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The Commodity Boom: Longer-Term Prospects

The enduring importance of commodities to the world economy and their volatility has been driven home with the rise, and recent decline, of prices for energy, metals, and food. Before they began to fall in the second half of 2008, the real prices of energy and metals more than doubled over the past five years, while the real price of internationally traded food commodities increased 75 percent (see chapter 1 for more detail on the most recent developments in commodity markets).

This chapter reviews the main characteristics of this most recent boom in commodity markets and examines the structure and behavior of both their demand and supply, with a view to better understanding prospects over the medium to long term. The discussion does not include forests or fisheries, given their complexity and the greater importance of issues related to the public commons than for oil, metals, minerals, and agricultural products.

Several important insights emerge from this chapter that are likely to drive developments over the next several decades.

The magnitude and duration of the commodity price boom are unprecedented.

- The upswing of the current boom lasted five years. Average commodity prices doubled in U.S. dollar terms (in part boosted by dollar depreciation), making this boom longer and stronger than any boom in the 20th century.
- Like earlier booms, this one ended when a slowdown in global growth eased demand pressures. The unusual strength and duration of this boom reflect the unusual resilience, until now, of global growth, particularly in developing countries.

For oils and metals, an extended period of low or falling prices created the conditions for the boom and help explain the weak supply response.

- Low prices throughout much of the 1980s and 1990s reflected periods of relatively weak growth and abundant spare capacity. Idle capacity arose, both because energy demand declined in the wake of high oil prices in the 1970s and early 1980s and because demand for oil and metals in the former Soviet Union (FSU) fell sharply when altered economic incentives caused these countries to radically increase the efficiency with which commodities are used.
- During the 1990s, much of the rising demand for oils and metals was met by the relatively easy rehabilitation of this already-existing capacity. This helped to keep global commodity prices low and deterred investment in new supply capacity, thus depressing activity in the sectors supplying inputs to commodity exploration and exploitation.

- As a result, a mismatch developed between the trend growth of demand and the trend growth of supply capacity. This mismatch became apparent in the early to mid-2000s, when spare capacity was exhausted and demand began to outstrip supply, pushing up oil and metals prices.
- Metals prices also were boosted by strong demand growth, linked to unusually high and rising metal intensities in China. Going forward, the intensity of metals demand in China should decline as investment rates fall and market mechanisms provoke an increase in efficiency similar to that observed in the FSU.

The supply response in oil and metals is expected to remain sluggish over the next few years, but new discoveries and technological progress are likely to boost supply over the long run.

- Ongoing shortages in the sectors that provide exploration and exploitation services, and the long lags between initial investments and the coming onstream of new production, suggest that supply conditions may remain relatively tight in the oil and metals sectors and that prices, although declining, are unlikely fall to their 1990s levels.
- Despite rising production levels, known reserves of most metals and oil have remained fairly constant because of new discoveries and improvements in extraction technology.
- Although oil prices are likely to fall below existing levels during the current downturn, they are expected to rise during the recovery and stabilize at around $75 a barrel in real terms because new supplies—for example, from offshore oil fields and Canadian tar sands—have higher production costs, and a majority of known reserves are located in regions that are politically unstable or not open to outside investors.
- Given continued technological progress and appropriate policies, high oil prices will prompt and use development of alternative energy sources (including renewables) and greater efforts at conservation, raising energy supplies and significantly reducing the demand for oil.
- For metals, slower growth in commodity-intensive developing countries (as population growth slows and income levels catch up with the West), the easing of China's investment surge, a rise in the share of total output held by the less-commodity-intensive service sector, and substitution away from expensive materials should slow demand over the long term, facilitating a decline in prices.

The extension of the boom to agricultural markets mainly reflects the rising demand for biofuels and high energy prices.

- Higher energy and fertilizer prices raised production costs in agriculture, and the combination of high oil prices and biofuel subsidies and mandates boosted demand for some food crops. Poor harvests in Australia also contributed to a decline in grain stocks.
- Demand growth for food and feed in developing countries (such as China and India) has not accelerated and was not a major contributor to the rise in food prices.
- Real-side speculation (the decision to hold on to physical stocks in anticipation of further price increases) and financial investments along with policy reactions such as the imposition of export bans, also contributed to the rapid increase in grain and oilseed prices during 2007 and 2008.

The prospects for growth in the supply of agricultural commodities at the global level are good, while demand growth is likely to slow.

- Historically, agricultural productivity has increased more quickly than population, allowing food production to keep pace with growing demand, even as the share of the population working in agriculture declined. Over the next 20 years, assuming sufficient investment is forthcoming in developing and high-income countries, the spread of more-intensive production techniques coupled with improved varieties that are emerging from recent advances in biotechnology, should allow global productivity gains on par with historical trends despite some productivity losses caused by climate change.

- Considerable potential remains for bringing new (albeit somewhat less productive) land under cultivation in Latin America, Africa, and the FSU countries.
- The demand for agricultural commodities will slow as population growth slows and as incomes in developing countries continue to rise (at higher incomes, the incremental rise in demand for agricultural commodities sparked by further increases in income is relatively small).
- Robust supply growth and slowing demand are expected to reduce agricultural prices in the long run. Increased demand for biofuels, however, will extend the period of high prices unless policies change or energy prices fall more rapidly than expected.
- A more-rapid-than-expected warming of the planet could reduce agricultural productivity sharply, leading to rising food prices.

While global supply prospects are good, unless policy responds forcefully, food production in many developing countries may fall short of output gains

Yield gains associated with the green revolution are waning in many countries. Productivity levels in much of Africa and Europe and Central Asia are also declining; they are only one half those of best-practice developing countries, even after having controlled for differences in climate and soil.

Unless large-scale agricultural investment and knowledge creation and dissemination are stepped up, food production in many of these countries will not keep pace with demand. As a result, these countries will become increasingly dependent on imported food.

Simulations suggest that if productivity growth in developing countries disappoints, global food prices will be higher, and many developing countries—especially those with rapidly growing populations—will be forced to import more-expensive food from high-income countries, where productivity growth shows fewer signs of waning.

The remainder of this chapter explores each of these themes in more detail. The next section compares the main characteristics of the current commodity price cycle with earlier ones. Then an examination of the long-term demand and supply sides of commodity markets follows. The chapter then brings the forecasts for supply and demand in commodity markets together to form a base-case scenario for prices, along with some alternative scenarios. While a wide range of future outcomes for supply, demand, and prices are possible, the simulations support a highest-probability outcome where today's high prices should induce sufficient additional supply to keep commodity prices well below their recent highs over the medium to long term—although they are not expected to descend as low as they were in the 1990s. A final section concludes.

Characteristics of the current commodity price boom

Booms and busts are relatively common occurrences in commodity markets (box 2.1 and figure 2.1). Like its predecessors, this episode of high prices has occurred during a period of strong global growth and heightened geopolitical uncertainty, and it generated significant inflationary pressures (see chapter 1).[1] However, this commodity boom was different in important ways as well. It was among the most marked of the past century in its

Box 2.1 Commodity price cycles

It is in the nature of commodities for their prices to show pronounced cyclical behavior. Indeed, some of the most influential early insights about the role of expectations in pricing behavior derived from observations of how the interaction between prices and quantities in agricultural markets tended to generate price cycles (Kaldor 1934).

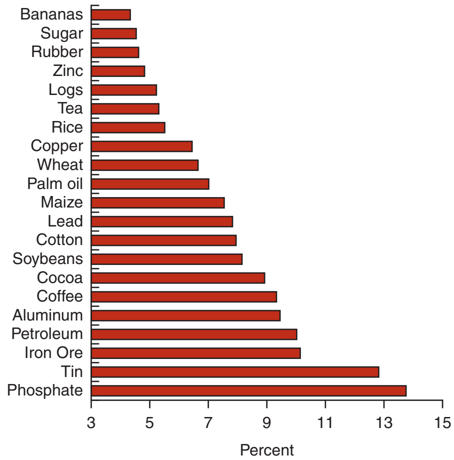
Prices in commodity markets tend to exhibit cyclical behavior because supply decisions (how much to plant, how many mine shafts to dig) must be made by market participants well before the final sale price of the commodity is known. Because producers in the market are uncertain about future demand and the production decisions of other producers, the tendency in the aggregate is for the independent production decisions to overcompensate for short-term imbalances between demand and supply and therefore for commodity prices to be volatile. The longer the lag between the production or investment decision of producers and the actual increase in output, the longer the cycle in prices.

Individual commodities differ in the extent to which they exhibit cyclical behavior and in the mechanisms underlying the cycles. The output of industrial commodities tends to be most volatile, mainly because their demand tends to fluctuate with the business cycle and (in the case of crude oil) to be subject to policy-related supply shocks (box figure 2.1a).

While prices of all commodities are sensitive to spare capacity, the duration of booms and busts in the metals, minerals, and the oil sectors tends to be longer than in agricultural markets because of the longer lags between investing in new capacity and the eventual increase in supply.

Their revenues also tend to be more volatile than revenues in agricultural commodities because changes in production mainly reflect demand shocks. As a result, both prices and quantities move in tandem, rising during periods of high demand and declining in periods of low demand. In contrast, demand for agricultural products tends to be more stable, and volatility tends to stem from supply shocks. As a result, price movements tend to reduce revenue volatility among agricultural commodities because prices tend to move in the opposite direction of supply shocks—rising when supply is low and falling when supply is ample. Thus, for example, copper, lead, and zinc have much higher price and revenue volatility than maize, soybeans, and wheat, but the differences in output volatility are much less marked (box figure 2.1b).

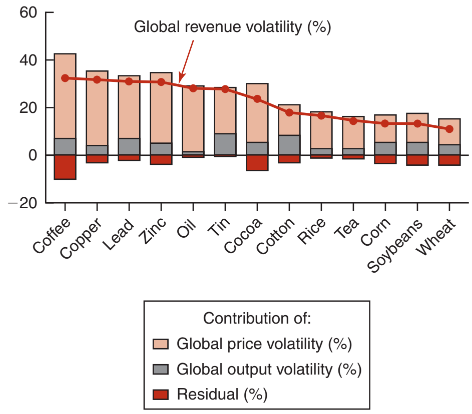
Box figure 2.1a Volatility of production around trend, 1960–2007



Source: World Bank.

Box figure 2.1b Volatility decomposition of global revenue for selected commodities, 1986–2006

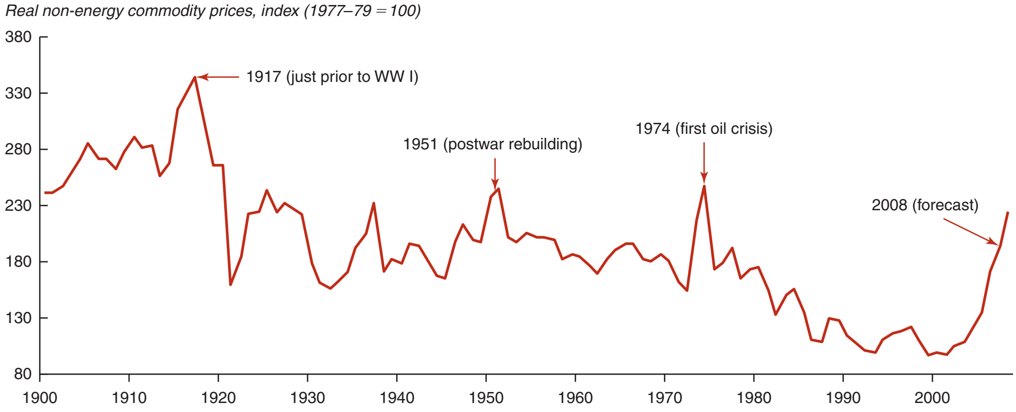
Volatility decomposition of select commodities (global), 1986–2006



Source: World Bank.

The current boom in agricultural prices is different in this regard, because it reflects a demand shock rather than a supply shock, meaning that prices have risen even as overall production (including that destined for biofuels) has increased.

Figure 2.1 The recent commodity boom was the largest and longest of any boom since 1900



Source: Grilli and Yang (1988) for 1900 to 1947; World Bank for 1948 to 2008.

magnitude, duration, and the number of commodity groups whose prices have increased.

The size of the price increases are unprecedented

The magnitude of commodity price increases during the current boom is without precedent. The real U.S. dollar price of commodities has increased by some 109 percent since 2003, or 130 percent since the earlier cyclical low in 1999. By contrast, the increase in earlier major booms never exceeded 60 percent (table 2.1).

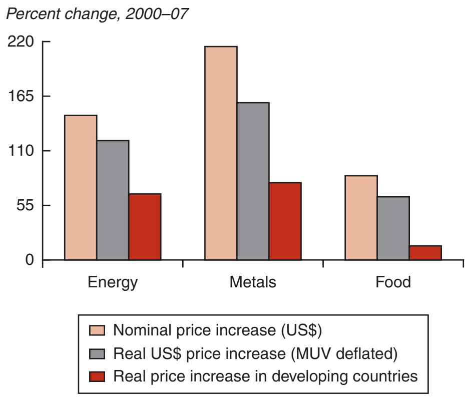
The unusual amplitude of the price increases during this boom partly reflects the

Table 2.1 Principal characteristics of major commodity booms

Common features	1915–17	1950–57	1973–74	2003–08
Rapid global real growth (average annual percent)	—	4.8	4.0	3.5
Major conflict and geopolitical uncertainty	World War I	Korean War	Yom Kippur War, Vietnam War	Iraq conflict
Inflation	Widespread	Limited	Widespread	Limited second round effects
Period of significant infrastructure investment	World War I	Postwar rebuilding in Europe and Japan	Not a period of significant investment	Rapid buildup of infrastructure in China
Centered in which major commodity groups	Metals, agriculture	Metals, agriculture	Oil, agriculture	Oil, metals, agriculture
Initial rise observed in prices of	Metals, agriculture	Metals	Oil	Oil
Preceded by extended period of low prices or investment	No	World War II destroyed much capacity	Low prices and a supply shock	Extended period of low prices
Percent increase in prices (previous trough to peak)	34	47	59	131
Years of rising prices prior to peak	4	3	2	5
Years of declining prices prior to trough	4	11	19	—

Source: World Bank.
— = Not available.

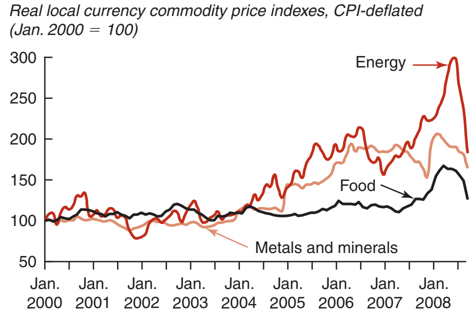
Figure 2.2 The real local currency price of commodities rose much less than the real dollar price



Source: World Bank.

Note: Real US$ price has been deflated by the unit value of manufactures (MUV); real price in developing countries represents a trade-weighted average of local currency price increases deflated by local consumer prices increases.

Figure 2.3 Oil and metal prices led this boom, with food prices rising only much later



Source: World Bank.

fact that the U.S. dollar has been depreciating during the same period and most primary commodity prices are quoted in dollars. The real commodity prices in developing countries (local currency prices deflated by local inflation), have increased by much less than their dollar counterparts. The real dollar price of internationally traded metals and minerals rose by 158 percent between 2000 and 2007, but by only 78 percent in developing countries. Similarly, the real dollar price of internationally traded food commodities increased 64 percent compared with a much lower 14 percent in developing countries (figure 2.2).[2]

The boom covers a wide range of commodities and has lasted much longer than previous ones

This boom also differs from earlier ones in the breadth of commodities that have seen their prices rise sharply. The initial acceleration in prices was first visible in the oil market and was quickly followed by developments in the metals and minerals market. The real price of agricultural products was broadly stable, especially in developing countries, and began to rise sharply only in early 2007 (figure 2.3).

