CHAPTER 3

WHERE ARE WE HEADED? PERSPECTIVES ON POTENTIAL OUTPUT

This chapter finds that potential output growth across advanced and emerging market economies has declined in recent years. In advanced economies, this decline started as far back as the early 2000s and worsened with the global financial crisis. In emerging market economies, in contrast, it began only after the crisis. The chapter's analysis suggests that potential output growth in advanced economies is likely to increase slightly from current rates as some crisis-related effects wear off, but to remain below precrisis rates in the medium term. The main reasons are aging populations and the gradual increase in capital growth from current rates as output and investment recover from the crisis. In contrast, in emerging market economies, potential output growth is expected to decline further, owing to aging populations, weaker investment, and lower total factor productivity growth as these economies catch up to the technological frontier.

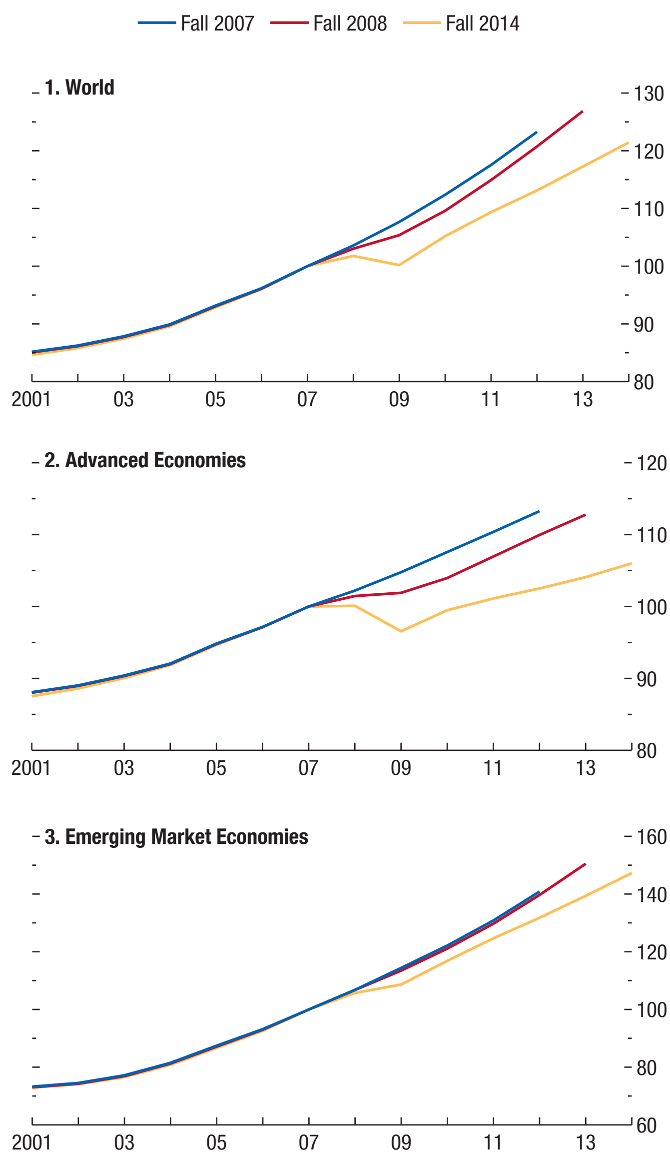
Introduction

Output across advanced and emerging market economies remains much lower than was expected in 2008, just before the onset of the global financial crisis, and its growth path has also been lower (Figure 3.1). Indeed, medium-term (five-year-ahead) growth expectations have been steadily revised downward since 2011 for both advanced and emerging market economies (Figure 3.2).

The repeated downward revisions to medium-term growth forecasts highlight the uncertainties surrounding prospects for the growth rate of potential output (potential growth). In advanced economies, the apparent decline in potential growth seems to have started as far back as the early 2000s and was worsened by the crisis.[1] In emerging market economies, on the other

Figure 3.1. Output Compared to Precrisis Expectations
(Index, 2007 = 100)

Output across advanced and emerging market economies remains much lower than was expected before the onset of the global financial crisis, and its growth path has also been lower.



Source: IMF staff estimates.
Note: The index is created using real GDP growth rates and their WEO forecasts. Economy groups are defined in Annex 3.1.

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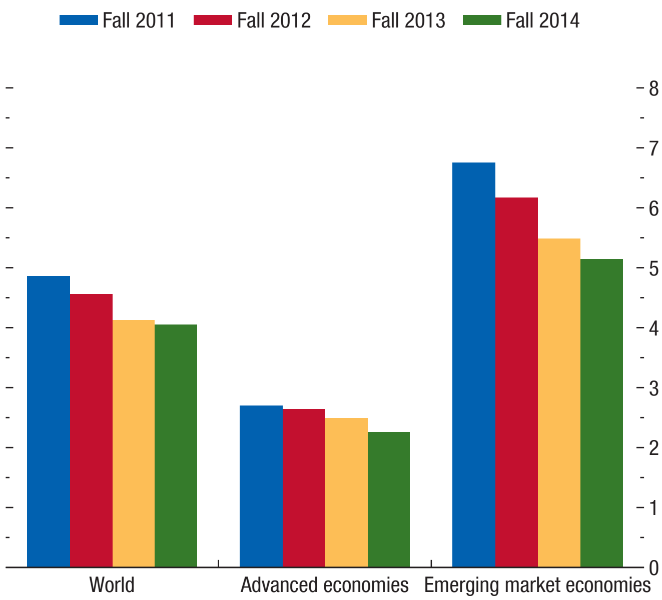
[1]Fernald (2012, 2014a, 2014b) shows that the slowdown in U.S. total factor productivity growth started well before the crisis (in the early 2000s). Balakrishnan and others (2015) find that for the United States, demographic trends explain about half of the decline

Figure 3.2. WEO Medium-Term Growth Projections
(Percent)

Medium-term growth expectations have steadily been revised downward since 2011 for both advanced and emerging market economies.



Source: IMF staff estimates.
Note: WEO medium-term growth projections are five-year-ahead growth forecasts. Economy groups are defined in Annex 3.1.

hand, the decline in both potential output and its growth rate appears to have emerged only in the wake of the crisis.

Assessing the medium-term trajectory of potential output is critical for the conduct of monetary and fiscal policy. A better understanding of how the components of potential growth—labor, capital accumulation, and total factor productivity—contribute to the overall slowdown can help inform the discussion on policies needed to raise it.

To contribute to the debate on prospects for potential output, this chapter constructs estimates of potential output for 16 major economies—members of the Group of Twenty (G20)—which accounted for about three-fourths of world GDP in 2014.[2] In this context, it seeks to answer the following questions:

- *Before the crisis:* How did potential output and its components evolve from the mid-1990s until the crisis?
- *During the crisis:* What happened to the level and growth rate of potential output and its components during the crisis?
- *Where are we headed?* What is the likely trajectory of potential output in the medium term (2015–20)? What are the policy implications?

The chapter starts with an overview of the concept and measurement of potential output used in the analysis. The subsequent sections then address each question in turn. The chapter's main findings are as follows:

- Before the crisis, potential growth began to decline in advanced economies while it increased in emerging market economies. In both cases, these dynamics were attributable mostly to changes in total factor productivity growth. In advanced economies, the decline reflected mainly a slowdown following a period of exceptional growth due to innovations in information technology, whereas in emerging market economies, the increase reflected mainly structural transformation.
- In the aftermath of the crisis, potential growth declined in both advanced and emerging market economies. Unlike previous financial crises, the global financial crisis is associated not only with a reduction in the level of potential output, but also with a reduction in its growth rate. In advanced economies, potential growth declined by about ½ percentage point, owing to reduced capital growth—particularly in the euro area countries analyzed in the chapter—and demographic factors not related to the crisis. In emerging market economies, potential growth declined by about 2 percentage points, with lower total factor productivity growth accounting for the entire decline.
- Looking forward, potential growth in advanced economies is expected to increase slightly, from an average of about 1.3 percent during 2008–14 to 1.6 percent during 2015–20. This growth is well below precrisis rates (2¼ percent during 2001–07) and stems from the negative effect of demographic factors on potential employment growth and the

in the labor force participation rate during the crisis. Chapter 3 in the April 2014 *World Economic Outlook* (WEO) and Chapter 4 of this WEO report find that the crisis has contributed to the decline in capital accumulation growth in advanced economies.

