CHAPTER 5

MACROECONOMIC ENVIRONMENT AND COMMODITY MARKETS: A LONGER-TERM OUTLOOK

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By most accounts, the recent commodity boom has been the longest and broadest (in terms of commodities involved) of the post-Second World War period (World Bank, 2009). Between 2003 and 2008, nominal energy and metal prices increased by 230 percent, food and precious metal prices doubled, and fertilizer prices increased fourfold. Although most prices have declined sharply since their mid-2008 peak, they are still considerably higher than their 2003 levels.

Apart from broad and sustained economic growth, the boom has been fuelled by a host of other factors, both macro and long-term as well as sector-specific and short-term. These include low past investment in extractive commodities, reflecting a prolonged period of declining prices due to excess capacity left after the collapse of the Soviet Union and weak demand after the 1997 East Asian (and other countries') financial crisis; a weak United States dollar (the currency of choice in most international commodity transactions); fiscal expansion and loose monetary policies in many countries; and investment fund activity by financial institutions, which chose to include commodities in their portfolios. In addition, the diversion of some food commodities to the production of biofuels (notably maize in the United States of America, and edible oils in Europe), adverse weather conditions (e.g., three droughts in Australia between 2001 and 2007, a heat-wave in central Asia during the summer of 2010), global stock declines of several agricultural commodities to historical lows, and government policies (e.g., export bans and prohibitive taxes) further contributed to the boom. Geo-political concerns played a key role as well, especially in energy markets.

In some sense, these factors created the "perfect storm", which reached its zenith in July 2008 when crude oil prices averaged USD 133 per barrel (up 94 percent from a year earlier) and rice prices doubled within just five months (from USD 375 per tonne in January to USD 757 per tonne in June 2008). The weakening and/or reversal of some of these factors, coupled with the financial crisis that erupted in September 2008 and the subsequent global economic downturn, induced sharp price declines across most commodity sectors. However, following the pick-up of growth in developed countries and the resilience of emerging economies, commodity prices began increasing again and, in February 2011, most key price indices had reached (or even exceeded) their 2008 peaks.

The recent boom has generated renewed interest in the determinants of commodity prices, including the role of commodity-specific factors, macro-economic fundamentals, and questions regarding whether a permanent shift in price trends has taken place. At the same time, food availability and food security concerns have generated calls for coordinated policy actions at the national (and perhaps international) level, reminiscent of actions taken in earlier booms. With this context in mind, this chapter identifies and analyses the dominant forces that are likely to shape long-term developments in commodity markets. Such forces include (but are not limited to) the increased interdependence between energy and non-energy markets; growth prospects, especially in developing countries, where most consumption growth is expected to take place; the effect of climate change in the production and trade of commodities; and, at the outset, what all this implies for poverty.

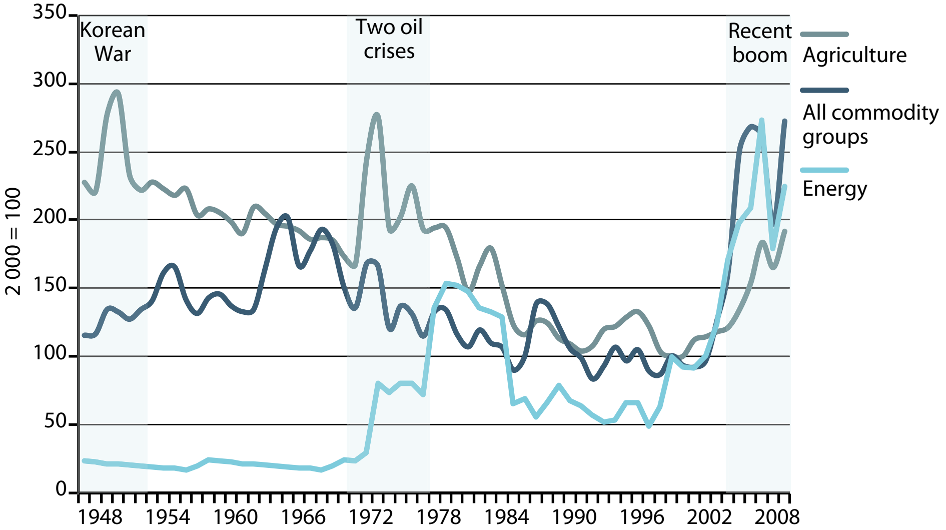
The following section provides a brief discussion of recent price trends, including the causes of the recent commodity price boom. This is followed by an analysis of the link between energy and non-energy prices. The next three sections deal with the issues of growth prospects, global warming and their implications for poverty. The last section concludes with a summary and a policy discussion.

The nature of the recent commodity boom

The recent commodity boom shares a number of similarities with earlier booms, but also has some differences. It involved almost all commodities (Figures 5.1 and 5.2), unlike earlier booms, which involved only agriculture (the Korean War) or agriculture and energy (the 1970s energy crisis). It was not associated with high inflation, as opposed to the 1970s boom, which was associated with inflationary pressures. On the other hand, all three booms took place against the backdrop of high and sustained economic growth. Furthermore, they all generated discussion of coordinated policy actions, owing to concerns about food security and energy availability.

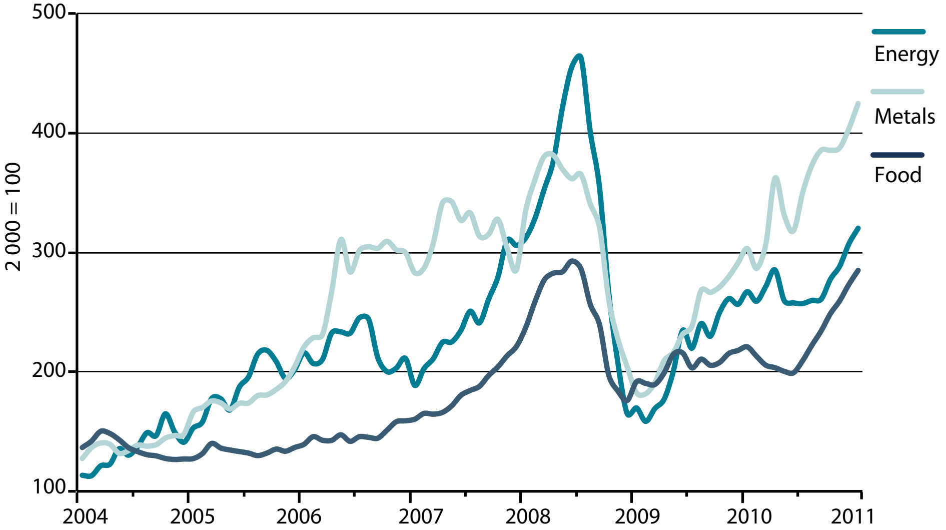
The reasons behind the recent boom are numerous and, as many analysts have argued, they created a “perfect storm”. On the one hand, most countries enjoyed sustained economic growth for a long period; during 2003 to 2007,

Figure 5.1
Commodity groups affected by booms, 1948 to 2008 (real prices, Manufacturing Unit Value index [MUV]-deflated)



Source: World Bank.

Figure 5.2
Commodity price fluctuations, before, during and after the financial crisis (real prices, MUV-deflated)



Source: World Bank.

growth in developing countries averaged 6.9 percent, the highest five-year average in recent history (the second highest five-year average, of 6.5 percent, occurred between 1969 and 1973). Fiscal expansion in many countries and low interest rates created an environment that favoured high commodity prices. The depreciation of the United States dollar played a role, as it is the currency of choice for most international transactions.

Box 5.1 - Experience with managing commodity markets

Long-term declines in and high variability of commodity prices have prompted many governments to take collective measures to prevent the decline or reduce the variability. Led by Brazil, coffee producers organized the 1962 International Coffee Agreement (and a subsequent series of agreements) to restrict exports and boost coffee prices. Similar efforts were undertaken by cocoa producers, while attempts were also made in other markets (e.g., cotton, grains). Oil producers formed the Organization of the Petroleum Exporting Countries (OPEC) in 1960, to raise prices through supply controls. Similar organizations of commodity producing countries also used buffer stocks to stabilize prices. Tin producers managed buffer stocks through the International Tin Agreement, to maintain prices within a range. The International Cocoa Agreement, formed in 1972, also attempted to stabilize prices through buffer stocks, but was suspended in 1988. The International Natural Rubber Organization was formed to stabilize rubber prices, but major producers withdrew from the organization following the East Asian financial crisis of 1997. With the exception of OPEC, all these agreements failed to achieve their stated objectives, as coordination and monitoring among many sovereign nations turned out to be a difficult task. Prior to the post-Second World War commodity agreements, another wave of agreements had been formed in response to the low prices following the Great Depression.

In the extractive sectors, especially energy commodities, underinvestment during the late 1980s and the 1990s left limited room for supply response. For example, during the early 1980s, total investment expenditures by the major United States multinational oil and gas companies averaged more than USD 130 billion per annum (in real 2006 terms). For the next 15 years, however, the annual average dropped by half (Figure 5.3). Similar reductions in investment took place in most metal sectors.

Another factor believed to have played a key role in the recent boom is the decision by managers of various investment, pension and sovereign wealth funds to include commodities in their holdings as a way of diversifying their portfolios away from traditional asset classes such as equities and bonds. Although evidence on the effect of investment fund activity on commodity prices has been mixed, many experts believe that such funds have been a key force behind the 2008 and 2010/2011 rallies (see discussion in Boxes 5.1 and 5.2, and Table 5.1, on different types of speculation, including investment fund activity).

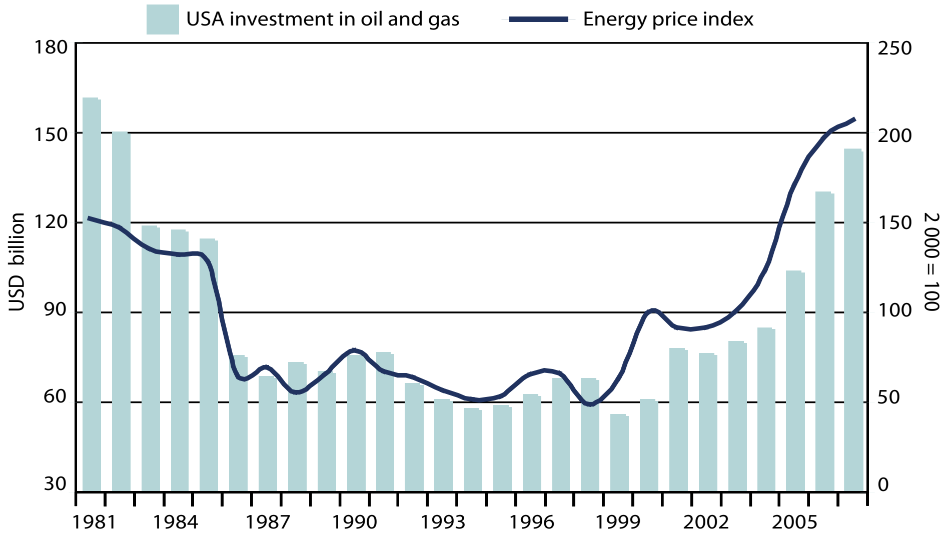
Box 5.2 - The role of speculation during the recent commodity boom

In the early 2000s, managers of various investment, pension and sovereign wealth funds began investing in commodity markets, either as a way to diversify away from existing assets (e.g., equities and bonds) or owing to their search for higher yields. Although estimates of how much money has been invested in commodity markets are not precise, a major investment bank put the figure (as of October 2010) at about USD 350 billion; it was about USD 250 billion in 2008 according to Masters (2008). Almost two-thirds of this is invested in energy commodities. Although such transactions are not associated with real demand for commodities, they may have influenced prices, for a number of reasons. First, because investment in commodities is a relatively new phenomenon, there have been mostly inflows (not outflows) of funds, implying that some markets may have been subject to extrapolative price behaviour (i.e., high prices leading to more buying by investment funds, leading to even higher prices, and so on). Second, these funds invest on the basis of fixed weights or past performance criteria, so investment often takes place in contrast to what market fundamentals would dictate. Third, the large size of these funds compared with commodity markets may exacerbate price movements. Their influence on prices is especially likely if the rapid expansion of these markets contributes to expectations of rising prices, thereby exacerbating swings, as argued by Soros (2008: 4), who called commodity index buying "intellectually unsound, potentially destabilizing and distinctly harmful in its economic consequences". Similar views are shared by numerous authors (e.g., Eckaus, 2008; Wray, 2008).

