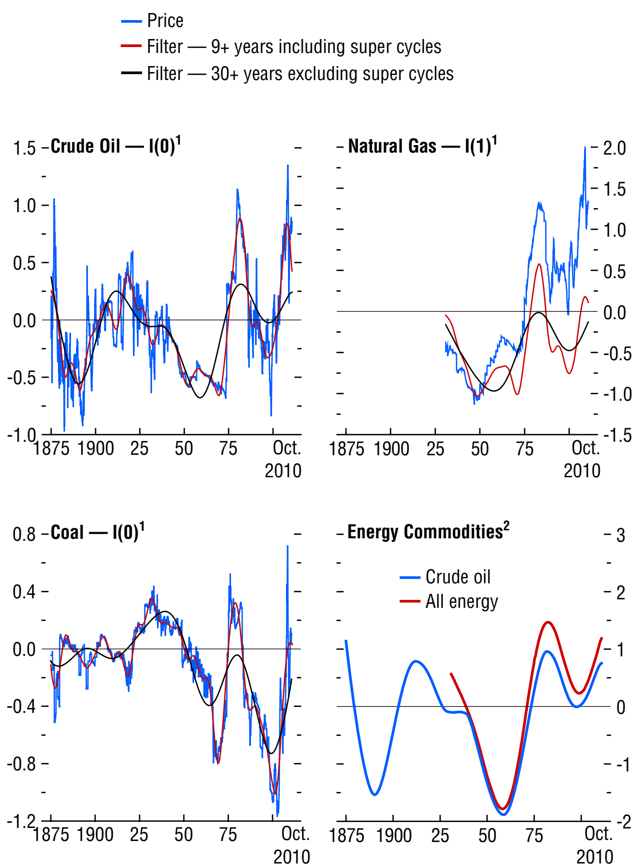
Long-term variation is assessed by passing prices through two low-pass filters: the first filter excludes all price fluctuations with a cycle period of less than nine years (and therefore includes super cycles); the second considers periods of more than 30 years (Figure 3.1).[5] Including super cycles generates more volatility but similar long-term trends. To provide a broader perspective on energy markets, coal and natural gas are included in the analysis. One noticeable result is that real oil prices have not trended persistently up or down throughout the sample period.[6] Instead, prices have experienced slow-

[5]This analysis uses U.S. dollar price series deflated by the U.S. consumer price index over sample periods with starting dates going back to 1875. Low-frequency components were extracted by a Christiano-Fitzgerald (2003) asymmetric filter (see Appendix 3.1).

[6]In other words, real oil prices are stationary. Where prices are nonstationary, as in the case of natural gas, and follow a unit root process, the drift, or long-term trend, is typically small. This is consistent with the findings of Cashin, McDermott, and Scott (2002), who note that trends in real commodity prices are small and dominated by price variability.

Figure 3.1. Energy Prices and Long-Term Price Trends

Following a period of increasing abundance during the 15 years through 2000, an upturn in long-term prices is evident across energy commodities.



Sources: Global Financial Data; IMF Primary Commodity Price System; and IMF staff calculations.

[1]U.S.-dollar-denominated commodity prices are deflated by the U.S. consumer price index in log deviations from the sample mean. Deviation between filtered components and price is accounted for by noise, business cycle frequencies, and random walk drift where I(1).

[2]First-principal component (standard deviation from mean) normalized to have unit variance.

moving fluctuations around long-term averages. This suggests that periods of changing oil scarcity have been long-lasting but have come to an end, and that investment, technology, and discovery are eventually responsive to price signals.

Following a period of increasing abundance during the 15 years through 2000, an upturn in long-term prices is evident across energy commodities. The first principal component of the three filtered energy prices—which accounts for about two-thirds of total variance—confirms that the common factor in energy scarcity has been rising since 2000 and was not interrupted by the Great Recession (bottom right panel).

What Lies behind the Apparent Increase in Oil Scarcity?

In the end, the signal from oil prices should reflect expectations of scarcity that must be considered in terms of underlying fundamentals. Understanding the signal from current market prices requires considering the prospects for demand and supply. Prospects for oil, as well as for other energy sources, are related strictly to primary energy demand. Therefore, this section first considers oil in the broader context of primary energy consumption before focusing on the supply and demand prospects for oil.

What are the prospects for overall energy consumption?

Oil is the most important source of primary energy in the world, accounting for about 33 percent of the total; the other two main fossil fuels, coal and natural gas, account for 28 and 23 percent, respectively.[7] Renewable sources of energy are in a rapid growth phase, but they still account for only a small fraction of primary energy supply.

The context for much of the current concern about oil scarcity is the increase in the growth rate of global primary energy consumption in the past decade (Figure 3.2, top panel). This acceleration

[7]See U.S. Energy Information Administration (EIA), *International Energy Outlook*, 2009. Primary energy includes fossil fuels (coal, oil, natural gas); nuclear energy; and renewable energy (geothermal, hydropower, solar, wind).

primarily reflects an upward shift in the growth of energy consumption in China. As a result, China's share of world consumption of primary energy has risen rapidly (bottom panel), and China is now the largest energy consumer in the world (International Energy Agency—IEA, *World Energy Outlook,* 2010).

Future energy consumption will depend largely on the impact of continued rapid GDP growth in China and other fast-growing emerging market economies. To gauge the prospects for energy demand, the analysis in this section focuses on the relationship between per capita energy consumption and per capita real income and is based on a simple regression using a data set for 55 economies during 1980–2008 (see Appendix 3.2 for details).

The estimates suggest that the relationship between per capita energy consumption and per capita GDP is nonlinear. High-income economies can sustain GDP growth with little if any increase in energy consumption. Indeed, for some countries in the Organization for Economic Cooperation and Development (OECD), energy consumption has been flat in recent years (Figure 3.3). In contrast, in low- and middle-income economies energy demand growth has closely followed growth in per capita income. The income elasticity of energy demand is close to unity: a 1 percent increase in real per capita GDP is associated with a 1 percent increase in per capita energy consumption. The experience of Korea exemplifies this one-to-one relationship. China's energy demand has so far closely followed this pattern (Figure 3.4).

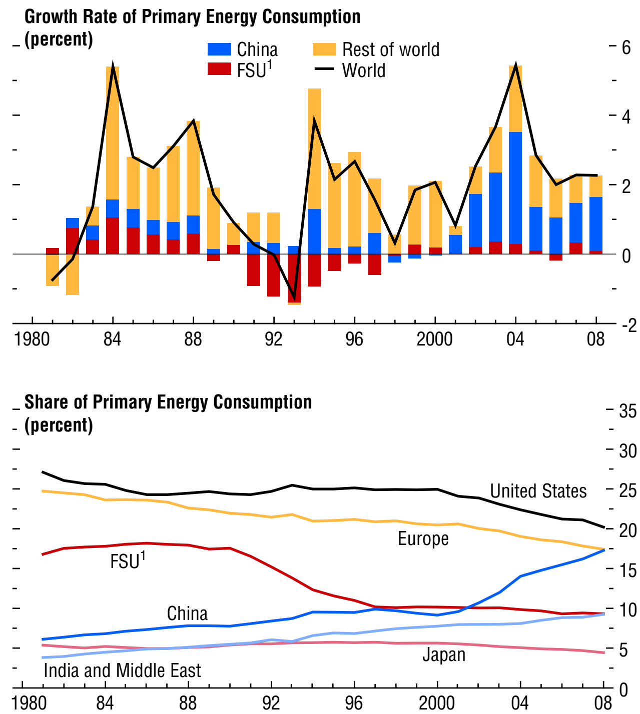
Given the empirical relationship estimated above and the most recent WEO forecast for China's per capita GDP, at current energy prices energy consumption in China is projected to double by 2017 and triple by 2025 from its 2008 level. But it remains to be seen whether China will be able to sustain such rapid growth. In fact, unlike Korea, China affects world market prices for primary energy sources, and rising prices might restrain economic growth and/or lead to a downward shift in the relationship between energy and income.

What are the prospects for oil demand?

GDP growth has been a major driver of oil demand in emerging market economies. Figure

Figure 3.2. Global Energy Demand, 1980–2008

The rapid increase in global primary energy consumption, particularly in China, has raised concerns about oil scarcity.

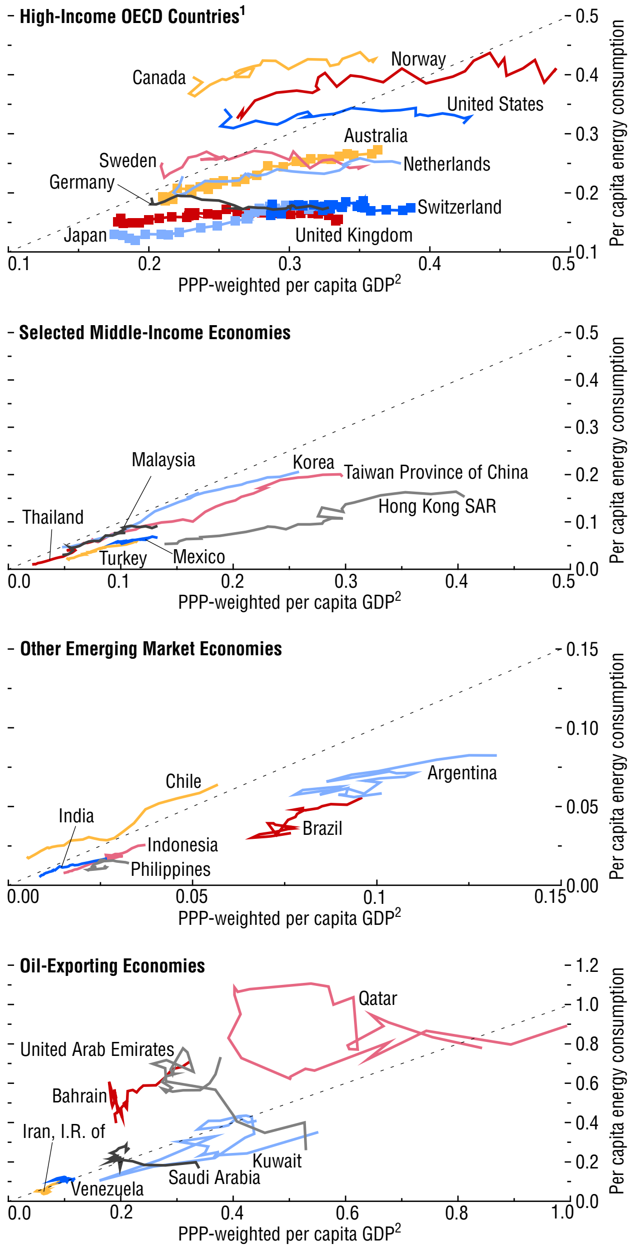


Source: International Energy Agency.
[1]FSU = former Soviet Union.

Figure 3.3. Relationship between per Capita Energy Consumption and GDP Growth

(Hundred thousands of 2005 U.S. dollars on x-axis; billions of British thermal units on y-axis)

Energy demand growth has closely followed growth in per capita income in low- and middle-income economies, whereas high-income economies can sustain GDP growth with little if any increase in energy consumption.



Sources: IMF, *International Financial Statistics;* International Energy Agency; World Bank, *World Development Indicators;* and IMF staff calculations.
[1]OECD = Organization for Economic Cooperation and Development.
[2]PPP = purchasing power parity.

3.5 shows how per capita oil consumption in the United States and other OECD economies has been broadly flat since the early 1980s, while it has risen rapidly in China. As a result, China's share in global oil consumption rose from 6 percent in 2000 to close to 11 percent in 2010. However, starting from a lower base, China's oil consumption is still only half as large as that of the United States (bottom panel).[8]

To gauge oil scarcity prospects, we first estimate oil consumption elasticities using a panel data approach.[9] Specifically, per capita oil consumption is regressed on its lagged value, real oil prices in local currency, a polynomial in real per capita GDP levels, the GDP growth rate, and a set of fixed effects (see Appendix 3.2). The data set starts in 1990 and includes 45 countries. The sample is divided into two groups, loosely named OECD and Non-OECD. Together, the two groups represented 84 percent of world oil consumption in 2009. (In addition, Appendix 3.2 examines a group of nine major oil-exporting economies and extends the sample to 1965.)[10]

The combined results for OECD and Non-OECD countries suggest very low short-term price elasticity, about –0.02 (Table 3.1).[11] This implies that a 10 percent increase in oil prices leads to a reduction in oil demand of only 0.2 percent. Although the long-term price elasticity is about four

[8]In 2008, coal accounted for 71 percent of total energy consumption in China, and oil and gas for only 19 and 3 percent, respectively. This is in contrast with the United States, where oil and gas accounted for 37 and 23 percent of total energy, respectively, and coal for 22 percent (U.S. EIA, *International Energy Outlook*, 2008).

[9]Other studies have attempted to estimate oil demand elasticities, such as Dargay and Gately (1995, 2010); Dargay, Gately, and Huntington (2007); Gately and Hillard (2002); Huntington (2002); and Cooper (2003), among others. Our framework is different, at least with respect to the sample period chosen, definition of country groups, and the overall econometric specification.

[10]The multicountry dimension helps overcome the downward bias problem that often arises when estimating demand price elasticities. Appendix 3.2 discusses identification issues in greater detail and presents robustness checks.