[2]The 10 advanced and 6 emerging market economies are Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Korea, Mexico, Russia, Spain, Turkey, the United Kingdom, and the United States. See Annex 3.1 for details. Data limitations preclude the analysis for Argentina, Indonesia, Saudi Arabia, and South Africa. Estimates for the European Union—the 20th economy in the G20—and the euro area are based on individual country estimates for France, Germany, Italy, and Spain.

gradual increase in capital growth from current rates as output and investment recover from the crisis. In emerging market economies, potential growth is expected to decline further, from an average of about 6.5 percent during 2008–14 to 5.2 percent during 2015–20. The decline is the result of population aging, structural constraints affecting capital growth, and lower total factor productivity growth as these economies get closer to the technological frontier.

Reduced prospects for potential growth in the medium term have important implications for policy. In advanced economies, lower potential growth will make it more difficult to reduce high public and private debt ratios. It is also likely to be associated with low equilibrium real interest rates, meaning that monetary policy in advanced economies may again be confronted with the problem of the zero lower bound if adverse growth shocks materialize. In emerging market economies, lower potential growth will make it more challenging to rebuild fiscal buffers.

This chapter's findings suggest that increasing potential output will need to be a policy priority in major advanced and emerging market economies. The reforms needed to achieve this objective vary across countries. In advanced economies, continued demand support is needed to offset the effects of protracted weak demand on investment and capital growth as well as on structural unemployment. In addition, policies and reforms that can increase supply should be adopted, such as product market reforms and higher spending on research and development, education, infrastructure, and policies to improve labor supply incentives. In emerging market economies, higher infrastructure spending is needed to remove critical bottlenecks, and structural reforms must be directed at business conditions, product markets, and education.

Potential Output: A Primer

Potential output is defined as the level of output consistent with stable inflation (no inflationary or deflationary pressure). In the short term, actual output will deviate temporarily from potential as shocks hit the economy. These deviations reflect the slow adjustment in wages and prices to shocks, which means that the reversion of output to its potential level is gradual. This slow adjustment due to "sticky" wages and prices is a key tenet of the New Keynesian macroeconomic framework used in this chapter.

The short-term divergence of actual from potential output is referred to as the output gap, or economic slack, and is an important concept for policymakers seeking to stabilize an economy. For example, output below potential (a negative output gap) implies that there is underemployment (excess supply) of capital and labor, which would prompt a looser macroeconomic policy stance, all else equal.

The *economic* definition of potential output differs from the widely used concept of trend output, because it relies on an explicit framework based on economic theory. Trend output, in contrast, is derived from simple statistical data filtering using various forms of moving averages or deterministic trends. This is equivalent to smoothing actual GDP over time, based on the implicit assumption that an economy is, on average, in a state of full capacity, without incorporating information from variables such as inflation or unemployment. Central banks and other policy institutions typically rely on the economic definition of potential output because the underlying economic framework allows policymakers to gauge the short-term trade-offs between output, inflation, and slack in the labor market.

The economic definition also differs from the concept of "sustainable" output, which seeks to capture macroeconomic stability more broadly. More specifically, output can be at potential (that is, without generating inflationary or deflationary pressure) but still not be sustainable. As discussed in more detail in Box 3.1, the reason is the possible presence of domestic or external macroeconomic imbalances (such as excessive credit growth).[3] These imbalances may subsequently lead to a sharp decline in potential output once they are corrected. However, assessing these imbalances in real time has proven to be difficult.

The definition of potential output used in this chapter is implemented empirically using multivariate filtering techniques (Blagrave and others 2015). These techniques feature a simple model that incorporates information on the relationship between cyclical unemployment—defined as the deviation of the unemployment rate from the structural unemployment rate or, more specifically, the nonaccelerating inflation rate of unemployment (NAIRU)—and inflation

[3]The concept of sustainable output is related to external sustainability, especially in the context of small open economies. For example, rapid credit growth can be fueled by capital inflows and current account deficits. The policy norms specified in the context of the IMF External Balance Assessment reflect some of these considerations (IMF 2013).

(Phillips curve) on one hand and between cyclical unemployment and the output gap (Okun's law) on the other. These relationships are given by the following equations:

$$\pi_t = \pi_t^e + \delta u_t + \varepsilon_t^\pi, \tag{3.1}$$

$$u_t = \tau y_t + \varepsilon_t^u, \tag{3.2}$$

in which π_t is inflation, y_t is the output gap, u_t is cyclical unemployment, π_t^e is inflation expectations, and ε_t^π and ε_t^u are shock, or disturbance, terms. The parameters in these equations (δ, τ)—or equivalently the strength of the aforementioned economic relationships—are estimated separately for each country, and together with data on actual output growth, inflation, and unemployment they provide an economic basis for identifying potential output and the NAIRU, which are unobserved.[4] In addition, the analysis uses Consensus Economics forecasts for both growth and inflation to help pin down the model's expectations for these variables: for example, if consensus expectations are for higher growth, the model-consistent expectation for growth would also tend to be higher, all else equal (see Annex 3.2 for complete details on the multivariate filtering framework).

Two situations help illustrate how the multivariate filtering framework uses the information from economic data to estimate potential. First, if at a point in time, actual inflation is below inflation expectations and unemployment is above the estimated equilibrium rate, the framework will identify a situation of excess supply (a negative output gap), all else equal. Second, consider a more complicated situation in which inflation rises sharply in one year but with no corresponding decrease in unemployment: these conflicting signals suggest a shock to inflation rather than excess demand (a positive output gap). In the second case, the multivariate filtering framework will assign a lower positive output gap than would otherwise be the case, especially if the rise in inflation in a given year unwinds in the following year—which is not uncommon following a sharp change in commodity prices or an increase in the value-added-tax rate.

In sum, the multivariate filtering framework specified in this chapter strikes a balance between statistical filters, which are easily applicable to a wide range of countries but are atheoretical, and structural models of potential output, which offer greater theoretical rigor but are difficult to construct and apply broadly.

As a caveat, it should be noted that potential output is not directly observable. Therefore, the estimates are subject to statistical and model uncertainty. The latter implies that the estimates tend to vary depending on the underlying methodology. In practice, however, the different methodologies deliver qualitatively similar results regarding the trajectory of potential output in advanced and emerging market economies, which is the focus of this chapter (see Annex 3.2).

With the estimates of potential output and the NAIRU in hand, the analysis proceeds to investigate the drivers of potential growth using a growth accounting framework. This framework describes how the economy's potential output is determined by the basic factor inputs (capital, labor) and productivity (total factor productivity). Specifically, the growth accounting framework is based on a standard Cobb-Douglas production function:

$$\bar{Y}_t = \bar{A}_t K_t^\alpha \bar{L}_t^{1-\alpha}, \tag{3.3}$$

in which $\bar{Y}_t$ is potential output, K_t is the stock of productive capital, $\bar{L}_t$ is potential employment, $\bar{A}_t$ is potential total factor productivity—which includes human capital—and is measured as a residual, and α is the share of capital in potential output.[5] Potential employment is then decomposed into the NAIRU, the working-age population, and the trend labor force participation rate:

$$\bar{L}_t = (1 - \bar{U}_t)\ W_t \overline{LFPR}_t, \tag{3.4}$$

in which $\bar{U}_t$ is the NAIRU as estimated in the multivariate filter, W_t is the working-age population, and $\overline{LFPR}_t$ is the trend labor force participation rate. The decomposition of potential employment also shows how demographic factors affect potential growth. Two variables play a key role in this regard: working-age population and trend labor force participation rates. The former is a function of the same variables as population growth more broadly. For example, declines in fertility rates slow future working-age population

[4]Although the estimated parameters are not time varying, recent evidence suggests that a great deal of the flattening of the Phillips curve relationship, which links inflation to cyclical unemployment (the parameter δ in equation 3.1), likely occurred before 1995, suggesting that the estimated parameters in this analysis should be broadly stable over the estimation period 1996–2014 (Chapter 3 in the April 2013 *World Economic Outlook*).