However, the empirical evidence regarding whether or not such funds contributed to the price boom has been, at best, mixed. In the non-ferrous metals market, Gilbert (2008) found no direct evidence of the impact of investor activity on the prices of metals, but some evidence of extrapolative price behaviour resulting in price movements that were not fully justified by market fundamentals. He also found strong evidence that the futures positions of index providers over the past two years have affected soybean (but not maize) prices in the United States futures exchanges. Plastina (2008) concluded that between January 2006 and February 2008, investment fund activity might have pushed cotton prices 14 percent higher than they would otherwise have been. On the other hand, two International Monetary Fund studies (IMF, 2006; 2008) failed to find evidence that speculation has 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 United States futures exchanges (Büyükşahin, Haigh and Robe, 2008; CFTC, 2008).

Although the empirical evidence regarding the effect of investment fund activity is mixed and inconclusive, the consensus among experts is that the large amount of money that goes into commodities certainly has an effect on prices. On the other hand, market fundamentals will determine the long-term trends of commodity prices, which implies that investment fund activity has induced higher price variability.

Figure 5.3
Energy investment (left axis) and prices (right axis) by major multinational oil companies



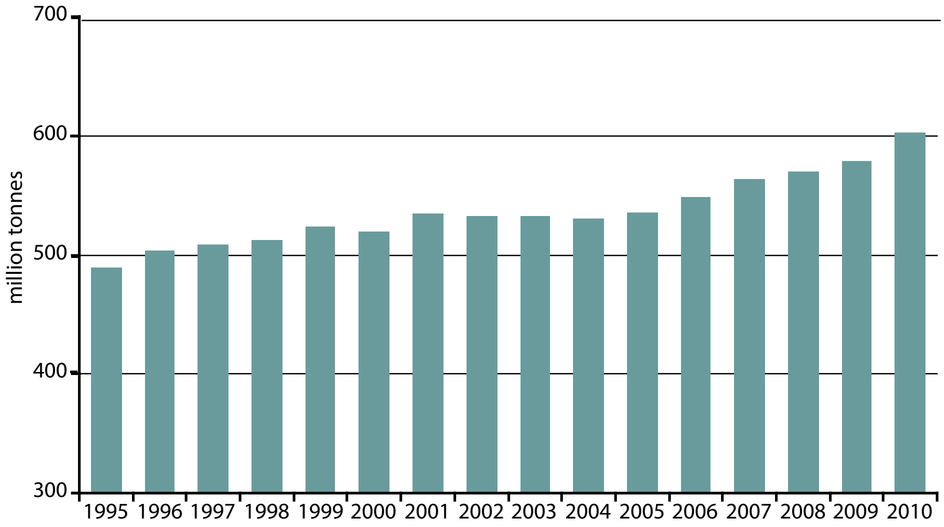
Sources: International Energy Authority (IEA); World Bank.

Table 5.1
The simplistic (and compartmentalized) view of speculation

Activity	*Function*	*Effect*
Speculation on futures exchanges	Important activity for the functioning of futures markets	Injects liquidity into the market and improves price discovery
Market manipulation	Isolated cases, such as cornering of the copper and silver markets	These are illegal activities
Building up of inventories	Accumulation of physical stocks with the expectation that price increases will generate profits	Traders buy at current prices to sell later, when the market is tight, thus balancing the market and reducing price variability
Commodity trading accounts	Professionally managed commodity investment vehicles taking into consideration market fundamentals	Enhanced price discovery through careful examination of the fundamentals and use of technical analysis
Hedge funds	Short-term profit seeking	Believed to induce short-term volatility (i.e., day-to-day)
Investment funds	Long positions in futures exchanges taken by investment, pension and sovereign wealth funds	May amplify commodity cycles owing to the size and nature of investment, but unlikely to affect long-term trends

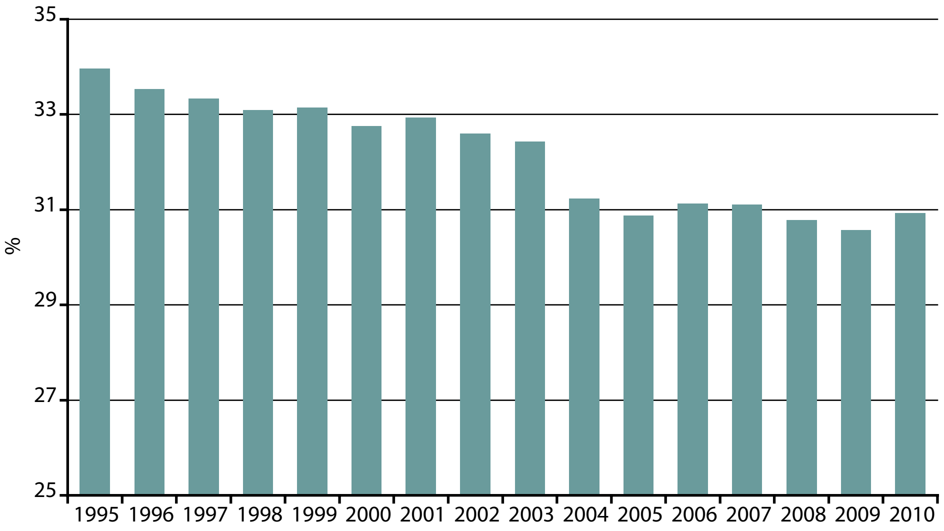
Source: Authors.

Figure 5.4
Rice, wheat and maize consumption in China and India



Source: World Bank calculation based on USDA data.

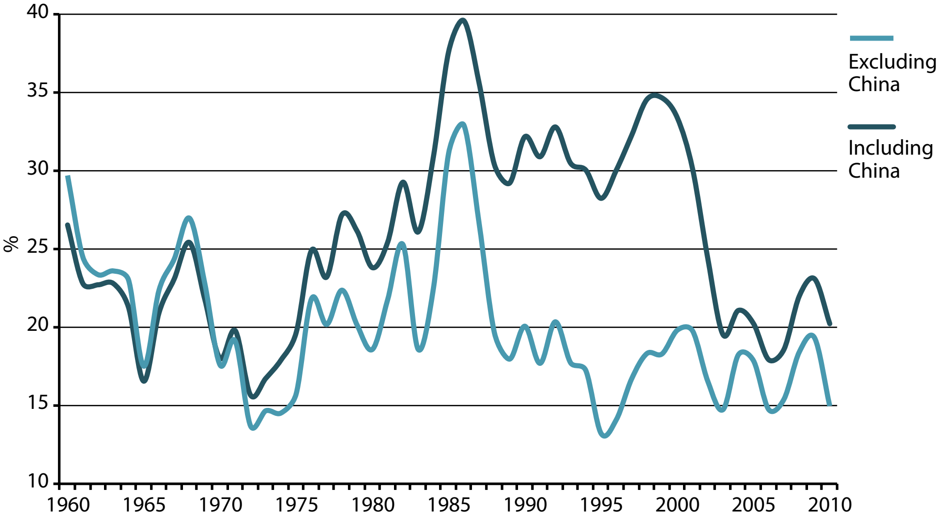
Figure 5.5
Rice, wheat and maize consumption in China and India, as percentage of world total



Source: World Bank calculation based on USDA data.

The diversion of considerable quantities of some food commodities for the production of biofuels has been another factor behind the boom. Almost 28 percent of United States maize area (corresponding to about 1.33 percent of global grain area) was diverted to ethanol production during 2008/2009. While the combined maize and oilseed area diverted to biofuel production corresponds to about 2 percent of global grain and oilseed area, the sharp increase in diversion of the last two to three years came at a time when global grain stocks were at historical lows, thus leaving limited room for adjustment by bringing more land into productive uses (see Figure 5.6 for historical stock-to-use ratios).

Figure 5.6
Global stock-to-use ratios, 1960 to 2010



Source: World Bank calculation based on USDA data.

When most prices began rallying during early 2008, many governments faced increased pressure from consumers of key food commodities (especially rice) to contain domestic food price inflation. In response, they imposed various export controls, including exports bans and prohibitive export taxes. Although such measures temporarily contained domestic price increases, they further exacerbated world price increases, especially in the rice market, which is very thin (less than 10 percent of global rice production is internationally traded). Some governments reacted in a similar fashion in 2010, when wheat prices began spiking, but the overall trade policy response has been much more muted.

In addition to these factors, increased grain consumption by low- and middle-income countries (especially China and India), due to rising incomes and changing diets (from grain to meat consumption), has often been cited as a key driving force of the boom, including the 2008 rally. However, as Figures 5.4 and 5.5 indicate, the combined grain consumption (for both human and animal use) by China and India increased only slightly after 1995, a period in which both countries enjoyed strong economic growth. More important, when expressed as a share of global consumption, grain consumption in these two countries declined between 1995 and 2007. This should not be surprising given the low income elasticity of grains even at low per capita incomes (Table 5.2).

Table 5.2
Income elasticities

Commodity group	Low income	Lower-middle income	Upper-middle income	High income
Grains	0.15	0.10	0.05	-0.01
Vegetable oils	0.50	0.65	0.78	0.41
Meats	0.31	0.51	0.68	0.38

Source: Authors' estimates based on panel estimation.

The energy/non-energy price link

It has become increasingly clear that the energy price increases of the last few years will reshape not only energy markets but also most other markets, including agriculture. For almost 20 years, the price of crude oil averaged about USD 20 per barrel (real 2000 terms). Most analysts and researchers now believe that the "new" equilibrium price of oil will be three to four times as much, with proportional changes expected to take place in all other types of energy. High energy prices, along with the high energy intensity of most commodities (especially agriculture), imply that developments in non-energy (especially food) markets will depend on the nature and degree of the energy/non-energy price link. The rest of this section elaborates on this issue.

The channels through which energy prices affect other commodities are numerous. On the supply side, energy enters the aggregate production function of most primary commodities through the use of various energy-intensive inputs and, often, transportation over long distances, which is an equally energy-demanding process. Some commodities have to go through an energy-intensive primary processing stage. Others can be used to produce substitutes for crude oil (e.g., maize and sugar for ethanol production, or edible oils for biodiesel production). In other cases, the main input may be a close substitute for crude oil, such as nitrogen fertilizer, which is made directly from natural gas. (The various transmission channels from energy to non-energy prices are discussed in, among others, Baffes, 2007; 2010; FAO, 2002; World Bank, 2009.)