[11]The combined elasticities are the weighted averages of the group elasticities. The weights are the normalization of the last-10-year average oil consumption shares—which for OECD and Non-OECD countries stand at 0.55 and 0.31, respectively. Hence, the two groups combined represent 86 percent of world oil demand over the period.

times larger, the number is still small, which implies that a 10 percent permanent increase in oil prices reduces oil demand by about 0.7 percent after 20 years.

The short-term income elasticity is about 0.68, implying that a 1 percent increase in income is associated with an increase in oil demand of 0.68 percent. The long-term elasticity is considerably smaller, at 0.29. This result indicates that oil consumption has been considerably less income-elastic than primary energy demand, which means that the world economy has been (slowly) substituting away from oil.[12] In addition, the fact that income elasticity is higher in the short term than in the long term suggests that the response of oil consumption to an income shock involves some cyclical overshooting. Initial responses, such as those during the global recovery of 2009–10, therefore may not be representative of longer-term trends.

The growing importance of emerging market economies appears to have reduced world oil demand price elasticity (in absolute terms) and increased income elasticity. As shown in Table 3.1, the point estimate of the short-term price elasticity for the Non-OECD group is much lower than for OECD countries—though not as precisely estimated. Short-term income elasticity is only slightly higher than for OECD countries; however, long-term income elasticity is significantly higher for emerging market economies, at 0.39. Nevertheless, this value is substantially below the one found for energy, which is almost 1, and the weighted average of the two groups gives a combined elasticity of only 0.29. These results suggest that, instead of economies becoming more energy efficient, oil intensity has been declining substantially, even in emerging market economies—most probably as a result of the growing importance of other energy sources.

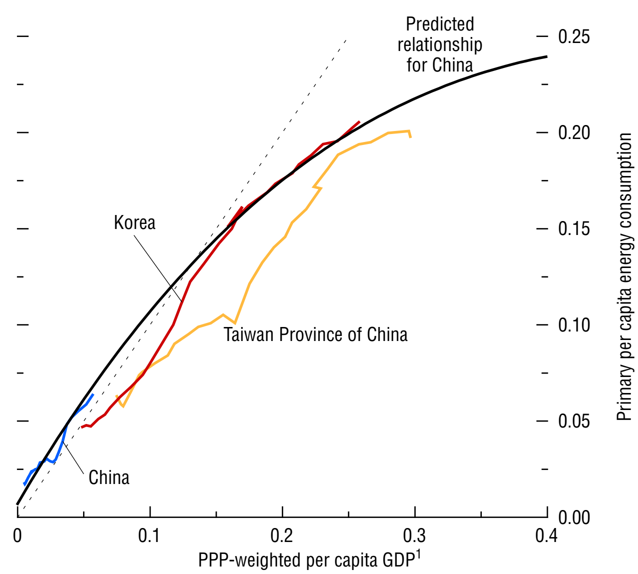
The surprisingly low price responsiveness of oil consumption in the OECD countries may reflect the lack of large-scale shifts in fuel use since the early 1990s. Most OECD countries saw a big switch away from oil in electric power generation in the early 1980s. After oil prices rose sharply compared

[12]In fact, the share of oil in total primary energy consumption has been decreasing since 1980, from 46 percent of the total in 1980 to 34 percent in 2009.

Figure 3.4. Primary Energy Consumption

(Hundred thousands of 2005 U.S. dollars on x-axis; billions of British thermal units on y-axis)

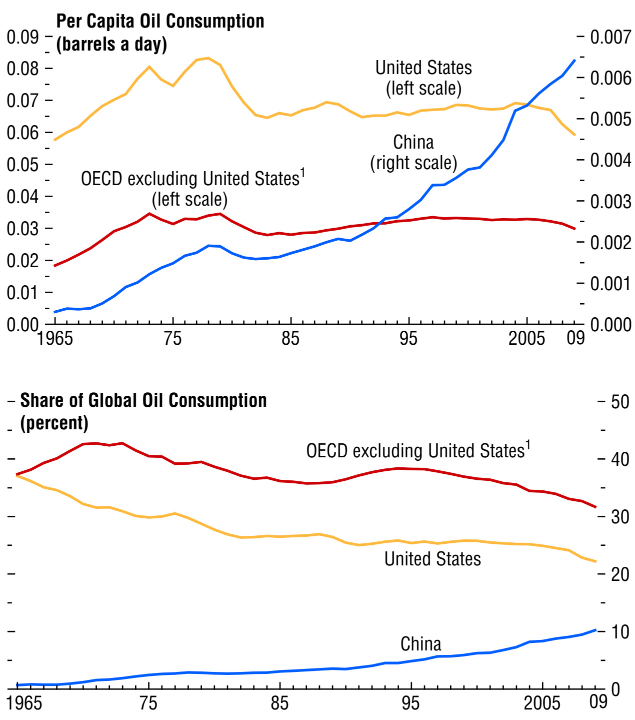
There has been a broadly one-to-one relationship between growth in per capita energy consumption and income in emerging market economies. China's energy demand has so far closely followed this pattern.



Sources: IMF, *International Financial Statistics;* International Energy Agency; World Bank, *World Development Indicators;* and IMF staff calculations.
[1]PPP = purchasing power parity.

Figure 3.5. Oil Consumption in China and in Selected Advanced Economies

Per capita oil consumption in the United States and other OECD[1] economies has been broadly flat since the 1980s, while it has risen rapidly in China.



Sources: BP, *Statistical Review of World Energy,* June 2010; World Bank, *World Development Indicators;* and IMF staff calculations.
[1]OECD = Organization for Economic Cooperation and Development.

with the prices of other fossil fuels in the 1970s, the power sector switched from oil to other inputs (Figure 3.6): some countries went back to coal (for example, the United States); others increased their nuclear capacity (for example, France) or turned to alternative energy sources. In fact, when the sample period is extended to the 1960s, the estimated price elasticities are higher (see Appendix 3.2). Today, however, the power sector is no longer an important oil consumer in OECD or emerging market economies. In fact, the transportation sector currently accounts for about 50 percent of total oil consumption.[13] A substantial part of the remainder goes to the petrochemical industry and for other miscellaneous uses outside the power sector. Given current technologies, it is harder to substitute other factors for oil in these sectors, explaining the break in the estimated elasticities.

Even though there has not been any substantial substitution away from oil in recent years, new backstop technologies are emerging in the transportation sector. Predicting the scope for substitution using these technologies in the coming years is difficult, but a big switch cannot be ruled out over the medium term. Addressing logistical problems will pose a formidable challenge, but there should be a threshold at which alternative options become economically viable if oil prices are sustained above a particular level.[14] A mitigating factor in this respect is that in emerging market economies, a good part

[13]This includes jet fuel for aviation, bunker fuel as a naval propellant, and diesel fuel (used in trucks, industrial machinery, and cars).

[14]A simple calculation can give some insight regarding the price threshold. Assume that the current cost premium for a plug-in electric car is $2,000, amortized on an annual basis. Furthermore, assuming a driver values mileage limitations and other logistical problems specific to electric cars at $1,000 a year and summing up the costs, we have a total premium of $3,000 over gas-engine cars. The next step is to calculate the breakeven point, which is found when the difference in operating costs of an electric car versus a gas-engine car is equal to the premium. U.S. average fuel consumption per vehicle was about 600 gallons in 2008 (see Federal Highway Administration, 2008, Table VM-1), while the retail gasoline price is roughly 0.035 times the imported oil price plus taxes. If we set the retail price of electricity for cars at 20 percent of the 2008 gasoline price, we get a backstop price for imported oil in the United States at about $155. Other important factors could affect our back-of-the-envelope calculations—for example, on the downside, increasing marginal costs of ramping up production that starts at a very low level or, on

Table 3.1. Oil Demand Price and Income Elasticities
(Subsample, 1990–2009)

	Short-Term Elasticity		Long-Term Elasticity	
	Price	Income	Price	Income
Combined OECD[1] and Non-OECD	–0.019 [–0.028, –0.009]	0.685 [0.562, 0.808]	–0.072 [–0.113, –0.032]	0.294 [0.128, 0.452]
OECD	–0.025 [–0.035, –0.015]	0.671 [0.548, 0.793]	–0.093 [–0.128, –0.057]	0.243 [0.092, 0.383]
Non-OECD	–0.007 [–0.016, 0.002]	0.711 [0.586, 0.836]	–0.035 [–0.087, 0.013]	0.385 [0.193, 0.577]

Source: IMF staff calculations.

Note: Median elasticities and confidence intervals showing 10th and 90th percentile of the distribution in brackets are estimated by Monte Carlo simulations. Long-term elasticities are calculated using a 20-year horizon.

[1]OECD = Organization for Economic Cooperation and Development.

of the infrastructure and distribution system is still under development and so, unlike in advanced economies, there will be less need to delay adoption of new technologies until current equipment and infrastructure become obsolete. Hence, it is conceivable that the (currently low) price responsiveness of oil demand could increase again, not only in OECD economies but also in emerging and developing economies.

What are the prospects for oil supply?

Prospects for oil supply are strongly dependent on production constraints in some major producing economies stemming from their oil fields reaching maturity—the stage when field production plateaus or declines. These constraints became obvious when global crude oil production stagnated broadly during the global economic boom in the mid-2000s (Figure 3.7, top left panel).[15] Most maturity-related declines have emerged in economies that are not members of the Organization of Petroleum Exporting Countries (OPEC), including Russia, but some OPEC producers reportedly also face challenges from mature fields, including Saudi Arabia (Figure 3.7, top right panel).[16]

Maturing is part of the normal life cycle of oil fields (Box 3.1). What is novel since the late 1990s is that such maturing started to affect the supply from major producing countries, beginning with the North Sea fields. The resulting constraints on non-OPEC production became evident in the early 2000s, when oil demand began to grow unexpectedly and OPEC's spare capacity declined.

The key question for the future is how the larger and likely growing number of maturing oil fields will affect the global oil supply outlook. In particular, is the broad stagnation in oil production over the past five years temporary or more permanent? The answer depends on how permanently the decline in production from maturing fields can be more than offset by increased production from newly discovered reservoirs, from known but undeveloped reservoirs, or from increased recovery from current fields, including the maturing ones (see IEA, *World Energy Outlook,* 2008). Realizing such an offset will require continued large-scale investment, which the experience of the past five years has shown to be a formidable challenge.

Information to date suggests that the challenge does not stem from a lack of desire to invest but rather from the lag between investment planning and delivery. Following sustained price increases, oil investment activity predictably turned around, partly involving the development of higher-cost oil from ultra-deep water or unconventional resources. Drilling activity—an integral part of exploration and development in the oil sector—rose noticeably over the past decade (Figure 3.7, bottom left panel). Similarly, Goldman Sachs (2010) estimates that

the upside, technological improvements and increasing returns to scale in the production of electric cars.

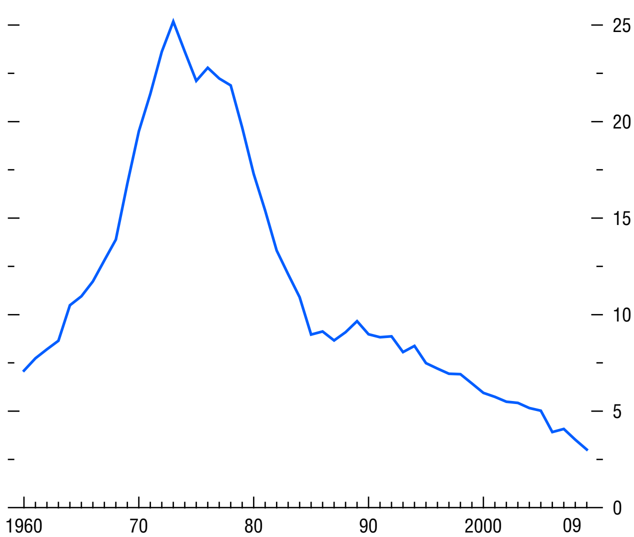
[15]Although market outcomes reflect both demand and supply developments, it would be difficult to attribute the stagnation entirely to factors other than new supply constraints, given the combination of rising prices and positive, albeit small, supply price elasticities as well as information about other factors (for example, conflict-related disruptions). See Hamilton (2009).

[16]See, for example, Sorrell and others (2010).

Figure 3.6. The Big Switch: Oil Share in the Electric Power Sector[1]

(Percent of total electricity production on y-axis)

After oil prices rose sharply relative to those of other fossil fuels in the 1970s, the power sector in most Organization for Economic Cooperation and Development countries switched away from oil for power generation in early 1980s.



Sources: International Energy Agency; and IMF staff calculations.
[1]Electricity generated by oil divided by total electricity production.

peak production from the oil projects in its Top 280 energy projects will amount to about 28 million barrels a day in 2020.[17] If the projects are executed and completed, these amounts could more than offset the decline from fields currently in operation, up to an aggregate decline rate of about 5 percent (the current production-weighted decline rate is estimated at about 4 to 4½ percent).

Despite the increased investment activity, however, improvements in delivery have been slow. As noted, time-to-build lags can be 10 years or longer in the mining and oil industries, depending on the complexity of the project. The turnaround in oil investment during the early 2000s therefore did not result in immediate capacity improvements, while the decline in oil investment from the mid-1980s to the late 1990s still had legacy effects. The latter will dissipate only slowly, as some of the new projects started over the past few years will not increase capacity for another 5 to 10 years.