[5]The measure of productive capital is consistent with the approach of estimating capital services (that is, excluding housing). See Beffy and others 2006 for a detailed discussion.

The residual is likely also to include utilization of the inputs of production (labor and capital)—such as hours worked and capacity utilization, labor quality (that is, human capital accumulation), and possible measurement errors in the inputs of production.

growth. The second demographic dimension is the age composition of the working-age population, which affects the aggregate participation rate, since the propensity to participate in the labor force starts declining steeply beyond a particular age threshold, typically in the early 50s. An increased share of older people in the population therefore lowers the average participation rate and thereby potential employment.[6]

Trend labor force participation rates are estimated using cohort-based models of participation. The cohort model allows for the estimation of trend labor force participation for each age-gender group, accounting for observables as well as age-gender-specific and birth-year-specific unobservable determinants of labor supply. For example, the labor force participation decision of youths typically depends on school enrollment rates, while that of prime-age women depends on educational attainment, marital status, and fertility rates. Older workers' labor force participation typically increases with higher life expectancy but decreases with the generosity of social security systems. Across all ages, particularly among women, participation is strongly influenced by cultural and institutional factors that evolve slowly and can shift the lifetime participation profile of different cohorts. For each country, group-specific trend participation rates are obtained based on these determinants, after the cyclical effects are purged. These estimates are then combined with data on the demographic distribution to compute the aggregate trend labor force participation rate (see Annex 3.3 for details).

Looking Back: How Did Potential Growth Evolve before the Crisis?

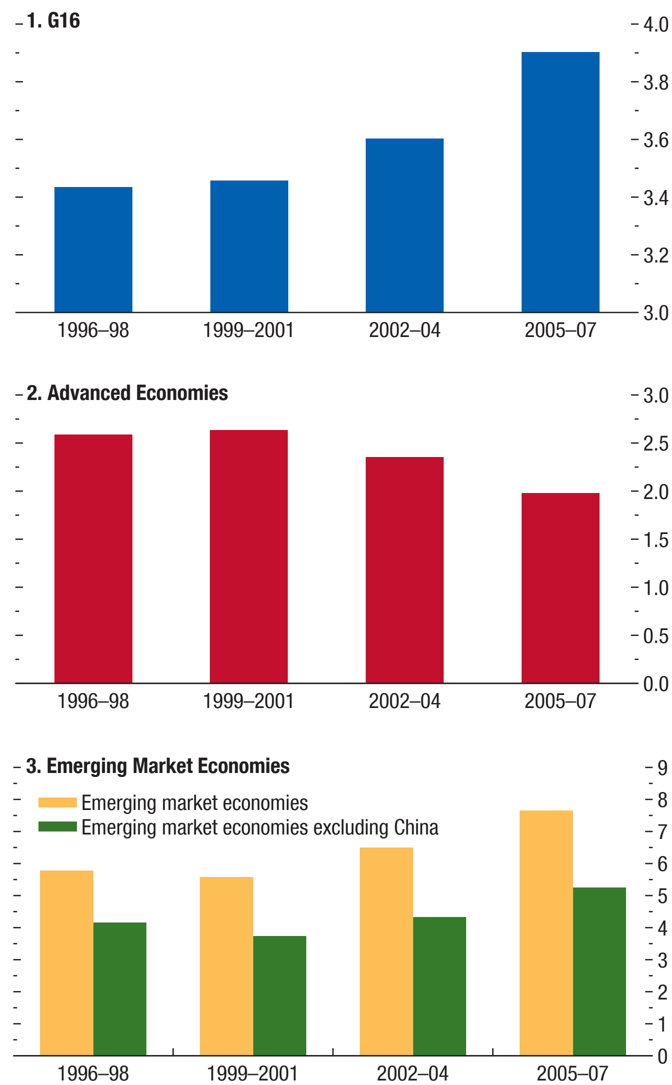
From the early 2000s until the global financial crisis, world potential growth was rising, but this masked a divergence across economies. Potential growth was actually declining in advanced economies, while it was increasing in emerging market economies (Figure 3.3). These patterns held for most countries within each group (Figure 3.4).[7] The following analysis shows that in both country groups the changes in potential growth were attributable mostly to changes in total factor productivity growth. Given the marked differences in the direction of changes and the underlying drivers, the results are presented separately for the two groups of economies.

[6]Demographic factors may also affect productivity (see, for example, Feyrer 2007) and investment (see, for example, Higgins 1998).

[7]A notable exception is Russia, where potential growth declined during 2001–07, from about 6.0 percent to about 5.1 percent.

Figure 3.3. Precrisis Potential Output Growth Evolution
(Percent)

From the late 1990s until the global financial crisis, world potential growth was rising, but this masked a divergence across economies. Potential growth was actually declining in advanced economies, while it was increasing in emerging market economies.



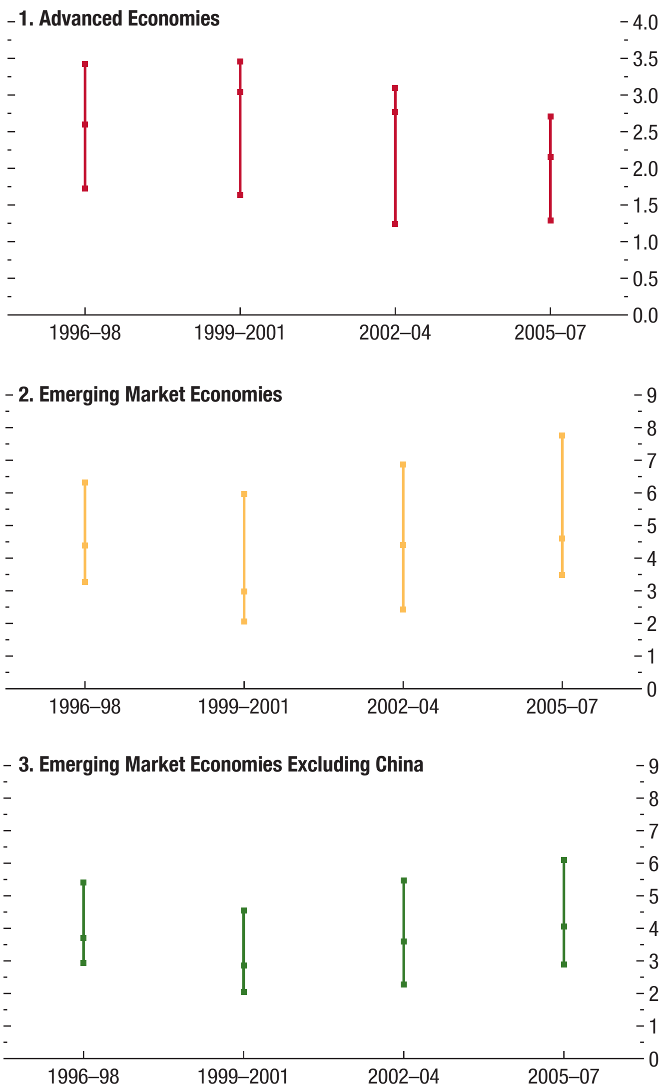
Source: IMF staff estimates.
Note: Economy groups are defined in Annex 3.1.