This section examines the energy/non-energy price link by estimating the following relationship:

$$\log(\text{NON\_ENERGY}_t) = \mu + \beta_1 \log(\text{ENERGY}_t) + \beta_2 \log(\text{MUV}_t) + \beta_3 \text{TIME} + \varepsilon_t. \quad (5.1)$$

where NON_ENERGY_t denotes the various non-energy United States dollar-based price indices at time t; ENERGY_t denotes the energy price index; MUV_t denotes the deflator; TIME is the time trend; ε_t denotes the error term; and μ, β_1, β_2, and β_3 denote parameters to be estimated. Annual data for a number of commodity indices and prices covering the period 1960 to 2008 are used in the analysis. Although the signs and magnitudes of the coefficients are not dictated by economic theory, β_1 and β_2 are expected to be positive because energy, as well as other goods and services (reflected by the measure of inflation), constitutes a key input to the production process of all commodities. On the other hand, β_3 is expected to be negative, at least for agricultural commodities – consistent with the long-term impact of technological progress on production costs, and the low income elasticity of most food commodities, especially cereals.

The estimates presented in Table 5.3 indicate that energy prices and, to a lesser extent, inflation and technological change explain a considerable part of commodity price variability (the adjusted R2 of all regressions averaged 0.85). Specifically, the parameter estimate of the non-energy index (top row of Table 5.3) is 0.28, implying that a 10 percent increase in energy prices is associated with a 2.8 percent increase in non-energy commodity prices, in the long run. Three earlier studies (Gilbert, 1989; Borensztein and Reinhart, 1994; Baffes, 2007) reported elasticities of 0.12, 0.11 and 0.16, respectively (Table 5.4). When the sample of the current analysis is adjusted to match the samples of these studies, the pass-through coefficients become remarkably similar (0.13, 0.12 and 0.18, respectively).

However, the transmission elasticity of the non-energy index masks some variations. The highest pass-through elasticity among the sub-indices is in fertilizer, estimated at 0.55; this is not surprising as nitrogen-based fertilizers are made directly from natural gas. Note that the fertilizer and energy price increases during the recent boom were in line with the increases experienced during the first oil shock: from 1973 to 1974 phosphate rock and urea prices increased fourfold and threefold, respectively, very similar to the crude oil price increase during that period, from USD 2.81 to USD 10.97 per barrel.

Table 5.3
Parameter estimates

Index	μ	β_1	β_2	$100^* \beta_3$	Adj-R^2	ADF
Non-energy	3.03[a]	0.28[a]	0.12	-0.01	0.9	-3.35[c]
	-6.54	-5.24	-0.68	-0.02		
Metals	3.77[a]	0.25[a]	-0.17	1.93[a]	0.82	-3.30[c]
	-4.8	-3.14	-0.6	-2.31		
Fertilizers	3.58[a]	0.55[a]	-0.3	0.39	0.81	-3.97[d]
	-4.12	-4.79	-0.95	-0.48		
Agriculture	2.51[a]	0.26[a]	0.33[a]	-0.99[a]	0.9	-3.81[d]
	-6.9	-5.54	-2.43	-2.73		
Beverages	1.83[a]	0.38[a]	0.55[a]	-3.12[a]	0.76	-4.95[d]
	-3.1	-4.87	-2.63	-5.22		
Raw materials	1.85[a]	0.11[a]	0.51[a]	0.08	0.91	-3.15[c]
	-4.16	-2.15	-3.15	-0.19		
Food	2.91[a]	0.27[a]	0.21	-0.71	0.85	-3.85[d]
	-7.11	-4.93	-1.39	-1.8		
Cereals	3.13[a]	0.28[a]	0.17	-0.87	0.78	-3.83[d]
	-5.94	-4.23	-0.89	-1.76		
Edible oils	3.33[a]	0.29[a]	0.12	-0.8	0.8	-2.82[b]
	-6.16	-4.51	-0.58	-1.5		
Other food	1.86[a]	0.22[a]	0.45[a]	-0.42	0.89	-3.60[d]
	-6.28	-3.81	-4.44	-1.18		
Precious metals	-1.40[a]	0.46[a]	1.05	-1.75	0.98	-3.91[d]
	-3.58	-9.4	-7.61	-3.68		

[a] Parameter estimate significant at the 5-percent level.

Rejection of the existence of one unit root at: [b] 10-percent level; [c] 5-percent level; and [d] 1-percent level of significance (the respective t-statistics are -2.60, -2.93 and -3.58). The lag length of the ADF equations was determined by minimizing the Schwarz-loss function.

Numbers in parentheses are absolute t-values (the corresponding variances have been estimated using White's method for heteroskedasticity-consistent standard errors).

ADF = the MacKinnon one-sided p-value based on the Augmented Dickey-Fuller equation (Dickey and Fuller, 1979).

Source: Authors' estimates.

The agriculture pass-through, estimated at 0.27, reflects a wide-ranging average: beverages (0.38), food (0.27) and raw materials (0.11). However, the elasticity estimates of the food price index components fall within a very narrow range: cereals (0.28), edible oils (0.29) and other food (0.22). The estimates for the key food commodities also fall within a relatively narrow range, from a low of 0.25 in rice to a high of 0.36 in soybeans (Table 5.5).

Table 5.4
Long-run transmission elasticities

Commodity	Holtham (1988) 1967:S1–1984:S2	Gilbert (1989) 1965:Q1–1986:Q2	Borensztein & Reinhart (1994) 1970:Q1–1992:Q3	Baffes (2007) 1960–2005	This study 1960–2008
Non-energy	—	0.12	0.11	0.16	0.28
Food	—	0.25	—	0.18	0.27
Raw materials	0.08	—	—	0.04	0.11
Metals	0.17	0.11	—	0.11	0.25

Holtham uses semi-annual data; Gilbert and Borensztein and Reinhart use quarterly data; and Baffes and the present study use annual data. Gilbert's elasticities denote averages based on four specifications; Holtham's raw materials elasticity is an average of two elasticities based on two sets of weights.

— = estimate not available.

Sources: Holtham, 1988; Gilbert, 1989; Borensztein and Reinhart, 1994; Baffes, 2007; authors' estimates.

Table 5.5
Parameter estimates

Index	μ	β_1	β_2	100* β_3	Adj-R^2	ADF
Wheat	3.27[a]	0.30[a]	0.12	-0.49	0.84	-4.35[c]
	(6.50)	(5.02)	(1.49)	(1.07)		
Maize	3.15[a]	0.27[a]	0.13	-0.74	0.80	-3.49[c]
	(6.23)	(4.66)	(0.70)	(1.58)		
Soybeans	3.58[a]	0.26[a]	0.25	-0.82	0.82	-3.85[d]
	(8.11)	(4.92)	(1.51)	(1.83)		
Rice	3.57[a]	0.25[a]	0.32	-1.62[a]	0.58	-4.05[d]
	(5.14)	(2.67)	(0.26)	(2.78)		
Palm oil	4.94[a]	0.35[a]	-0.01	-0.95	0.63	-3.16[c]
	(6.44)	(3.72)	(0.02)	(1.38)		
Soybean oil	5.25[a]	0.36[a]	-0.09	-0.42	0.70	-2.56
	(7.83)	(4.13)	(0.39)	(0.53)		

[a] Parameter estimate significant at the 5-percent level.

Rejection of the existence of one unit root at: [b] 10-percent level; [c] 5-percent level; and [d] 1-percent level of significance (the respective t-statistics are -2.60, -2.93 and -3.58). The lag length of the ADF equations was determined by minimizing the Schwarz-loss function.

Numbers in parentheses are absolute t-values (the corresponding variances have been estimated using White's method for heteroskedasticity-consistent standard errors).

ADF = the MacKinnon one-sided p-value based on the Augmented Dickey-Fuller equation (Dickey and Fuller, 1979).

Source: Authors' estimates.

Three key conclusions emerge from these results. First, most commodities respond strongly to energy prices, and the response appears to strengthen in periods of high prices, as confirmed by the considerable increases in the values of estimated elasticities observed when the recent boom is included in the analysis. The implication is that as long as energy prices remain elevated, not only are non-energy commodity prices expected to be high, but also analysing the respective markets requires understanding of the energy markets.

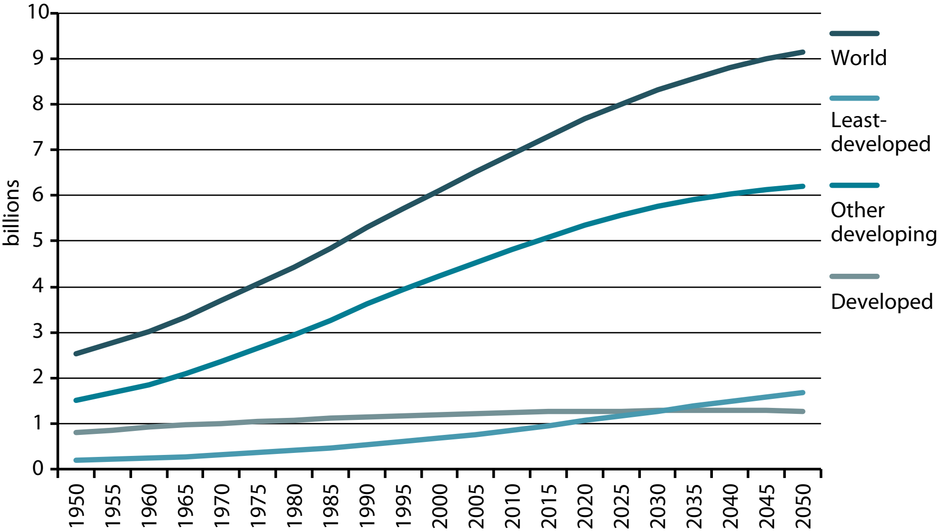
Second, while the transmission elasticities are broadly similar, this is not the case for the inflation coefficients, estimates of which vary considerably in terms of sign, magnitude and level of significance. The inflation coefficient is positive and significantly different from zero only for agriculture (and some of its sub-indices), while being effectively zero for metals and fertilizers. All this implies that the relationship between inflation and nominal commodity prices is much more complex and, perhaps, changeable over time. This may not be surprising, considering that during 1972 to 1980 (a period that includes both oil shocks) the MUV increased by 45 percent, while during 2000 to 2008, it increased by half as much. The nominal non-energy price index increases during these two eight-year periods were identical, at 170 percent.

Third, the trend parameter estimates are spread over an even wider range than the energy pass-through and inflation are. For example, the non-energy price index shows no trend at all, while the metal price index exhibits a positive annual trend of almost 2 percent, and the agriculture index shows a 1 percent negative annual trend. Furthermore, the trend parameter estimates of the agriculture sub-indices vary considerably, from 0.08 for raw materials to -3.12 for beverages, a result that confirms Deaton's (1999: 27) observation that what commodity prices lack in trend, they make up for in variability. The trend estimate of the food index, -0.71, significant at the 10 percent level, may add another dimension to the debate on the long-term decline of primary commodity prices, often discussed in the context of the Prebisch-Singer hypothesis (Spraos, 1980, and others).

The macroeconomic environment

A number of factors will shape the macroeconomic environment and agricultural supply and demand balances over the medium term (to 2030) and the longer term (to 2050). The starting point of any such analysis is demographics. Between 1950 and 2000, the world saw a huge expansion in global population, with an increase of some 3.6 billion people, or 250 percent (Figure 5.7). Over the next 50 years, the expansion will slow down considerably although, according to the United Nations (UN) medium variant, an increase of 50 percent over 2000 will be coming off a much higher base, so will still represent a rise of 3 billion people. The distributional implications of the population rise are also important. There will be nearly no increase in high-income countries, but a 150 percent increase in the least-developed countries.[1] Many of the least-developed countries have been under significant stress to feed their growing populations, owing to both natural and human-incurred reasons. On the other hand, high-income countries have both stagnating populations and food demand, and robust agriculture. This combination could lead to increased reliance on food imports among the least-developed countries, with other developing regions lying somewhere in between – some with surpluses, such as many Latin American countries, and others with potentially growing deficits, such as some in Asia. The bottom line is that agricultural production has to increase at an average of 0.8 percent per annum simply to accommodate population growth, and in the least-developed countries it will have to grow at an average of 1.8 percent per annum over the 50-year period.