Investment delivery has also been hampered by a surge in investment costs and by unexpected bottlenecks in oil investment services. As shown in the bottom right panel of Figure 3.7, one indicator of investment cost—the U.S. producer price index for oil and gas well drilling—almost tripled between 2003 and 2005, suggesting relatively weaker investment incentives. Higher cost and bottleneck problems, in turn, led investors to take a wait-and-see approach, and project approvals declined during 2007–08. Investment costs declined after the Great Recession but are still much higher in real terms. Similarly, bottlenecks in oil investment services have become less severe. But they are still present and will likely unwind only gradually.

Capacity increases are also constrained by restrictions on oil investment other than those related to pollution or other environment-related externalities, which have limited the overall investment response to high prices.[18] First, many areas are essentially closed to participation by outside investors and are developed exclusively by national oil companies.

[17]According to estimates by Goldman Sachs (2010), all projects achieve positive net present values with oil prices above $80 a barrel (in constant U.S. dollars).

[18]See Box 1.5 in the April 2008 *World Economic Outlook* for a detailed discussion.

While some national oil companies have ramped up capital expenditure in response to higher prices, others have been constrained by short-term budgetary revenue considerations. The lack of outside participation may also prevent the necessary upgrades in technology for exploration and development. Second, rising oil prices have also prompted changes in the regulatory environment, especially with respect to taxation and ownership, which have raised costs or reduced profitability and thereby slowed investment.

Against this backdrop, net capacity will likely build only gradually. A return to the trend growth of 1.8 percent in oil production experienced during 1981–2005 seems unlikely at this point despite the current investment effort, given continued field declines in some major producers.[19] In other words, prospects are for a downshift in the trend growth rate of oil supply. Current medium-term forecasts by the International Energy Agency (IEA, 2010a and 2010b), for example, suggest only modest increases in new net capacity over the next five years (Figure 3.8). Because capacity increases are the main drivers of supply growth—the short-term price elasticity of supply is very low, with most estimates ranging between 0.01 and 0.1—supply increases will likely be equally modest, except for the buffer provided by OPEC spare capacity.[20] The latter is currently estimated at some 6 million barrels a day. Assuming that between two-thirds and four-fifths of that spare capacity will eventually be tapped, cumulative oil supply growth during 2011–15 could amount to 6 to 8 percent, or 1¼ to 1½ percent annually on average, if the price of oil remains broadly constant in real terms.[21]

It is likely that part of the downshift in the oil supply trend has already been factored into current oil pricing. Nevertheless, predictions of the extent

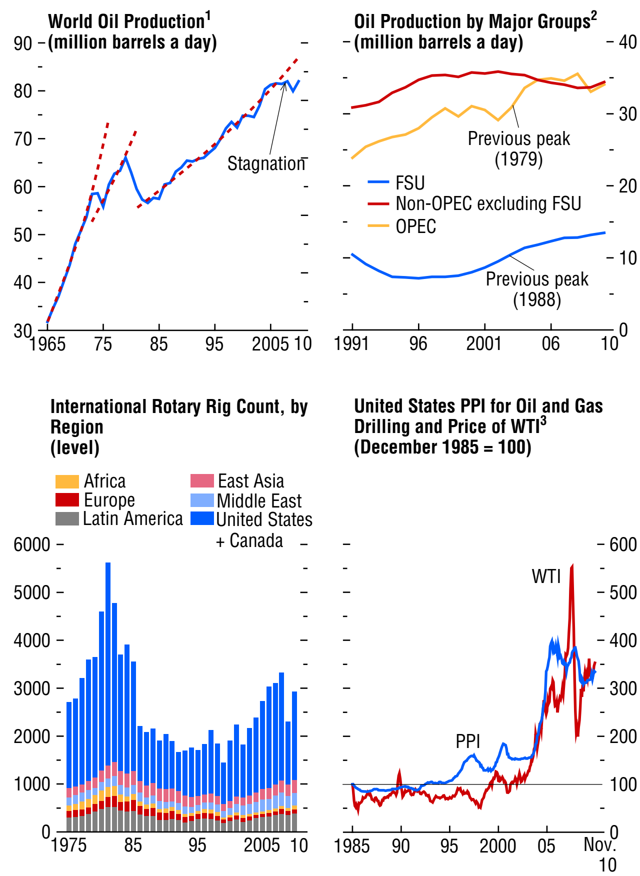
[19]We exclude from the calculation all periods of turbulence in world oil markets, such as the early 1980s, and we also exclude the post-2005 period, which, as shown in Hamilton (2009), already exhibited a below-trend output growth rate. A downshift would also be consistent with the investment oil prediction from Goldman Sachs's Top 280 energy project inventory noted earlier.

[20]See, for example, Dées and others (2007) for recent estimates of supply elasticities.

[21]This assumes that OPEC keeps a spare capacity buffer of 2 million barrels a day, which is in line with its stated intentions.

Figure 3.7. Global Oil Market Developments

Global crude oil production stagnated broadly during the global economic boom in the mid-2000s, notably in countries that are not members of the Organization of Petroleum Exporting Countries. The lag between investment planning and delivery seems to be the challenge in the medium term.

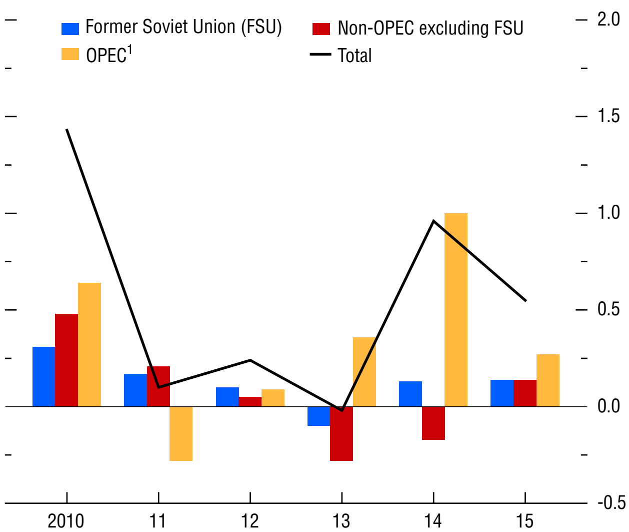


Sources: Bakker Hughes; BP, *Statistical Review of World Energy;* and Haver Analytics.
[1]Piecewise linear trend.
[2]FSU = former Soviet Union; OPEC = Organization of Petroleum Exporting Countries.
[3]PPI = producer price index; WTI = West Texas Intermediate.

Figure 3.8. Projected Growth in Crude Oil Capacity

(Million barrels a day)

Despite the current investment effort, new net capacity in oil production will increase only modestly in the medium term given continued field declines in some major producers.



Sources: International Energy Agency, *Medium-Term Oil Market Report,* June 2010 and December 2010 update.
[1]Including spare capacity; OPEC = Organization of Petroleum Exporting Countries.

and speed of capacity buildup are usually characterized by a high amount of uncertainty. Indeed, project delivery was typically overestimated over the past few years, and some of the underlying risk factors are still present.

Such risk factors include uncertainty about time-to-build lags, potentially rising investment costs if the global economy continues on a brisk expansion, and risks to investment regimes. In addition, there is considerable uncertainty about the future paths of decline rates in maturing fields (see Box 3.1). Finally, geopolitical risks, both short- and long-term, remain, and changes in oil scarcity could be accompanied by changes in the market shares of large producers. Therefore, there is a risk of larger-than-anticipated oil scarcity. The possibilities range from larger downshifts in trend supply growth to an outright decline in oil production, either temporarily or more permanently.[22]

What Are the Implications for Oil Scarcity?

The main reason behind continued, if not increased, oil scarcity is the tension between, on the one hand, the downshift in oil supply trends by some ¼ to ½ percent, with further downside risk, and, on the other hand, the strong momentum in oil demand growth stemming mainly from rapid income growth in emerging market economies.

The current WEO forecast is for an annual average world GDP growth rate of about 4.6 percent over the period 2011–15. The extent of market tension generated by these rates of global growth will depend on the income elasticity of oil demand. If a global short-term income elasticity of 0.68 (as estimated in the previous section) held throughout 2011–15, oil demand growth would remain above the growth in production at unchanged prices. Because price elasticities are very small, only substantial price increases would succeed in balancing the market, as described in the following example. At unchanged prices, if oil supply grows by 1.5 percent,

[22]For example, recent medium-term production forecasts by the U.S. EIA suggest annual oil production capacity growth of 0.9 percent over the period 2011–15. Other medium-term scenarios predicting low if any trend growth in oil production include British Petroleum (2011) and Shell (2011).

then oil demand growth will exceed that of supply by about 1.5 percentage points (4.6 × 0.68 – 1.5). With demand price elasticity at –0.02 and no supply response, the oil price should increase by 75 percent to rebalance the oil market.

The assumption of a zero supply response is clearly unrealistic. Moreover, as discussed earlier, there is strong evidence that longer-term income elasticities are lower than short-term ones.[23] The tension between moderate supply growth and continued high global economic growth could thus be resolved with smaller and, most likely, more gradual oil price increases, with some accompanying demand moderation. Nevertheless, with important downside risks to supply, oil scarcity risks will remain.

Oil scarcity risks must also be considered in the context of the overall energy market. If the supply of other primary energy sources continues to grow faster than the supply of oil, the past pattern of relatively slower oil demand growth in an environment of rapid GDP growth could be sustained. As of now, the situation seems promising. In particular, the so-called shale gas revolution may become a game changer and lay the foundation for a more global market for natural gas (Box 3.2). Natural gas could also become viable for applications that have so far relied almost exclusively on oil, including transportation.

Oil Scarcity and the Global Economy

To assess the implications of greater oil scarcity for global economic growth and current account imbalances, this section uses simulation analysis based on the IMF's Global Integrated Monetary and Fiscal Model (GIMF), a multiregion dynamic general equilibrium model.[24] The GIMF includes several features found to be important for replicating real-world behavior, including households' and firms' finite planning horizons, gradual adjustment of prices and nominal wages to unexpected changes, and macrofinancial linkages in the form of a financial accelerator. The version used here has six economic regions—oil exporters, the United States, the euro area, Japan, emerging Asia, and remaining countries. All regions are assumed to have flexible exchange rates.

The main simulation considers the effects of a downshift in the trend growth rate of world oil output in a controlled setting (Figure 3.9).[25] The motivation for the experiment follows from the analysis of oil demand and supply prospects in the previous sections. Because these prospects are subject to a great deal of uncertainty, the simulations assume that economic actors are surprised when the oil growth rate starts to decline.[26] This section also considers three sets of scenarios to examine the impact of changes in significant parameters.

What Is the Model and How Is It Calibrated?

To understand the global economic impact of oil scarcity, we need to look at a few aspects of the model setup. The main difference between this application and the standard version of the GIMF is that oil is a third factor in an economy's production, in addition to capital and labor, and a second factor in final consumption, in addition to goods and services. The price and availability of oil therefore influence production as well as consumption possibilities.

The price responsiveness of oil demand, which reflects the degree to which other inputs can substitute for oil, is an important parameter determining the impact of changes in oil market conditions. In the benchmark simulation, the long-term price elasticity of oil demand in both production and consumption is assumed to equal 0.08, while the short-term elasticity is about 0.02. This is consistent with the estimates for the 1990–2009 sample in the previous section.

[23]In the present discussion of oil demand, the combined income elasticity is 0.29 over a 20-year horizon.

[24]For a presentation of the structure of the GIMF, see Kumhof, Muir, and Mursula (2010). For applications, see Kumhof and Laxton (2007, 2009), Freedman and others (2010), and Clinton and others (2010).