Advanced Economies

In advanced economies, potential growth declined during the period, from about 2.4 percent to about 1.9 percent (Figure 3.5, panel 1). A drop in total factor productivity growth from about 0.9 percent to about 0.5 percent accounted for most of the decline. Poten-

Figure 3.4. Variation in Potential Output Growth across Countries
(Percent)

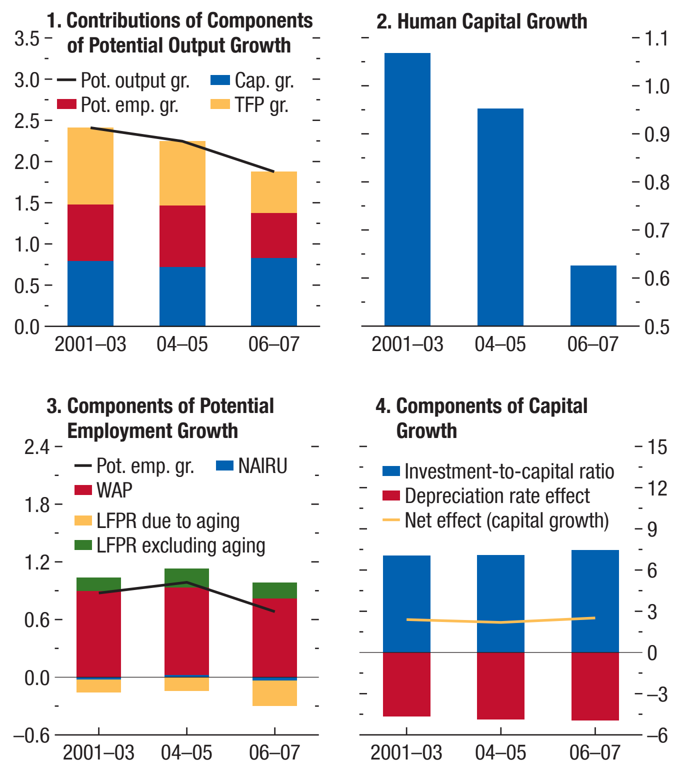
The patterns of potential output growth held for most countries within each group.



Source: IMF staff estimates.
Note: The upper and lower ends of each line show the top and bottom quartiles; the marker within the line shows the median within the group over the corresponding period. Economy groups are defined in Annex 3.1.

Figure 3.5. Determinants of Potential Output Growth in Advanced Economies
(Percent)

In advanced economies, potential growth declined in 2001–07 because of lower total factor productivity growth, resulting in part from a decline in human capital growth. Potential employment growth fell only slightly as a result of demographic factors. Growth in the capital stock remained stable.



Sources: Barro and Lee 2010; and IMF staff estimates.
Note: Human capital is measured as the percentage of people in the population over 15 years old who have secondary education or higher. Advanced economies are defined in Annex 3.1. Cap. gr. = capital growth; LFPR = labor force participation rate; NAIRU = nonaccelerating inflation rate of unemployment; pot. emp. gr. = potential employment growth; pot. output gr. = potential output growth; TFP gr. = total factor productivity growth (including human capital growth); WAP = working-age population.

tial employment growth fell only slightly, while capital growth remained broadly stable.

Total Factor Productivity Growth

Several developments may explain the decline in total factor productivity growth. First, in the United States, whose technological development is commonly regarded as representing the world frontier, the growth in total factor productivity started to decline in 2003. This decline seems to reflect the waning of the exceptional growth effects of information and communications technology as a general purpose technology observed in the late 1990s to early 2000s (Fernald 2014a, 2014b).[8] In particular, industry-level data suggest that the slowdown in U.S. total factor

[8]The reduced dynamism of the U.S. economy—as measured by rates of firm entry and job creation and destruction—may have also contributed to the observed decline (Decker and others 2013).

productivity growth occurred mainly in sectors that produce or intensively use information and communications technology. The decline in U.S. total factor productivity growth may, in turn, have spilled over to other advanced economies (Box 3.2). Second, total factor productivity growth in many advanced economies declined as a result of a shift of resources away from sectors with high productivity (such as manufacturing and information and communications technology) toward those with low productivity (such as personal services, construction, and nonmarket services) (Box 3.3; Dabla-Norris and others, forthcoming).

In addition, human capital growth—which is a component of total factor productivity growth as used in this chapter—declined during 2001–07, from about 1.1 percent to about 0.6 percent (Figure 3.5, panel 2).[9] This decline partly reflects a reduction in the marginal return to additional education as educational attainment in these economies increases (Johansson and others 2013; Riosmena and others 2008).[10]

Potential Employment Growth

Potential employment growth fell slightly during 2001–07, from about 0.9 percent to about 0.6 percent (Figure 3.5, panel 3). The cause was demographic factors, which reduced the growth rate of the working-age population and the trend labor force participation rate.[11]

On average, the growth in the working-age population (ages 15 and older) declined slightly during the period: the effect of smaller young cohorts (because of reduced fertility in most advanced economies) was partly offset by the maturing of postwar baby boom cohorts. In some European countries, including Italy and Spain, increased immigration spurred working-age population growth. In Japan and Korea, working-age population growth has been on a steep downward trend because of the absence of immigration and declining birth rates since the 1980s.

Another outcome of this demographic transition is the increasing average age of the population. People older than the prime working age (that is, older than 54) have a lower propensity to participate in the labor force. Therefore, population aging has been lowering trend participation rates, which on average has lowered employment growth by about 0.2 percentage point a year. At the same time, higher rates of female participation in the labor force in most advanced economies increased the average labor force participation rate by roughly the same amount as aging reduced it, leading to only a modest decline in overall potential employment growth. Two notable cases in which potential employment growth has been slowing more markedly are the United States—where the rate of female participation has flattened—and Japan, where aging pressures have been too strong to be offset by the modest rise in the rate of female participation.

Capital Growth

Growth in the capital stock remained stable during the period (Figure 3.5, panel 1) as the modest increase in the investment-to-capital ratio was offset by the increase in capital depreciation (Figure 3.5, panel 4).[12]

Emerging Market Economies

In emerging market economies, potential growth increased from about 6.1 percent to about 7.4 percent during 2001–07 (Figure 3.6, panel 1). While this exceptional growth was partly driven by China's strong performance, potential growth also increased substantially in other emerging market economies during this period, from about 3.7 percent to about 5.2 percent (Figure 3.3, panel 3).

The acceleration in total factor productivity explains the bulk of the increase in potential growth in emerging market economies during the period. In addition, a sustained increase in investment-to-capital ratios drove the increase in capital accumulation growth. In contrast, potential employment growth declined because of demographic factors.

Total Factor Productivity Growth

Total factor productivity growth increased from about 3.2 percent to 4.2 percent in the period (Figure 3.6,

[9]Human capital is measured by the formal level of schooling obtained, given limited data availability of measures of educational quality, including skills acquired—such as the PISA (Programme for International Study Assessment)—for some emerging market economies analyzed in the chapter. Specifically, human capital accumulation is measured as the percentage of secondary and tertiary schooling in a population (Barro and Lee 2010). Using other indicators of human capital accumulation, such as the number of years of schooling, produces a similar pattern.

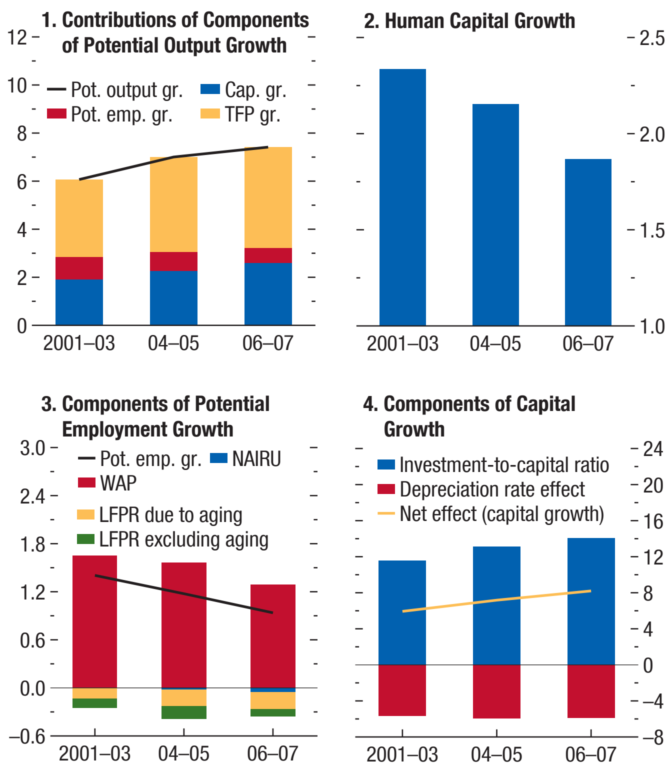
[10]This measure of human capital is, in practice, bounded, with the maximum given by the entire population having tertiary schooling. This implies a limit to human capital growth in the long term.