This is very different from the 1950s boom, when post–World War II rebuilding (and fears of shortages) increased metals prices and poor harvests raised agricultural prices, but the price of oil remained flat. In the 1970s boom, agricultural and oil prices increased, but metals prices rose initially and then collapsed with the decline in aggregate demand.

The current price boom is unusually long. The U.S. dollar price of internationally traded commodities has been rising for more than five years, much longer than the price booms of the 1950s and 1970s. Only the 1917 boom saw a sustained increase in commodity prices over a similarly long period (four years).

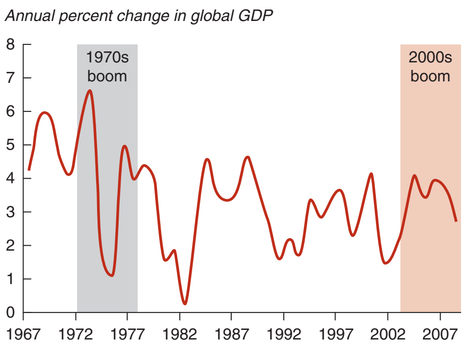
Typically a commodity price boom is followed by a bust as demand reacts to high prices by contracting and supply reacts by expanding. For example, the 1970s and 1980s busts were associated with a sharp slowdown in world output, which eased demand pressures at the same time as supply was rebounding. Until most recently, the current boom has been marked by a weak supply response (see below) and sustained global growth.

The roots of the boom in commodity prices

This commodity price boom has been supported by strong growth in global demand, primarily from developing countries. With the possible exception of a few metals, however, the strong GDP growth of the past five years does not by itself account for the magnitude or duration of the current boom (box 2.2). Global GDP was actually growing faster in the lead-up to the 1970s boom, with Japan—taking the role China plays today—emerging as a new economic power with growth in excess of 10 percent (figure 2.4). However, the strength and duration of this boom owes much to the resilience of developing-country growth, which continued at high levels for much longer than during previous episodes of high commodity prices. On the one hand, this reflected the surprising facility with which both industrial and developing countries absorbed the initial very large hikes in commodity prices—itself a reflection of the very buoyant external conditions, including notably historically low interest rates, weak inflation, and ample liquidity (see World Bank 2007a, 2008).

Other important factors were also at work. The supply response in extractive industries has been muted because of the low prices of the late 1980s and 1990s, which reduced incentives to develop new deposits and to invest in the physical and human capital required to expand supply. In agriculture, higher oil and fertilizer prices, along with increased demand from biofuels and a reduction in grain stocks, have been more important than fast growth per se.

Figure 2.4 Global growth lasted longer and was stronger during the recent commodity boom than in earlier ones



Source: World Bank.

An extended period of low prices depressed investment in new capacity

The influence of low prices was perhaps most marked in the oil sector, where following the oil shocks of the 1970s and 1980s, conservation efforts and substitution toward other sources of energy depressed demand for oil and oil prices. Indeed, it took 15 years for world oil demand to regain its 1979 level. Meanwhile, the expansion of oil production, particularly in the North Sea, Mexico, and Alaska eliminated the market power that the Organization of Petroleum-Exporting Countries (OPEC) had exploited to keep prices high even in the face of rapidly declining demand. By mid-1986, nominal prices had fallen to less than $10 a barrel and OPEC's spare production capacity was equal to 8.7 mb/d—more than 13 percent of world demand at that time.[3]

Global spare capacity was further augmented during the 1990s, when demand for oil in the FSU declined precipitously and more or less permanently. As the prices of primary commodities were allowed to reflect world prices and many of the energy- (and metals-) intensive industries that had characterized the Soviet era closed or retooled, demand for energy (and metals) in these countries declined rapidly. Overall, oil demand declined by 40 percent between 1987 (its peak) and 1999—or by 5 million barrels a day—the equivalent of 7 percent of world demand in 2000.

Initially, oil production in the FSU fell by about as much, so there was an enormous buildup of dormant capacity. Including OPEC's surplus capacity of about 5 mb/d, total dormant capacity from these countries equaled around 10 mb/d in 1995 (figure 2.5).[4]

Box 2.2 Developing-country growth and global commodity demand in the recent past

The growth surge of developing countries between 2003 and 2007 contributed to strong demand for commodities. Had output expanded more slowly, in line with the long-term growth potential of developing countries—estimated to be about 6.4 percent—oil demand would have been lower by only about 1 million barrels a day, or just under 1.2 percent of world consumption; demand for metals would have been about 1.5 percent lower and demand for grains about 1.9 percent lower.

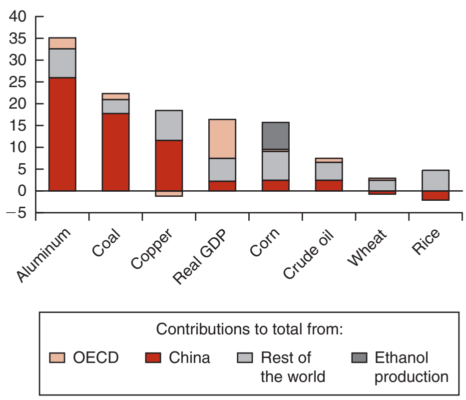
Overall, demand for most commodities at the global level rose less quickly than world GDP, and for most commodities, the contribution of developing countries to the increase in commodity demand was in line with their GDP growth (box figure). Incremental developing-country demand for some commodities was much stronger than in high-income countries, both because developing-country GDP was growing at a faster rate and because relatively commodity-intensive manufacturing activities were being transferred from high-income to developing countries in this time period—a factor that by itself should have had no impact on global commodity demand.

Indeed, despite the acceleration in world GDP, consumption for most commodities did not rise rapidly. Coal and certain metals represent notable exceptions, and here the demand of China has played a particular role. Between 2003 and 2007, China's consumption of aluminum increased by 7.1 million tons, or 26 percent of world demand. Coal consumption increased by 458 million (oil equivalent) tons, or 18 percent of global demand. However, China's production of these commodities increased by almost as much—7.0 million tons in the case of aluminum and 421 tons in the case of coal—so its demand surge contributed relatively little to overall market tightness. Indeed, by mid-2008, the price of aluminum rose by only 74 percent compared with its average value in the 1990s (versus 200 percent for metals and minerals in general), and coal rose by 392 percent, about the same as natural gas, but much less than oil.

Importantly, despite rapid gains in developing-country GDP and income growth, grain demand did not accelerate appreciably for developing countries considered as a whole or for China alone. In fact, Chinese consumption of wheat and rice declined, and China's contribution to incremental global corn demand was roughly in line with its increase in GDP.

Box figure 2.2 China was the key global metals contributor to global demand growth

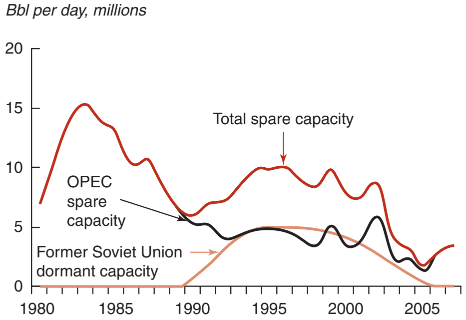
Percent increase in global commodity demand, 2003–07



Source: World Bank.

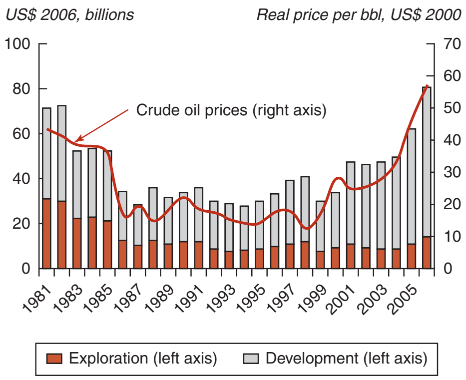
The buildup of excess capacity meant that the real price of oil during the 1990s remained low, at $16 a barrel, equivalent to half the price experienced during 1985. It also meant that there was little incentive to invest in new, higher-cost oil fields. Overall spending by major American multinational oil companies on exploration for new wells and the development of existing wells declined by more than 50 percent, from $72 billion in 1980 to $30 billion in 1999 (figure 2.6).[5] As a result, demand for the inputs required for oil exploration and extraction was weak, and capacity in these supporting industries declined, as did the number of new engineers trained to find and extract oil.[6]

Figure 2.5 Dormant capacity helped keep oil prices low in the 1990s



Source: World Bank, British Petroleum, International Energy Agency, Petroleum Economics Ltd.

Figure 2.6 Real spending by major American multinational oil companies declined by 60 percent in the 1980s



Source: Energy Information Agency; World Bank.

As the transition continued, oil-producing firms in the region were able to rehabilitate existing capacity relatively easily and to reorient expanding output to Western markets, where demand continued to rise. Between 1995 and 2005, world oil demand increased by nearly 14 mb/d, with 8 mb/d of that total being met by the dormant capacity in the countries of the FSU and OPEC.[7] As a result, underlying capacity grew less than half as fast as demand throughout the period.

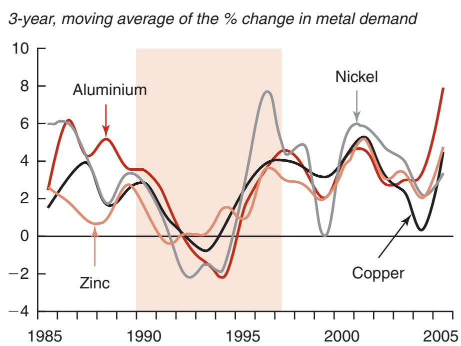
With spare and dormant capacity absorbed, prices surged in 2004

By 2004, the dormant capacity that had been created by the decline in demand in the FSU had been reabsorbed. When demand growth (which had been subdued following the bursting of the Internet bubble) regained strength, supply was unable to keep pace, in turn resulting in a surge in prices.[8]

Metal demand also declined sharply as numerous heavy industries in the FSU went out of business. Global demand for metals and minerals eased sharply beginning in 1990 and only returned to trend rates in 1997 (figure 2.7). As was the case in the oil sector, the pickup in metals prices beginning in 2003 did not reflect unusually strong demand—except for aluminum—whose price, as it happens, has been relatively stable. Rather, it reflected low stock levels and depressed capacity.

Indeed, the strong correlation between the prices of metals and minerals on the one hand and oil on the other during 2003–06 is unusual. Historically, the correlation between the prices of these commodities tends to be much less pronounced than between oil and agricultural goods (table 2.2) because high oil prices tend to cut into industrial production and demand for metals, while food demand is relatively inelastic.

Figure 2.7 Global metal demand also fell during the transition



Source: World Bank, International Monetary Fund.

Table 2.2 Comovement among major commodity prices, 1960–2007

Commodity	Maize	Wheat	Rice	Coffee	Cotton	Copper	Aluminum	Iron ore	Gold
Wheat	0.91								
Rice	0.82	0.81							
Coffee	0.70	0.45	0.63						
Cotton	0.83	0.80	0.82	0.82					
Copper	0.75	0.55	0.71	0.35	0.75				
Aluminum	0.70	0.46	0.63	0.37	0.76	0.41			
Iron ore	0.72	0.49	0.63	0.36	0.76	0.0	0.34		
Gold	0.69	0.0	0.65	0.54	0.80	0.0	0.44	0.0	
Crude oil	0.72	0.55	0.65	0.58	0.81	0.0	0.48	0.0	0.83

Source: World Bank.
Note: The numbers are the adjusted R^2s of a regression of each price on all other prices (individually), a time trend, and the MUV, both directions. The residual was tested for stationarity (5% level of significance). If cointegration was confirmed in one direction, the table reports the respective adjusted R^2. If cointegration was found in both directions, the higher adjusted R^2 is reported. If no cointegration was found, implying that any correlation would, in fact, be a spurious correlation, the result was not reported, and the respective cell shows 0.0 (e.g., gold with wheat or copper).

Increasing prices sparked a boom in investment in the oil, metals, and minerals markets

Global private investment in exploration for nonferrous metals rose from $2 billion in 2002 to $7 billion in 2006 and to an estimated $9 billion in 2007. Overall investment in the sector more than doubled between 2001 and 2005 in a number of mineral-rich countries including Canada, Mexico, the Russian Federation, South Africa, and the United States (UNCTAD 2007). At the same time, investment in the oil sector increased dramatically, 75 percent in the case of the American multinational companies (see figure 2.6).

After years of low investment, the ability of service sectors to deliver inputs to the commodity-producing firms had atrophied. As a result, the surge in demand for investment goods over the last several years has exceeded capacity by a wide margin and costs have skyrocketed.

In the oil sector, operating costs have more than doubled, and the cost of inputs to exploration and extraction have increased substantially. For example, the day-rate price of semisubmersible rigs in the Gulf of Mexico (0–3,000 ft. water depth) increased from $36,000 in 2000 to $325,000 in March 2008, a ninefold increase. Similar increases have been observed in other items, such as water jack-up rigs, whose day rates have increased fivefold in West Africa.

Such factors have put upward pressure on the costs of developing new mines and oil fields. Operating costs for marginal producers rose by 25 percent for copper and 28 percent for aluminum between 2002 and 2005 (IMF 2006), and in the case of at least one nickel project, they rose by 170 percent.[9] Higher costs are reported to have increased the cost of extracting a barrel of crude from Canada's oil sands to $75, while deepwater offshore projects may cost more than $50 a barrel.

Although higher prices are inducing substantial increases in capacity in the input industry, that capacity will not be in place for several years. As a result, some delivery times have more than doubled. For example, in the mining sector it currently takes 45 months to deliver a grinding mill, compared with a more normal 20 months; for rope shovels the delivery time has gone from 9 months to 24. Large haul trucks, normally available within 4 months, now take 2 years.[10] Other services may take even longer to come into balance; the training of technical personnel such as engineers typically takes many years.

As a consequence, it may take some time before the surge in investment now under way leads to a surge in the delivery of inputs, and even more time before delivery of inputs translates into actual increases in oil, metal, and mineral production. All of this suggests that notwithstanding recent declines, supply will continue to be relatively scarce for several more years and that prices will remain higher than in the 1990s for some time.

The boom in agricultural prices reflects both high costs stemming from oil prices and increased demand from biofuels

The rise in the price of agricultural commodities occurred much later than it did for either oil or metals and minerals. Dollar prices were rising as early as 2003, but these increases mainly reflected exchange rate movements. Relative to consumer prices in developing countries, internationally traded food prices were broadly stable until 2007, when the prices of internationally traded food commodities (such as maize, wheat, and soybeans) rose very rapidly (figure 2.8).

The timing of the rise in agricultural prices points strongly to the impact of energy markets (box 2.3) First, agriculture production is fairly energy intensive. The increase in oil prices raised the price of fuels to power machinery and irrigation systems; it also raised the price of fertilizer and other chemicals that are energy intensive to produce. The impact across different countries is difficult to quantify owing to a lack of data. In the United States, fuel, fertilizer, and chemicals accounted for 34 percent of maize production costs and 27 percent of wheat production costs in 2007 (USDA 2008). Energy, fertilizer, and chemicals would typically make up a smaller share of production costs in developing countries, because production is less intensive. Nevertheless such costs can be significant where intensive techniques are used. Thus, fertilizer is estimated to have accounted for 18 percent of variable costs for irrigated wheat in the Indian Punjab in 2002 and for 34 percent of soybean costs in the Mato Grosso, Brazil (World Bank 2007b).