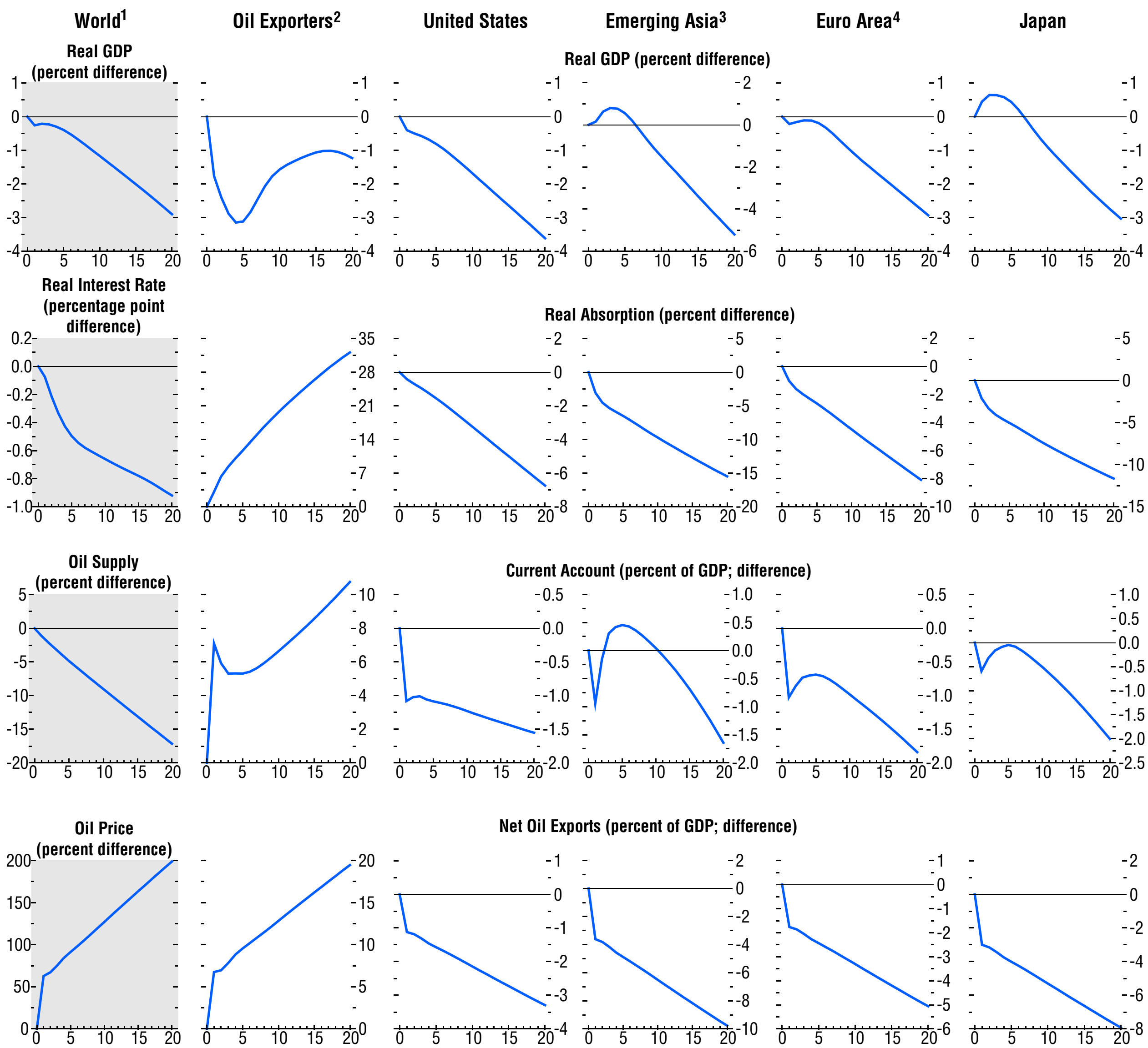
[25]Figure 3.9 also has a full listing of the countries included in each group.

[26]Actors are assumed to acquire full and immediate knowledge about the extent of the change in oil scarcity. In practice, information may be incomplete, and economic actors may learn only over time about the full extent of resource scarcity. The main effect of this delayed acquisition of knowledge would be smaller initial effects, but qualitatively the results remain broadly similar.

Figure 3.9. Oil Scarcity and the Global Economy: Benchmark Scenario

(Years on x-axis)

This scenario considers the effects of a downshift in the trend growth rate of world oil output by 1 percentage point each year and the eventual return to the initial growth rate in year 25.



Source: Global Integrated Monetary and Fiscal Model.

[1]World: Total of all countries accounts for 78.78 percent of world GDP.

[2]Oil Exporters: Algeria, Angola, Azerbaijan, Bahrain, Canada, Republic of Congo, Equatorial Guinea, Iraq, Kuwait, Libya, Mexico, Nigeria, Norway, Oman, Qatar, Russia, Saudi Arabia, United Arab Emirates, and Venezuela.

[3]Emerging Asia: China, Hong Kong SAR, India, Indonesia, Korea, Malaysia, Philippines, Singapore, and Thailand.

[4]Euro area: Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovak Republic, Slovenia, and Spain.

Another important parameter is the contribution of oil to output, which in the benchmark will be determined by the oil cost share. Based on recent historical data, it has been calibrated at 2 to 5 percent, depending on the sector and region.

The supply side of oil has several elements. First, there is an exogenous endowment of oil. The growth in that endowment is assumed to fall below historical trends. This represents the constraints from maturing fields on global oil supply discussed earlier. The second element is a positive supply response to higher oil prices, but with a low price elasticity of 0.03. The third element is extraction cost. Here we assume that, initially, 40 percent of oil revenue must be used to pay for intermediate goods inputs; thereafter, the real extraction cost per barrel of oil increases at a constant annual rate of 2 percent.[27]

An important element in tracing the effects of oil scarcity is the use of the oil rent, the difference between the market price and extraction costs. This rent is distributed between the domestic private sector and the government. In advanced economies, the government is assumed to receive only a very small portion of these receipts, while in oil exporters it receives 90 percent. Critically, it is assumed that the government does not spend the additional funds immediately but accumulates them in a U.S.-dollar-based fund that is spent at a rate of 3 percent a year. One of the key effects of an increase in the oil price, therefore, is a dramatic increase in world savings due to governments' low propensity to consume out of oil revenues.

Finally, although the GIMF is well suited to medium- and long-term analysis, some complex factors that are not part of the model (for example, the nature of the oil shock, its transmission through financial markets, confidence effects) may be at play in the short term that amplify the initial output response to an oil scarcity shock. Box 3.3 explains in greater detail the nature of the problem and the most relevant amplification channels highlighted in the literature.

[27]Together, the second and third elements mimic the possibility of replacing crude oil from conventional sources with oil from higher-cost unconventional sources (see, for example, IEA, *World Energy Outlook,* 2008, p. 218)

How Will Lower Oil Supply Trends Affect the Global Economy?

The benchmark simulation analyzes the impact of a decline in the average growth rate of world oil production by 1 percentage point below its historical trend starting in year 1 and an eventual return to its initial growth rate in year 25. Figure 3.9 shows the impact on a number of variables, expressed as deviations in percentage points (or percent) from a situation in which oil production grows at its historical trend rate of 1.8 percent.

Beginning with the global impact, the unexpected persistent reduction in oil supply growth leads to an immediate oil price spike of some 60 percent. This reflects the very low short-term oil demand elasticity. Because the decline in supply is persistent, the real oil price continues to increase thereafter, because market equilibrium requires some "demand destruction." Over a 20-year horizon, the cumulative oil price increase amounts to about 200 percent.

The reduced availability of oil and the resulting higher oil prices lead to a reduction in GDP levels in oil importers in the longer term. In the short to medium term, however, the global adjustment is shaped by the wealth transfer from oil importers to oil exporters, which has large effects on trade and capital flows. With rising oil prices, oil exporters experience sustained increases in income and wealth. As a result, their domestic demand (domestic absorption) increases ahead of GDP at more than 1.5 percent annually. The higher spending leads to upward domestic price pressures and a large real appreciation of the domestic currency. This reduces output in the tradables sector (other than oil), thereby reducing GDP by more than 3 percent over the first five years, followed by a recovery as government spending starts to consume a share of the growing oil fund. The current account improvement in this group of economies, which equals about 6 percent of GDP in the short term and more than 10 percent after 20 years, is due entirely to the higher value of oil exports. Goods exports fall relative to GDP, and the non-oil current account deteriorates. But the government's very low propensity to consume out of the oil fund means that the size of that deterioration remains moderate.

Domestic absorption by oil importers contracts over time as a result of lower oil availability, by 0.35 to 0.75 percent a year depending on the region. Their GDP also declines, but they initially experience two countervailing effects that support output. The first, and more important, is a surge in goods exports to oil importers to satisfy their increasing domestic demand. The second is a surge in investment demand in response to lower world real interest rates. This is because the oil exporters' additional oil revenue, which accrues primarily to governments, leads to higher saving, which reduces world real interest rates by almost 100 basis points over 20 years.[28] This effect is reminiscent of the international lending boom in the 1970s and early 1980s following large oil price increases. Regional differences among oil importers in this phase of the adjustment stem mostly from differences in the strength of their export links with oil exporters, with GDP in emerging Asia and Japan benefiting the most from the consumption boom in that region. In addition, emerging Asia also benefits more from lower world real interest rates, in view of the region's higher propensity to invest. Global imbalances worsen in this scenario over the short to medium term. The United States and euro area current accounts deteriorate as a result of costlier oil imports, while during a lengthy transition period the current accounts of surplus regions improve (emerging Asia), or remain nearly unchanged (Japan), as they export more goods to oil exporters. The long-term effects are not particularly large, however: oil importers' current accounts deteriorate by 1.5 to 2 percentage points of GDP by year 20. This is explained by oil's relatively low share in aggregate costs.

In the benchmark simulation, the longer-term output effects are not very severe. For oil importers, output falls cumulatively by between 3 percent (Japan, euro area) and 5 percent (emerging Asia) after 20 years, corresponding to about 0.15 to 0.25 percent a year, compared with a situation in which oil production follows past trends. The regional differences in the size of the long-term output effects reflect differences in the shares of oil in production and consumption. For oil exporters, the initial real output loss due to lower oil production is also amplified by the deterioration of the non-oil trade balance due to appreciation in the real exchange value of the currency.

[28]They start to increase again soon after the 20-year horizon, as the government spends more and more of its accumulated oil funds.

Alternative Scenarios

This section explores the sensitivity of the benchmark results to three of the underlying assumptions—namely, the role played by oil's price elasticity of demand, the effect of a more sizable shock to oil supply trends, and the importance of oil for aggregate production. In the accompanying figures, the benchmark simulation results are shown as a solid blue line, and each alternative scenario is shown as a dashed red line.

Scenario 1: greater substitution away from oil

A first alternative scenario considers a higher value for the long-term price elasticity of demand, consistent with greater substitution away from oil during periods of high oil prices. The scenario is based on a higher, more optimistic long-term elasticity of 0.3, almost five times as high as that used in the benchmark scenario. The feasibility of greater substitution is subject to uncertainty because it is difficult to predict the path of the technological developments required to bring it about.[29]

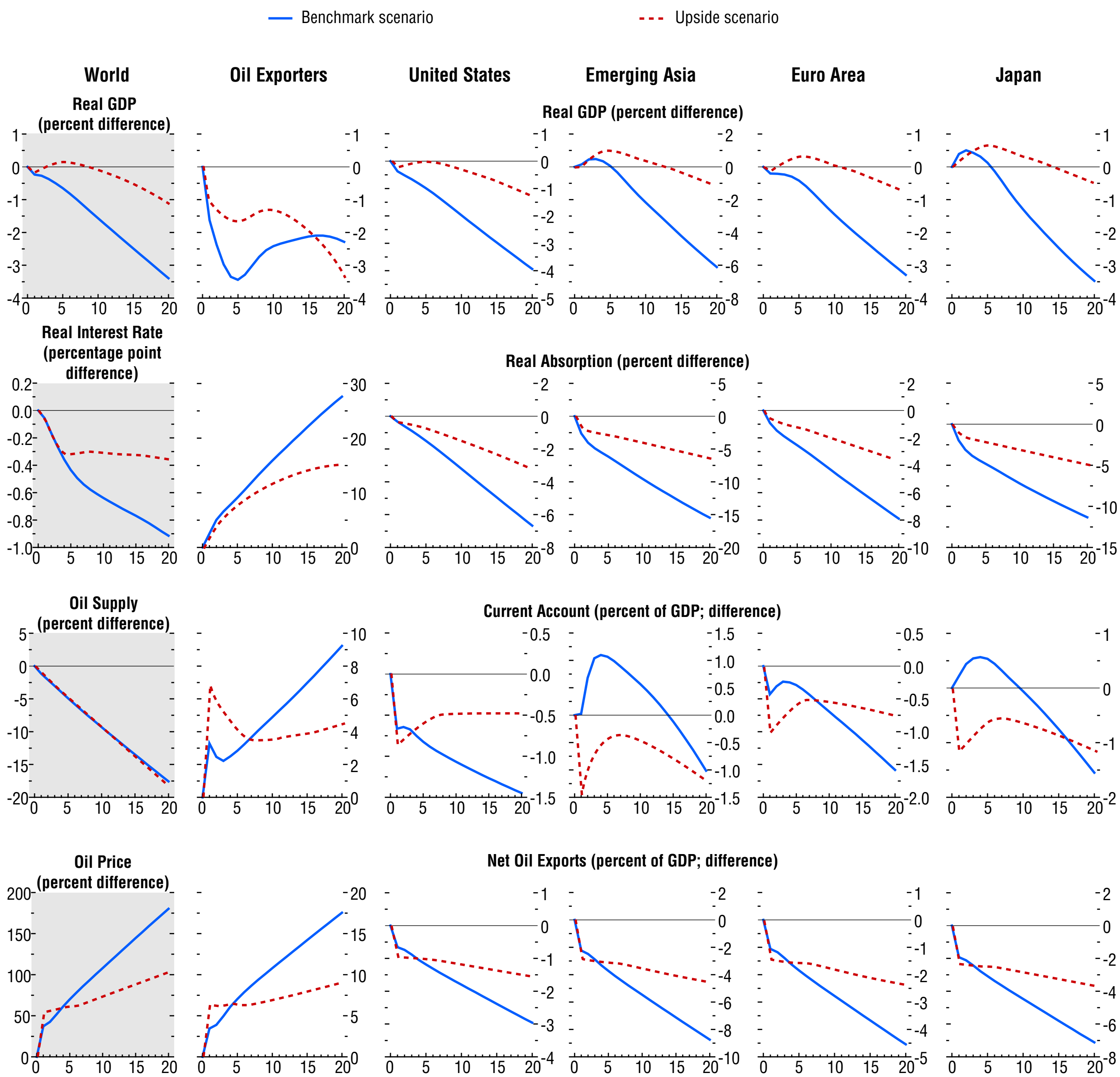
This alternative scenario has world oil prices increasing by only 100 percent after 20 years, rather than 200 percent as in the benchmark scenario (Figure 3.10). This reduces the drop in world output by two-thirds and by even more in oil importers. The longer-term current account developments are also much more favorable, mainly because easier substitution away from oil allows importers to keep the net oil import balance in check. This simulation highlights the fact that fairly high demand elasticities would be required to negate the effects of lower oil availability.