Figure 5.7
Population expansion: history and projection



Source: UN Population Division. http://esa.un.org/unpp/index.aspl.

The economic factors that will determine food supply and balances can be divided into the two categories of demand and supply factors, which will be regionally differentiated. Historically, demand has been conditioned by two factors: income growth and shifts in tastes (often derived from income growth), examples of which include switches from diets based largely on grains to more reliance on meat- and dairy-based proteins. In most high-income and some

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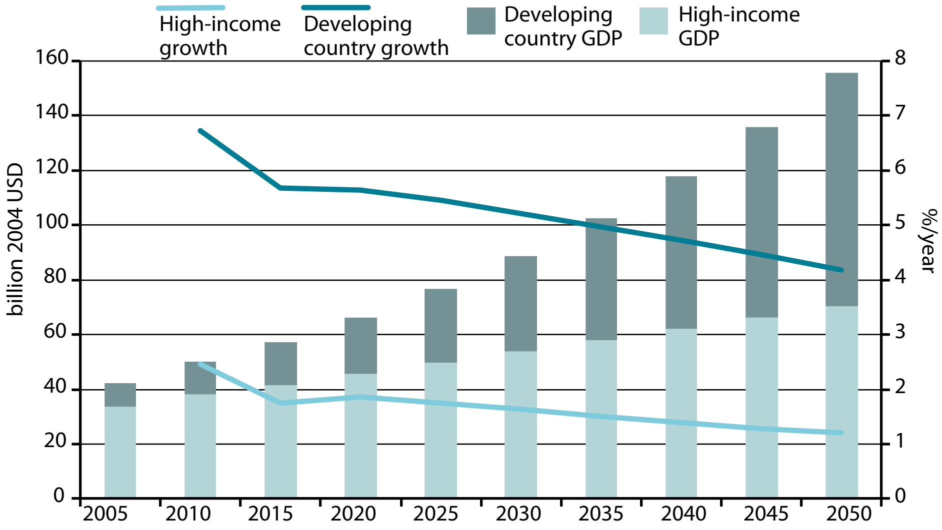
[1] Using today's definition of least-developed.

developing countries, the income elasticity is nearly 0 for many food commodities as saturation points have been reached.[2] There is nonetheless a substantial portion of the global population that would potentially demand relatively more food as incomes rise. The World Bank's most recent estimate of the incidence of poverty (at the USD 2 per day level) in developing countries was about 47 percent in 2005, declining to about 33 percent by 2015. In addition, the intensification of meat and dairy consumption would raise the demand for grain-based feed in larger proportion than any relative drop in household-based grain demand.

Although income growth is regularly projected over the medium- and long-term horizons, it should be kept in mind that these are strictly scenario-based (or "what if?") projections, and not statistically based as the more standard short-term forecasts of economic growth are. The projections in this paper use a hybrid system, which in the short and medium terms relies more on estimates of potential growth using statistical techniques, but over the longer term switches to a more judgemental forecast that relies on two assumptions: i) long-term per capita growth in high-income countries will slow to 1.0 to 1.5 percent per annum; and ii) developing countries will converge towards the per capita incomes of high-income countries, but at different rates.

Figure 5.8
GDP growth scenario



Source: Simulation results with the World Bank's ENVISAGE model.

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[2] It could be argued that demand may even decline as health and environmental concerns lead to changing dietary habits and lower overall food consumption.

The baseline projection has the global economy increasing at an average rate of about 2.9 percent between 2005 and 2050 (Figure 5.8). This breaks out into 1.6 percent for high-income countries and a brisk 5.2 percent for developing countries. One of the key consequences of this differential in growth rates is a very large shift in share of global output. In 2005, developing countries had a roughly 20 percent share in global output (at market exchange rates). By 2050, this jumps to about 55 percent. On a per capita basis, the growth differential narrows, as population growth is near zero in high-income countries. At market exchange rates, there is a narrowing of the income gap, but it remains substantial. In 2005, per capita incomes were some 20 times higher in high-income than in developing countries. This ratio drops to six by 2050, but varies greatly across regions, with a low of 3.5 in East Asia and the Pacific and a high of 20 in sub-Saharan Africa.

With average per capita incomes rising by 2.2 percent per annum between 2005 and 2050, an income elasticity of 0.5 would yield an increase in food demand of 1.1 percent, to be added to the 0.8 percent increase in population for a total increase of 1.9 percent per annum. This simple estimate may be an overstatement, as income elasticity for food would be expected to decline as incomes rise and is already near zero in most high-income countries. On the other hand, counterbalancing factors that would lead to a rise could include an increasing demand for meat and dairy and new competition emerging from biofuels.

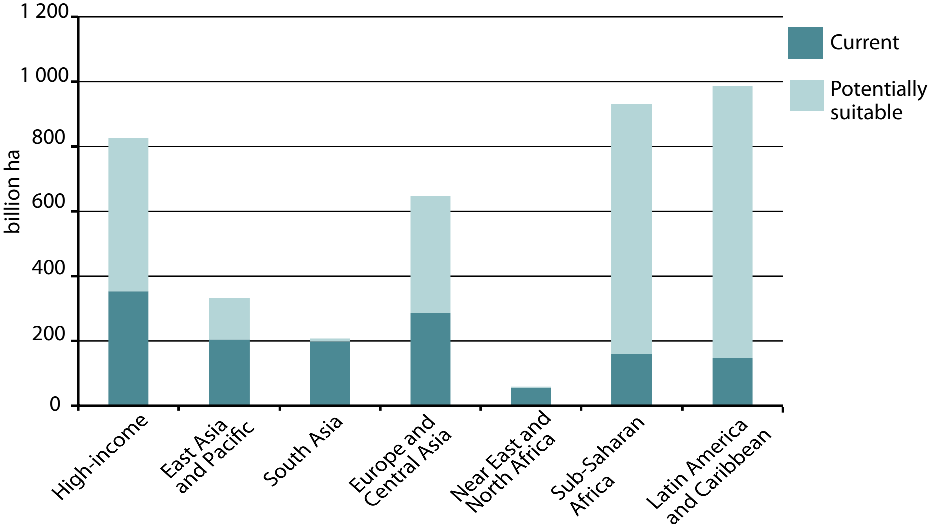
The factors behind demand growth are likely to be relatively stable compared with supply-side variables. Ultimately, supply growth will be driven by the different degrees of intensification (getting more from the same amount of land) and extensification (expanding the land area under cultivation). The cost and availability of other inputs, notably water, are also important factors, but are more difficult to integrate into the current analysis.

Based on the latest available FAO data, there is significant scope for extensification in many regions of the world (Figure 5.9). Whether this potential supply is exploited or not will depend on, among other factors, the affordability of expansion in terms of infrastructure development, and the potential negative externalities of expansion (e.g., environmental degradation). Which regions expand land use will also influence changes in the patterns of food trade. For example, Latin America, which has relatively large tracts of productive non-forest land available, could see a fairly rapid expansion of its production and exportable surplus.

The huge increase in world population but stagnant or even falling agricultural prices of the last few decades have been supported by sizeable improvement in agricultural productivity growth (Coelli and Rao, 2005; World Bank, 2009), particularly in Asia, but also in North America. This rapid growth has recently tapered somewhat. For example, yield growth in wheat and rice declined from about 2 percent between 1965 and 1999, to less than 1 percent between 2000 and

2008. This is cause for concern about the future, particularly as this decline has trended well with the decline in expenditures on research and development (R&D). There are opportunities available, in part because many regions are well behind the frontier – such as Europe and Central Asia and sub-Saharan Africa – and also because the frontier can still be pushed out, notably with state-of-the-art gene-based R&D.

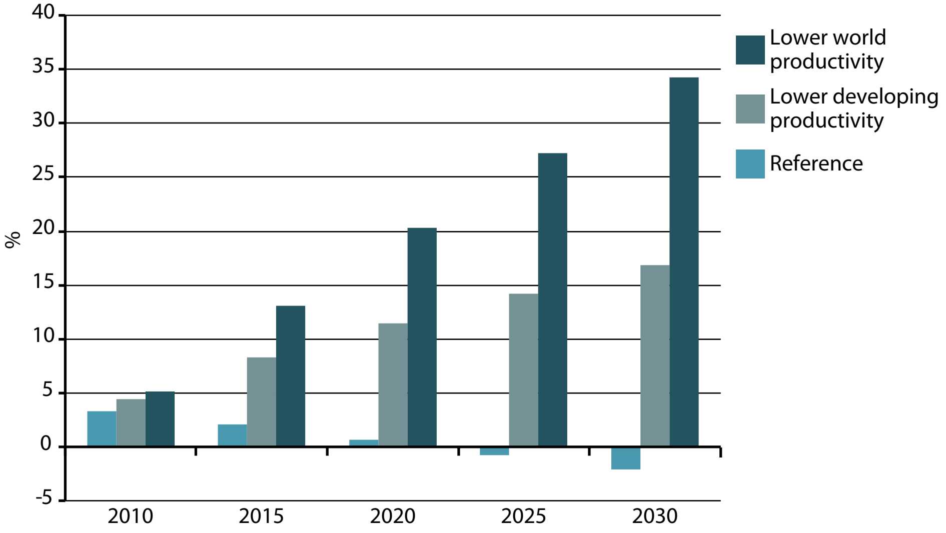
Figure 5.9
Land under cultivation and potentially suitable



Source: FAO.

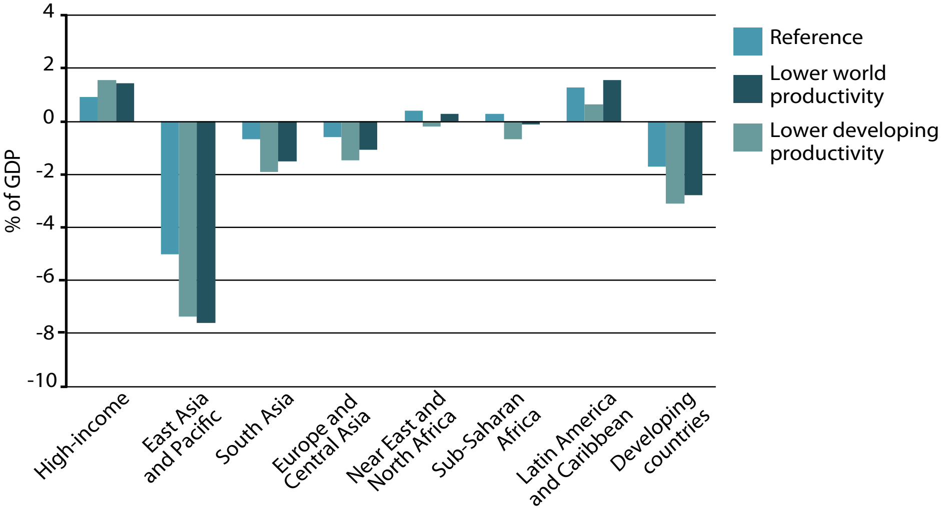
Part of the analysis of long-term trends relies on an analytical framework that allows integration of the various components – demographics, income growth, structural and taste changes, productivity and evolving factor supplies – into a consistent model of the global economy. The World Bank's ENVironmental Impact and Sustainability Applied General Equilibrium (ENVISAGE) model is a dynamic computable general equilibrium (CGE) model, described in greater detail in Annex 5.1. ENVISAGE has several advantages: first, it is global, with supply/demand balances guaranteed at the global level – differences between domestic production and demand are met through exporting surpluses or importing to meet deficits; second, it encompasses all economic activity, so if a country becomes a net importer of food, it must export more of other commodities; and third, it is based on a consistent microeconomic underpinning that facilitates what-if analysis. For example, What if productivity is higher or lower? What if demand for meat and

Figure 5.10
Changes in world agricultural prices under different productivity assumptions



Source: Simulation results with the World Bank's ENVISAGE model.