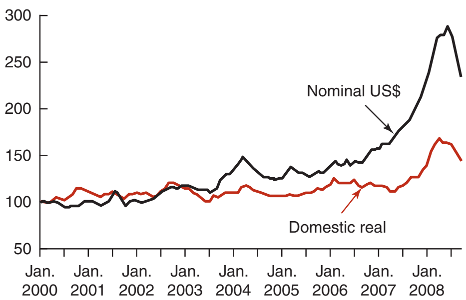
Second, high oil prices sparked an increase in biofuel production in the United States and Europe that boosted demand for certain grains and oilseeds thus contributing to their rapid price rise in the course of 2007 and early 2008 (Mitchell 2008). Overall, two-thirds of the increase in world maize production since 2004 has gone to meet increased biofuel demand in the United States, thereby reducing the quantity available for food and feed uses. Estimates of the impact of increased demand for biofuels on the rise in nominal maize prices range from 70 percent (Lipsky 2008), to 60 percent (Collins 2008), to 47 percent (Rosegrant and others 2008).

The increased demand for crops used for biofuels contributed to price increases for other food by reducing the land allocated to other crops. For example, in the United States high prices increased land devoted to maize production by 22 percent in 2007, with most of the increase at the expense of soybeans, the production of which declined by 16 percent. Area planted to rapeseed and sunflowers—used for biodiesel production—increased in Europe and elsewhere at the expense of wheat. Moreover, rising prices for maize, wheat, and soybeans redirected consumer demand toward other food products, aggravating price pressures on other grains. For example, rice prices rose from $376 a ton in January 2008 to $907

Figure 2.8 Real food prices were broadly stable in developing countries until mid-2007

Food price indexes

US$ nominal and domestic CPI-deflated price indexes (Jan. 2000 = 100)



Source: World Bank.

Note: Individual country data deflated by local consumer price index and aggregated by country shares in global imports.

Box 2.3 The historical link between crude oil and other commodity prices

Crude oil prices affect the prices of other commodities in a number of ways. On the supply side, crude oil enters the aggregate production function of most primary commodities through the use of various energy-intensive inputs and, often, transportation over long distances, an energy-demanding process. Some commodities, such as aluminum, have to go through an energy-intensive primary processing stage.

On the demand side, some commodities compete directly with synthetic products, which are produced from crude oil (cotton with man-made fibers, natural rubber with synthetic rubber). The demand for other commodities (maize, sugar, rapeseed, and other oils) has increased to produce biofuels. And the price of energy commodities such as gas and coal are affected because of their substitutability with crude oil.

Increases in crude oil prices also increase the disposable income of oil-exporting countries. Because these countries are heavy consumers of some commodities (e.g. tea and gold), and demand for these products is sensitive to incomes, high oil prices sharply increased regional demand for these products. Finally, crude oil price spikes are often associated with inflationary pressures. As a result, the demand (and hence the price) of precious metals often rise with oil prices, because investors and households view these metals as more secure ways for storing wealth.

Crude oil price increases reduce the disposable incomes of consumers, which, in turn, may slow industrial production. In principle, lower disposable income should have a negative impact on the consumption of food commodities. However, because the income elasticity for most food commodities is small, this effect is limited, and the positive impact of crude oil price increases on the prices of food commodities—through increased production and transportation costs—tends to overshadow the negative impact of reduced global consumption.

In contrast, the negative effect of high energy prices on industrial production reduces the demand for metals, thereby putting downward pressure on their prices. This tends to offset the positive effect from higher production and transportation costs. As a result the correlation between metals and oil prices is much lower than between oil and food prices (see table 2.2).

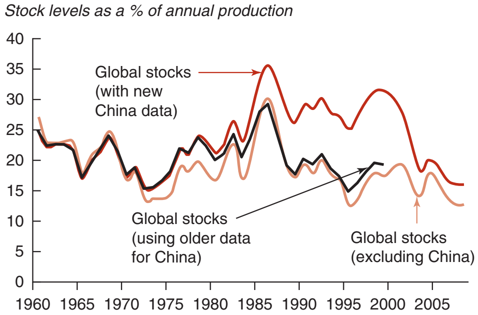
a ton in April, partly in response to the growing concern about the adequacy of global food supplies and the 120 percent increase in wheat prices during the previous six months.

While biofuels have contributed to higher food crop prices, they also represent an opportunity for profitable production in developing countries (OECD 2007; GTZ 2006). Additional ethanol production need not imply reducing food crops production. Brazil, for example, is a low-cost producer of ethanol from sugarcane and has an estimated 180 million hectares of pasture that could be used to produce additional sugarcane for ethanol—without reducing the food sugar crop. Many Sub-Saharan African countries, including Angola, Mozambique, and Tanzania, also have the potential to produce ethanol profitably from sugarcane on land that is not used for food crop production. Finally, nonfood crops such as *jatropha* can be used to produce biodiesel in many developing countries.[11]

In addition to the impact of oil markets, food prices were boosted by a series of poor wheat harvests, notably in Australia.[12] Before the run-up of prices in 2007, wheat stocks had fallen to the second lowest level of the past 40 years (figure 2.9).

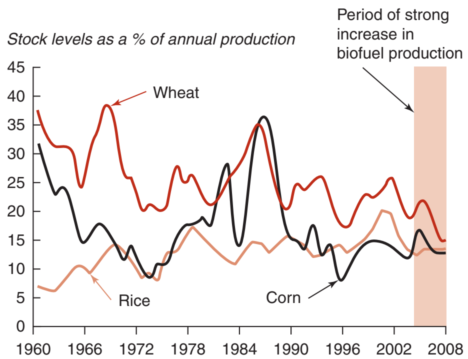
Reported global stocks of corn and rice declined before 2007, mainly due to a reduction of very large government stocks in China. Because these stocks have been greatly underestimated for the past 30 years (figure 2.10), current stock levels are not that different than what the world

Figure 2.9 Most of the decline in global grain stocks reflects lower stocks in China



Source: World Bank.

Figure 2.10 Outside of China, only wheat stocks are unusually low



Source: World Bank.

thought them to be during the early 1990s. It is thus unclear whether market participants took the decline in global stocks as a signal of coming scarcity or simply a return to stock levels that were consistent with relatively low prices a decade ago.

Government policy and investment fund activity may have exacerbated the increase in commodity prices

The extent of food price rises during this boom was probably exacerbated by the actions of governments, which impeded market forces that otherwise would have helped to attenuate the rise in prices and shorten the duration of the boom. As discussed in chapter 3, although the various subsidies and price controls that were in place or were introduced muted the poverty impact of higher prices, they have also reduced producers' incentives to increase output and consumers' incentives to substitute less-costly items in their food baskets. And export bans limited supplies available on international markets. For example, India's ban on rice exports in April 2008 was followed by other rice exporters, which prompted some countries, notably the Philippines, to increase rice imports to build up strategic reserves, thus further boosting international prices.

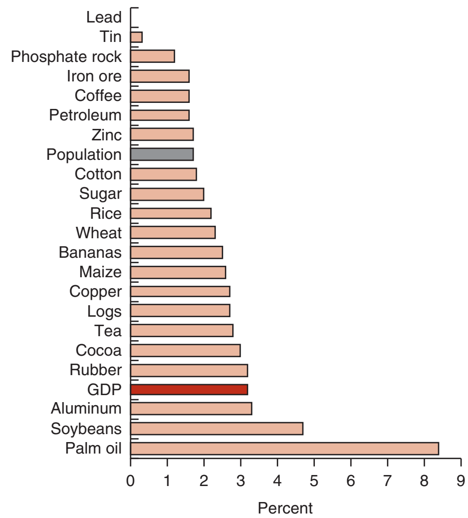
The activities of financial investors may have contributed to price rises as well. Traditionally, hedgers and speculators have been the dominant players in futures exchanges, but over the past few years, investment funds have become important players as well. Such funds may have indirectly influenced commodity prices. Since 2003 index fund investors, who allocate funds across a basket of commodity futures, have invested almost $250 billion in U.S. commodity markets, about half of it in energy commodities (Masters 2008). While such purchases create no real demand for commodities, they may have influenced prices because these funds are large compared with their physical market counterparts and because they have expanded rapidly. Their influence on prices is especially likely, if the rapid expansion of these markets contributed to expectations of rising prices, thereby exacerbating swings, as argued by Soros (2008).

The empirical evidence on whether such funds have contributed to the recent price surge is mixed. In the nonferrous metals market (where a similar buildup of financial positions has occurred), Gilbert (2008) found no direct evidence of the impact of investor activity on the prices of metals but some evidence of extrapolative price behavior that resulted in price movements not fully justified by market fundamentals. He also found strong evidence that futures positions of index providers over the past two years have affected soybean (but not maize) prices. Similarly, Plastina (2008) concluded that between January 2006 and February 2008, investment fund activity might have pushed cotton prices 14 percent higher than they would have been otherwise. On the other hand, two IMF (2006, 2008) studies failed to find evidence that speculators have had a systematic influence on commodity prices. A similar conclusion was reached by a series of studies undertaken by the Commodities Futures Trading Commission, the agency that regulates U.S. futures exchanges (Büyükşahin, Haigh, and Robe 2008; ITF 2008).

Although evidence that financial investments have contributed to the rapid run-up in commodity prices is limited, it seems likely that real-side speculation (the decision to hold stocks in anticipation of further price increases or to order more than needed now for the same reasons) likely contributed to the rapid increase in prices during 2007 and 2008.[13]

Figure 2.11 Demand for most commodities has grown less rapidly than GDP but more rapidly than population

Average annual growth rate, 1975–2006



Source: World Bank.

Long-term demand prospects

The longevity of the current boom and the wide range of commodities that have been affected have prompted many observers to wonder if the global economy is moving into a new era characterized by relative shortage and permanently higher (and even permanently rising) commodity prices. This section looks at demand and supply conditions in commodity markets over the medium to long term and concludes that slower population and GDP growth, changes in the structure of GDP, and technological improvements in production and use of commodities make this scenario unlikely.

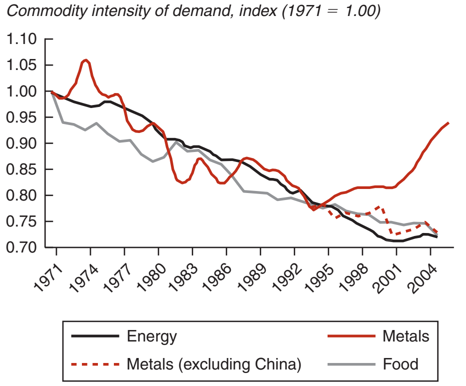
Demand for (and supply of) commodities over the past 35 years has been rising steadily. The quantity of energy consumed has increased by an average of 2.2 percent a year during 1970–2005, that of metals and minerals by 3.1 percent, and that of food by around 2.2 percent. However, demand for these commodities has grown less quickly than GDP, albeit more quickly than population (figure 2.11).

Expressed another way, the commodity intensity of GDP has been declining. For oil and food, this process has been going on continuously since the 1970s. For metals, the same trend was observed until the mid-1990s when it began to reverse (figure 2.12)

More generally, growth in the demand for commodities is influenced by a wide range of factors including several fundamental economic drivers.

Incomes and population. As per capita incomes rise, demand for commodities also tends to increase, but the sensitivity of demand to an increase in income differs across commodities and changes as income levels rise. For example, at low-income levels, demand for grains rises relatively quickly as income increases, but as per capita incomes reach about $3,000 dollars, the pace at which grains demand rises declines, ultimately falling to close to zero. Thus, a 10 percent increase in

Figure 2.12 The quantity of most commodities used per unit of GDP was declining until recently



Source: World Bank.

Table 2.4 Modern goods make less intensive use of commodities
(US$)

Good	Value per kilogram
Iron ore	0.04
Steam coal	0.07
Wheat	0.27
Crude oil	0.47
Standard steel	0.56
Newsprint	0.89
Supertanker	4.00
Motor car	33.00
Dishwasher	56.00
TV set	133.00
Submarine	222.00
Large passenger aircraft	1,334.00
Laptop computer	2,224.00
Mobile telephone	4,448.00
Jet fighter	13,344.00
Windows 2000 Software, CD Rom	44,480.00
Telecom satellite	88,960.00
Banking services	∞

Source: Radetzki 2008a.

incomes is associated with a 6 percent increase in grains demand in low-income countries but almost no increase in high-income countries (table 2.3). As a result, beyond a certain income level, grains demand is mainly dictated by population growth. The sensitivity of demand for metals to incomes is much higher but tends not to change as income levels rise. Energy is the reverse of grains, with the demand for energy rising more rapidly than incomes in high-income countries.

The composition of GDP. Commodity demand depends on more than just GDP. The composition of demand also plays an important role. Over time, the commodity intensity of GDP has declined partly because demand has evolved toward goods and services that are much less intensive in their use of commodities. This trend is illustrated in table 2.4, which shows the value per kilogram of a variety of different products. Newer products, such as computers and mobile telephones, have a growing share in world GDP and contain very little in the way of commodities (proxied here by their weight).

The same effect can be seen at the sectoral level. Industrial activity tends to be more commodity intensive than agricultural activity, which in turn is more commodity intensive than services. Thus, part of the declining commodity intensity of demand over the past 35 years reflects the rise of the service sector, which accounted for 50 percent of world GDP in 1971 and 69 percent in 2005—a trend that is shared by both high-income and developing countries.

Table 2.3 Impact of a 10 percent increase in incomes on commodity demand
(Percent)

Income group	Grains	Energy	Metals
Low	6.0	4.5	10.1
Lower middle	3.3	7.2	10.1
Upper middle	1.4	9.2	10.1
High	0.0	1.1	10.1

Source: World Bank.

Technological change. Increased efficiency in the use of commodities in production and consumption has also contributed significantly to the dematerialization of economic activity. Examples include improvements in gas mileage in automobiles and the substitution of artificial for natural fibers in clothing.

Table 2.5 Fundamental economic factors drive future commodity demand

Period	Average annual growth rate: Per capita income	Population	GDP	Share of services in GDP	Share of services in GDP
			(percent)		(percent)
1990s					
World	1.2	1.5	2.7	0.99	64.6
High income	1.8	0.7	2.5	0.89	67.8
Low and middle income	2.0	1.6	3.6	1.73	49.8
Low income	2.3	2.2	4.5	0.96	44.3
Middle income	2.2	1.2	3.5	1.84	50.8
2000s					
World	1.8	1.2	3.1	0.47	68.5
High income	1.7	0.7	2.5	0.51	71.8
Low and middle income	4.2	1.3	5.6	0.24	53.8
Low income	4.1	1.9	6.1	1.50	49.4
Middle income	4.6	0.9	5.5	0.04	54.5
2015–30					
World	1.7	0.8	2.5	−0.41	50.3
High income	1.2	0.1	1.3	0.02	59.0
Low and middle income	3.9	0.9	4.9	−0.07	35.6
Low income	3.8	1.5	5.4	−0.02	44.0
Middle income	4.1	0.7	4.8	−0.08	35.0
Change (2015–30 vs. 2000s)					
World	−0.2	−0.4	−0.6	−0.88	−18.3
High-income	−0.5	−0.7	−1.2	−0.49	−12.8
Low and middle income	−0.3	−0.4	−0.7	−0.31	−18.2
Low income	−0.3	−0.4	−0.7	−1.52	−5.4
Middle income	−0.5	−0.2	−0.7	−0.12	−19.5

Source: World Bank LINKAGES model.

Long-term projections suggest that the main factors driving commodity demand will slow

To a significant degree, future demand for commodities will reflect the combined impact of, GDP growth, changes in the composition of demand, and technological progress (table 2.5).