[29]Hirsch, Bezdek, and Wendling (2005, 2010), for example, examine alternative fuels and technologies and conclude that substitution away from oil on a large scale would be extremely expensive and time-consuming. See also Ayres (2007).

Figure 3.10. Alternative Scenario 1: Greater Substitution away from Oil

(Years on x-axis)

This scenario considers a higher value for the price elasticity of demand (0.3, compared with 0.08 in the baseline scenario), consistent with greater substitution away from oil.



Source: Global Integrated Monetary and Fiscal Model.
Note: For the list of countries in each group, see Figure 3.9.

Scenario 2: greater declines in oil production

Another alternative scenario considers the implications of a more pessimistic assumption for the declines in world oil output—3.8 percent rather than 1 percent annually—accompanied by a 4 percent annual increase in real extraction costs per barrel rather than 2 percent (Figure 3.11). This implies that, barring any increase due to the supply response to higher prices, oil production declines by 2 percent annually—a scenario that reflects the concerns of peak oil proponents, who argue that oil supplies have already peaked and will decline rapidly.[30] In this scenario, the longer-term output and current account effects are roughly three to four times as large as in the benchmark scenario, meaning they increase roughly in proportion to the size of the shock. Declines in absorption in oil importers are now on the order of 1.25 to 3 percent annually over the period shown, while in oil exporters, domestic absorption increases by more than 6 percent annually. Current account deterioration in oil importers is also much more serious, averaging 6 to 8 percentage points of GDP over the long term.

The most striking aspect of this scenario is, however, that supply reductions of this magnitude would require an increase of more than 200 percent in the oil price on impact and an 800 percent increase over 20 years. Relative price changes of this magnitude would be unprecedented and would likely have nonlinear effects on activity that the model does not adequately capture. Furthermore, the increase in world savings implied by this scenario is so large that several regions could, after the first few years, experience nominal interest rates that approach zero, which could make it difficult to carry out monetary policy.

Scenario 3: greater economic role for oil

In the benchmark scenario, the output contribution of oil is equal to its cost share. Some researchers in the natural sciences have argued that this understates the importance of energy, including oil, for economic activity.[31] Economists have also identified channels that amplify the effects of oil shocks.[32] To explore the implications of a potentially larger contribution by oil to output, the third alternative scenario assumes that part of total factor productivity represents technologies that are possible and remain usable only when there is a ready supply of oil. This effect is assumed to be external so that the beneficial effects of oil are not captured exclusively by the suppliers of oil but rather by all factors of production in proportion to their cost-share coefficients. The implication is that a negative oil supply shock resembles a negative technology shock.[33]

Figure 3.12 compares the benchmark scenario to a downside one in which the contribution of oil to output (either directly or as an enabler of technology) amounts to 25 percent in the tradables sector and 20 percent in the nontradables sector (rather than 5 percent and 2 percent). The simulations show that a higher output contribution by oil has small effects on current accounts: the main effects are on growth, with the deterioration in all regions' GDP larger by about a factor of two than in the baseline.

Summary of the simulations

The alternative scenarios indicate that the extent to which oil scarcity will constrain global economic development depends critically on a small number of key factors. If, as in the benchmark scenario, the trend growth rate of oil output declined only modestly, world output would eventually suffer but the effect might not be dramatic. If higher oil prices

[30]Sorrell and others (2010) provide an overview, noting that several studies predict absolute global decline rates of at least 2 percent starting in the near future.

[31]Ayres and Warr (2005); and Kümmel, Henn, and Lindenberger (2002) have estimated aggregate production functions in capital, labor, and energy for a number of industrialized countries and have found output contributions of energy that range from 30 percent to more than 60 percent. See also Ayres and Warr (2010), Kümmel (forthcoming), and Hall and Klitgaard (forthcoming). Because oil represents only a fraction, albeit large and critical, of aggregate energy inputs, values smaller than 30 to 60 percent are appropriate to illustrate this scenario.

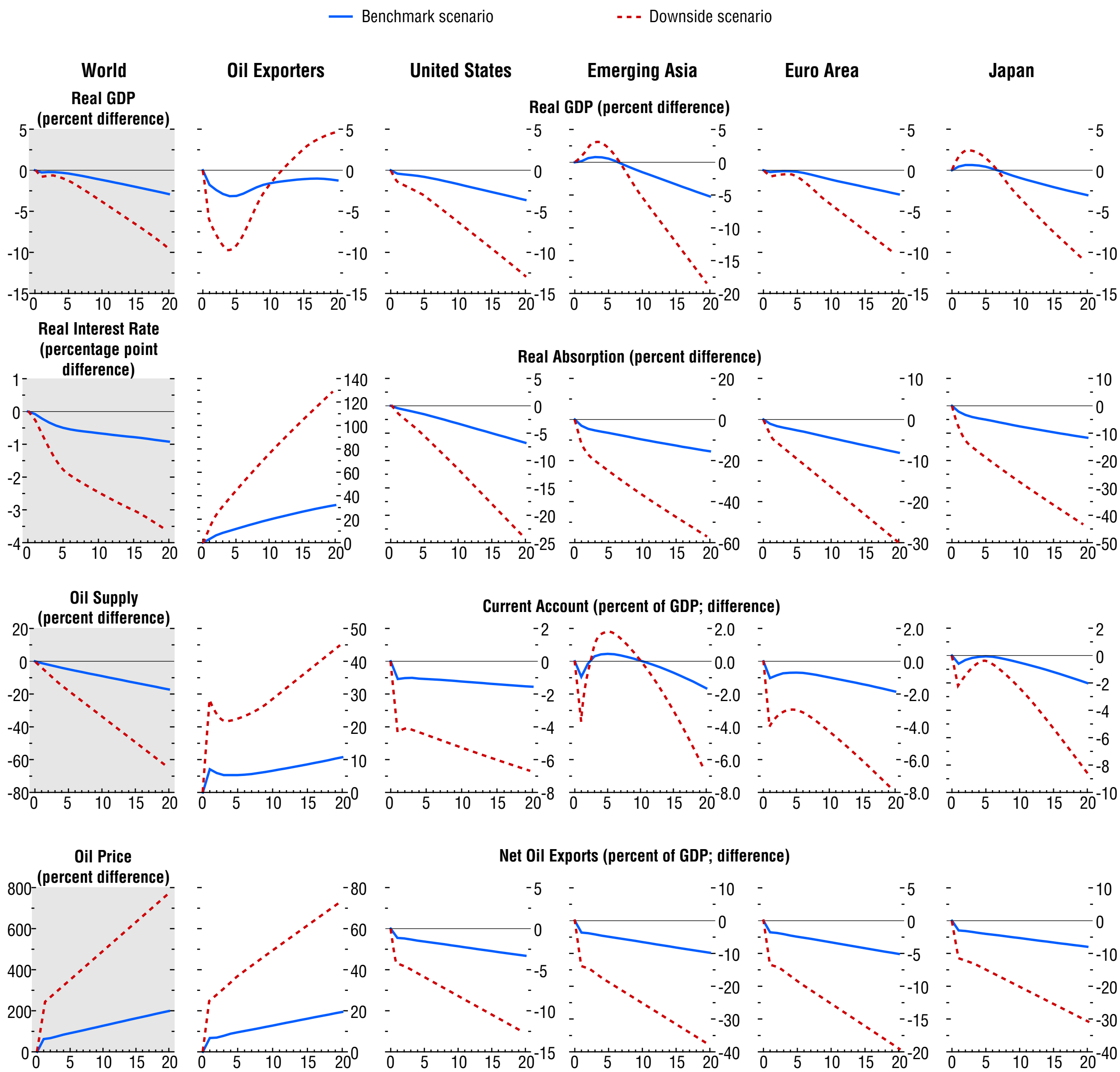
[32]In Finn (2000), an oil shock can reduce capital utilization and induce a stronger drop in output than indicated by oil's cost share.

[33]There are many examples of such effects, such as the obsolescence of many private automotive transportation efficiencies and technologies if a large-scale switch to public transportation becomes necessary. But another important aspect is the fact, stressed by the IEA's *World Energy Outlook,* 2010*,* that in the future a much higher share of the world economy's investment funds and innovation potential will have to be devoted to the oil sector just to maintain current levels of production. It is not implausible to expect this to exert a downward drag on the growth of productivity elsewhere in the economy.

Figure 3.11. Alternative Scenario 2: Greater Decline in Oil Production

(Years on x-axis)

This scenario considers the implications of a more pessimistic assumption for the decline rate of oil production (3.8 percentage points annually, compared with 1 percentage point in the baseline scenario).

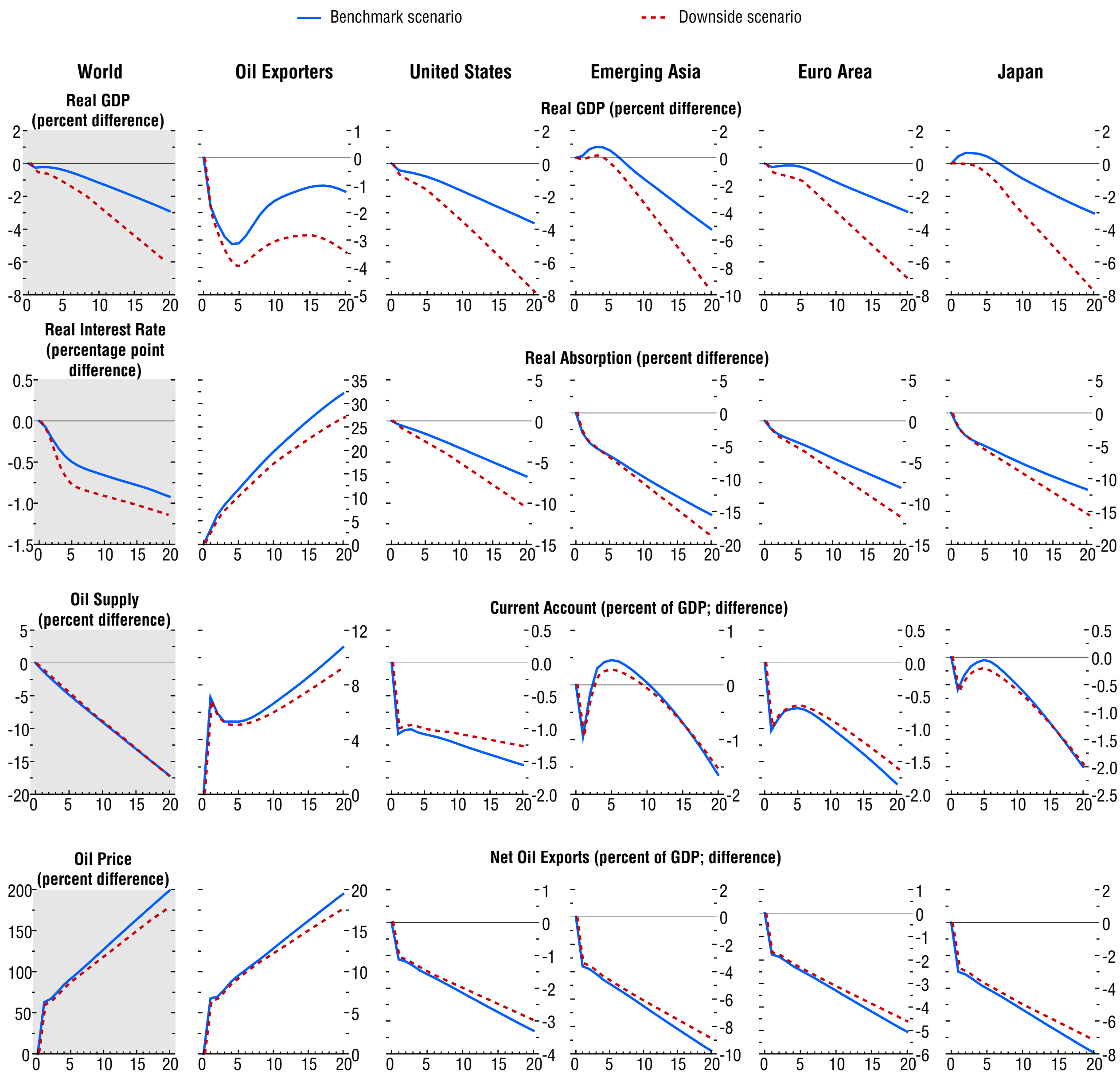


Source: Global Integrated Monetary and Fiscal Model.
Note: For the list of countries in each group, see Figure 3.9.

Figure 3.12. Alternative Scenario 3: Greater Economic Role for Oil

(Years on x-axis)

This scenario considers a higher contribution of oil to output: 25 percent for the tradables sector (compared with 5 percent in the baseline scenario) and 20 percent in the nontradables sector (compared with 2 percent in the baseline scenario).