[11]See Annex Figure 3.3.1 for the evolution of demographic profiles in advanced economies.

[12]The investment-to-output ratio followed a similar pattern.

Figure 3.6. Determinants of Potential Output Growth in Emerging Market Economies
(Percent)

In emerging market economies, potential growth increased in 2001–07 on the back of strong total factor productivity growth—despite a marked decline in human capital growth—and capital growth. In contrast, demographic factors contributed to the decline in potential employment growth.



Sources: Barro and Lee 2010; and IMF staff estimates.
Note: Human capital is measured as the percentage of people in the population over 15 years old who have secondary education or higher. Emerging market economies are defined in Annex 3.1. Cap. gr. = capital growth; LFPR = labor force participation rate; NAIRU = nonaccelerating inflation rate of unemployment; pot. emp. gr. = potential employment growth; pot. output gr. = potential output growth; TFP gr. = total factor productivity growth (including human capital growth); WAP = working-age population.

panel 1). Possible explanations for this increase include (1) an expansion of global and regional value chains, which stimulates technology and knowledge transfers (Dabla-Norris and others 2013); (2) shifts of resources to higher-productivity sectors, particularly in China, India, Mexico, and Turkey (McMillan and Rodrik 2011); (3) greater diversification, which tends to concentrate exports in sectors characterized by technology spillovers and upgrading of product quality (Papageorgiou and Spatafora 2012; Henn, Papageorgiou, and Spatafora 2014); and (4) productivity gains associated with structural reforms (Cubeddu and others 2014).

Human capital growth declined from about 2.3 percent to about 1.9 percent in the period (Figure 3.6, panel 2), with the notable exception of Turkey, where it increased. As for advanced economies, this decline partly reflects a lower marginal return to additional education as attainment increases.

Potential Employment Growth

Demographic factors contributed to a decline in potential employment growth, from about 1.5 percent to about 1.0 percent during the period (Figure 3.6, panel 3).[13]

Decreases in fertility (generally associated with higher incomes) markedly reduced the growth rate of the working-age population during the period, though from much higher levels than in advanced economies.[14] The growth slowdown was sharpest in China, where the rate declined by half, from about 2 percent to 1 percent during the five years starting in 2003. In other emerging market economies, particularly Mexico, working-age population growth was stable at about 2 percent. In addition, participation rates of young and prime-age workers in China, India, and Turkey have been trending downward, reflecting wealth effects and increased pursuit of education.

Rising life expectancy and falling fertility also led to an overall aging of the working-age population during the period, which in turn exerted downward pressure on average participation rates. These forces, which were strongest in China and Russia, lowered potential employment growth during 2001–07 by 0.2 percentage point a year on average.

Capital Growth

Capital growth increased, from about 5.9 percent to about 8.2 percent, during 2001–07 (Figure 3.6, panel 4), contributing about 0.7 percentage point to the increase in potential growth (Figure 3.6, panel 1). This acceleration in capital accumulation was driven by the strong increase in the investment-to-capital ratio during the period—from about 11.6 percent to about 14.1 percent (Figure 3.6, panel 4). The ratio was boosted by strong growth in the terms of trade and more favorable

[13]See Annex Figure 3.3.1 for the evolution of demographic profiles in emerging market economies.

[14]Various theories have been put forward in the demographic and growth literature about the factors driving the demographic transition of falling fertility associated with higher income. One causal channel that has received empirical support is the reduction in child and infant mortality. See Kalemli-Ozcan 2002 for a review of the literature.

financing conditions, including lower interest rates in advanced economies (Cubeddu and others 2014).

How Did Potential Growth Evolve during the Crisis?

The previous section shows that potential output growth in advanced economies was slowing even before the global financial crisis, whereas it was rising in emerging market economies. Shortly after the crisis hit in September 2008, economic activity collapsed, and more than six years after the crisis, growth is still weaker than was expected before the crisis. The protracted weakness in economic activity suggests that it partly relates to weaker potential output, not just cyclical factors. A key question is whether persistent lower growth reflects mostly temporary effects from crisis-related changes in the level of potential output or whether this crisis, unlike earlier ones, has also triggered a decline in potential growth. This section examines this question theoretically and empirically.

How Can Financial Crises Affect Potential Growth? A Theoretical Framework

Financial crises may permanently reduce the level of potential output through a number of channels: investment in productive capital, potential employment, total factor productivity, and sectoral reallocation of resources. Declines in the level of potential output will also temporarily reduce potential growth, but it is harder to make the case on theoretical grounds that financial crises permanently reduce potential growth, as the following discussion illustrates.

- *Investment in productive capital:* Financial crises can lower potential output through their negative effects on investment in productive capital. As discussed in Chapter 4, the collapse in economic activity during the global financial crisis can explain much of the decline in investment, and financial factors are an important transmission channel. For example, as the supply of credit becomes more limited, firms may face less advantageous financing terms and tighter lending standards for an extended period (Claessens and Kose 2013).[15] Moreover, financial crises weaken firms' incentives to invest because risks and uncertainty about expected returns tend to increase (Pindyck 1991; Pindyck and Solimano 1993). Financial crises may permanently reduce the level of potential output and have long-lasting effects on potential growth if investment-to-capital ratios remain depressed for an extended period.[16] As output and investment recover from crises, capital will return to its equilibrium growth path, but more gradually since it is a slow-moving variable.[17]
- *Structural unemployment:* Severe financial crises, which tend to be followed by long and deep recessions, may lead to a permanent decline in the level of potential output by increasing structural unemployment or the NAIRU as a result of hysteresis effects (Blanchard and Summers 1986; Ball 2009). This is particularly the case for economies with rigid labor market institutions (Blanchard and Wolfers 2000; Bassanini and Duval 2006; Bernal-Verdugo, Furceri, and Guillaume 2013). Increases in the NAIRU will lead to a temporary decline in the growth rate of potential employment and thus potential output, but such growth effects will vanish in the medium term as the NAIRU stabilizes.
- *Labor force participation rates:* Financial crises may also reduce the level of potential output by leading to a persistent or even a permanent reduction in participation rates. High unemployment rates may discourage workers from searching for jobs (discouraged-worker effect) and force them to exit the labor force (Elmeskov and Pichelman 1993). This is particularly the case for older workers and in countries where social transfer programs provide early retirement incentives (Nickell and Van Ours 2000; Autor and Duggan 2003; Coile and Levine 2007, 2009). Again, while this channel can lead to

[15]Financial crises differ from other types of recessions in that they are often associated with "creditless recoveries" (Claessens and Terrones 2012; Claessens and Kose 2013).

[16]Capital stock growth is equal to the ratio of investment to the previous year's capital minus the depreciation rate:

$$\Delta K_t/K_{t-1} = I_t/K_{t-1} - \delta_t,$$

in which K is the stock of capital, I the level of investment, and δ denotes capital depreciation. Moreover, the ratio of investment to the previous year's capital can be further decomposed as

$$I_t/K_{t-1} = (1 + g) \times I_{t-1}/K_{t-1},$$

in which g is the growth rate of investment. This identity shows that as investment growth picks up, capital growth will increase, but more gradually, since its evolution depends also on the lagged investment-to-capital ratio (I_{t-1}/K_{t-1}).

[17]In balanced growth, the capital-to-output ratio is constant. After a shock, the ratio will eventually return to its equilibrium growth path because of the economy's mean reversion tendencies. Hall (2014) argues that the recovery from the shortfall in U.S. capital may take place only gradually over a decade or more.

temporarily lower potential output growth, it will ultimately have only level effects.

- *Sectoral reallocation:* Financial crises may also increase the level of structural unemployment through sectoral reallocation, to the extent that job separations are associated with substantial reallocation costs (Loungani and Rogerson 1989; Figura and Wascher 2010; Reifschneider, Wascher, and Wilcox 2013). Sectoral reallocation may also affect the level of potential output by reducing productivity levels if the displaced capital is highly specific to the affected sector (Ramey and Shapiro 2001). However, sectoral reallocation has an uncertain effect on aggregate productivity because labor may reallocate from high- to low-productivity sectors and vice versa.[18] Possible damage to productivity could persist and could reduce potential growth for an extended period given sufficiently long-lasting reallocation.
- *Total factor productivity:* Financial crises can have conflicting effects on total factor productivity, and the net effect is impossible to specify in advance. On one hand, financial crises may lower total factor productivity by reducing investment in innovation through research and development, which is highly procyclical. On the other hand, such crises may also tend to raise total factor productivity to the extent that they give firms a stronger incentive to improve their efficiency and by leading to "creative destruction" or Schumpeterian growth (Aghion and Howitt 2006).