- *Population growth* over the next two decades is expected to slow significantly from 1.2 percent during the 2000s to about 0.8 percent in the period 2015–30, which should help moderate commodity demand compared with past demand.
- *Per capita income growth* is also projected to slow somewhat for the world as a whole, mainly because incomes in the largest developing countries are expected to rise less quickly than they did during the 1990s. Nevertheless, developing-country per capita incomes are projected to triple, rising from $1,550 to $4,650 between 2004 and 2030. This means that, although global demand for grains and some metals is likely to decelerate, energy demand is likely to strengthen.
- *The composition of GDP* is not expected to continue to move toward services but to stabilize more or less at current levels. This suggests that commodity intensities may decline less rapidly than they have in the past.
- *Prospects for technological progress* are the least certain element likely to determine future commodity demand. Should policy succeed in continuing past gains, then this too should tend to moderate commodity demand.

The remainder of this section discusses in more detail how these factors and technological change are expected to play out in individual commodity markets.

Demand prospects for energy

Rising incomes and technology are expected to play crucial roles in determining future energy demand. Assuming no improvement in energy efficiency, given expected increases in incomes and population, demand for energy would rise by more than 120 percent between now and 2030, with growth in developing countries responsible for three-fourths of that increase. Assuming the composition of energy demand and supply did not change, that would imply that demand for oil would more than double, from 82 mb/d in 2007 to 174 mb/d in 2030.

Efficiency gains and conservation efforts reduced energy demand by 50 percent over the past 35 years

Of course, these assumptions are somewhat simplistic, viewed against the light of recent history. Energy efficiency over the past 50 years has in fact improved sharply. Since 1960, the efficiency of jet transport has more than tripled (Lee and others 2001) while fuel efficiency in cars has also increased significantly. Overall, between 1970 and 2004, technological change lowered energy demand 56 percent from what it would have been otherwise (IEA 2007). Much of the improvement resulted from substitution and conservation prompted by higher prices. Ongoing technological change and increased efficiency in China (Lin and others 2006) and the FSU countries (see earlier discussion) also played important roles.[14]

Looking forward, similar improvements in energy efficiency are possible if supported by an appropriate policy mix. Of particular importance will be efficiency in the transport sector, which is expected to account for some 75 percent of the increase in future oil use, largely because of rising incomes and car ownership in developing countries (IEA 2007).

A number of technologies currently available as prototypes or in early stages of commercialization could help more than double fuel efficiency over the next several decades. In 2005, about 8 liters of fuel were needed to drive 100 kilometers; by 2050, fewer than 3 liters may be needed (IEA 2008a). Even more optimistic scenarios project that by 2050, 90 percent of the vehicles in the high-income world and 75 percent in the developing world will be powered by alternative fuels, such as plug-in hybrids (hybrid cars with large batteries that can be plugged into the main electrical network), electric, and hydrogen-powered cars. Such a shift would reduce considerably private transportation's dependence on liquid fuels. Indeed, prototype and soon-to-be-released electric and hydrogen-powered cars already exist (box 2.4).

Strong growth in developing countries is expected to dominate future energy demand

Assuming that energy efficiency continues to improve at about the same rate as in the past, total demand for energy is projected to rise by 55 percent between now and 2030, with 80 percent of that emanating from fast-growing developing countries (table 2.6). Overall, weaker population growth and technological change are likely to outweigh the impact of rising developing-country incomes and their increased weight in overall demand. Hence the rate of growth of energy demand is expected to ease over time, declining from an average of 1.8 percent during the past 15 years to about 1.3 percent in the period 2015–30.

In the baseline scenario, climatic and environmental concerns are expected to contribute to a modest shift away from petroleum products toward less carbon-intensive fuel sources, such as natural gas, and renewable fuels, such as wind, solar, and geothermal. Oil's share in overall energy consumption is expected to decline, with demand rising more slowly. Demand growth is projected to fall from 1.7 percent a year in 2005–15 to 1.1 percent in 2015–30, reaching between 112 and 118 million barrels a day by 2030.

Box 2.4 Alternative fuels for transportation

Hydrogen and electricity are emerging fuels for transportation; fully ethanol-powered and flex-fuel cars are already well-established commercial successes in Brazil and increasingly in the United States and Europe. Existing hybrid cars offer a 50 percent improvement in fuel efficiency for city driving, while plug-in hybrid cars have the potential of reducing reliance on gasoline even more. Hydrogen-fuel-cell and all-electric cars could reduce that dependence to zero, but considerable progress needs to be made in increasing the efficiency of battery technology and in the production and conversion of hydrogen into electricity before these vehicles will be competitive.

Currently, most major car manufacturers have prototype versions of all such cars. General Motors has announced its intention to sell commercially as soon as 2010 an extended-range electric vehicle (the "Volt"), which is a battery-powered electric car that uses a small flex-fuel engine to extend its range for highway driving. The Volt is expected to be able to run up to 40 miles a day (more than the average daily driving distance of 75 percent of Americans) on batteries alone and 250 miles using its flex-fuel generator. The car is expected to have an EPA rating of 100 miles a gallon (Connor 2008), and its operating costs could be 0.02 cents a mile or one-sixth the cost of a vehicle powered with gasoline at $3.80 a gallon (Padget 2008).

Meanwhile, Honda is already leasing a limited number of hydrogen-fuel-cell-powered cars to the general public in southern California. While costs of operation are similar to gas-powered cars, the cars themselves are extremely expensive and the leases being offered imply a substantial subsidy. The cost of fuel-cell stack systems (the mechanism that converts hydrogen into power and that uses platinum) will have to decline tenfold before these vehicles become economically viable.

For both plug-in hybrids and electric cars, the major stumbling block is the size, weight, and cost of the battery required to power them. With current technology, the battery needed to power an electric car 500 kilometers weighs five times as much as the equivalent amount of gasoline and would cost $50,000. Over the next several decades, technological progress achieved through the commercialization of hybrid cars is expected to raise battery efficiency and reduce costs, so that plug-in hybrids will be widely available by 2020.

Prospects for all-electric cars are less clear, mainly because of the time that it takes to recharge batteries, a factor that makes them much less attractive than gas-powered vehicles. Here hydrogen-fuel-cell-powered cars could have an advantage if the costs associated with the fuel stack can be resolved.

Source: IEA 2008a.

Another important feature of the composition of energy demand is the importance of coal, which currently accounts for more than a quarter of global energy consumption. Coal is primarily used by developing countries (62 percent), with China accounting for more than 40 percent of global consumption. The baseline simulations indicate a slight increase in coal's share, from 25.3 percent in 2005 to 27.8 percent in 2015. However, the projection is subject to two risks: on the upside, if new clean coal technologies (including carbon sequestration) come on board, coal's share in global energy consumption is likely to be much higher. However, if such technologies do not materialize, coal use is likely to be subjected to significant environmental regulation that could significantly reduce its economic attractiveness.

The future path and mix of energy demand will depend on policy

Simulations suggest that a more aggressive stance toward reducing carbon emissions could generate a further moderation in energy demand and in fossil-fuel use. For example, a $21 tax per ton of carbon dioxide could be expected to reduce demand for energy by 33 percent (see the simulations at the end of the chapter). Because of its high carbon content,

Table 2.6 Energy demand is projected to slow in the baseline scenario

Contributions to annual average global growth in energy demand (percentage points)

	1990–2005	2005–15	2015–30
World	1.4	1.1	0.6
High-income countries	0.7	0.4	0.3
Developing countries	2.2	3.4	2.0
Middle-income countries	−0.1	2.4	1.5
Low-income countries	4.1	3.9	2.2

Shares in total energy demand (percent of total)

	1970	1990	2005	2015	2030
Coal	26.0	25.3	25.3	27.8	28.2
Oil	44.0	36.7	35.0	32.9	31.5
Gas	16.0	19.1	20.6	21.2	22.3
Nuclear	1.0	6.0	6.3	5.6	4.8
Hydro	2.0	2.1	2.2	2.3	2.3
Biomass, waste	11.0	10.3	10.1	9.3	9.1
Other renewables	—	0.4	0.5	1.0	1.7

Source: World Bank ENVISAGE model (forecast); IEA (historical data).
— = Not available.

demand for coal would decline most sharply under such a scenario, with natural gas and other low-carbon energies increasing their share in total demand.

An even more aggressive set of policies, including a significant policy initiative to increase energy efficiency and reduce carbon emissions to below their 2005 levels, could see energy demand fall even further (table 2.7).

Demand prospects for metals and minerals

Demand for metals and minerals is also closely related to GDP and the mix of GDP—with manufacturing and investment activities associated with relatively high commodity intensities. Like oil, the evolution of metals intensities reflects technological change, the growing importance of services in the economies of high-income countries, and other structural changes in demand.

Table 2.7 Energy demand could decline further under more aggressive climate change policies

Energy source	Baseline	Stable emissions	Aggressive
	(percent change in energy consumption)		
Coal	198	−15	−22
Oil	57	10	−29
Gas	96	68	25
Biomass, waste	48	144	214

Source: IEA 2008a.

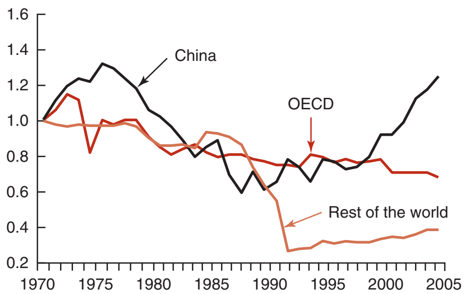
After falling for years, metals intensities in developing countries are rising, especially in China

The reversal of the trend decline in metals intensities that began in the mid-1990s (see figure 2.10) reflects very different trends in high-income countries, most developing countries, and China (figure 2.13). The trend decline observed for all three groups between 1970 and 1990 has continued among high-income countries, apace with the continued transfer of commodity-intensive manufacturing activities to developing countries. In developing countries excluding China, the same process has driven a slight rise in metal intensities beginning in 1992, after their fall attributable to the efficiency improvements associated with the end of the FSU.

China stands out as the country where intensities have increased the most. After declining for years, they began to rise gradually toward the beginning of the 1990s and then sharply accelerated around 1998, reflecting a rapid increase in manufacturing activity and a

Figure 2.13 Metal intensities have declined steadily in high-income countries but have reversed in China since 1993

Quantity of metals used per unit of GDP, index (1971 = 1.00)



Source: World Bank.

Box 2.5 Understanding the rise in Chinese metal intensities

China's accession to the World Trade Organization and the boom in manufacturing activity that accession generated certainly played a role in increasing metals demand. However, the long-term investments in new capacity and infrastructure that began at the same time as WTO accession were likely just as important. Overall investment in China increased from 36 percent of GDP in the early 1990s to around 45 percent currently, a result both of increased manufacturing and rapid urbanization (over the same period, the share of the population living in cities increased from 30 to 40 percent). Similarly, part of the increase in China's energy demand was associated with an acceleration in steel and cement production (Lin and others 2006). These structural changes entailed substantial investments in infrastructure and were associated with a rapid increase in automobile production—all heavy consumers of metals.

As of 2007, more than 50 percent of Chinese steel and 44 percent of copper demand was used in construction and infrastructure. While China's specialization in manufacturing is likely to persist, investment rates are projected to decline over time (the average life span of infrastructure investments exceeds 50 years) so China's metal intensity is expected to stabilize and then decline, as did the metal intensities of other Asian countries, such as Japan and the Republic of Korea, that followed a manufacturing- and export-intensive development path (Mitchell, Tan, and Timmer 2007).

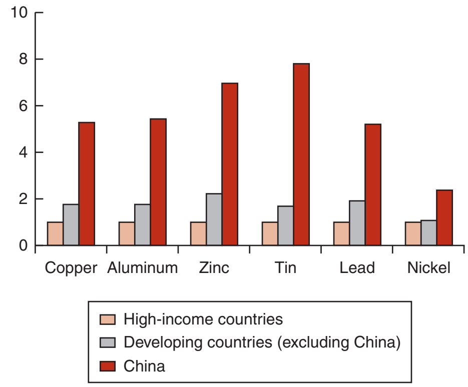
sharp uptick in investment. The increase in the Chinese investment ratio came partly from the need to create capacity to meet the manufacturing boom, but the increase also reflects significant investment in support of infrastructure in response to increased urbanization (box 2.5).

Except for a few export- and manufacturing-intensive Asian economies, other developing countries, including those at much higher levels of income than China, have not seen metal intensities rise in this way. Metal intensities in Brazil, India, and South Africa, for example, remained flat or continued to decline during the same period.[15] As a consequence, the strong acceleration in metal demand observed in China is not expected to be repeated in other developing countries.

Not only have Chinese metal intensities been rising, they are also as much as 7.5 times as high as in high-income countries and 4 times as high as in other developing countries (figure 2.14). While some of the same factors (high investment rate, large manufacturing sector) that explain the increase in Chinese intensities likely explain these differences, the fact that the former Soviet Union also had similarly high intensities before its economic transition suggests that perhaps nonmarket factors continue to influence allocation of these resources in a way not seen elsewhere.

Figure 2.14 Metal intensities in China are much higher than elsewhere

Metal intensity indexes, 2000–06 averages (high-income countries = 1)



Source: World Bank.

Slowing global growth and a decline in Chinese metals intensity should see demand growth for metals slow over the next 25 years

Over the next quarter of a century, metal intensities in developing countries are likely to stabilize and begin declining once again. Several factors should contribute to the reassertion of the earlier downward trend.

A slowing in the pace at which global manufacturing capacity is transferred to the developing world is projected to result in a leveling off and eventual decline in manufactures' share in Chinese GDP, from about 40 percent in 2005 to around 33 percent in 2030. This slowing in turn should be reflected in a decline in metals intensities. Less-rapid growth in manufacturing and the gradual completion of investment projects are expected to cause the share of investment in GDP to decline considerably, which should also serve to lower Chinese metal intensities. Finally, the rising influence of market forces in determining allocation decisions in China should also cause a drop in the quantity of metal used per unit of output.

In the rest of the developing world, similar forces should be at work, which, coupled with rising incomes and increased service-sector demand, is expected to reduce the metals intensity of demand.[16]

Nevertheless, growth in China and developing countries more generally is expected to continue to outpace growth in the rest of the world throughout the projection period. Given China's high metal intensities, developing-country growth should keep global metal intensities from falling, at least initially. However, the beginning of the decline in Chinese metal intensities should be reflected in a significant weakening in the rate of growth of metals demand during the period 2015–30. Overall, global demand for metals is expected to continue to grow somewhat more quickly than global GDP, at about 4.0 percent through 2015, before slowing to around 2.5 percent in the period 2015–30, a pace significantly slower than that of projected GDP growth itself.

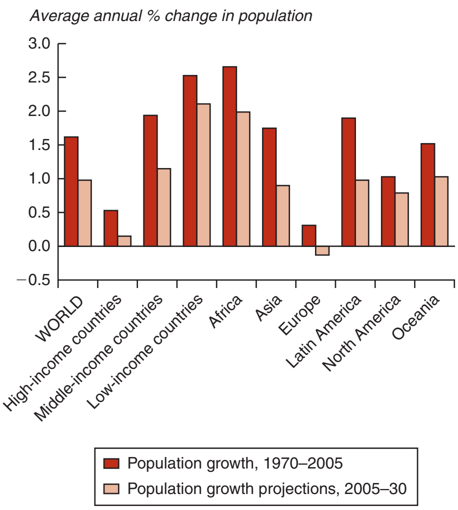
Demand for food and other agricultural products

The weaker growth in population and GDP expected over the next few decades (see table 2.4) should cause global demand for food to grow less quickly over the next 25 years.

Overall, the global population growth rate is projected to decline from an annual average of 1.6 percent between 1970 and 2005 to about 1.0 percent over the following 25 years. While most of the slowdown is expected to take place in high-income countries, population growth rates in every developing region are expected to decline between 0.4 and 0.8 percentage points (figure 2.15).