Source: Global Integrated Monetary and Fiscal Model.
Note: For the list of countries in each group, see Figure 3.9.

brought about easier substitution away from oil, not just temporarily but over a prolonged period, the effects could be even less severe. But if the reductions in oil output were in line with the more pessimistic studies of peak oil proponents or if the contribution of oil to output proved much larger than its cost share, the effects could be dramatic, suggesting a need for urgent policy action. In the longer term, the worst effects would be experienced by regions whose production is highly oil intensive, such as emerging Asia, and/or with weak export links to oil exporters, such as the United States.

Additional Considerations

In each of the GIMF scenarios, the transition to a new equilibrium is, by assumption, a smooth process: consumers in oil-exporting economies easily absorb large surpluses in goods exports from oil importers, financial markets efficiently absorb and intermediate a flood of savings from oil exporters, businesses respond flexibly to higher oil prices by reallocating resources, and workers readily accept lower real wages. Some of these assumptions, however, may be too optimistic.

The experience of the 1970s suggests caution when it comes to the efficient intermediation of large net capital flows from oil exporters. If not efficiently allocated, risk premiums could increase in parts of the world where borrowers are vulnerable. This, in turn, could prevent borrowers from taking advantage of lower risk-free interest rates, which is an important mitigation mechanism in the face of oil scarcity. If private as well as public saving rates increase in oil-exporting economies, this problem could intensify.

A smooth reallocation of resources among inputs and across sectors as the economy adjusts to less oil is also a very strong assumption. Unlike in the model, real economies have many and highly interdependent industries. Several industries, including car manufacturing, airlines, trucking, long-distance trade, and tourism, would be affected by an oil shock much earlier and much more seriously than others.[34] The adverse effects of large-scale bankruptcies in such industries could spread to the rest of the economy, either through corporate balance sheets (intercompany credit, interdependence of industries such as construction and tourism) or through bank balance sheets (lack of credit after loan losses).

In recent years, labor market flexibility has helped improve the absorption of oil shocks (Blanchard and Galí, 2007). In the case of larger and more persistent oil price increases, however, workers may resist a series of real wage cuts, which would significantly raise the output cost of the shock during the long transition period.

Finally, the simulations do not consider the possibility that some oil exporters might reserve an increasing share of their stagnating or decreasing oil output for domestic use, for example through fuel subsidies, in order to support energy-intensive industries (for example, petrochemicals) and also to forestall domestic unrest. If this were to happen, the amount of oil available to oil importers could shrink much faster than world oil output, with obvious negative consequences for growth in those regions.

Implications for the Outlook and Policies

The analysis of energy prices in this chapter suggests that oil and other energy markets have entered a period of increased scarcity—a period of higher-than-average prices—as they have on earlier occasions. Past experience suggests that such periods can last a long time even if they eventually give way to periods of renewed abundance.

When it comes to crude oil scarcity, high prices reflect the tension between the increase in oil consumption growth, driven mainly by fast-growing emerging market economies, and the downshift in oil supply growth. Scarcity is reinforced by the low responsiveness of both oil demand and oil supply to price changes. However, the longer-term income elasticity of global demand for oil is below that of the demand for primary energy, which indicates that oil-saving efforts, technological change, and the move to a more service-based economy may all have an appreciable effect.

The analysis shows that the constraints on global growth in the medium to longer term from gradual

[34]Even industries that could adapt to the increases in oil prices implied by the benchmark scenario might find it almost impossible to adjust to the 800 percent price increase implied by the second downside scenario.

and moderate increases in oil scarcity—those involving lower trend growth rather than sustained declines—could be relatively minor. In particular, a sizable downshift in oil supply trend growth of 1 percentage point appears to slow annual global growth by less than ¼ percent.

Such benign effects on output, however, should not be taken for granted. Important downside risks to oil investment and capacity growth, both above and below the ground, imply that oil scarcity could be more severe. Moreover, unexpected increases in oil scarcity and resource scarcity more broadly might not materialize as small, gradual changes but as larger, discrete changes. In practice, it will be difficult to draw a sharp distinction between unexpected changes in oil scarcity and more traditional temporary oil supply shocks, especially in the short term when many of the effects on the global economy will be similar. In addition, it is uncertain whether the world economy can really adjust as smoothly as the model envisages. Finally, there are risks related to the scope for the substitution away from oil, on both the upside and the downside. The adverse effects could be larger, especially if the availability of oil affects economy-wide productivity, for example by making some current production technologies redundant.

Therefore, the state of oil scarcity needs to be monitored carefully; the global economy is still in the early stages of the new era of maturity in major oil-producing economies.

What are the policy implications? Fundamentally, there are two broad areas for action. First, given the potential for unexpected increases in the scarcity of oil and other resources, policymakers should review whether current policy frameworks facilitate adjustment to unexpected changes in oil scarcity. Second, consideration should be given to policies aimed at lowering the risk of oil scarcity, including through the development of sustainable alternative sources of energy.

Macroeconomic and structural policies can help economies adjust to unexpected changes in oil scarcity. Real rigidities in product and labor markets may exacerbate the initial shock by preventing the smooth reallocation of resources. Policies aimed at easing adjustment in relative prices and resources would therefore be helpful. In labor markets, for example, relaxing employment protection policies in some circumstances could be useful, as too many restrictions can delay adjustment in real wages and hamper reallocation of jobs from sectors most affected by scarcity to sectors that are less affected.

In this respect, increased oil scarcity will pose fiscal policy challenges. In the face of an oil scarcity shock, the trend toward increasing end-user subsidies for petroleum products in many economies would put fiscal positions in oil importers at risk because the fiscal cost of the subsidies could increase dramatically.[35] On the other hand, there is a need to protect the poor. Hence, the priority in many economies should be to reduce fuel and other subsidies, especially if they are not well targeted, while putting in place targeted and cost-effective social safety nets. Such a strategy would not only help protect fiscal positions, but would also strengthen the role of price signals in the use of energy resources and reduce greenhouse gas emissions.[36]

On the structural policy side, the focus should be on strengthening the role of price signals in the adjustment to increased scarcity. Such policies would increase the price responsiveness of supply and demand, thereby allowing for smaller price responses to unexpected changes in scarcity. On the supply side, oil companies should be able to respond to higher prices under predictable investment and tax regimes that take into account differences in extraction costs and allow investors to be compensated for taking technological and geological risks. On the demand side, as noted above, a reduction in fuel and other subsidies at a global level would also increase the price elasticity of oil demand (in absolute value terms), thereby facilitating oil market adjustment and reducing oil price volatility.

Regarding policies aimed at lowering the worst-case risks of oil scarcity, a widely debated issue is whether to preemptively reduce oil consumption—through taxes or support for the development and deployment of new, oil-saving technologies—and to foster alternative sources of energy. Proponents argue that such interventions, if well engineered,

[35]Coady and others (2010) analyze the recent trends in fuel subsidies and discuss policy options to protect vulnerable segments of the population while also protecting fiscal positions.

[36]See Jones and Keen (2009) for a discussion.

would smoothly reduce oil demand, rebalancing tensions between demand and supply, and thus would reduce the risk of worst-case scarcity itself.

There are, however, several issues that need to be addressed before policy interventions to reduce oil consumption are implemented. Such interventions come at a cost, and their net benefits need to be evaluated. For example, lowering oil consumption through higher taxes could reduce growth and welfare during the period before serious scarcity has emerged. The calculations to establish costs and benefits are complex. This is mainly because the net benefits ultimately depend on the probability of significantly higher scarcity and the present discounted value of expected costs that the higher scarcity would impose, which are hard to quantify.

Finally, the model simulations indicate that persistent oil supply shocks would imply a surge in global capital flows and a widening of current account imbalances. This makes it even more important to strengthen global cooperation to reduce the risks associated with growing current account imbalances and of large capital flows to emerging market economies. Continued progress with financial sector reform also has a very important role to play, since the efficient intermediation of these capital flows will be of paramount importance for financial stability.

Appendix 3.1. Low-Frequency Filtering for Extracting Business Cycle Trends

Filtering methods allow for gradual change in long-term trends as well as cycles of different frequencies. The ideal band-pass filter, which isolates only specified frequencies, uses an infinite number of leads and lags when calculating the filter weights. However, a finite number of leads and lags must be used in practice, and so a truncation decision needs to be made. Christiano and Fitzgerald (2003) propose asymmetric filters, which have the advantage of computing cyclical components for all observations at the beginning and end of the data span.[37] Given our interest in whether a long-term cycle is emerging in the final years of our data sample, this asymmetric Christiano and Fitzgerald filter is used to calculate long-term components at the end of our data sample, with adjustments for I(1) series, including crude oil, natural gas, and coal.

Appendix 3.2. The Energy and Oil Empirical Models

The Energy Model

We estimate the following relationship, where i denotes the country and t denotes years:

$$e_{it} = \alpha_i + P(y_{it}) + u_{it}, \qquad (3.1)$$

where e is energy per capita; y is real per capita GDP; and $P(y)$ is a third-order polynomial; fixed effects are captured by α_i.

The Oil Model

We estimate the following oil demand:

$$o_{it} = \alpha_i + \lambda_t + \rho o_{it-1} + \beta \log(p_{it}) + \gamma\Delta \log(y_{it}) + P(y_{it}) + u_{it}, \qquad (3.2)$$

where o is oil per capita; y is real per capita GDP at purchasing power parity; $P()$ is a third-order polynomial; p is the real price of oil in local currency; fixed effects are captured by α_i; and λ_t represents time dummies.[38]

None of the results shown have used time dummies; however, dummies have been used as alternatives to split the sample into pre- and post-1990s periods to test for the big switch.

When estimating high versus low oil price environments we use log differences for both oil and prices. In this case, given the formulation on growth rates, no persistence is introduced.

Identification Issues

As explained in the text, estimating a demand schedule has to overcome the pitfall of introducing a downward bias in the price elasticities. Here we address this problem, explaining how the cross-country dimension reduces the usual bias and describe the results of a robustness test.

The usual problem is that a shock in the demand equation, changing total quantity demanded, has an impact on price. This implies a positive correlation between price and the error term, biasing the estimate downward. However, we are not estimating the aggregate oil demand schedule but many demand schedules for each country. Most of those economies are small relative to the size of the oil market; hence, oil demand shocks in a generic country have only a minor impact on oil prices. More precisely, we can split the oil demand shock of a country i into an idiosyncratic component (country specific) and a common component shared by all countries (common). Country-specific shocks have no effect on the oil price by construction. Some examples of those shocks are changes in energy regulation, tax codes, the composition of the industrial sector, and all sorts

[37]The above results are very robust even when we extend the data series with forecast series, based on the autoregressive integrated moving average (ARIMA) specification or random walk, and use more leads for filtering at the end of the actual sample periods.

[38]The Organization for Economic Cooperation and Development (OECD) comprises Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, and United States. "Remaining countries" are OECD countries plus Argentina, Bangladesh, Brazil, Bulgaria, Chile, China, Colombia, Egypt, Hong Kong SAR, Hungary, India, Indonesia, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Romania, South Africa, former Soviet Union, Taiwan Province of China, Thailand, and Turkey. The oil-exporting countries comprise Algeria, Islamic Republic of Iran, Kuwait, Norway, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela.

Table 3.2. Oil Demand Price and Income Elasticities, Including Oil-Exporting Economies
(Subsample, 1990–2009)

	Short-Term Elasticity		Long-Term Elasticity	
	Price	Income	Price	Income
Combined OECD,[1] Non-OECD, and Major Oil-Exporting Economies	–0.017 [–0.028, –0.006]	0.676 [0.551, 0.801]	–0.067 [–0.132, –0.005]	0.474 [0.210, 0.753]
Major Oil-Exporting Economies	–0.001 [–0.028, 0.025]	0.565 [0.424, 0.703]	–0.018 [–0.368, 0.337]	2.751 [1.246, 4.552]

Source: IMF staff calculations.

Note: Median elasticities and confidence intervals showing 10th and 90th percentile of the distribution in brackets are estimated by Monte Carlo simulations. Long-term elasticities are calculated using a 20-year horizon. For OECD and non-OECD data, see Table 3.1.

[1]OECD = Organization for Economic Cooperation and Development.

of energy subsidies. When those changes are unrelated across countries they constitute country-specific oil demand shocks. Common shocks do have an impact on oil prices and introduce a downward bias. However, because we control for GDP growth, it is not easy to think of other common shocks. A potential candidate is the precautionary demand shock, as stressed recently by Kilian (2009). However, those shocks are not supposed to be very persistent; hence, at an annual frequency, their effect on oil consumption is small. In other words, there are reasons to believe that common shocks apart from the global business cycle play a minor role. The downward bias in our estimates should therefore be small.

To corroborate this assumption, we reestimated our equation using the oil-supply-shock-based price series of Cavallo and Wu (2006) instead of actual oil prices.[39] This series was constructed using only oil supply shocks that were identified with a narrative approach examining daily oil-related events during 1984–2007. In principle, this approach eliminates price movements due to an oil demand shock, thus removing the downward bias previously described.