Figure 5.11
Net agricultural trade under different productivity assumptions, 2030



Source: Simulation results with the World Bank's ENVISAGE model.

dairy in developing countries follows a different pattern from that in high-income countries? What if energy prices rise? How does this affect the cost structure of food supply? Will it induce more demand for biofuels? The remainder of this section explores some of these fundamental questions with the assistance of the model.

The baseline scenario, with productivity growth of 2.1 percent per annum in agriculture, yields a benign price pattern for overall agriculture, i.e., there is a small negative trend over the long term, with global supply/demand balances more or less lined up (Figure 5.10). This has been the pattern for the last 30 to 40 years. Supply/demand balances at a regional level may widen, as some countries have little room for expansion and see a shift in comparative advantage for other goods. In the absence of new support policies, East Asia could see a relatively large increase in net agricultural imports, with high-income countries and Latin America and the Caribbean having exportable surpluses (Figure 5.11).

As noted earlier, assumptions regarding productivity are key to determining the potential stress on food markets. To assess the impact of the baseline assumption on agricultural productivity, two additional scenarios are undertaken. In the first scenario, developing countries are assumed to have half the productivity growth in agriculture of the baseline assumption. This could be driven by a number of factors, including failure to ramp up research and development expenditures, resistance to genetically modified organism technology, reduced effectiveness of inputs, lower land productivity (due to increasing salinity, for example) or inadequate supply of water. The model suggests that in this case, global agricultural prices would rise modestly compared with today's levels. However, developing countries' reliance on agricultural imports would also increase, again with rising dependence in Asia. Latin America and the Caribbean remains a net agricultural exporter.

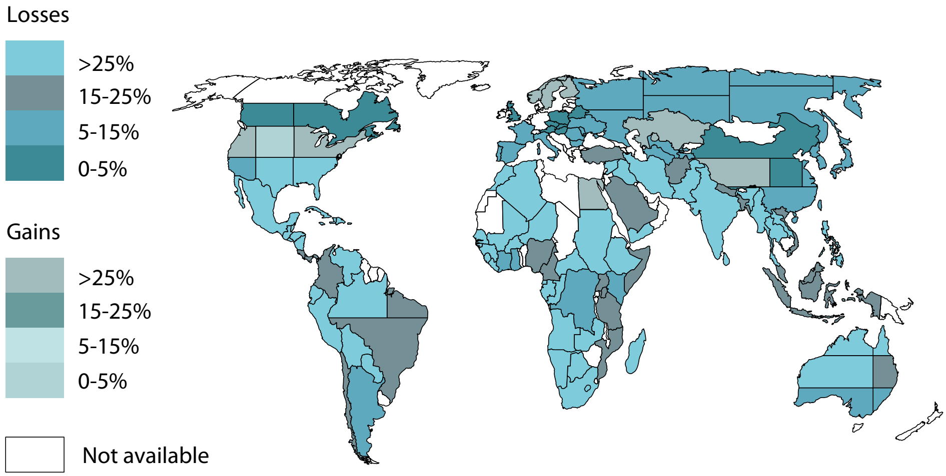
If global productivity is halved, agricultural prices will rise by significantly more – nearly 35 percent above the base year in 2030, compared with about 16 percent when only developing country agriculture is subjected to the lower productivity growth. The impact on trade balances is more mixed, in most cases lying between the baseline level and the scenario in which only developing country agriculture is affected. Note that the net trade numbers are in value terms, so the change in net trade is partly the result of higher agricultural prices, and is not simply a volume phenomenon.

Climate change

One issue that might be looming large in the next few decades is the impact of climate change on global agriculture. Some estimates suggest that a rise of 2.5 °C could lower agricultural productivity by up to 40 percent, including in some very large countries such as India (Cline, 2007). The net impact of climate change on agriculture, at least at the global level, is still being debated. Some regions, notably the higher latitudes, could benefit from longer growing periods, largely offsetting the damage in regions in the lower latitudes, but also inducing further changes in trading patterns. There is also uncertainty regarding the impact of carbon fertilization. There is some evidence that higher concentrations of carbon may induce growth, at least to a certain point, and this could offset higher temperatures. Finally, although the general circulation models (GCMs) have a relatively high degree of consistency regarding temperature increases, there is much less consensus on rain patterns and the overall supply of water for agricultural purposes. In the longer run, appropriate adaptation policies may allow many regions to adapt to incremental changes in weather; however, extreme weather events may be more damaging and much more costly to cope with.

One of the features of the ENVISAGE model is that it incorporates the full cycle of greenhouse gas emissions from human activities, atmospheric concentrations and radiative forcing, and changes in temperature. This class of model is known as an "integrated assessment model", and also couples changes in global temperature to economic damage. Currently, damage to agriculture is incurred only through impacts on agricultural productivity.[3]

Figure 5.12
Impact of climate change on agricultural production, without the carbon fertilization effect



Source: Cline, 2007.

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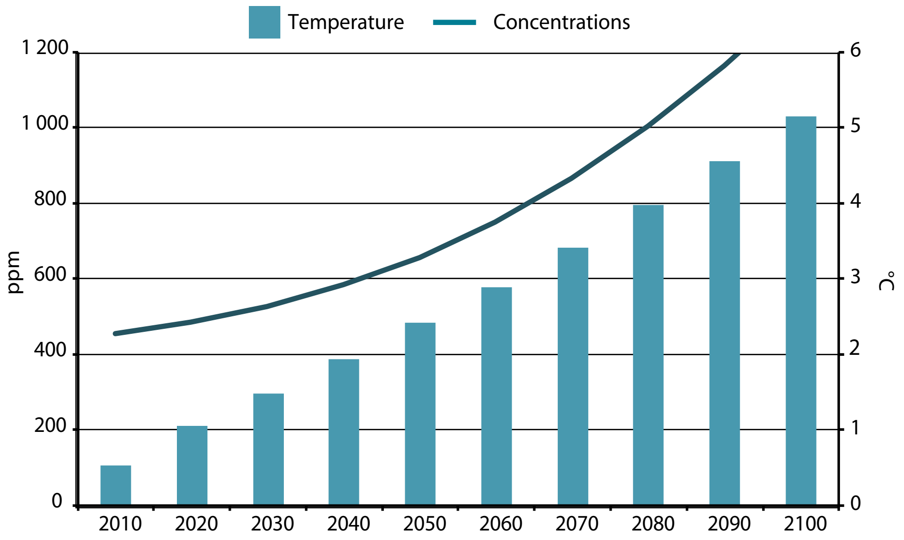
[3] The ENVISAGE model is currently being modified to handle a broader set of climate change impacts, including sea-level rise, health and labour productivity effects, and water stress.

Figure 5.12 depicts how climate-induced agricultural damage is allocated across the globe, based on the estimates produced by Cline (2007). The figure clearly shows the concentration of damage in lower latitudes and largely in developing countries. In a way, it represents a "worst-case" scenario in that it estimates damage in the absence of the carbon fertilization effect. For the baseline scenario, the damage has been assumed to be the average of the situations with and without the carbon fertilization effect. Cline's estimates are based on the assumption that the increase in temperature of 2.5 °C will occur around 2080. This is based on scenarios developed at the end of the 1990s that assumed a lower profile of emissions than that observed over the last decade, in spite of the current crisis. The damage functions in ENVISAGE are calibrated to Cline's estimated impacts for a temperature change of 2.5 °C. For technical reasons this study has specified and calibrated linear damage functions. This may overstate damage in the short term, particularly in certain regions where warming could be beneficial, such as in higher latitudes, and understate damage in the long run, as many damage functions in the literature are assumed to be non-linear (e.g., Nordhaus, 2008).

For the purposes of climate analysis the model runs until 2100, but this chapter focuses on the period up to 2030. The projected atmospheric emissions profile used in this chapter is significantly higher than most of those that form the basis of the climate change analysis recently presented in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) (Metz *et al*., 2007). The scenarios in AR4 were generated around 2000 and largely underestimated both output and emission growth over the last decade, notwithstanding the recent financial crisis. As a result, the baseline scenario shows much greater emission growth and, if this pattern continues, puts the world on a trajectory of much higher temperature changes than the AR4 median of about 3 °C by the end of the century (Figure 5.13). With a higher temperature profile than the AR4 median, estimated climate change impacts on agriculture occur much earlier than assumed in the Cline study, as the 2.5 °C level is reached in 2050 rather than 2080.

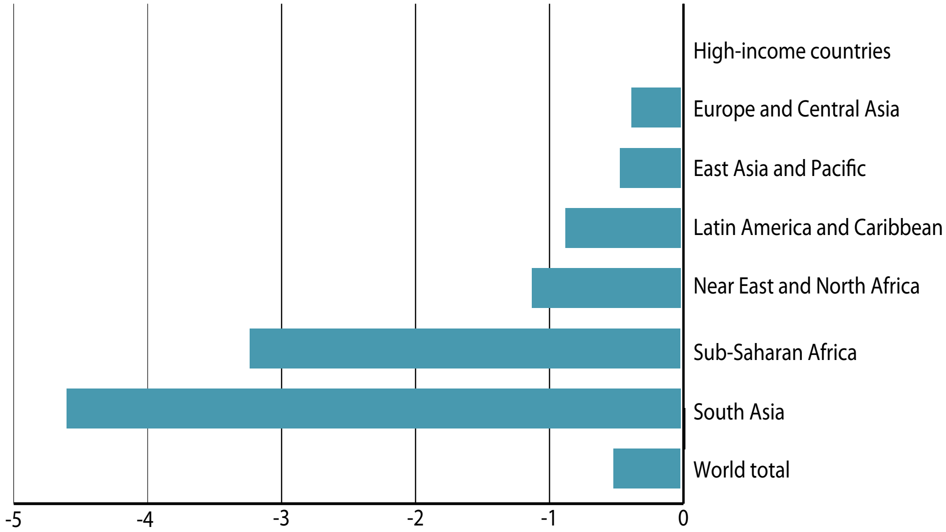
Climate damage is built into the standard baseline. To isolate the impact of climate change, an alternative scenario is simulated that assumes no climate change damage. All other exogenous assumptions are the same in the two scenarios. In this alternative scenario, agricultural productivity matches the exogenous assumption of 2.1 percent uniform growth with no deviation. The impacts on real income from climate damage even in 2030 could be substantial. South Asia would take the most significant hit, with a loss in real income of more than 2 percent in 2030, more than double the loss of the next hardest-hit region, sub-Saharan Africa (Figure 5.14). The relatively large losses in these two regions reflect two factors:

Figure 5.13
Baseline emission concentrations (left axis) and temperatures (right axis)



ppm = parts per million
Source: Simulation results with the World Bank's ENVISAGE model.

Figure 5.14
Potential impacts of climate change on real incomes, by region, 2030



Source: Simulation results with the World Bank's ENVISAGE model.

first, agriculture remains important despite relatively rapid economic growth; and second, existing studies suggest that the greatest damage is occurring in these two regions, as summarized in Cline's (2007) estimates.