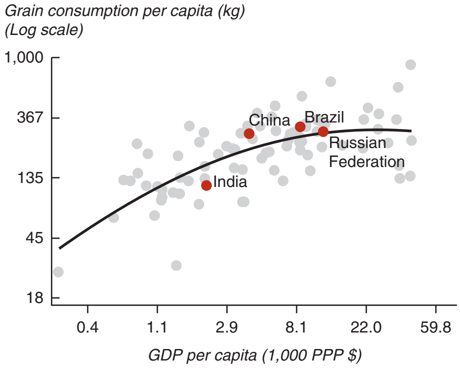
Rising incomes in developing countries imply that per capita food consumption will increase in most of these countries, but the impact on overall demand is expected to be small. As the earlier analysis suggested, a 10 percent increase in per capita income will increase grain demand by 6 percent in poor countries (those with per capita incomes below $2,000), but only by 2 percent in middle-income countries.[17] Most of the heavily populated developing regions have already

Figure 2.15 Weaker population growth should slow demand for food



Source: UN 2006.

Figure 2.16 Per capita grain demand tends to stop rising when income reaches around $5,000



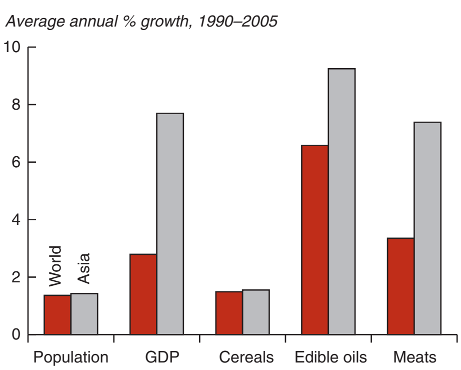
Source: World Bank.

Note: Curve fitted on a log scale.

achieved incomes associated with income elasticities close to 0.2 (figure 2.16).[18]

Demand for meat and dairy products (and feed grains) will likely expand more rapidly because these products tend to be more income elastic than basic food stuffs.[19] For example, in Asia, demand growth for meat and edible oils outstripped population growth by a wide margin over the past 15 years, even rising somewhat faster than GDP in the case of edible oils (figure 2.17).

Figure 2.17 Demand for edible oils grew much faster than population in Asia



Source: World Bank.

Table 2.8 Developing countries will account for most of the projected demand for various foods, 2000–30

	All agriculture	Cereal	Edible oils	Meats
WORLD	1.5	1.2	2.3	1.7
Developed	0.7	0.9	2.0	—
Transition	0.5	0.8	1.7	—
Developing	2.0	1.4	2.5	2.4
Sub-Saharan Africa	2.8	2.5	2.9	3.3
Middle East and North Africa	2.2	2.1	2.3	3.3
Latin America and the Caribbean	1.8	1.2	2.6	2.0
South Asia	2.3	1.6	2.7	4.0
East Asia and Pacific	1.7	1.2	2.4	2.1

Source: FAO (2006, pp. 33, 39–42, 47).
— = Not available.

Slower population growth will dampen demand for agricultural products

Overall demand for food should slow over the next few decades, despite income gains. The Food and Agriculture Organization (FAO) estimates global food demand will increase by about 1.5 percent a year between now and 2030, with cereals, edible oils, and meats growing at 1.2, 2.3, and 1.7 percent, respectively—somewhat slower than they did between 1990 and 2006 (table 2.8). Developing countries have higher income elasticities, faster income and population growth, and relatively large populations, compared with high-income countries. Thus, three-quarters of the additional global demand for food between now and 2030 will emanate from developing countries.

The implications of biofuels demand for agricultural prices

The production of biofuels in Brazil, the United States, and the European Union (which together account for more than 90 percent of global output) has increased by 18 percent a year since 2000. Biofuels now use 16 percent of global sugarcane production, 9 percent of global vegetable oils production, and 13 percent of global maize production, and have been the key contributor to the rise in food crop prices in recent years (Mitchell 2008).

The rapid expansion of production capacity in the United States and Europe was prompted by generous subsidies and use mandates, but high energy prices have made continued production without subsidies profitable in many cases. As a result, demand for biofuels may mean that in the future prices for crops used to produce biofuels will be higher, and more volatile, than if these crops were used only for food.

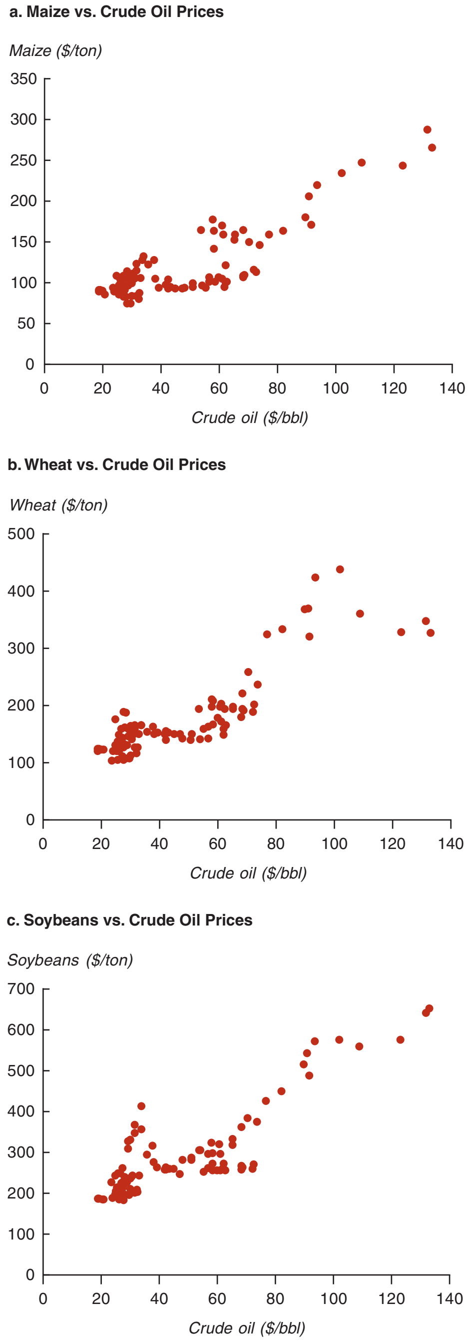
Indeed, when oil prices exceed the threshold of roughly $50 a barrel, a strong correlation can be observed between the price of crude oil and crop prices that does not exist when prices are below $50 a barrel (figure 2.18). At oil prices below $50 a barrel, ethanol production is not very profitable. However, at $50 a barrel, a 1 percent increase in oil prices results more or less in a 0.9 percent increase in maize prices, because every dollar increase in the price of oil increases the profitability of ethanol and hence biofuel demand for maize.[20] Since the oil market is much larger than the market for maize (if all the maize currently produced in the world were converted into ethanol, it would equal only 8 percent of global gasoline supplies), the price of maize is now effectively determined by the price of oil.

The impact of biofuels is not limited to the crops used for biofuel production. As more cropland shifts to produce the now-more-profitable biofuel crops, then the supply of other crops declines (or less productive land is brought under cultivation), thus raising food prices in general. As a consequence, the price of wheat and soybeans have also become more sensitive to oil prices in excess of $50.

The future impact of the oil market on the demand for food crops and their prices is uncertain. Technological improvements may lower the cost of producing ethanol, in turn lowering the threshold oil price above which crops used for biofuels become sensitive to oil prices. But technological change may also give rise to other nonfood sources (such as cellulose) for biofuel production or to other energy alternatives such as solar, wind, and hydrogen-based

Figure 2.18 Food crop prices have become sensitive to oil prices

Oil price per barrel versus food price per ton



Source: World Bank.

systems. Should this occur, demand for biofuel food crops would drop off and food prices with it.

Long-term supply prospects

The slowing of growth should bring commodity prices down by roughly 25 percent in 2009 (see chapter 1). But over the medium to long term, they are not expected to decline to the levels observed in the 1990s. How far they come down, and their future trajectory, will depend not only on the demand factors already discussed but also on the pace at which finite resources are exhausted; improvements in the efficiency with which commodities are found, extracted, and grown; and the policies that are put into place to promote long-term supply.

Energy and metals supply

Supply prospects for both oil and metals depend on the competing forces of resource exhaustion and the declining quality of new sources, on the one hand, and the pace of new discoveries and improvements in the technology with which commodities are discovered and extracted, on the other.

The world is unlikely to run out of oil, metals, and minerals in the foreseeable future

Despite ultimately finite quantities of oil, metals, and minerals in the earth's crust, there is little likelihood that the world will run out of natural resources (or food) in coming decades. The existence of ample (and growing) reserves, and a history of significant improvements in the technology with which resources are found and extracted, suggests that supply will continue to rise in pace with demand. True resource exhaustion is unlikely not least because, as resources become scarcer, their prices rise, consumption declines, and alternatives that once may have been uneconomic are substituted for the scarce (and expensive) commodity.

Indeed, over the past 50 years these forces have enabled global production of most commodities to rise despite falling, or at best stable, real prices. Production of aluminum, for example, increased fivefold between 1965 and 2007, while that of crude oil, copper, and wheat increased 2.6, 3.2, and 2.8 times, respectively (figure 2.19).

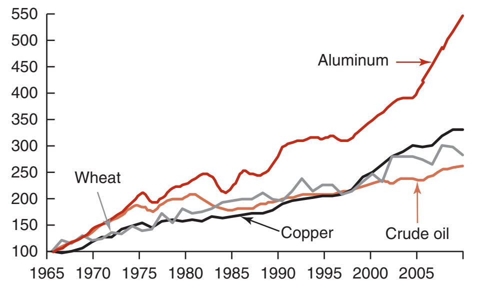
Technological change has kept extraction costs in check even as the quality of mines and wells declined

Although the quality of newly discovered mines and oil wells (and the ease with which they can be exploited) tends to be lower on average than older ones, technological improvements have reduced the cost of producing most commodities over the past 50 years, allowing effective supply to keep pace with demand (box 2.6).

In the case of oil, declining yields from onshore wells pushed exploration into offshore fields that are much more difficult and expensive to exploit. Improved technologies allowed these sources to be exploited profitably even at low prices and even though they are much more challenging to drill than existing wells. As a result, nearly all of the additional increase in global oil production since 1978 has come from offshore wells (figure 2.20).[21]

Figure 2.19 Output of virtually all commodities has increased since 1965

Output volumes, 1965–2007, index (1965 = 100)



Source: World Bank.

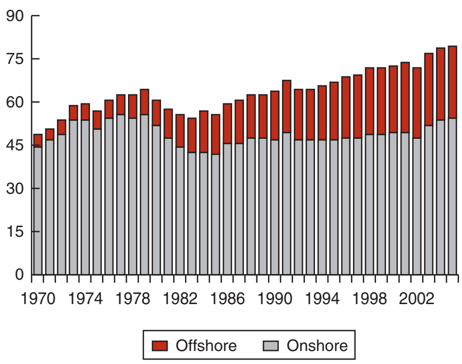
Box 2.6 Declining costs of resource extraction

Rising costs for producing a unit of output represent a good a priori indicator of increasing scarcity. The fact that the prices of most commodities have remained stable or declined for most of the past 100 years is therefore a good indicator that at least until 2003 the world was not running out of them (Radetzki 2008a).

Production costs—especially for the marginal producer—are an even better indicator. For the median producer, the real cost of producing a ton of metal between 1985 and 2002 declined by 28 percent for aluminum and copper and by 21 percent for nickel (IMF 2006). For high-cost producers, the decline was the same for aluminum but was only 18 percent for copper and nickel. Those numbers suggest that while new projects to extract copper and nickel were more expensive than preexisting ones, technological change had nevertheless reduced the costs of production by more than the lower quality of the underlying vein or its remoteness had raised them.

Similarly, the average cost of bringing a new oil field into production declined from $29 a barrel in 1981 to $9 in 1999 (IEA 2001). These cost reductions would be all the more marked if the numbers were expressed in real terms. And although not all of this cost decline can be attributed to technological change, much can (Bohi 1999). Indeed, improvements in extractive technology allowed copper prices to decline more or less continuously between 1890 and 1970 even as the average grade of copper ore in the United States fell from 6 percent to less than 2 percent between 1890 and 1920 and to less than 1 percent by 1960 (Lowell 1970).

Figure 2.20 Almost all of the additional oil supply since the 1970s has come from nontraditional sources



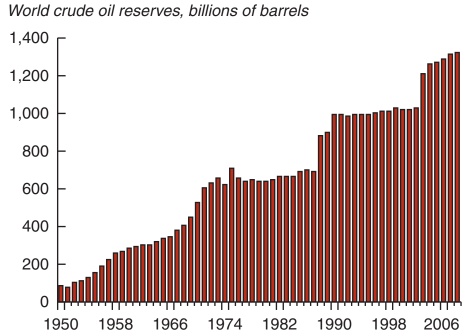
Source: Sandrea and Sandrea 2007.

Technology has also helped maintain surprisingly stable ratios of reserves to output

Advances in the technology with which new reserves are discovered and in the efficiency with which the final product is extracted from ore beds or wells has meant that known reserves of most extractive commodities have increased over time—despite rising production.

Such technological improvements help explain the substantial rise in estimates of reserves over past decades. Two authoritative sources of such data for oil are the *Oil and Gas Journal*, which reports annual estimates of proven reserves (figure 2.21), and the

Figure 2.21 Rather than declining, known oil reserves keep rising



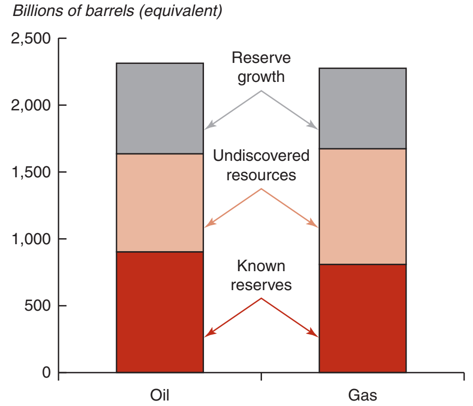
Source: Oil and Gas Journal.

Table 2.9 Historically, estimates of oil reserves have kept pace with production

Category	Date of assessment 1981	1985	1990	1993	1996
	(billions of barrels)				
Cumulative production	445	524	629	699	710
Known reserves	724	795	1,053	1,103	891
Undiscovered conventional resources	550	425	489	471	732
Expected reserve growth	—	—	—	—	688
Estimated total resources	**1,719**	**1,744**	**2,171**	**2,273**	**3,021**
Total resources still in ground (percent)	74	70	71	69	76

Source: U.S. Geological Survey, World Bank calculations.
Note: Estimated total resources is the sum of the first three rows. Total resources still in ground is one minus the ratio of cumulative production over total resources.
— = Data are not available (the concept of reserve growth was first introduced in 1996).

Figure 2.22 Gas reserves are almost as large as oil reserves



Source: U.S. Geological Survey.

United States Geological Survey (USGS), which attempts to quantify the resource base of the world's major basins by including assessments of known reserves, undiscovered resources, and reserve growth (table 2.9).[22]

Estimates from the *Oil and Gas Journal*, which include unconventional sources of hydrocarbon fuels such as Canadian oil sands and oil shale, show known reserves rising from just over 600 billion barrels in 1980 to 1.3 trillion barrels by 2008. Furthermore, the reserve estimates for a number of major producers in the Middle East have not changed for years, reflecting both their current size compared with production levels (national-reserve-to-production levels imply adequate reserves for 82 years of production for the Middle East–producing countries) and the fact that for decades these countries have not felt an incentive to explore in more depth the potential for additional reserves nor to verify existing reserve estimates.