The reestimation of our model over the period 1990–2007 with the Cavallo-Wu price series (CW) and our regular series (old) suggests that the estimated coefficients are remarkably similar. The new and old price elasticities are not statistically different.[40] It is also worth noting that the CW price elasticity is more precisely estimated than ours, which adds support to their identification strategy. If the CW narrative approach captured only meaningless noise, the estimated coefficient—and, thus, the oil price elasticity—would not have been statistically different from zero when using their series.

[39]The log changes of the oil price series were provided by Tao Wu.

[40]The 99 percent confidence intervals of both estimates overlap.

The Role of Major Oil Exporters

The share of world oil consumption for our oil-exporter region increased from 4 percent in 1980 to almost 9 percent in 2009. Given the special features of this region, if its share keeps increasing, the oil market prospects could deteriorate. In Table 3.2, we show the estimated elasticities for this group of economies. Price elasticities are not at all significant. This is not completely surprising: subsidized oil products and a strong wealth effect related to oil price movements alter the usual relationship between prices and demand. In fact, higher prices could easily lead to higher oil demand in an oil-exporting country.

Another striking difference from the other regions studied is the high value of long-term income elasticity: a 1 percent increase in income is associated with a 2.7 percent increase in oil consumption! This probably reflects those economies' scant incentives to introduce oil-saving technologies.

Overall, even though the oil consumption share of oil exporters is still small, the combined results for the three groups are clearly affected. In particular, the long-term income elasticity, while still lower than for the short term, stands now at 0.47, compared with the 0.29 found before. The median estimate of price elasticity is only mildly reduced, but the uncertainty of the estimate becomes much higher.

Table 3.3. Oil Demand Price and Income Elasticities in the Extended Sample
(Full sample, 1965–2009)

	Short-Term Elasticity		Long-Term Elasticity	
	Price	Income	Price	Income
OECD[1]	–0.039 [–0.044, –0.033]	0.704 [0.603, 0.803]	–0.576 [–0.673, –0.489]	–0.385 [–0.567, –0.208]
Non-OECD	–0.010 [–0.015, –0.006]	0.741 [0.663, 0.818]	–0.131 [–0.196, –0.070]	0.589 [0.382, 0.777]

Source: IMF staff calculations.

Note: Median elasticities and confidence intervals showing 10th and 90th percentile of the distribution in brackets are estimated by Monte Carlo simulations. Long-term elasticities are calculated using a 20-year horizon.

[1]OECD = Organization for Economic Cooperation and Development.

Extended Sample: 1965–2009

As Table 3.3 shows, price elasticities are higher, especially for OECD countries, which confirms the argument in the main text. Moreover, since the "big switch" happened during a period when many OECD countries experienced relatively high per capita GDP growth, we also observe a change of sign (from negative to positive) of the long-term income elasticity between the two samples: economic growth helped introduce oil-efficient capital goods and technologies. Similar results are obtained when we use time dummies for the early 1980s to control for the big switch.

Low and High Oil Price Environments

To examine whether high oil prices are more conducive to substitution away from oil than low oil prices, we split the sample into periods of high and low oil prices (defined as oil prices above and below the sample average). The results (Table 3.4) suggest that during periods of low oil prices, price elasticity is not statistically different from zero; the only variable that matters in the oil demand schedule is GDP growth. In contrast, during periods of high oil prices, price elasticity is much higher, at 0.38, and is statistically significant. At the same time, short-term income elasticity is slightly lower.

This result also suggests that when oil prices are low, their fluctuation has only a minor impact on households' and businesses' decisions, given that they do not substantially affect their total expenditures. However, when prices are already high, a further increase may induce a much higher number of households and businesses to switch to more oil-efficient equipment and technologies and/or to change their behavior.

Table 3.4. Oil Demand Price and Income Short-Term Elasticities: High versus Low Oil Price Environments
(Subsample, 1990–2009)

	Price	Income
High Oil Prices	–0.038 [–0.070, –0.006]	0.649 [0.466, 0.832]
Low Oil Prices	*	0.786 [0.667, 0.904]

Source: IMF staff calculations.

Note: * indicates that the value is not statistically different from zero. Median elasticities and confidence intervals showing 10th and 90th percentile of the distribution in brackets are estimated by Monte Carlo simulations. Long-term elasticities are calculated using a 20-year horizon.

Box 3.1. Life Cycle Constraints on Global Oil Production

Oil reservoirs have a life cycle with three main phases: youth, maturity, and decline. This box discusses these life cycle stages and the implications for global oil supply prospects.

After discovery and development, oil reservoirs enter a period of youth during which flow production increases. At maturity, production peaks and then starts to decline. Maturity patterns vary across fields. In some, production plateaus at its peak and decline sets in only much later.

The life cycle reflects a combination of geological, technological, and economic factors. From a geological point of view, there is the natural phenomenon of declining reservoir pressure or water breakthroughs once a substantial part of the oil in a reservoir has been extracted. Technological intervention can influence the timing of production peaks and the rate of decline through secondary and enhanced recovery methods, although applying these methods comes at a cost that generally increases with the extent of depletion.[1] At some point it becomes too costly to prevent decline through ever more intensive intervention.

Life cycle patterns have been well established for individual oil reservoirs and fields.[2] A widely debated issue is whether life cycle patterns are of more general relevance for regional and even global oil production. The proposition that global oil production has already peaked or will peak in the medium term is a generalization of the life cycle hypothesis. But such peak oil propositions are dependent on additional assumptions.

A first assumption is that large oil fields are discovered first. In part this seems to be supported by historical data (Figure 3.1.1, top panel). In fact, the "giant" fields in the United States, the Middle East, and Russia discovered before the 1970s have been the backbone of global oil production for decades (IEA, *World Energy Outlook,* 2008). Many of those

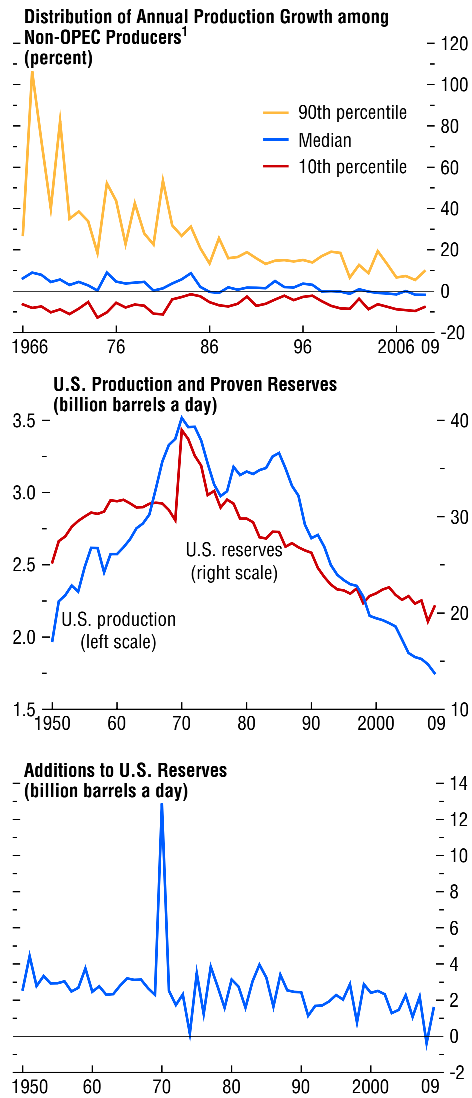
The author of this box is Thomas Helbling.

[1]The costs involve both capital costs—considerable investment is a prerequisite, especially for enhanced recovery—and operating costs, including the cost of the gas or water used in recovery.

[2]A field is a collection of reservoirs in geographical proximity based on a single geological structure. Sorrell and others (2010) provide a good overview of the evidence of life cycle patterns in oil production.

Figure 3.1.1. Life Cycle of Global Oil Production

Many giant oil fields have reached maturity. However, the decline rate of oil production has been relatively low because the marginal return from additional drilling has been high enough to support continued exploration and oil investment.



Sources: BP, *Statistical Review of World Energy*, June 2010; U.S. Energy Information Administration; and IMF staff calculations.
[1]OPEC = Organization of Petroleum Exporting Countries.

Box 3.1 *(continued)*

fields have reached maturity, and so the peak oil argument goes as follows: since large fields are less likely to be discovered, to offset the decline of current large fields we need an unrealistically high rate of small-field discovery.

However, views on the scope for future discoveries differ considerably. The most recent assessments by the U.S. Geological Survey released in 2000—a standard reference—suggest that there are between 1 and 2.7 trillion barrels of conventional oil still in the ground that are technically recoverable. The range reflects different probabilities attached to the discovery of new reservoirs of oil that is technically recoverable and the growth of reserves in fields already in production.[3] The lower bound of the band reflects oil that is technically recoverable and consists mostly of current proven reserves. The fact that important oil discoveries continue to be made and that many promising areas have not yet been extensively explored suggests that this lower bound is likely pessimistic for a baseline projection.

The second assumption concerns the extent of the drag from declining production in mature fields. The main issue is whether past patterns in so-called observed decline rates provide a good basis for forecasts. There is a distinction between the natural decline rate, that is, the rate without any postpeak intervention, and the managed decline rate, with intervention after the peak. Some analysts see little scope for changing past patterns. In their view, production-weighted global decline rates, which are currently estimated at some 4 percent, are expected to increase further in the future as decline in large mature fields accelerates. However, observed decline rates are a function of technology and investment, factors that usually are not considered in the curve-fitting approaches used to predict decline rates. The use of secondary and enhanced recovery techniques is costly, and so investment in decline management will be a function of current and expected market conditions. Given that oil prices were low between the mid-1980s and the early 2000s, it is plausible that forecasts based on past patterns are not valid in a high-price environment. With prospects for continued high oil prices, field management and attempts to increase recovery rates are likely to play a more prominent role than in the past, implying lower global rates of decline. Moreover, technological developments have improved the scope for enhanced recovery at lower cost.

The experience with oil production in the United States provides some grounds for cautious optimism. U.S. oil production peaked in 1970, as some geologists had predicted it would (middle panel).[4] This corroborates the view that decline is difficult to overcome once it begins. Nevertheless, overall, U.S. oil production has declined by less than many predicted using curve fitting (see Lynch, 2002). The average rate of decline has been steady at about 1 percent a year since the 1970s.

The relatively low decline rate reflects a number of factors. Most important, the marginal return from additional drilling, as measured by reserve additions, has been high enough to support continued exploration and oil investment (bottom panel). This happened despite the presumption that discovery and development activity are increasingly less likely to result in reserve growth the more an area has already been explored and developed—as should be the case for the United States.[5] Finally, the U.S. experience also highlights the important influence of market conditions and incentives on exploration and investment and the importance of relatively low barriers to entry in the oil sector.[6] This has led

[3]Historically, the upgrading of reserve estimates because of increased knowledge about reservoir properties and the effectiveness of the installed capital after the beginning of production has been an important source of measured reserve growth. Cumulative production in many fields that are still producing is already well above initial reserve estimates.

[4]The prediction of a production peak between 1965 and 1970 in the lower 48 U.S. states by the late M. King Hubbert is well known.

[5]In the well-known model of Pindyck (1978), additional drilling and development have positive marginal returns. But these benefits from additional investment must be weighed against increasing marginal costs from diminishing returns from all past exploration and developing efforts. These costs are believed to be increasing with the cumulative past efforts (see, for example, Uhler, 1976; or Pesaran, 1990).

[6]Kaufmann (1991) notes that oil market conditions explain a significant part of the deviations of actual oil production from the levels predicted by so-called Hubbert curves.

Box 3.1 *(continued)*

exploration and subsequent reservoir development to respond strongly to price signals.[7] In fact, exploration activity has remained higher in the United States than in some areas with more potential.

The conclusion is that there are constraints on global oil production from life cycle patterns in oil production. The main reasons for these constraints are the broadly synchronized maturing of major large oil fields that have been the backbone of global oil production. Nevertheless, there remain important questions about the strength of these constraints. The U.S. experience suggests that managed decline is possible, especially in areas with many and large fields, including for example Saudi Arabia. It also underscores the risks of restricting investment in the oil sector, which can hamper the process of exploration and development.

[7]Dahl and Duggan (1998) survey the evidence.

Box 3.2. Unconventional Natural Gas: A Game Changer?

Shale gas has emerged as a major new source of natural gas in the United States and could become a new source of supply elsewhere, with major implications for gas markets across the globe. This new energy source accounted for about half of total U.S. gas production in 2010 (Figure 3.2.1) and for three-quarters of global unconventional gas output (U.S. EIA, *International Energy Outlook*, 2010). This box discusses the potential and limitations of the recent "shale gas revolution."

Natural gas resources are classified as conventional or unconventional depending on the technology necessary for exploitation. Conventional gas is found either in easily accessible gas reservoirs or in oil wells. Unconventional natural gas resources include tight gas sands, coalbed methane, and shale gas, and these require more advanced extraction technology. Shale gas is natural gas trapped deep in sedimentary rock and diffused over a relatively large area. The existence of unconventional gas reservoirs has long been recognized. However, the technology to produce economically viable unconventional gas on a large scale emerged only in the past decade.[1]

The global resource base for unconventional gas, which includes gas reservoirs that have not yet been developed or found and which is more uncertain with regard to recoverability, is considerably larger and exceeds that of conventional natural gas (Table 3.2.1).[2] In terms of production share, unconventional gas amounted to 12 percent of 2008 total global natural gas production, and the International Energy Agency expects it to rise to 15 percent by 2030 (IEA, *World Energy Outlook*, 2009). Yet there are sufficient resources for much larger expansion. At current global production rates, today's worldwide proven reserves (conventional and unconventional) could sustain current production for 58 years (IEA, *World Energy Outlook*, 2009),[3] whereas the combined resources equal 250 years of current production.