In this alternative scenario, the impact on high-income countries is negligible in the short term. This arises partly from gains in the terms of trade, as world prices rise in the with-damage scenario. The net trade position of all developing regions deteriorates in the with-damage scenario, albeit somewhat modestly by 2030, and improves (modestly) for high-income countries. In the long run, climate damage is bound to increase, both because the climate will deteriorate and because of non-linear effects (not currently captured in the model).

Biofuels

The expansion of ethanol based on grain feedstock is quite different from that of sugar cane-based ethanol, especially in Latin America. In the latter, the trade-off between food and fuel is somewhat limited. Moreover, sugar cane expansion will occur first in Latin America and then in other countries with low-cost sugar production. Most of this expansion will occur on land where there is limited competition among crops. In contrast, ethanol based on grains has a direct effect on several important competing crops, including oilseeds. The expansion of biodiesel has a strong and direct implication for vegetable oil prices, and feedstock and food demands are in direct competition. Large-scale biodiesel expansion will push vegetable oil prices higher. Hence, the expansion of biofuel based on grains and oilseed products is a potential exacerbating factor for higher food prices and could compromise access to food for the poorest people on the planet. The most affected food prices would be those for grains, vegetable oils, meat and dairy products, which are intensive in feedstocks.

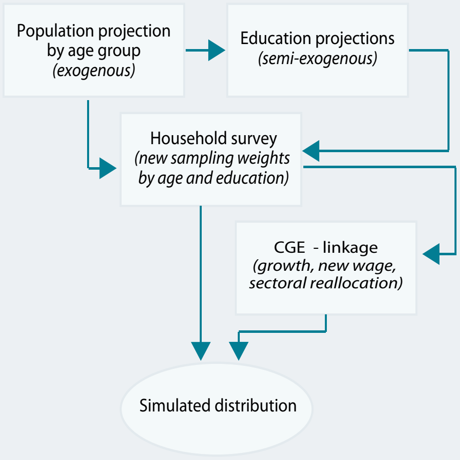
If cellulosic/biomass ethanol can become profitable, the trade-off between food and fuel may be less important and be confined to oilseed-based biofuels. The development of biofuels is also determined by their return, which in turn is largely determined by fossil energy prices and feedstock prices. Low fossil energy prices will undermine the development of large biofuel sectors and reduce the trade-off between food and fuel. Of course, large and forced biofuel mandates could change this result. A recent study suggests that the existing biofuel mandates for 2020 would have only modest impacts on global food prices, partly because they are not particularly ambitious (Timilsina *et al.*, 2010). Sugar prices would rise the most (by 7 percent), with grain and oilseed prices rising by less than 4 percent – although potentially with greater impacts on trade patterns, as countries have different mandate targets and comparative advantage in biofuels production varies across regions. These are long-term equilibrium effects, it is likely that the short-term impacts could be more significant. Over the longer term, it is still difficult to know what policies will prevail in 2050. Biofuels, both first- and second-generation, are an area of active research.

Poverty implications

The assumptions in the baseline scenario explained in the previous section were used to “roll” the global economy to 2050. This section concentrates on the global distributional effects of the expected changes in per capita incomes and income distribution within countries.[4] Evaluation of these distributional effects is based on the World Bank’s Global Income Distribution Dynamics (GIDD) model. This macro-micro simulation framework is overviewed in Box 5.3 and explained in detail in Bussolo, de Hoyos and Medvedev (2010).

Box 5.3 - The global income distribution dynamics model

The World Bank Development Economics Prospects Group developed the GIDD model, the first global CGE-micro-simulation model. The GIDD model takes into account the macro nature of growth and economic policies and adds a microeconomic – household and individual – dimension.



The GIDD model includes distributional data for 121 countries and covers 90 percent of the world population. Academics and development practitioners can use the model to assess the growth and distribution effects of global policies such as, among others, multilateral trade liberalization, and policies dealing with international migration and climate change. The GIDD model also allows analysis of the impacts on global income distribution from different global growth scenarios, and distinction between changes due to shifts in average income between countries and those attributable to widening disparities within countries.

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[4] This section relies on the methodology used in Bussolo *et al.* (2008), which projects the global economy to 2030. Nevertheless, it has some minor variations: it uses the latest version of the GIDD model (December 2010), which has 2005 instead of 2000 as the base year, and uses the latest purchasing power parity (PPP) conversion factors. As a result, slight differences may emerge between the two documents, but these will not compromise the messages and authors’ conclusions in either of them.

The macro-micro modelling framework described here explicitly considers long-term time horizons during which changes in the demographic structure may become a crucial component of both growth and distribution dynamics. The GIDD model's empirical framework is schematically represented in the Figure above.

The expected changes in population structure by age (upper left of the Figure) are exogenous, meaning that fertility decisions and mortality rates are determined outside the model. The change in shares of the population by education level incorporates the expected demographic changes (the arrow linking the top left box to the top right box). New sets of population shares by age and education subgroup are then computed, and household sampling weights are rescaled, according to the demographic and educational changes (the larger box in the middle of the Figure). The impact of changes in the demographic structure on labour supply (by skill level) is incorporated into the CGE model, which then provides a set of link variables for the micro-simulation:

a) change in the allocation of workers across sectors in the economy;
b) change in returns to labour, by skill and occupation group;
c) change in the relative prices of food and non-food consumption baskets;
d) differentiation in per capita income/consumption growth rates across countries.

The final distribution is obtained by applying the changes in these link variables to the reweighted household survey (bottom link in the Figure).

Figure 5.15 plots Lorenz curves for the observed global income distribution in 2005 and the projected distribution in 2050. It appears that the largest changes in income distribution between 2005 and 2050 are expected to be around the middle of the income distribution rather than towards the upper or lower tails. In fact, because the two Lorenz curves intersect at these tails, it is not possible to say that the 2050 distribution Lorenz curve dominates that of 2005. In other words, it cannot be claimed that inequality in 2050 is lower than in 2005, regardless of the inequality measure being used. However, using standard inequality statistics such as the Gini, the Theil and the mean logarithmic deviation – i.e., indicators that do not give too much weight to the extreme parts of the distribution – a marked reduction of inequality, as shown in Tables 5.6 and 5.7, is recorded during the period considered here.

Table 5.6
Global income inequality

Index	2005	2050	Dispersion only	Convergence only
Gini	0.697	0.616	0.701	0.616
Theil	1.046	0.717	1.059	0.719
Mean log deviation	0.942	0.723	0.954	0.723

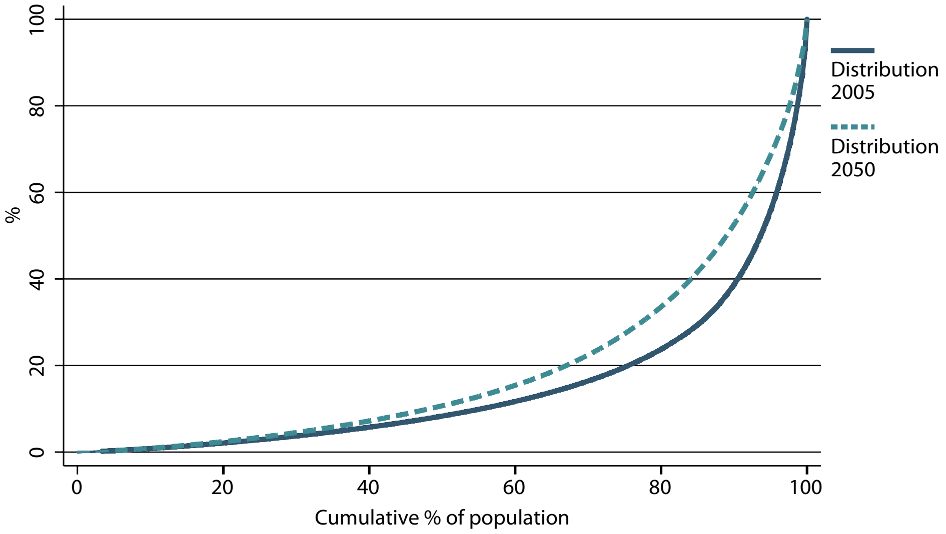
Source: Authors' estimates.

Table 5.7
Income inequality, by region

	Gini		Theil		Mean Log Dev	
Region	2005	2050	2005	2050	2005	2050
Developed countries	0.394	0.378	0.270	0.245	0.277	0.257
Developing countries	0.552	0.588	0.623	0.664	0.529	0.629
East Asia and Pacific	0.421	0.479	0.311	0.399	0.293	0.411
Eastern Europe and Central Asia	0.394	0.513	0.257	0.441	0.280	0.490
Latin America and Caribbean	0.599	0.605	0.714	0.707	0.699	0.719
Near East and North Africa	0.399	0.405	0.284	0.298	0.261	0.271
South Asia	0.297	0.326	0.156	0.183	0.141	0.176
Sub-Saharan Africa	0.495	0.488	0.499	0.481	0.425	0.410

Source: Authors' estimates.

Figure 5.15
Changes in the Lorenz curve dominance for 2005 and 2050 distributions (cumulative income share)



Source: Authors' calculations.

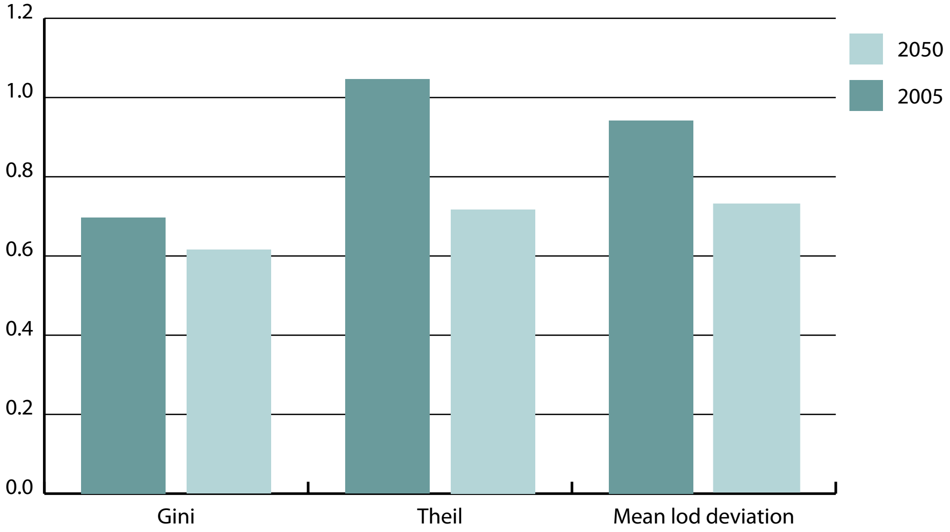
The remainder of this section analyses the drivers of these expected distributional changes by means of three complementary approaches. First, the analysis is conducted in terms of the convergence and dispersion components, i.e., the changes in income disparities among and within countries. This is taken up in the next two subsections, which show that the reduction in global income inequality between 2005 and 2050 is the outcome of two opposing forces: the inequality-reducing convergence effect and the inequality-enhancing dispersion effect. In other words, poor countries will catch up, but at a cost in terms of higher within-country and within-region income inequality. Second, the expected poverty effects of the new income distribution in 2050 are analysed using two approaches: the standard absolute poverty line of USD 1.25 a day; and a weakly relative poverty line suggested by Ravallion and Chen (2009). Third, as global poverty is expected to be substantially reduced by 2050, the emergence of a global middle class is analysed following the methodology presented in Bussolo *et al.* (2008).