On the other hand, according to the USGS estimates (which include undiscovered resources), total resources increased from 1.7 trillion barrels in 1981 to 3.0 trillion barrels in 1996, so the amount of known oil still in the ground remained stable, at around 70 percent of the total of oil ever found (see table 2.9).

Reserves of natural gas estimates are equally high. According to the USGS, they were at 2.3 trillion barrels of oil equivalent in 2003, almost as large as crude oil reserves (figure 2.22).

Yet, among the key hydrocarbon sources of energy, coal is perhaps the most abundant. As of 2007, the reserves-to-production ratio was estimated at 133 years, according to BP. However, as mentioned earlier, the use of coal will depend on the degree to which new technological advances will be able to ameliorate the environmental concerns.

Finally, expansion of nuclear energy (and other renewable fuel) supplies could lessen the relative importance of hydrocarbon-based fuels. For example, in addition to the existence of abundant feed stocks (at current consumption rates, known uranium reserves are expected to last almost a century), current modern nuclear technologies not only produce much less nuclear waste but also have lower likelihood of accidents compared with nuclear power plants in the past.

Reserves of metals and minerals have also tended to rise with output

The story for metals and minerals is somewhat more nuanced. Reserves expressed as a share of production for a number of metals did decline during the 1980s and 1990s. In part this reflected their relative abundance (reserves exceeded more than 40 years for bauxite, copper, iron ore, and nickel), continued rising production levels, declining prices, and underinvestment. It also reflected the fact that reserves are really a measure of the inventory that producers have readily available for future delivery, rather than a measure of the physical quantity remaining of a commodity. With demand and prices weak, and inventories (reserves) ample, firms had little incentive to invest in additional inventory.

Since 2003, when metal prices began rising and production accelerated, exploration expenditures have picked up (see earlier discussion). For some metals, the reserve-to-production ratios have increased as a result (table 2.10).

Increasing scarcity is unlikely to result in resource exhaustion

Although the history of reserves data suggests that much more oil is likely to be discovered, ultimately the quantity of available oil is finite. Long before the world begins to run out of oil, however, prices would begin to rise and consumption growth would slow. As a result, alternatives such as natural gas, nuclear power, and renewable energy sources would increase their output share (see earlier discussion on long-term demand). Reserves of crude oil would not decline as rapidly as they would have had prices not increased, and its use would be reserved for those products (plastics, chemicals, and polymers) where few alternatives exist.

Overall, high prices will encourage increased supply and substitution of alternative sources

As indicated earlier, the supply of crude oil is expected to continue to expand over the next few decades, reaching about 112 mb/d by 2030. The supply of other energy sources is expected to increase more rapidly than that for oil, with coal and natural gas projected to increase their shares in total energy supply from 46 percent in 2005 to 51 percent in 2030. Renewable energy sources are projected to see their share in total energy supply rise from about 0.45 percent to about 1.7 percent over the same period (table 2.11).

Biofuels are a source of renewable energy whose share of global liquids production has

Table 2.10 Increased investment has stabilized reserve-to-production ratios for some commodities

Year	Oil	Coal	Bauxite	Iron ore	Copper	Lead	Nickel	Tin	Zinc
Proven reserves									
	billions of barrels	(Millions of metric tons)							
1980	667	—	25,000	250,000	493	127	55	10	162
1990	1,003	—	22,000	150,000	350	70	49	8	147
2000	1,104	984,211	24,000	140,000	340	64	58	7	190
2007	1,238	847,488	25,000	150,000	490	79	67	6	180
Reserves/production ratio									
	(Years of production equivalent)								
1980	29	—	280	280	64	36	77	42	26
1990	42	—	193	178	41	20	53	37	21
2000	40	230	178	132	26	21	46	29	22
2007	42	133	132	79	31	22	40	20	17

Source: Radetzki (2008a, 2008b), British Petroleum, U.S. Geological Survey.

Table 2.11 Oil's share in global energy supply is projected to decline

	Average annual growth rate (%)		
Energy source	1990–2005	2005–15	2015–30
Coal	1.8	3.3	1.5
Oil	1.5	1.7	1.1
Gas	2.3	2.6	1.7
Nuclear	2.1	1.1	0.4
Hydro	2.1	2.7	1.6
Biomass & Waste	1.6	1.5	1.3
Other renewables	3.8	9.0	5.2
Total	**1.8**	**2.3**	**1.4**

	Share in total energy supply (percent)			
	1990	2005	2015	2030
Coal	25.3	25.3	27.8	28.2
Oil	36.7	35.0	32.9	31.5
Gas	19.1	20.6	21.2	22.3
Nuclear	6.0	6.3	5.6	4.8
Hydro	2.1	2.2	2.3	2.3
Biomass, waste	10.3	10.1	9.3	9.1
Other renewables	0.4	0.5	1.0	1.7
Total	**100**	**100**	**100**	**100**

Source: IEA 2008a.

reached 1.6 percent, largely because of government encouragement (box 2.7). Recent projections suggest that biofuel production will reach the equivalent of 1.95 mb/d of oil by 2013 (a 45 percent increase over 2008), corresponding to 2.1 percent of the projected global oil demand (IEA 2008b; FAPRI 2008).[23] While popular, biofuels are controversial, in part because energy is required to produce energy, so the net addition to the global energy supply from corn-based ethanol is relatively small (Kojima, Mitchell, and Ward 2006), and in part because biofuels yield only limited environmental benefits (Searchinger and others 2008; Fargione and others 2008).

Long-term projections for metals and minerals supplies are optimistic, with expectations that production will increase by a further 3.0 percent a year between now and 2030. At the same time, the trend toward substitution of alternative metal products is likely to continue. For example, copper initially displaced lead in plumbing applications, only to be displaced by plastics most recently and by sand (fiber optics) in telecommunications applications. And the rapid expansion in demand for aluminum, shown in figure 2.19, partly reflects its increasing use as a lightweight alternative for steel.

Another element of growing importance in the metals markets is the role of recycling, which currently ranges from 55 percent of final demand in the case of lead to about 5 percent in the case of zinc. In developed economies, the proportion of metal available from scrap is higher because of greater inventories embodied in old cars and infrastructure that can be recycled. Future increases in scrap's share of the metal supply in emerging economies will slow the rate of growth of demand for mined metal.[24]

Actual results will depend on policy choices and technological progress

Supply of both energy and metals over the long term depends critically on policies and the pace of technological change. Rising concerns about the environmental consequences of economic activity, notably but not exclusively those associated with climate change, may alter the regulatory environment in important ways.

Emissions abatement policies may restrict the use of hydrocarbons, either through mandates or tax policy that alters the economics of both demand and supply—potentially extending reserve-to-production ratios significantly. Environmental concerns may also restrict the use of extraction and production techniques in other primary sectors in ways that reduce supply or significantly raise production costs. In the IEA's aggressive emissions abatement scenarios, global oil demand falls by 29 percent.

How successful alternative fuels and improved extraction technologies will be in enabling the kind of substitution and increased supply that has been observed in the past will depend on how successful policy is in supporting the creation and diffusion of new technologies. Particularly important for poor countries will be efforts to create affordable

Box 2.7 The rise of biofuel production

While biofuels have been used since the early days of the automobile (Henry Ford's 1908 Model T car was designed to run on maize-based ethanol), limited supplies and the availability of cheaper and more efficient petroleum products diminished the use of biofuels (except for a brief revival during the petroleum shortages of World War II).

In the United States, various amendments to the 1970 Clean Air Act and the 1992 Energy Policy Act were instituted that favored the use of biofuels, especially maize-based ethanol. More recently, the 2007 Energy Independence and Security Act called for a fourfold increase in biofuel production by 2022. As a result, an estimated 25 percent of U.S. maize output in 2007–08 was diverted to ethanol production. In 2007, the United States produced 6.6 billion gallons of ethanol, roughly equivalent to 4.5 percent of its gasoline consumption.

The European Union began instituting mandatory use of biodiesel (mostly from rapeseed oil) as early as 1992. During 2008, its biofuel output was expected to reach 225,000 barrels a day of oil equivalent, representing about 1.5 percent of its crude oil consumption. The European Union has a target 5.75 percent of biofuel use by 2010, whereas a 2008 European Commission directive proposed a 10 percent use mandate by 2020.

In the 1970s, Brazil offered incentives to both sugarcane producers and its car industry to encourage biofuels, and by the mid-1980s, Brazil was producing 3 billion gallons of sugarcane-based ethanol a year, while 90 percent of Brazilian-made cars were designed to run on ethanol. The biofuel program almost collapsed during the 1990s when the price of oil was low, offshore oil discoveries weakened political support for biofuels, and high sugar prices strained the subsidy program and diverted sugarcane to the world market. However, the recent crude oil price spike along with the introduction of "flex-fuel" cars that can use any combination of gas and ethanol has encouraged reliance on ethanol.

In Brazil, the government no longer provides subsidies to either the car or the sugar industry, and the cost of producing ethanol is $1.40 a gallon (very low compared with maize-based ethanol or edible oil–based biodiesel), making the industry competitive even if crude oil prices decline to $40 a barrel (Kojima and Johnson 2005).

and durable solar cells, whereas at the global level efforts to reduce dependence on liquids for transportation—such as a breakthrough in battery technologies or hydrogen generation—will be key.[25]

The structure of energy markets, including the market power and supply decisions made by OPEC may also play a role. The concentration of oil reserves in the hands of a few countries could limit the increase in exploration and production anticipated in response to high prices (box 2.8). OPEC controls three-quarters of the world's oil reserves and dominates export markets.[26] Moreover, a number of producers have made their reserves and fields off limits to private investors; two of these countries (Mexico and Saudi Arabia) officially prohibit the participation of foreign companies, even in a consultancy capacity. In the baseline scenario, more than 75 percent of the increase in global production is expected to come from OPEC member countries. Should they decide to restrict supply, oil prices could be sharply higher in the medium term, and demand much lower. Although such an episode would likely be very painful, ultimately it would speed the switch into alternative energy sources (much as it did in the 1980s) and result in a significant decline in the long-term demand for oil.

Agricultural supply

Increases in cultivated land and yields are likely to result in strong growth in agricultural production and declines in prices from their current high levels, as has occurred during the

Box 2.8 State-owned firms and output efficiency

The rising share of oil reserves and global production controlled by state-owned firms has prompted concerns about future supply. The concerns are about:

- Cartel-like behavior
- The efficiency and responsiveness of state-owned firms to economic incentives
- The denial of access to multinational firms, which have historically been among the most efficient

State-owned firms need not be less responsive or less efficient than privately owned ones. To maximize productivity, however, policy makers need to ensure that government-owned or -controlled firms are not overburdened with very high effective tax rates (including profit remittances to the state and obligations to sell oil at below-market prices) or social mandates that limit the extent to which they are able to invest in new technologies, infrastructure, and fields.

In some countries, such responsibilities have been associated with disappointing results. For example, oil production in República Bolivariana de Venezuela has declined 19 percent since 2000, while it has been stagnant and is now declining in Mexico; both are countries with restrictive legislation or practice.

This contrasts with the 45 percent increase in production and 49 percent increase in reserves (not including the new Tupi field) recorded by Brazil's state-owned Petrobras, which has been encouraged to reinvest profits and hire foreign experts when needed.

past 50 years. However, supply growth will remain sensitive to public policy as well as to investments in infrastructure and research. Furthermore, prospects are subject to significant risks, both upside (rapid technological change) and downside (impacts of environment and climate change and links to oil prices through inputs and biofuels demand).

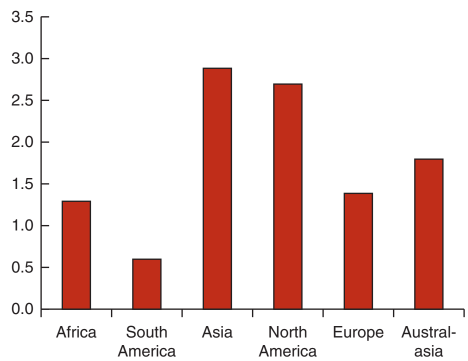
Rising productivity and land under cultivation have boosted agricultural production

The past half century has witnessed a steady increase in agricultural output, both in absolute and per capita terms. Total factor productivity in the agricultural sector has increased by between 2.1 and 2.5 percent each year (Coelli and Rao 2005; Martin and Mitra 2001) over the past 20 years, with the largest productivity gains recorded in Asia and North America (figure 2.23).

Reflecting this strong productivity growth, most of the increase in agricultural output over the past 40 years is attributable to increased yields rather than to increases in the quantity of cropped land (figure 2.24). Similar gains were observed in the livestock sector, with the quantity of meat produced per animal rising by 1.7 percent for chicken and 3.5 percent for pork between 1980 and 2005 (FAO 2006). Growth in productivity was responsible for half of the increase in output since 1960 in China and India and between 30 and 40 percent of the increase in other East Asian countries (World Bank 2008). These productivity improvements enabled a decline in the share of labor force employed in agriculture (even as

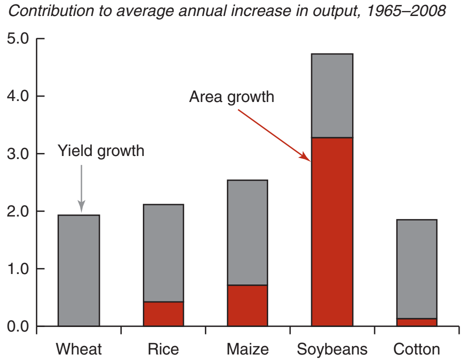
Figure 2.23 Agricultural productivity has been rising rapidly over the past 20 years

Average, annual percentage change in agricultural TFP, 1980–2000



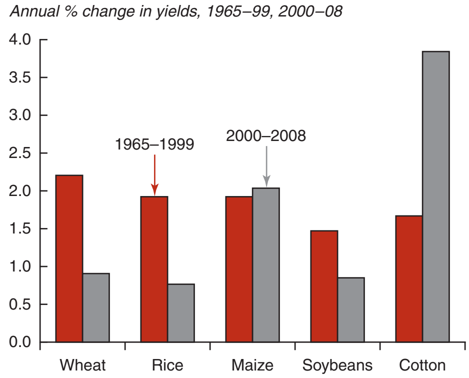
Source: Coelli and Rao 2005.

Figure 2.24 For key crops, most of the increase in output was due to increased yield, not increased area planted



Source: World Bank calculations based on U.S. Department of Agriculture data.

Figure 2.25 Yield growth has decelerated recently



Source: World Bank calculations based on U.S. Department of Agriculture data.

production and population increased) and a 25 percent increase in the average caloric per capita consumption in developing countries during the past 30 years.[27]

Among developing countries, crop productivity increases (which control for increases in inputs such as capital and labor) have been driven mainly by the expansion of irrigation, improved seed varieties, and increased use of fertilizer. Worldwide, the area devoted to improved varieties has been expanding continuously. In 2000, high-yielding grain varieties were used on 90 percent of planted area in South and East Asia, up from 10 percent in 1970 (World Bank 2007b). The use of improved varieties is expanding in all regions, including Sub-Saharan Africa, where it now represents almost one-quarter of cropped land.

Fertilizer use is also up. In developing countries it has risen from only 10 percent of global use in the 1960s to 77 percent now (FAO 2008). However, fertilizer use in sub-Saharan Africa is minimal, accounting for less than 3 percent of global use versus a 40 percent share in East Asia.

Most recently, yield growth has declined for some commodities, notably wheat, rice, and soybeans (figure 2.25). While such weakening in yield gains has been attributed to exhaustion of the gains that came from the introduction of green revolution technologies, persistently low commodity prices have also played a role. Yields gains in other commodities have accelerated because of greater use of genetically modified varieties, which boosted yields in cotton in China and India by 19 and 26 percent, respectively (World Bank 2007b). In addition, maize yields have benefited from the more extensive use of techniques made economically profitable by high prices.