The specific effect of financial crises on the human capital component of total factor productivity (as used in this chapter) is also ambiguous. On one hand, human capital accumulation can be countercyclical because, during downturns, firms have more of an incentive to reorganize and retrain (Aghion and Saint-Paul 1998b) and because individuals may spend more time learning given the lower returns to working (Aghion and Saint-Paul 1998a; Blackburn and Galindev 2003). On the other hand, human capital accumulation may decrease during recessions because of reduced "learning by doing" (Martin and Rogers 1997, 2000).

In sum, while possible adverse effects of financial crises may permanently reduce the level of total factor productivity and therefore lead to temporary declines in its growth rate, they are unlikely to have long-term effects on growth (Hall 2014).

Potential Growth in the Aftermath of the Global Financial Crisis

This section examines the evolution of potential growth in the aftermath of the global financial crisis in advanced and emerging market economies and assesses whether the theoretical considerations regarding the transmission channels are borne out in the data.

The analysis presented in the section shows that potential growth has declined in both advanced and emerging market economies in the aftermath of the crisis.[19] This decline was sharpest immediately after the crisis (2008–10), but potential growth had not yet recovered to precrisis rates as of 2014. This suggests the possibility of persistent effects on growth, which distinguishes the global financial crisis from other financial crises: previous work examining earlier crises has not found that these episodes affect the *growth rate* of potential output (Cerra and Saxena 2008; October 2009 *World Economic Outlook*, Chapter 4; Furceri and Mourougane 2012). However, the results of the analysis also highlight that some of the decline in potential growth should not be attributed to the crisis. In advanced economies, there are continued effects from demographic trends. In emerging market economies, the factors responsible for this decline are more difficult to identify and could include developments not related to the crisis, such as convergence of total factor productivity to the technological frontier and reduced growth in input utilization—such as hours worked and capacity utilization—and in the stock of human capital.

Advanced Economies

In advanced economies, potential growth fell from slightly less than 2 percent in the precrisis period (2006–07) to about 1½ percent during 2013–14. The decline was larger in euro area economies (about ½ percentage point) than in the United States and in other advanced economies (about ⅓ percentage point).

[18]Data availability limitations preclude an examination of this channel for the global financial crisis, but Box 3.4 shows that it has played a significant role in explaining the adverse effect of past financial crises on overall productivity.

[19]See Annex 3.4 for an econometric analysis of the possible effects of the crisis on the levels and the growth rates of potential output in advanced and emerging market economies.

For advanced economies as a whole, the decline in potential growth can be attributed to an important extent to the effect of the global financial crisis on investment (see Chapter 4) and thus on capital growth (Figure 3.7, panels 1–4). In particular, capital growth declined by about 0.8 percentage point in the aftermath of the crisis, contributing to a reduction in potential growth of about ¼ percentage point during the same period. This effect is larger for euro area countries (0.4 percentage point)—possibly because of tighter financial conditions—than for the United States (about ¼ percentage point) and other advanced economies (0.15 percentage point).

Potential employment growth also declined, from about 0.8 percent to about 0.4 percent over this period, contributing to a reduction in potential growth of about ¼ percentage point (Figure 3.7, panels 5–8). The decline in potential employment growth was larger in euro area economies (0.6 percentage point) than in the United States (0.3 percentage point) and other advanced economies (0.4 percentage point). However, it appears that this persistent decline in potential employment growth is not associated with scars from the crisis (namely, the change in the NAIRU and in labor force participation rates). Specifically, the temporary effects on growth from crisis-related changes in the NAIRU and labor force participation rates had worn off as of 2014. Instead, the persistent decline is attributable to demographic factors that negatively affected the growth of the working-age population and labor participation rates.

Similarly, the short-term effects of the crisis on total factor productivity growth observed during 2008–09 have already completely unwound.[20] In 2014, total factor productivity growth is estimated to have returned to the rates observed immediately before the crisis.

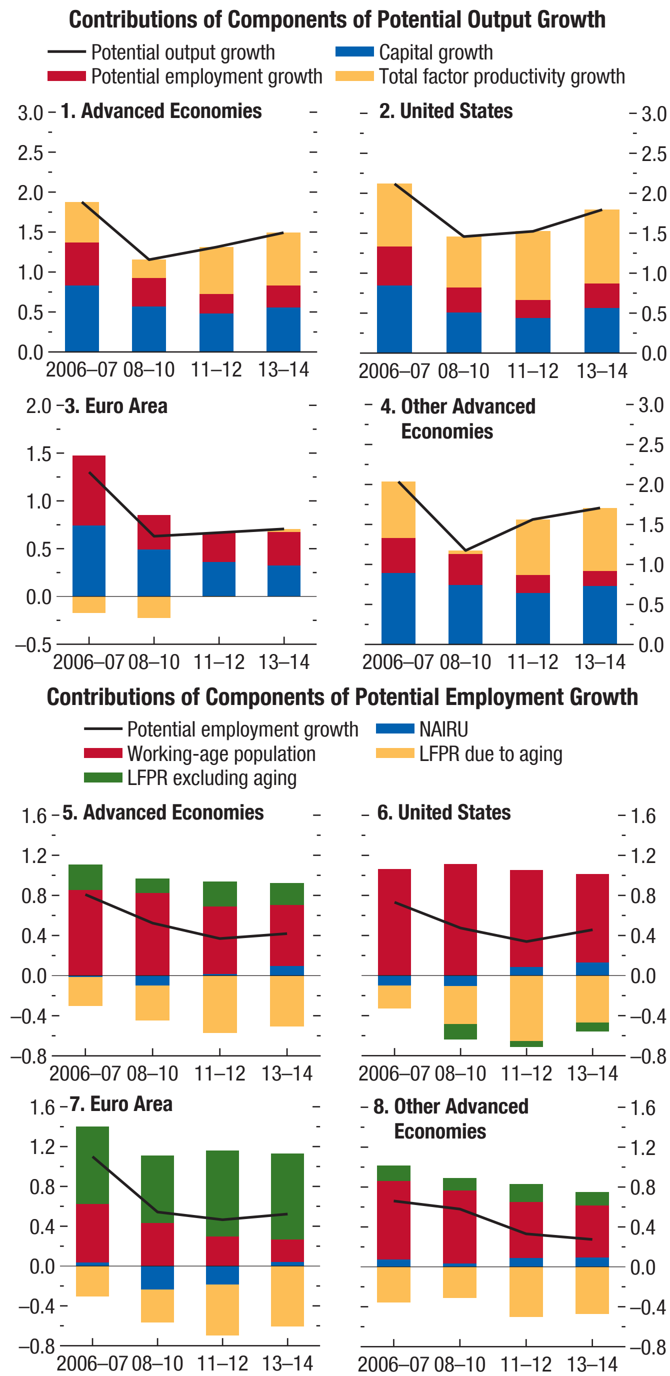
Emerging Market Economies

In emerging market economies, potential growth declined from about 7½ percent in the precrisis period (2006–07) to about 5½ percent during 2013–14 (Figure 3.8, panel 1). Although this decline was driven by the significant reduction in potential growth in China (about 3 percentage points) (Figure 3.8, panel 2), potential growth also declined substantially in other emerging market economies during this period,

[20]This result is consistent with previous evidence on the effect of the crisis on U.S. total factor productivity growth (Fernald 2014a, 2014b; Hall 2014).