The dispersion and convergence component

The dispersion component should be understood as the outcome of all the changes outlined by the baseline scenario in the previous section, but keeping constant average incomes in each country. Within countries, income distribution is expected to be altered by demographic changes, changes in skilled-to-unskilled wage remuneration, and rural-urban migration. Figure 5.16 plots non-parametric kernel densities of the global income distribution in 2005, together with the hypothetical distribution for the dispersion component, capturing only the changes in within-country inequality between 2005 and 2050. This hypothetical distribution was created by dividing household incomes in 2050 by the country-specific growth rate of average incomes between 2005 and 2050. At the global level, distributional changes within countries in this hypothetical distribution almost match the original distribution, having an almost neutral inequality effect at the global scale, with the income distribution barely increasing in Gini points (Table 5.6).

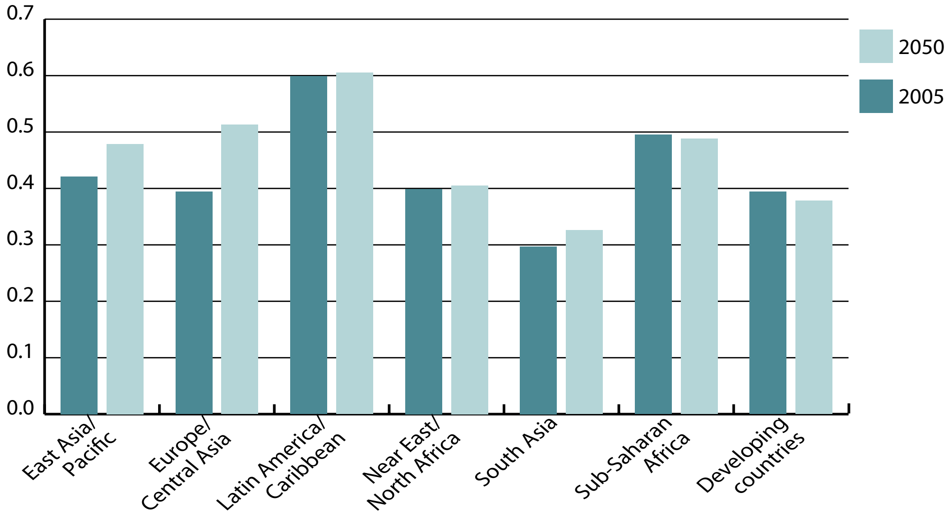
On the other hand, the convergence component takes into account each country's income variation as projected from the baseline scenario, but maintains constant global average income. Three aspects determine the existence, sign and magnitude of each country's contribution to the convergence component: i) a country will have a global distributional impact if its rate of growth differs from the global average; ii) if the country satisfies this condition, the sign of the distributional effect will depend on the country's initial position in the global distribution; and iii) the magnitude of the impact is determined by the size of the growth rate differentials (with respect to the global average) and the country's share in the global population. Hence, initially poor countries with higher-than-average growth rates will have an inequality-reducing effect whose magnitude will be determined by the size of the country's population.

Figure 5.16
Global income inequality reduction, 2005 to 2050



Source: Authors' calculations.

Figure 5.17
Within-region income inequality



Source: Authors' calculations.

Figure 5.17 shows the change of the global income distribution due to differences in growth rates among countries when global average income is kept constant. Had the convergence effect been the only change taking place between 2005 and 2050, global inequality would have been reduced by 8.0 Gini points (Table 5.6). This means that the improvement in global income distribution reported can be explained mainly by growth rate differentials across countries, with poor countries catching up with middle- and high-income countries.

Poverty

Measurement of global poverty in developing countries has typically been based on absolute poverty measures. The typical practice for an absolute measure is to set a monetary quantity, called the poverty line, which represents the minimum income needed to acquire a set of goods that will suffice for some established basic human needs. Poverty lines are typically based on the food needed to attain a recommended daily caloric ingestion. In addition to these basic poverty lines, some countries draw complementary ones that set the minimum income needed to satisfy more complex human needs, such as health and education. At the global level, the World Bank's USD 1.25 and USD 2 a day are the best-known examples of absolute poverty lines.

Alternatively, the common practice in Organisation for Economic Co-operation and Development (OECD) countries is to use relative poverty lines. These monetary quantities are periodically adjusted, not as the minimum income needed to acquire a given basket of goods, but as a constant proportion of the countries' mean or median incomes. The first argument for using relative rather than absolute poverty measures relies on the "welfarist" assumption that people attach value to their own income relative to the average in their own society – often cited as the "theory of relative deprivation" or the "relative income hypothesis". The second argument is that relative poverty lines allow for differences in the cost of social inclusion. Following Ravallion and Chen (2009), these are defined as the expenditure needed to cover certain commodities that are deemed to have a social role in assuring that a person can participate with dignity in customary social and economic activities.

Despite these two arguments, relative poverty lines have not been used for the study of poverty in very-low-income countries because they are scale-independent; in other words, if all incomes in a society grow at the same rate, no change in poverty will occur.

Ravallion and Chen (2009) discuss all these aspects rigorously and outline an alternative measure. Using a large sample of poverty lines collected by the World Bank, they calibrate a new measure for studying global poverty called the weakly relative poverty line. The proposed weakly relative poverty line is, in general terms, a combination of the two previous approaches: i) for very low levels of income, it functions as an absolute poverty line set at the World Bank's USD 1.25 a day level (at 2005 PPP); and ii) for medium and higher incomes, it functions as a relative poverty line. Empirical implementation applied the following formula:

$$Z_i \equiv \max [\$1.25, a + \frac{M_i}{3}] \qquad (5.2)$$

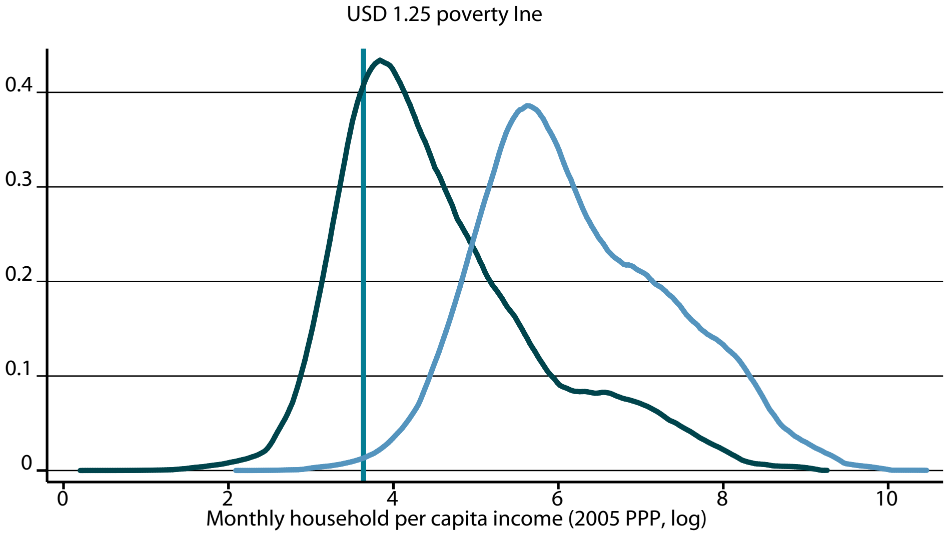
where Z_i is the value of the poverty line; M_i is the mean daily income in country *i*; and α is estimated by Ravallion and Chen (2009) to be PPP USD 0.60. The advantage of using the weakly relative poverty line is that it will provide a better understanding about poverty and exclusion in the projected income distribution for 2050 than the absolute poverty measure will (Figures 5.18 and 5.19). Table 5.8 summarizes the regional headcount ratios of absolute and weakly relative poverty in 2005 and 2050. While absolute poverty vanishes in all regions, weakly relative poverty still accounts for a large share of the population, especially in underperforming Latin America. According to the baseline scenario, the increase in weakly relative poverty reported by Ravallion and Chen (2009) experienced during the late 1980s and until 2000 is reversed by 2050 in almost all regions. Table 5.8 shows the headcount indices for absolute and weakly relative poverty in 2005 and 2050, and changes in the number of poor in both periods.

Table 5.8
Poverty estimates

	Absolute poverty (USD 1.25 per day PPP)			Weakly relative poverty		
Region	Headcount index 2005	Headcount index 2050	-Δ poverty *(millions)*	Headcount index 2005	Headcount index 2050	-Δ poverty *(millions)*
Developing countries	21.9	0.4	1,185	31.96	12.4	843
East Asia and Pacific	15.8	0.0	-87	30.4	12.1	277
Eastern Europe and Central Asia	4.4	0.0	20	12.6	5.5	35
Latin America and Caribbean	8.1	1.0	35	33.3	31.3	(67)
Near East and North Africa	4.1	0.0	8	19.0	10.5	5
South Asia	40.5	0.0	583	40.8	4.0	499
Sub-Saharan Africa	51.7	2.8	252	55.5	20.3	104

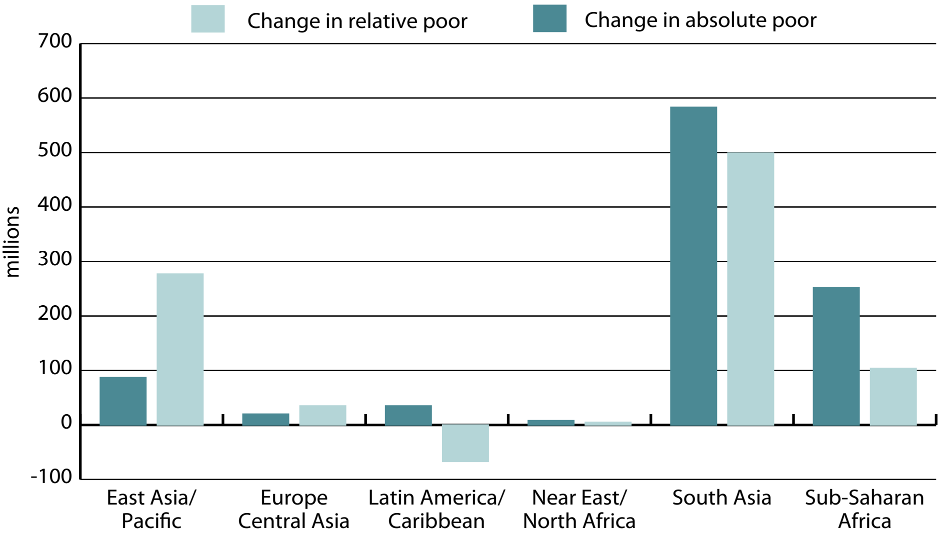
Source: Authors' estimates.

Figure 5.18
Income distribution diversity, 2005 and 2050



Source: Authors' calculations.

Figure 5.19
Changes in absolute and relative poverty



Sources: Relative poverty measured from Ravallion and Chen, 2009; authors' calculations.

The most interesting result is that while other regions perform relatively well, in Latin America the number of weakly relative poor actually increases (by 67 million), partly reflecting that this is the world's most unequal region. Within this Latin America and the Caribbean, the large majority of countries will see increases in the number of people living in relative poverty, Mexico being the most affected. Mexico alone accounts for half the increase in the number of relative poor in Latin America, followed by Brazil (11 million), Ecuador (4.8 million) and Colombia (4 million).

In sub-Saharan Africa, absolute poverty is expected to be reduced from 51.2 to 2.8 percent of the population and, remarkably, weakly poverty from 55.5 to 20.3 percent. The country that will perform the best is the United Republic of Tanzania, which will reduce its relative poverty rate by almost 70 percent, with 20 million fewer people living in absolute poverty. Nigeria and Ethiopia will reduce their net numbers of poor drastically, by 34 and 20 million respectively; however, in relative terms, the best performers are Malawi, Burundi, Guinea and Rwanda, all of which will reduce relative poverty by more than 50 percentage points.