The recent slowing of productivity gains and the spike in food prices have raised concerns about long-term output trends. Fears of a food shortage over the long term are unwarranted, however, given the enormous potential for increasing agricultural output through cultivating unused land and increases in yields.

Although much of the best agricultural land is already in use, significant opportunities for increasing output remain simply by increasing the amount of land under cultivation. About 12 percent of arable land worldwide that is not currently forested could be brought into agricultural production relatively easily (Thompson 2008). Considerable amounts of arable and unforested land in Africa could be brought into production assuming appropriate infrastructure were put into place, while in

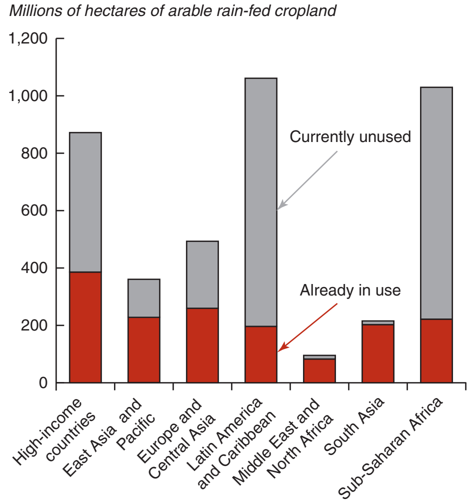
Brazil about 180 million arable hectares that are currently used as pasture could eventually be brought into food crops. Sizable amounts of unused or underutilized land also exist in Ukraine and Russia.[28]

Another source of additional farmland is the 18 million hectares in the United States and Europe that have been set aside to reduce supply and keep producer prices high (Normila, Effland, and Young 2004). Recent changes to the Common Agricultural Policy have authorized European farmers to use about half of that land, which could see the amount of land applied to agriculture in Europe rise by 3.5 percent this year. Similarly, the United States recently released 1.5 million acres of the land fallowed by its conservation program.

However, the new land is less productive than existing land and will be more costly to exploit, especially in an environment of high prices for energy and equipment. Furthermore, the expansion of new land (especially in Africa) will require large investments in infrastructure and likely will take decades to expand significantly.

These calculations do not include land that is currently forested but that is suitable for rainfed crop production. Such lands exceed by one and one-half times the total currently used for agriculture (figure 2.26). Bringing all of this land into crop production is probably neither desirable nor likely, but its existence means that the agricultural supply potential of the planet is far from exhausted.

Figure 2.26 The stock of unused but potentially arable land is enormous



Source: Food and Agriculture Organization.

Technological gains are likely to drive continued increases in yields

Much of the increase in agricultural productivity over the past 50 years came about through often scientifically simple improvements in agricultural technique, including increased use of irrigation, fertilizers, and commercially optimized seeds. The adoption of these techniques in the developing world is most advanced in Asia, and its impact on yields is evident in the very strong productivity growth enjoyed by the region over the past half century (table 2.12). Considerable potential exists for extending the same kind of gains to other regions, particularly Sub-Saharan Africa and many countries in Europe and Central Asia, that have adopted these techniques less extensively (table 2.13).[29] However, such expansion will require policies to encourage research and

Table 2.12 Potential gains from extending the green revolution remain large

Region	Actual production	Potential production	Poential gain	Potential gain (Percent of current production)
	(Millions of metric tons)			
High income	423	440	17	3.9
East Asia and the Pacific	501	508	7	1.4
Europe and Central Asia	130	191	60	46.5
Latin America and the Caribbean	140	161	21	15.0
Middle East and North Africa	50	57	7	14.3
South Asia	250	259	9	3.7
Sub-Saharan Africa	56	81	25	43.9
Total	1,551	1,697	146	9.4

Source: World Bank.

Table 2.13 With some exceptions, yield growth for key agricultural commodities has been highest in South and East Asia

Category	Wheat	Rice	Maize	Soybeans	Cotton
	(Annual percent change in yields, 1965–2006)				
World	2.0	1.7	1.8	1.5	1.7
Income level					
High income	1.6	0.9	1.6	1.3	1.6
Middle income	2.0	1.9	2.6	2.8	2.3
Low income	2.6	2.0	1.1	1.4	3.1
Region					
East Asia and the Pacific	3.8	1.8	2.9	1.9	2.7
Europe and Central Asia	0.1	0.0	0.8	−0.1	0.7
Latin America and the Caribbean	2.0	2.5	2.6	1.3	2.1
Middle East and North Africa	2.5	1.2	2.7	3.0	1.2
South Asia	2.6	2.1	1.6	1.5	3.1
Sub-Saharan Africa	2.2	0.7	0.7	3.2	1.6

Source: World Bank calculations based on U.S. Department of Agriculture data.

development (R&D) and extension directed particularly at small-holders. If these countries were to adopt more intensive techniques like those used in Asia and elsewhere, global production of cereals could be increased by as much as 9.4 percent, enough to meet several years' worth of increasing global demand.

Based on similar observations, the FAO in its most recent long-term forecasting exercise expects global agricultural production to rise by 1.5 percent a year for the next three decades, somewhat slower than over the past 50 years but still significantly faster than projected population growth.

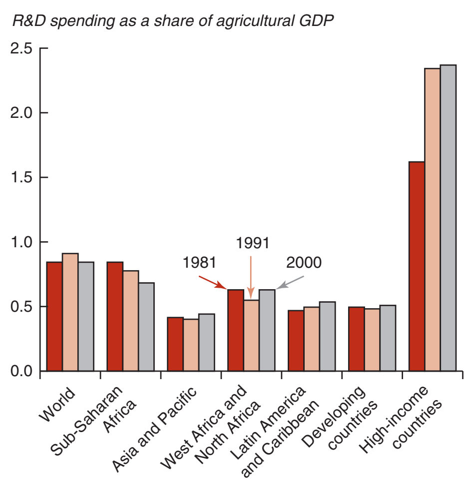
Prospects will depend on a number of uncertain factors

Of course, the long-term supply prospects for agricultural commodities are far from certain. Past productivity gains are an imperfect indicator of what might be expected in the future. Moreover, a number of looming issues in the global economy could affect supply conditions in important ways.

Public investment in infrastructure and R&D will be critical to realizing potential productivity gains and to ensuring that such gains benefit the poor. About 95 percent of developing-country R&D expenditures in agriculture is publicly funded. As a result, this R&D is mainly dependent on administrative decisions, which may or may not respond to market conditions. Therefore, it is imperative that efforts to increase food production in low-income countries should be part of a comprehensive effort that includes investment in R&D as well as dissemination efforts.[30] Notwithstanding the swings in the prices of agricultural products, agricultural R&D has remained remarkably stable as a share of agricultural value added, at about 0.85 percent between 1981 and 2000. Moreover, developing countries are spending much less on R&D than are high-income countries, both in absolute terms and as a share of agricultural GDP (figure 2.27).

Recent advances in biotechnology may offer developing countries additional improvements in yields through the introduction of new plant varieties with heightened resistance to drought, rain, diseases, and pestilence—characteristics

Figure 2.27 Developing countries spend less on agricultural R&D than high-income countries



Source: Pardey, Alston, and Jones 2008.

Box 2.9 Genetically modified crops—the next green revolution?

The most important recent technological breakthrough in agriculture has been the development of genetically modified (GM) crops. These crops tend to be more disease resistant than traditional varieties and lower cost because of increased yields and the need for fewer pesticides.

Originally developed in the United States, they have spread to many countries, including many in the developing world. In 2006, farmers in 22 countries planted GM seeds on 100 million hectares, corresponding to about 8 percent of global crop area (World Bank 2007b). Although GM crops were initially taken up by commercial farming, increasingly small farmers are now using the technology.

Yet GM crops have not been adopted widely in developing countries despite considerable potential in crops, such as bananas, that suffer large losses from disease. This lack of uptake results partly from concerns over environmental and food safety risks and partly from private producers of these seeds that are unwilling to allow them to be distributed in countries where they are unable to enforce their property rights.

Some countries (such as China) have gotten around this problem by developing their own varieties in public research agencies that they make available to smallholders. Other countries (such as Burkina Faso) have entered into agreements with private companies that allow them to develop GM seeds to be used by smallholders under a general licensing agreement.

The current generation of GM technology has concentrated on internalizing resistance to diseases and pests. Research in the pipeline, however, focuses on developing varieties with other characteristics such as increased tolerance to drought, wetness, and temperature, as well as slowing product deterioration. As a result, whereas the first generation of GM crops was tailored to the agriculture of the developed world, the second generation may be better suited to resolving the kinds of problems found in the production systems of developing countries.

that might be especially desirable during a period of climate change. However, like the chemical-based pesticides and fertilizers that helped generate substantial improvements to yields during the green revolution, they may also carry with them hidden risks such as cross-plant genetic contamination and potential health impacts because of unexpected interactions with human biology. Transparent and cost-effective regulatory systems that inspire public confidence will be needed to evaluate risks and benefits on a case-by-case basis.

Moreover, the diffusion of these innovations into developing countries has been uneven, partly because of the high cost of these seeds and their incompatibility with traditional agricultural methods and partly because of the unwillingness of seed companies to market them into countries with weak regulatory frameworks and intellectual property regimes (box 2.9).

In the long term, climate change and water scarcity could have significant impacts on yields

Global temperatures are expected to rise by 0.4 degrees Celsius between now and 2030. This could lead to an overall decline in agricultural productivity of between 1 and 10 percent by 2030 (compared with a counterfactual where average global temperatures remained stable), with India, Sub-Saharan Africa, and parts of Latin America being most affected (see next section).

Over the longer term, the impacts of climate change could be much more serious, with agricultural productivity in many developing regions, notably Africa, potentially declining by as much as 25 percent as compared with a baseline of temperatures remaining stable at their 2030 levels (Cline 2007).

Sustainable water supply forms another longer-term risk facing future agricultural supply. About 85 percent of water use in developing countries goes to agriculture, with less than one-fifth of the cultivated area in developing countries producing two-fifths of the value of agricultural output (World Bank 2007b). Already 15–35 percent of water withdrawals worldwide are not sustainable, in the sense that the amount being withdrawn from aquifers or rivers exceeds the rate at which the source is naturally resupplied. Perhaps the most notable example of unsustainable use was the rapid expansion of cotton production in the Aral Sea basin, which has resulted in the disappearance of 90 percent of the sea's surface area and a broadly based environmental disaster. Improving water management will require countries to take more responsibility for shared water resources, ensuring that they are priced appropriately and that adequate water management institutions are put in place to prevent a recurrence.

Projections

As anyone following commodity markets over the recent past can attest, forecasting future demand, supply, and prices in commodity markets is—at best—a hazardous undertaking. While some commodities, especially extracted commodities such as oil and metals, may become more scarce in coming decades, there is little likelihood of a serious shortfall in supply. Nevertheless, the overall balance between demand and supply is very uncertain. It will depend on a wide range of factors, including climate change, productivity developments in commodity supply and commodity demand markets, GDP and population growth, and the policy environment. The remainder of this chapter attempts to quantify the range of possible outcomes in commodity markets.

Agricultural prices are likely to decline over the long term

As discussed in chapter 1, agricultural prices are forecast to decline over the next two years but remain well above the levels of the first half of this decade. While the long-term outlook for agricultural prices is particularly uncertain, this decline is expected to continue through the forecast period.

As outlined earlier, the growth in demand for agricultural products is expected to be somewhat weaker in the next several decades because of slower population growth and the limited impact of higher incomes on food demand. On the supply side, the availability of additional land and further productivity improvements should enable production to keep pace with demand even as the agricultural sector continues to release labor to work in other parts of the global economy.

Based on long-term forecasts of population and incomes and a continuation of the historical experience of rising productivity, annual demand and supply are projected to grow by about 1.7 percent on average between 2008 and 2030. This would imply a continued decline in agricultural prices of about 0.7 percent a year relative to manufacturing prices and the share of the unskilled labor force working in agriculture declines by 6 percentage points (table 2.14).

One particularly difficult issue in the long-term forecasts for agricultural production and prices concerns the impact of climate change. Human-induced global warming has begun to change growing conditions around the world, particularly in developing countries. In many countries, and for many crops, ideal growing temperatures have been surpassed, stressing the growth of plants. Perhaps more significantly, more-extreme water-related events are occurring, including more periods of persistent droughts, drier soils from higher temperatures, changing patterns of rainfall (for example the monsoon arriving earlier or later), and more severe rainfall falling in shorter periods. These climate events can reduce immediate production and impair agricultural development, as poor farmers faced with drought may be forced to sell or eat animals, while severe storms damage other types of capital such as irrigation canals.

Forecasts of the rise in temperature and the impact on agriculture over the next two decades are extremely uncertain. Lobell and others (2008) anticipate that southern Africa,

Table 2.14 Agricultural sector simulation results, 2005–30

	Results in 2030 by scenario			
	Baseline	I. Global productivity slowdown	II. Developing-country slowdown	III. Strong demand for biofuels
Total factor productivity[a]				
Developing countries	2.1	1.2	1.2	2.1
High-income countries	2.1	1.2	2.1	2.1
Output[a]	1.7	1.9	1.9	2.4
Prices[a]	−0.7	0.3	−0.1	−0.5
Employment (unskilled in develoing countries)[a]	−6.0	−4.8	−5.3	−5.4
Change in real income[b]		−3.4	−2.3	−1.8

Source: World Bank ENVISAGE model.
a. Change in share of total employment between 2005 and 2030.
b. Percent of base income.

South Asia, and parts of Latin America will rank among the hardest-hit areas, with maize production in southern Africa, for example, potentially falling as much as 30 percent below what it would have been without climate change by 2030.

Our base case in table 2.14 assumes significant damage from climate change over the long run. However, over the projection period 2030, the impacts are relatively modest. To date, global temperatures have risen 0.8° C since 1900 and are projected to rise a further 0.4° C by 2030 (Cline 2007). Scaling Cline's 2080 estimates of damage to agriculture by the estimated temperature change in 2030 leads to an overall decline in agricultural productivity of between 1 and 10 percent by 2030 (compared with a future where average global temperatures remain stable), with Canada and Europe least affected and India, Sub-Saharan Africa, and parts of Latin America most affected.[31] Were there to be no climate change between now and 2030, global agricultural productivity would be nearly 4 percent higher, and the world price of food 5.3 percent lower.

These projections are subject to other important uncertainties. In particular, the projected productivity gains are contingent on policies being put in place that permit productivity gains to continue rising as they have in the recent past. The policies include the removal of trade distortions, progress to limit the increase in carbon emissions, construction of infrastructure, and R&D investments in developing countries with lagging productivity.

As shown in Scenario I, should global agricultural productivity rise by only 1.2 percent a year on average instead of the 2.1 percent projected in the baseline, then prices, rather than declining, can be expected to rise by as much as 0.3 percent a year relative to manufactures—reversing the trend decline of the past 100 years. Reduced productivity includes increasing the quantity of cereal required to produce meat and as a result total agricultural output rises, even though final consumption declines by 0.3 percent per annum. Final demand does not decline by more, because lower productivity is partially compensated for by increased inputs, including a 1.2 percentage point increase in the share of agricultural workers in the labor force compared with the base case. Overall, by the end of the projection period, real incomes in developing countries would be lower by about 3.4 percent compared with the baseline.

Consistent with Scenario II, should the weaker productivity be limited to developing countries, in part because climate change is expected to affect them more adversely and perhaps because policy fails to step up infrastructure, R&D, and dissemination of investments, the overall impact in markets would be attenuated somewhat. Prices would fall by only 0.17 percent a year (compared with a decline of 0.7 percent a year in the base case), and agricultural sector employment would rise slightly compared with the baseline. But developing countries, especially those whose populations continue to grow relatively rapidly would become much more dependent on high-income countries for their food supply.