Figure 3.7. Components of Potential Output Growth during the Global Financial Crisis in Advanced Economies
(Percent)

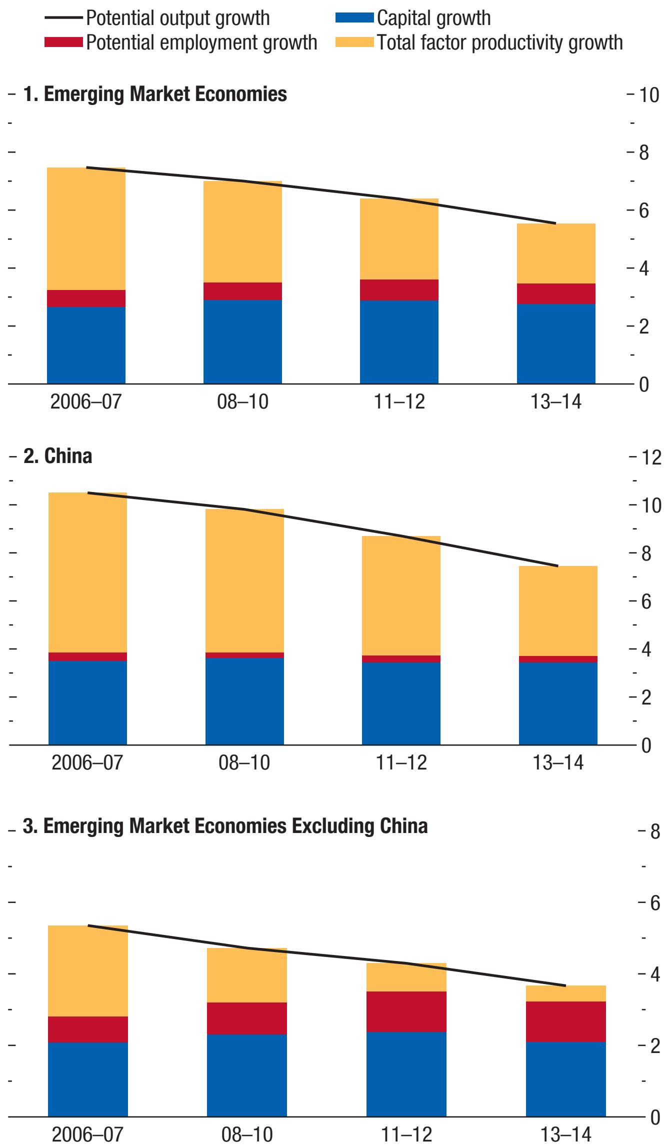
In advanced economies, the decline in potential growth during the global financial crisis is mainly attributable to the effects of the crisis on capital growth. Potential employment also declined during this period, although the decline is mainly explained by demographic factors. The effect of the global financial crisis on total factor productivity has completely unwound.



Source: IMF staff estimates.
Note: Economy groups are defined in Annex 3.1. LFPR = labor force participation rate; NAIRU = nonaccelerating inflation rate of unemployment.

Figure 3.8. Components of Potential Output Growth during the Global Financial Crisis in Emerging Market Economies
(Percent)

In emerging market economies, the decline of potential growth during the global financial crisis is mainly explained by a reduction in total factor productivity growth. Potential employment and capital growth were not affected by the crisis.



Source: IMF staff estimates.
Note: Economy groups are defined in Annex 3.1.

from about 5½ percent to 3½ percent (Figure 3.8, panel 3). For emerging market economies as a group, the decline in total factor productivity growth—from about 4¼ percent to about 2¼ percent during this period—accounted for the entire decline in potential growth (Figure 3.8, panel 1). In contrast, potential employment growth remained broadly stable, and capital growth was not affected by the crisis and actually increased temporarily—likely because of some countries' efforts to counter the effects of the crisis by adopting investment stimulus measures.

The fact that almost all of the decline in postcrisis potential output growth in emerging market economies results from a decline in total factor productivity growth—measured as a residual in the growth-accounting framework—does not fit easily with theoretical predictions. Although this decline may partly reflect the higher volatility in measured total factor productivity in emerging market economies—which in turn might reflect greater measurement errors (Cubeddu and others 2014)—other factors could be at work. These factors could include a gradual slowdown in convergence to the technological frontier after rapid catchup in the decade before the crisis, reduced growth in input utilization, and lower human capital growth.[21]

Where Are We Headed?

What is the likely trajectory of potential output in the medium term? To answer this question, this section considers prospects for the components of potential growth—labor, capital, and total factor productivity—in the medium term, which is defined here as the six-year period from 2015 to 2020. The scenario presented in the section builds on the previous analysis of the evolution of potential growth until now and extends it, based on projected demographic patterns and the experience from past financial crises.[22] This scenario should be considered as illustrative, given the considerable uncertainty surrounding many elements of the analysis, including possible errors in demographic projections, alongside the wide variations in the experience with previous crises.

[21]In emerging market economies, human capital growth declined by about 1 percentage point during the crisis (see Annex Figure 3.5.1).

[22]Demographic projections are based on estimates of fertility and mortality rates, and net migration flows. See the UN *World Population Prospects: The 2012 Revision* (http://esa.un.org/wpp/) for details.

Advanced Economies

The medium-term outlook for potential growth is constructed by considering the prospects for each of its components:

- Potential employment growth is expected to decline further compared with precrisis rates. This decline entirely reflects demographic factors, which negatively affect both the growth of the working-age population and trend labor force participation rates (Figure 3.9, panel 1). The negative growth effects from crisis-related changes in the levels of structural unemployment and labor force participation rates have already worn off, as discussed previously.

Working-age population growth is likely to decline significantly in most advanced economies, particularly Germany and Japan, where it will reach about –0.2 percent a year by 2020.[23] At the same time, rapid aging is expected to further decrease average trend labor force participation rates, offsetting the positive effect of continued population increases on overall labor supply. This decline is projected to be strongest in Canada, where aging alone should reduce the overall participation rate by more than 2 percentage points in the medium term. Overall, potential employment growth in advanced economies is expected to decline by about 0.2 percentage point compared with precrisis rates.

- Capital growth is likely to remain below precrisis rates through 2020.

As discussed in the theoretical framework, if investment-to-capital ratios remain below precrisis levels for an extended period, capital growth will return to its equilibrium growth path only very gradually. In other words, the contribution of capital growth to potential output may stay low for a long time. The key question, therefore, is what the experience from past financial crises suggests about the likely trajectory of the investment-to-capital ratio—which determines the rate of capital stock growth, given depreciation rates—in the medium term.[24]

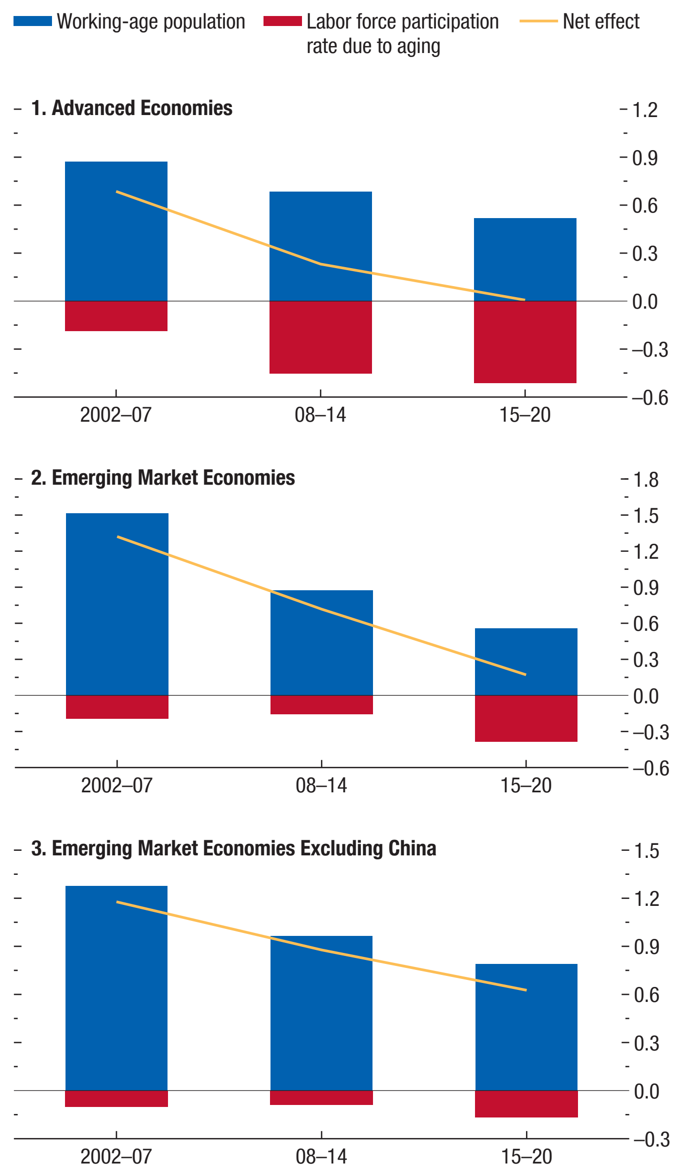
The evidence from the aftermath of previous financial crises suggests that full reversal of the decline in the investment-to-capital ratio by 2020 is unlikely. Econometric estimates suggest that there are significant and long-lasting declines in the investment-to-capital

[23]In the case of Germany, this decline could be partly offset if recent exceptional net immigration flows persist and exceed those projected in the 2012 revision of the UN *World Population Prospects*.