The new middle class and beyond

In addition to the analysis of global poverty, the emergence of countries in the new middle class is of high importance because of the changes in global consumption patterns expected to accompany economic growth. Individuals in 2050 will be healthier and more educated, with higher expectations about their role in life, greater political participation and increasingly complex needs. As a result, the demand for more and better goods and services will rise as a vast number of families in developing countries emerge from poverty. This study uses the definition of absolute global middle class (GMC) used by Bussolo *et al.* (2008) to quantify the number of people who will be part of this group in the hypothetical income distribution for 2050. The GMC is defined as all the world citizens living with incomes between the current Brazilian and Italian averages.

The GMC will grow from about 450 million in 2005 to 2.1 billion in 2050, and from 8.2 to 28.4 percent of the global population (Table 5.9). Furthermore, the composition of this group of consumers is likely to change radically: while in 2005, developing country nationals accounted for 56 percent of the GMC, by 2050 they are likely to represent nearly all of this group. The biggest contributors to the increase in GMC numbers are the most populous Asian countries, led by China and India. These two countries alone are responsible for nearly two-thirds of the entire increase in the GMC, with China accounting for 30 percent and India another 35 percent. More surprisingly, as a result of sustained economic growth in China and according to the scenario described in the previous section, by 2050, 40 percent of the Chinese population will surpass GMC status.

Table 5.9
Composition of the global middle class

Region	2005 (millions)	2005 (%)	2050 (millions)	2050 (%)
Developed countries	190.8	33.0	27.1	4.3
Developing countries	260.2	6.4	2 117.3	29.7
East Asia and Pacific	41.1	2.3	785.7	35.0
Eastern Europe and Central Asia	85.9	19.7	117.9	30.5
Latin America and Caribbean	107.5	20.3	245.9	31.8
Near East and North Africa	18.3	8.9	151.2	47.0
South Asia	0.6	< 0.1	657.6	29.2
Sub-Saharan Africa	6.8	1.3	159.1	16.6
Total	451.0	8.15	2 144.3	28.4

Source: Authors' estimates.

There are several reasons for the projected dramatic increase in the GMC and the major shift in composition in favour of low- and middle-income countries. Faster population growth in the developing world is responsible for some of the change in composition. Thus, regions with population growth above the world average (e.g., South Asia and sub-Saharan Africa) will increase their shares in the GMC. However, the main determinant for joining the middle class is not population growth, but income growth. Although East Asia's population will grow more slowly than the world average, this region is projected to increase its share of GMC residents by more than 30 percentage points, compared with 15 percentage points in sub-Saharan Africa. This difference arises because annual per capita income growth in Asia is forecast to be more than twice that in sub-Saharan Africa, easily offsetting the decline in the former's population share.

Most developing country members of today's (2005's) GMC earn incomes far above the averages of their own countries of residence. In other words, being classified as middle class at the global level is equivalent to being at the top of the income distribution in many low-income countries. For example, in the study sample, in 2005, 180 million (out of the total 260 million) developing country citizens in the GMC are in the top 20 percent of earners within their own countries. Thus, for many nations, the correspondence between the GMC and the within-country middle class is quite low. The situation will change dramatically by 2050. A full 60 percent of developing country members of the GMC will be earning incomes in the seventh decile or lower of the national scale. For example, in China, in 2005, 27 million people belonged to the GMC, all earning more than what 90 percent of all Chinese citizens earned. By 2050, there will be 517 million

Chinese in the GMC, their earnings ranging from the fifth to the ninth deciles of the Chinese national income distribution.

Consistent with these data, by 2050 the middle class, together with the rich, will account for a larger share of the population in a greater number of countries. In 2005, the members of these two groups exceeded 40 percent of the population in only six developing countries, which were home to 3.0 percent of the population of the developing world. By 2050, the middle class and rich will exceed 40 percent of the population in 58 developing countries (as classified today), which will account for 72 percent of the world's developing country population.

Conclusions

At a minimum, the price spikes of 2007/2008 shook global complacency regarding agriculture, after a period of neglect driven in part by globally benign price changes and no major supply disruptions. Experts were aware of the falls in agricultural productivity growth and expenditures on R&D, but in a crowded field of international economic policy issues, the warning signs were largely ignored. As regards agriculture, the focus has been far more on farm support policies and trade barriers than on fundamental supply issues. Is the world now witnessing a structural shift, with higher and growing agricultural prices, or are the events of 2007/2008 and 2011 just bumps in the road? This paper suggests that the answer lies somewhere between these two extremes. There is a structural shift in agricultural markets, with greater linkages to energy markets than in the past. Higher energy prices could induce a stronger shift to biofuels, generating competing pressures on resources and higher food prices. Potentially this linkage could be strengthened if climate mitigation policies raise the end-use prices of conventional fossil fuels and induce further substitution by biofuels. At the same time, there are reasons to believe that the world can adjust to these imminent changes. Declining population growth and food saturation will temper food demand growth in the future, and health and environmental concerns could even induce a shift in tastes that would temper demand even further. There is also sufficient land to allow some expansion, if managed appropriately and sustainably. This will require investment in infrastructure, which could be onerous, particularly in the poorer parts of the world. The ability to raise productivity is also a concern, particularly in an environment with growing climate stress. This too will require resources to enhance R&D, perhaps with an emphasis on regions where productivity lags far behind best practices.

However, even if there is manageable stress at the global level, changing environments at the regional level are likely to have repercussions on distribution, both across and within countries. Managing these stresses may be more difficult, as food security at both the household and national levels is often a priority for policy-makers. And as witnessed in the most recent crisis, policy-makers naturally make the most rational decisions for their own stakeholders, even if better overall policies could be implemented with the right coordination.

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ANNEX 5.1

THE MODEL USED FOR CLIMATE CHANGE SIMULATIONS

The quantitative analysis of the climate change section of this chapter relies extensively on the World Bank's dynamic global computable general equilibrium model, ENVironmental Impact and Sustainability Applied General Equilibrium Model (ENVISAGE) (van der Mensbrugghe, 2009). Underlying this model is the 2004-based Release 7 of the Global Trade Analysis Project (GTAP) database, which divides the world economy into 112 countries/regions (of which 94 are countries) and 57 commodities.[5] For modelling purposes, the underlying database is typically aggregated to a more manageable set of regions and sectors, which are selected according to the objectives of the particular study. In this chapter, the focus is on the agriculture and food sectors, but also energy, to capture the emergence of biofuels and the linkage between energy and agriculture. ENVISAGE has been designed for climate change studies, so the standard GTAP data are supplemented by several satellite accounts. These include energy data in volume, carbon emissions linked to the burning of fossil fuels, and emissions from the other Kyoto greenhouse gases – methane, nitrous oxides and the fluorinated gases. Both methane and nitrous oxides are linked to agricultural production. The other greenhouse gases differ from carbon emissions. First, they have a more exhaustive set of drivers, because they can be associated with all intermediate inputs, not simply fossil fuels, as well as factor inputs (e.g., land in the case of methane generated by rice production) and output. Second, technologies for their abatement are more complex than those for fossil fuel-based carbon emissions. With current technologies, the latter can only be abated by either lowering consumption of fossil fuels or substituting with lower- or zero-emission fuels. For the other greenhouse gases, abatement technologies may involve different production methods, although presumably at a higher cost.

In this chapter, the GTAP data were supplemented with a more exhaustive set of electricity activities, splitting the single GTAP electricity sector into five production activities: coal-fired, oil and gas-fired, nuclear, hydroelectric, and other (including all existing renewables). For long-term scenario analysis, several new energy technologies were introduced. These initially have low penetration,

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[5] More on the GTAP data can be found at www.gtap.org.

but under certain circumstances they could potentially replace conventional technologies. They include first- and second-generation biofuels as potential substitutes in the transport sector, and coal and gas carbon capture and storage in the power sector.

In most respects, the ENVISAGE model is a rather classical recursive dynamic global CGE with a time horizon spanning 2004 to 2100. Production is based on the capital-labour substitution with capital and energy near-complements in the short term and with substitutes in the longer term. A vintage production structure is employed that allows for partial capital mobility across sectors in the short term, or a putty-semi-putty technology. Vintage capital is associated with lower production flexibility, whereas new capital is more flexible; aggregate flexibility thus depends on the share of vintage capital in total capital, with greater flexibility associated with those economies with the highest savings rates. Factor payments accrue to a single representative household in each region, and this household allocates income among savings and expenditures on goods and services. The model allows for significant flexibility in specifying consumer demand. The top-level utility function can be specified using one of three demand systems: constant difference in elasticities (Hertel, 1997), extended linear expenditure system (Lluch, 1973) and Almost Ideal Directly Additive Demand Systems (AIDADS, Rimmer and Powell, 1996). The top-level utility function can be specified at a different commodity aggregation than production. A transition matrix, which allows for commodity substitution, converts consumer goods to produced goods. Energy demand is specified as a single bundle for each agent in the economy. Energy demand is then split into demand for specific types of energy using a nested constant elasticity of substitution (CES) structure. Trade is specified using the ubiquitous Armington assumption (Armington, 1969), although the model allows for homogeneous commodities as well. Government plays a relatively passive role, collecting taxes and spending on goods and services. The government's fiscal balance is fixed in any given year (and declines towards 0 from its initial position by 2015), and the household direct tax schedule shifts to achieve the fiscal target. The latter implies that changes in indirect taxes (e.g., import tariffs or carbon taxes) are recycled to households in lump-sum fashion. Investment is savings-driven and savings rates are influenced by the overall growth rate and by demographic factors such as dependency ratios. The current account balance for each region is fixed in any given year. The base year balances converge towards zero at some date (currently set at 2025). An *ex-ante* shift in either import demand or export supply influences the real exchange rate. Thus, for example, if a country is forced to import more food owing to climate damage to its agriculture, this would normally entail a real exchange rate depreciation that increases demand for its exports to pay for the additional food imports.

ENVISAGE has been developed as an integrated assessment model. Emissions of the greenhouse gases generated by the economic part of the model lead to changes in atmospheric concentrations. A simple reduced-form atmospheric model converts changes in the stock of atmospheric concentrations into changes in radiative forcing and global mean temperature. The resulting changes in global mean temperature feed back into the economy through damage functions that affect various economic drivers. In the current version of the model, the only feedback is through changes in agricultural productivity. The agricultural damage functions have been calibrated to the estimates from the recent study by Cline (2007).

Dynamics in ENVISAGE are driven by three key factors. The first is demographics, which describe population and labour force rates of growth. Following common practice, the baseline in this chapter uses the medium variant from the UN populations forecast, with growth of the labour force equated to growth of the working-age population (defined as those between 15 and 65 years of age). The second key driver is formed by savings and investment, which jointly determine the overall level of capital stock (along with the rate of depreciation). In ENVISAGE the savings function is partially determined by demographics. Generally speaking, savings will rise as dependency ratios (both under-15 and over-65) fall.

The third driver is productivity. ENVISAGE differentiates productivity across broad sectors: agriculture, energy, manufacturing, and services. Agriculture's productivity growth has two components to be calibrated: the exogenous component is calibrated to 2.1 percentage points per year, consistent with recent trends (World Bank, 2008); and the endogenous component comes from a linear damage function that links increases in global temperature to declines in agricultural total factor productivity (TFP) and is calibrated according to Cline's average estimates with and without carbon fertilization (Cline, 2007).

Productivity in other sectors is unaffected by climate change, and is calibrated through 2015 to match the World Bank's medium- and long-term forecast. After 2015, productivity growth in the United States of America is calibrated to achieve a long-term average (2004 to 2100) growth in real GDP per capita of 1.2 percent per year, with faster growth in the first half of the century, while productivity in other countries/regions is calibrated based on simple convergence assumptions.