Scenario III examines the potential impact of biofuels production on food prices. While biofuels have made a major contribution to the rise in food prices over the past two years, their impact in the future is difficult to estimate. The decline in oil prices has already contributed to the decline in food prices via its influence on biofuel demand for food crops. Should oil prices remain moderate as projected (see below), the influence of biofuels on food prices should also stabilize. If technological progress improves the attractiveness of nonfood biofuels inputs, the link between oil and food prices may be broken. Alternatively, biofuels could have a significant impact on food prices if oil prices remain high or the cost of biofuels production declines.

The simulation reported in table 2.14 explores the implications of a permanent increase in the rate of growth of demand for food products as source material for biofuels. Under this scenario, global demand is expected to grow twice as fast as it does in the baseline. In this instance, agricultural employment increases by 0.6 percent of the labor force, output of other grains (including maize) rises by 350 percent, but food prices increase by much less, due to substitution away from these products.

Over the long run oil prices are expected to stabilize (in real terms) at around $75

As described in chapter 1, despite rather recent volatility, oil prices are not expected to fall much below $60 in the medium term. Oil demand should pick up as the global economy recovers, but supply conditions should also have recovered, enabling the real price of oil to rise gradually to around the $75 range. This forecast assumes that, in the absence of policy changes, demand for energy will continue to rise faster than GDP. The actual rate of increase of demand and how it is met will depend critically on policies, technological change, and the level of reserves.

The simulations presented in table 2.15 illustrate the potential impacts of four alternative scenarios.

Table 2.15 Energy sector simulation results, 2005–30

		Results in 2030 by scenario				
	2004	Baseline	I. High demand	II. Carbon tax	III. Alternative energy	IV. Weak oil supply
Energy demand (average annual percent growth)						
Coal		4.9	5.7	2.2	2.5	5.4
Oil		1.6	1.8	1.6	1.4	0.2
Natural gas (excluding distribution)		1.3	1.8	1.0	−0.2	1.3
Total		3.0	3.5	1.7	1.6	2.9
Prices ($ per ton of oil equivalent)						
Coal	59	60	62	55	54	60
Crude oil	256	428	475	420	219	760
Natural gas	157	288	306	281	231	296
Production level						
Coal (metric tons)	5,680	18,312	21,907	10,184	10,185	19,993
Crude oil (mbd)	75	113	117	112	78	78
Natural gas (1e12 BTU)	59,435	82,951	93,105	76,020	56,156	84,356
Share in total energy supply (percent)						
Coal	33.4	53.9	57.2	37.7	42.3	63.1
Oil	47.3	33.5	30.5	46.2	45.6	23.8
Natural gas	19.3	12.5	12.3	16.1	12.1	13.0

Source: World Bank ENVISAGE model.

In Scenario I, energy demand rises 0.5 percent faster (3.5 percent versus 3.0 percent) than in the baseline each year because energy-saving technologies and conservation measures fail to come onstream as rapidly as anticipated.[32] This results in higher prices for all forms of energy. The higher price of energy means that global GDP grows somewhat more slowly, with the cumulative impact on the level of output, compared with the base case, equal to 2.7 percent in 2030. Most of the increase in demand is concentrated in the use of coal (in absolute and percentage terms). Relatively higher supply elasticities for coal and gas lead to higher volume shifts for these two fuels, whereas the tighter supply of the oil markets leads to a concomitantly higher price rise for oil and a relative shift away from oil consumption.

Scenario II examines the impact of a more concerted effort to limit carbon emissions. In this scenario, it is assumed that policies are put into place beginning in 2011 that are consistent with achieving a target concentration of 500 parts per million of carbon dioxide in the atmosphere by 2050. This implies a shadow price of carbon of \$21 per ton of CO_2 in 2030 and a stock of emissions of around 11 gigatons of carbon in 2030, a reduction of 32 percent from the base-case level.[33]

Such a carbon price would lead to a significant drop in energy demand, with coal taking the largest hit (from 4.9 percent to 2.2 percent). Coal would be most affected because it releases the most carbon emissions per unit of equivalent energy. But a more significant factor is the large wedge in the price of coal (per unit of energy) compared with oil and gas. In other words, the uniform price of carbon has a much larger percentage increase on the price of coal than on oil and natural gas. As a corollary, the countries with the greatest coal consumption experience the largest decline in energy demand.

Scenario III illustrates a situation where a combination of policies to promote conservation, increase fuel efficiency, and invest in alternative sources of energy such as solar and wind power succeeds in reducing the demand for traditional fossil fuels. In this scenario, the global energy demand is lower by about the same amount as in the carbon tax scenario, but prices of crude oil and natural gas are much lower. By the end of the period, coal consumption is down by 45 percent from the base case (from 4.9 percent to 2.5 percent), while natural gas and crude oil are 30 percent lower than they are in the carbon tax scenario.

The price of various forms of energy in the long run is little different from the baseline scenario because the additional carbon tax induces sufficient reductions in energy demand to lower the final price by almost as much as the tax itself.

Finally, under Scenario IV, oil reserves deplete more quickly than in the baseline scenario, either because current estimates of reserves prove too optimistic or because additional technology improvements do not materialize. In this scenario, oil supply, instead of growing at about 1 percent a year, is broadly stable, with production of about 78 mb/d in 2030. Oil prices are about 80 percent higher and demand 32 percent lower than in the baseline, with the difference being made up by about a 9 percent stronger growth in consumption of coal.

The price of oil in this scenario rises to about \$122 a barrel but not higher because of increased supply from alternative energy sources induced by the higher prices.

Overall, the impact on global growth in Scenario IV would be limited. By 2030 global GDP would be only 1.4 percentage points below the level in the base case. The bulk of this decline would be felt by the middle-income developing countries, where energy intensities are highest.

Taken together, these scenarios illustrate the considerable uncertainty surrounding the assumptions of the base case. Nevertheless, even the pessimistic scenarios have a limited impact on global welfare. Over the long run, economies have considerable potential to adjust to higher oil prices through switching to other energy sources and conservation, thus moderating the impact of higher oil prices on growth and poverty reduction.

Conclusions

The almost unprecedented duration and size of the recent commodity price boom gave the impression, at least as can be judged by the popular press, that the world is running out of natural resources. This is not true. A combination of circumstances have shaped this boom: an unusually long period of above-potential growth among developing countries; a long period of low oil and metals prices that eroded supply capacity, in part driven by the expansion of net oil exports from the transition economies of Eastern Europe once domestic prices increased to world levels; the depreciation of the dollar; the increase in subsidies for biofuels that diverted resources from growing crops for food; declines in grain stocks; increasing demand from developing-country consumers of oil and raw materials; and continued global economic expansion in the face of rising commodity prices. As the rapid decline of commodity prices since mid-2008 attests, the current boom is best understood as yet another cycle in a long history of commodity price cycles.

This does not mean that commodity prices are necessarily going to fall all the way back to the levels of the 1990s, nor are they likely to return to recent heights when demand recovers. In the oil and metals markets, it will take time to build the machines and train the engineers required to find and exploit new resources, and this kind of exploration will require that oil prices be maintained at around $75 a barrel in real terms.

However, in the long run, it will be difficult to sustain very high oil prices (in excess of $100 a barrel) for a lengthy period, because alternative sources of oil (such as Canadian oil sands and more-expensive offshore sources) and substitutes for oil (such as solar, wind, and biofuels) would become profitable, while the potential for reductions in demand from conservation remain large. On average, the weakening of global demand and increased supply have caused metal prices to fall by more than 40 percent from their recent peaks. Nevertheless, they remain 2.5 times higher than they were in the 1990s and even though they are projected to decline a further 20-odd percent (see chapter 1) in 2009, these prices are high enough to ensure that sufficient further supply will be forthcoming over the medium term. In the longer run, metals demand should slow as Chinese metal intensities first stabilize and then fall, both because of lower investment rates and because of a higher share of services in Chinese GDP.

In agriculture, slower population growth should slow demand for food, while productivity growth should be sufficient to ensure future supply at the global level. However, prospects for individual countries are less clear. Yields have been declining among many of the countries that had the strongest gains from the Green Revolution, unless they step up investments in infrastructure and R&D and remain open to new technologies, agricultural productivity growth in developing countries may decline. Moreover, for those countries with relatively high population growth, many of which are in Africa, failure to make investments to boost agricultural productivity may see them cease to be self-sufficient and forced to import increasingly expensive food from high-income countries where agricultural productivity continues to rise much faster than the population.

Central to these forecasts, and particularly uncertain, are the prospects for technological progress. Technology will determine the availability of oil reserves and the costs of extraction, the price levels at which different oil substitutes become profitable, the potential for economizing on scarce oil and metals, and the likelihood of rapid increases in crop yields. Making assumptions for technological progress 25 years in the future is a perilous undertaking. Most likely to be missed are technological surprises that enable rapid increases in productivity. So in a sense these forecasts are conservative. But even without counting on technological miracles, under reasonable assumptions the supply of commodities is likely to increase rapidly enough over the long run to meet anticipated increases in demand at prices that are lower than the current levels.

Notes

1. The 1916–17 boom was associated with the First World War. Similarly, all three booms since 1945 have been associated with a major, though geographically confined, military conflict (Korea, Vietnam, and Iraq) and heightened geopolitical uncertainty, which translated into market fears about the availability of supplies.

2. However, real prices of domestic food commodities in developing countries increased by an additional 28 percent during the first three quarters of 2008.

3. This capacity was partly and temporarily utilized during the time of the first Gulf war, when 5 mb/d of capacity was shut in Iraq and Kuwait.

4. OPEC surplus capacity typically refers to capacity that can be brought onstream within 90 days. Here, OPEC's surplus is conservatively estimated as that lying dormant from previously higher (though not peak) levels.

5. Although less important than in the past, these firms still account for almost 50 percent of global upstream spending.

6. Upstream expenditures and the price of crude oil are highly correlated; the correlation coefficient between spending per barrel of oil and the price of oil is 0.95.

7. The balance of supply was made up from OPEC natural gas liquids (1.8 mb/d); non-OPEC, non-FSU production growth (3.1 mb/d); and rising OPEC capacity.

8. The pickup in oil demand was led by China, where demand for electricity had outstripped supply from public sector utilities, resulting in a spike in the private use of diesel oil for electrical generators.

9. Private communication with David Humphreys, chief economist at Norilsk Nickel.

10. The contrast between inputs in metal and inputs in the agricultural sectors is noteworthy. In agriculture, the same type of machinery can be used for virtually all crops in all countries of the world. However, machinery in metals is custom-made for each mine.

11. *Jatropha curcus L.* is a bush or small tree used as a hedge by farmers in developing countries because it is not browsed by animals. It produces a fruit with high oil content, suitable for biodiesel production.

12. The poor harvests in Australia come against a backdrop of an unprecedented, decade-long period of unusually low rainfall and record-high temperatures, which are at least partly a result of climate change. These events have severely stressed water supplies in the east and southwest of the country (http://www.bom.gov.au/climate/drought/drought.shtml).

13. When hoarding and real-side speculation occur in response to expectations of a future shortfall, stocks (and prices) tend to increase in the short run (relative to a baseline where the behavior did not occur). In turn, this ensures that future stocks are higher and future prices lower than they would have been otherwise. At the same time it encourages producers to increase output, thereby accelerating a return to more normal prices.

14. In member countries of the Organisation for Economic Co-operation and Development, high prices induced a substantial switch away from oil and toward coal, natural gas, and nuclear power for electrical generation.

15. Exceptions include nickel, which has been rising in Brazil; copper, which has been rising in India; and aluminum, which has been rising in South Africa.

16. Although developing countries now account for almost half of the world's metal consumption, it should be noted that their average per capita use of metals is only a fraction of that in the developed economies.

17. These income levels correspond roughly to the midpoint in the World Bank's official range for lower-middle-income countries and close to the upper range for upper-middle-income countries.

18. At incomes of less than $1 a day (or annual per capita income of less than $350), consumption of basic staples such as maize, wheat, and rice tends to increase along with income. At higher incomes, per capita consumption of staples tends to remain stable, so the growth of staples consumption falls below income growth.

19. The income elasticity for meat products exceeds 3.0 for per capita incomes below $4,500 and declines to 2.6 for countries with incomes in excess of $25,000.

20. When oil costs $120 a barrel (as it did in early 2008), wholesale gas prices would be around $3.25 a gallon in the United States, and the fuel-equivalent ethanol price would be $2.44 a gallon. At that price, ethanol production from maize is profitable as long as maize prices do not exceed $245 a ton, which was more or less the price of maize at that time.

21. Global production from onshore sources in 2004 was 54 mb/day, almost identical to the 1973 level.

22. Reserve growth refers to the increase in the estimated sizes of fields that occurs as oil and gas fields are developed. In the United States, the world's most intensely explored country, reserve growth is a major component of remaining oil and gas resources. It is hypothesized that reserve growth can occur worldwide in similar proportions as exploration of new fields matures. Undiscovered resources, on the other hand, are resources postulated from geologic information and theory to exist outside of known oil and gas fields (Kleitt and others 2000).

23. If all announced projects materialize, potential capacity could reach 3.3 mb/d.

24. Concerns over the environment are likely to be another constraint in future mining activities.

25. Like electric cars, hydrogen-powered vehicles allow the consumption of the power and the consumption of the propellant to be geographically separated. For electric cars, the energy source (be it coal, nuclear, or solar) that powers the car is consumed at the power-producing plant, whereas for hydrogen-powered cars (as distinct from hydrogen fuel-cell cars), it is expended in the plant that separates the hydrogen from water. Thus a hydrogen-powered car can be considered just another form of battery-powered car.

26. If OPEC is considered as a single producer, then both oil-export and oil-reserve markets are highly concentrated (Herfindahl index of 0.53 and to 0.57, respectively). However, if the member countries were to act independently, the market would not be particularly concentrated (Herfindahl index of 0.07 and 0.09, respectively).

27. Specifically, average caloric consumption in developing countries rose from 2,110 kilocalories per person per day to 2,650 (FAO 2006, p. 3).

28. Much of the underutilized land in the former Soviet bloc was cultivated in the Soviet era but was left to fallow when price signals rather than command and control began to determine land use decisions.

29. The potential gains in the table reflect estimates of the increase in production that could be expected if fertilizer production in countries in each of these regions were brought up to the 75th percentile level—roughly the level in Pakistan. In contrast with the calculations of Coelli and Rao (2005), which yield broadly similar results, these control for climatic conditions, income per capita, and soil conditions.

30. Investment expenditures in extractive industries are highly correlated with the respective prices. For example, when crude oil prices declined by 50 percent from 1980 to 2000, investment expenditures followed suit.

31. These estimates do not include the carbon fertilization effect (on which scientific evidence is mixed), whereby increases in atmospheric carbon concentration enhance plant growth The simulations may be overestimating the negative impacts. The Cline estimates have been scaled assuming linearity, but some evidence suggests that the actual damage functions are nonlinear. These simulations may therefore overestimate damages in the short run and underestimate them in the long run.

32. The baseline scenario incorporates an increase in efficiency of energy use of 1 percent a year. This represents the culmination of new scientific advances (for example, the use of carbon fiber materials instead of metals); the replacement of old, more-energy-intensive capital with new capital; and changes in behavior (for example, switching from large vehicles to smaller ones).

33. The questions regarding who should bear the burden on reducing carbon emissions are critically important but are set aside in this simulation to investigate the impact on overall demand and prices. The revenues generated by the price of carbon are assumed to be recycled domestically with no international transfers.

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