Shale gas extraction has so far been confined to the United States, but there is growing interest in exploiting unconventional sources of gas across the globe. In fact, a number of countries have started

The authors of this box are Reda Cherif and Ananthakrishnan Prasad.

[1]Unconventional gas extraction typically involves horizontal drilling and hydraulic fracturing (making fractures in the rock and injecting a fluid to increase permeability).

[2]About 380 trillion cubic meters (tcm) of unconventional resources are estimated to have highly likely recoverability (IEA, *World Energy Outlook*, 2010). The remaining recoverable conventional gas resources are estimated at 400 tcm.

[3]The Middle East and North Africa region has more than 40 percent of the world's proven gas reserves, with scope for new discoveries. The Islamic Republic of Iran, Qatar, and Russia hold about half of global proven gas reserves.

Table 3.2.1. Unconventional Natural Gas Resources, 2009
(Trillions of cubic meters)

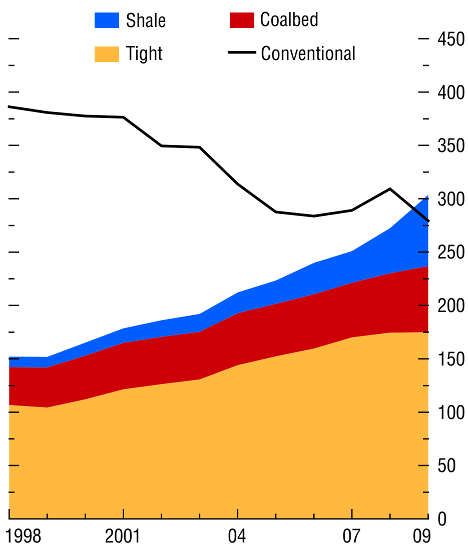
	Tight Gas	Coalbed Methane	Shale Gas	Total
Middle East and North Africa	23	0	72	95
Sub-Saharan Africa	22	1	8	31
Former Soviet Union	25	112	18	155
Asia-Pacific	52	48	174	274
Central Asia and China	10	34	100	144
OECD[1] Pacific	20	13	65	98
South Asia	6	1	0	7
Other Asia-Pacific	16	0	9	25
North America	39	85	109	233
Latin America	37	1	60	98
Europe	12	7	15	34
Central and Eastern Europe	2	3	1	6
Western	10	4	14	28
World	210	254	456	920

Source: International Energy Agency, *World Energy Outlook*, 2009.

[1]OECD = Organization for Economic Cooperation and Development.

Box 3.2 *(continued)*

Figure 3.2.1. U.S. Natural Gas Supply, 1998–2009
(Billions of cubic meters)



Sources: International Energy Agency; U.S. Energy Information Administration; and IMF staff calculations.

exploring potentially large shale gas resources, including Australia, Austria, Canada, China, Germany, Hungary, India, Poland, Saudi Arabia, and the United Kingdom.

In some countries assessing the commercial viability of reserves and developing the resource base could take up to a decade. There are a number of technical and political challenges: shale gas recovery requires large drilling areas that in some cases may cross borders, affect a large number of residents, and ultimately draw opposition on environmental grounds because of the risk of groundwater contamination with fracture fluids. For example, Europe, with high population density and many national borders, could face difficulties in regulating exploitation permits. Nevertheless, some eastern European countries, particularly Poland, are actively exploring their potential. China is targeting shale gas production of 30 billion cubic meters a year, which is about half the country's 2009 natural gas consumption.

Long-term marginal costs and the role of shale gas in the energy mix are difficult to project. Shale gas production is characterized by high initial production rates followed by a rapid decline.[4] The market price therefore needs to cover relatively high operating costs (when compared with conventional natural gas production) and provide for fast investment amortization. A Massachusetts Institute of Technology study (MIT, 2010) estimates that the breakeven price for the exploitation of shale gas is in the range of $4 to $8 per million cubic feet (at constant 2007 prices). So far, the U.S. benchmark (Henry Hub) natural gas spot price has fluctuated within this breakeven range, even though it remains well below precrisis levels. As a result, production has continued to grow rapidly despite concerns about the impact of current low prices.

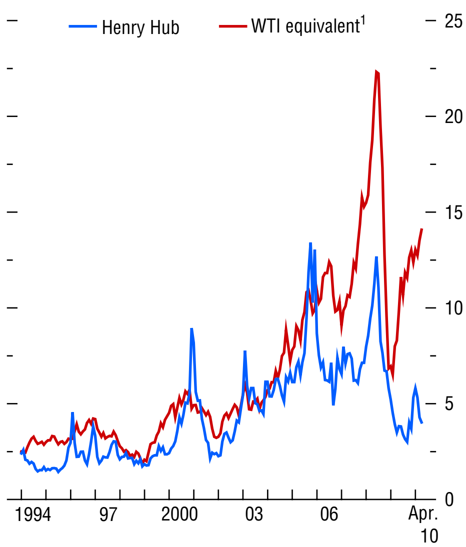
The rapid increase in shale gas supply partly explains the recent decoupling of natural gas prices from oil prices in the United States. If prices per unit of energy were the same, the price of natural gas would be one-sixth the oil price per barrel. Figure 3.2.2 shows that this parity held broadly in the U.S. spot market until late 2005. Since then, gas has become cheaper than oil, suggesting that arbitrage remains limited given that gas and oil are not good substitutes in many applications—transportation being a prime example.

Increased shale gas supply in the United States has led to a redirection of liquefied natural gas (LNG) supplies to other markets, notably Europe and Asia, which has raised questions about traditional contract pricing arrangements. In Europe and Asia, gas prices remained indexed to oil prices in long-term contracts (Table 3.2.2), but the combination of increased U.S. shale gas production and increased LNG supply and distribution capacity outside North America could lead to a decoupling of oil and gas prices as in the United States. This pressure on contract arrangements

[4]The average decline rate (weighted by production) of the Barnett shale horizontal wells is 39 percent in the second year and 50 percent in the third year relative to the first year (IEA, *World Energy Outlook*, 2009).

Box 3.2 *(continued)*

Figure 3.2.2. U.S. Natural Gas versus Oil Spot Prices
(U.S. dollars per million British thermal units)



Source: Dow Jones & Company.
[1]WTI = West Texas Intermediate.

Table 3.2.2. Composition of Wholesale Gas Transactions: United States and Europe, 2007
(Percent)

	Spot Market Prices	Oil-Indexed Prices	Other
North America	98.7	0	1.3
Europe	22	72.2	5.8

Source: International Energy Agency, *World Energy Outlook* (2009).

has led to the emergence of spot price markets similar to those in the United States. Greater LNG transportation capacity has also facilitated price arbitrage between markets.

In conclusion, shale gas has the potential to change prospects for natural gas as a source of primary energy, but it remains difficult to predict the extent to which this potential can be realized. Lower relative prices for gas will probably lead to a greater market share of natural gas in total primary energy, with the power sector likely the main beneficiary. But large-scale shale gas production will have to start outside the United States for this energy source to realize its full potential.

Box 3.3. Short-Term Effects of Oil Shocks on Economic Activity

The short-term impact of large, unexpected oil price changes—typically referred to as oil shocks—on economic activity is hard to quantify and can be quite different from the impact over the long term. Both the nature of the oil price shock and the mix of short-term transmission channels at work can contribute to such differences. This box considers these issues and describes how the short-term impact of oil shocks may differ from the model simulations presented in this chapter.

The nature of the oil price shock is the most important determinant of its eventual impact on economic activity. If an unexpected increase in oil prices is driven by an unexpected boom in world economic growth (a demand shock), oil prices and GDP growth are likely to move together initially: the higher prices moderate the initial boom but do not cause a downturn. However, supply shocks due to factors such as a temporary disruption in oil production caused by geopolitical events or a permanent decline in the availability of oil are likely to raise oil prices regardless of global economic conditions and, depending on the magnitude of the supply disruption, may cause a loss of output.[1]

The expected duration of a supply shock is also likely to shape its macroeconomic effects. Producers and consumers base their decisions, in part, on expectations of future prices. As a result, a shock that is expected to be temporary (for example, supply disruptions due to short-lived geopolitical disturbances) should affect these plans less than a shock that is very persistent.

The analysis in this chapter considers an unexpected permanent supply reduction and suggests a relatively benign macroeconomic impact over the medium to long term. This should not be surprising; over this horizon, the share of oil in the cost of production should shape most of the GDP impact of an oil price shock. In particular, although oil is either a direct or an indirect factor of production for many final and intermediate goods (from perfume to jet fuel), oil's overall cost share as a proportion of GDP is quite small, ranging from 2 to 5 percent depending on the country. In principle, for an oil importer, the elasticity of GDP with respect to an oil price change induced by a supply shock should be about equal to that of the cost share—that is, quite small. Moreover, for the entire world—which includes oil exporters where higher oil prices stimulate demand for goods and services—the impact can be even smaller.

In the short term, however, other factors and amplification channels may significantly affect the response of output to an unexpected oil price hike. These channels are, however, hard to consider in a large-scale model, and they may not play a significant role in all instances in practice.

A first channel is related to the possibility that oil price spikes (particularly those associated with geopolitical events) make both firms and households more risk-averse.[2] Higher uncertainty regarding future economic prospects can cause firms and households to postpone decisions that are difficult to reverse, such as hiring, investing, and buying durable goods. Financial markets may exacerbate these effects if imperfect information or herd behavior in markets contributes to a sharp decline in liquidity and a sharp adjustment in asset prices.

A second channel is the reallocation of the factors of production. Industries and firms that produce oil-intensive goods or use them as inputs

The main authors of this box are Andrea Pescatori, Shaun Roache, and Joong Shik Kang.

[1]Precautionary demand can exacerbate the oil price effects of small oil supply disruptions or supply concerns (Kilian, 2009).

[2]Studies have noted how small increases in the probability of very unlikely but catastrophic events (such as oil shortages, political turmoil, and the shutdown of some industries) can have dramatic effects on human behavior.

Box 3.3 *(continued)*

are particularly vulnerable to oil price increases. Some of these industries and firms may no longer be profitable if oil prices stay high for long. This can either depress their profit margins or decrease demand for their products when the oil price increases are passed on to consumers.[3] At a macroeconomic level, the exit of such firms involves reallocation of capital and labor to other industries, a process that can take some time and involve large sunk costs.[4] More generally, the adverse effects of large-scale bankruptcies in hard-hit industries can spread to the rest of the economy through either corporate or bank balance sheets.

Policy mistakes can also exacerbate the effects of an oil supply shock. For instance, monetary policy can contribute to destabilizing output by mistakenly fighting a temporary oil-induced surge in headline inflation.[5] Price controls can lead to rationing and shortages, which may have played a role in amplifying the effects of the 1973 oil shock.[6]

Quantifying the short-term impact on growth of oil shocks has been a daunting challenge in the empirical literature (Table 3.3.1). It can be difficult to determine the nature of the shock—whether induced by demand or supply—and the interplay of the amplification channels described above. But another challenge arises from recent structural changes in economies. For example, there is general agreement that recent oil price hikes have affected output less than those during the 1970s. Some possible explanations include that recent increases were driven mainly by demand, that monetary policy forestalled damaging second-round effects on wages, that real wage rigidities have diminished, and that the oil intensity of advanced economies has fallen a lot.[7] Disentangling demand from supply shocks is the key challenge facing empirical work that tries to quantify the relationship between oil prices and activity.

Table 3.3.1. Annualized Percent Impact of a 10 Percent Oil Price Increase on Real U.S. GDP Growth after One Year

	GDP Peak Response (percent)	Sample Period
	Older Sample Period	
Rotemberg-Woodford (1996)	–2.00	1948–80
Hamilton (1996)	–0.75	1948–73
Blanchard-Galí (2007)	–0.40	1970–83
	Recent Sample Period	
Hamilton (1996)	–0.20	1974–94
Kilian (2009)[1]	< –1.00	1975–2007
Blanchard-Galí (2007)	–0.15	1984–2007
Cavallo-Wu (2006)	–0.40	1984–2007

Sources: Blanchard and Galí (2007); Cavallo and Wu (2006); Hamilton (1996); Rotemberg and Woodford (1996); and IMF staff calculations.

Note: The oil price series used may differ across studies. In all studies, oil price changes are meant to be induced by oil supply shocks and not driven by global demand.

[1]IMF staff calculations are based on Kilian (2009) results.

[3]For example, the U.S. auto industry was hit hard by the 2007–08 gasoline price increase.

[4]Reallocating labor usually involves a loss of human capital, given that some skills are job-specific. One firm's capital goods may be less productive in another firm or just too costly to move.

[5]The role played by monetary policy in amplifying the initial oil shock is still debated (see Hamilton, 1996; Bernanke, Gertler, and Watson, 1997; and Hamilton and Herrera, 2004).

[6]In particular for gasoline (see Ramey and Vine, 2010).

[7]See Blanchard and Galí (2007) and Nakov and Pescatori (2010).

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