[24]Capital stock growth is equal to the investment-to-capital ratio minus the depreciation rate.

Figure 3.9. Effect of Demographics on Employment Growth
(Percent)

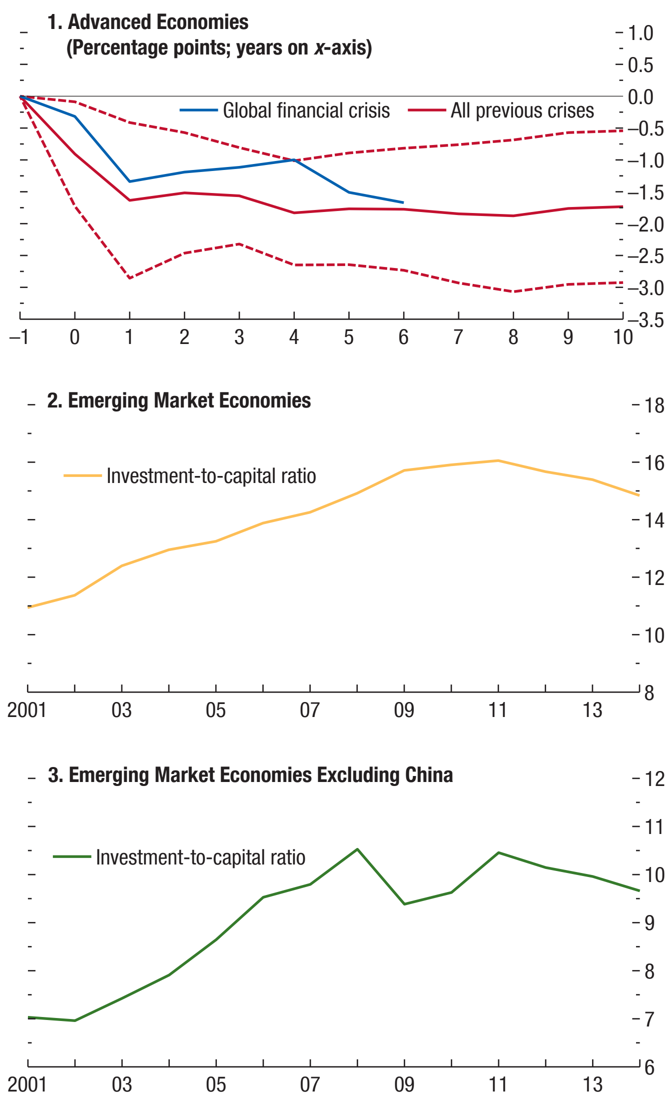
Potential employment growth is expected to decline further in both advanced and emerging market economies compared to precrisis rates. This is a result of demographic factors negatively affecting both the growth of the working-age population and trend labor force participation rates.



Source: IMF staff estimates.
Note: Economy groups are defined in Annex 3.1.

Figure 3.10. Investment-to-Capital Ratio
(Percent, unless noted otherwise)

In both advanced and emerging market economies, the investment-to-capital ratio is likely to remain below precrisis rates over the medium term.



Sources: Laeven and Valencia 2014; and IMF staff estimates.
Note: In panel 1, the blue line represents the effect of the global financial crisis, and red lines represent the effect of previous financial crises (based on Laeven and Valencia 2014), on the investment-to-capital ratio. Dashed red lines denote 90 percent confidence bands. Economy groups are defined in Annex 3.1.

ratio after financial crises (Figure 3.10, panel 1). Typically, the decline in this ratio is about 1.7 percentage points six years after the crisis. This estimated medium-term effect matches the estimated postcrisis decline in the investment-to-capital ratio in advanced economies up to 2014.[25] Part of the decline may also reflect firms' responses to lower labor force growth, which makes it possible to maintain the capital-per-worker ratio with less investment. If investment ratios in advanced economies remain low for as long as they have in previous financial crises, capital stock growth will remain below precrisis rates—at about 1¾ percent. This, in turn, will lower potential growth by about 0.2 percentage point compared with precrisis rates.

- The deceleration in total factor productivity levels observed before the crisis is likely to be lasting, implying that total factor productivity growth will return to rates seen immediately before the crisis, but not higher.

The findings of this chapter suggest that trend total factor productivity growth began declining before the crisis. Even though the effect of the crisis has faded, total factor productivity growth is unlikely to return rapidly to the exceptionally high rates observed in the early 2000s—although this possibility cannot be dismissed—especially in regard to the many European countries without sizable information and communications technology sectors (European Commission 2014).[26] In addition, human capital growth—a component of total factor productivity growth as used in the chapter—is also expected to slow down as the marginal return to additional education decreases (see Annex Figure 3.5.1, panel 1).

Emerging Market Economies

The prospects for evolution of the components of potential growth in emerging market economies are as follows:

- Potential employment growth is expected to decline further in the medium term. As in advanced economies, this reflects demographic factors' drag on both the growth of the working-age population and trend

[25]These results are in line with the permanent effect of financial crises on the investment-to-output ratio found in previous studies (Furceri and Mourougane 2012; April 2014 *World Economic Outlook,* Chapter 3).

[26]As illustrated by Byrne, Oliner, and Sichel (2013), views about the future pace of total factor productivity growth vary considerably. See Gordon 2012, Gordon 2014, and Mokyr 2014 for a debate about long-term perspectives on productivity in the United States.

labor force participation rates (Figure 3.9, panels 2 and 3).

Working-age population growth is likely to slow faster, most sharply in China, and remain negative in Russia. Aging is expected to accelerate, lowering trend labor force participation rates and, together with slower population growth, reducing potential employment growth from 0.5 percent to 0.1 percent a year in the medium term. Again, this effect should be strongest in China, but it should also be strong in Brazil, particularly if growth in female participation rates remains at levels observed in recent years. Overall, potential employment growth in emerging market economies is expected to decline further by about 0.6 percentage point in the medium term.

- Capital growth is expected to slow further from current rates, following a gradual decline in investment after the boom years of the 2000s (see Box 4.1).

Investment-to-capital ratios have already fallen by 1.2 percentage points since 2011, leading to a reduction in capital growth of about 0.15 percentage point for the same period (Figure 3.10, panels 2 and 3), and are likely to remain below precrisis rates. This is because of less favorable external financing conditions, softer or flat commodity prices, and infrastructure bottlenecks. In the case of China, the investment-to-capital ratio—and hence capital growth—may continue to decline because of a rebalancing of growth away from investment and toward consumption. In particular, if investment-to-capital ratios remain at the rates observed in 2014 in emerging markets excluding China, and gradually decline in China in the medium term as a result of rebalancing, capital growth will remain ½ percentage point below precrisis rates.

- Total factor productivity growth is expected to remain below its precrisis rates for the next five years.

Total factor productivity growth is likely to rise moderately in the medium term as some crisis-related factors wear off. However, it is assumed to regress toward its historical mean rate (Pritchett and Summers 2014) and remain below precrisis rates as these economies approach the technological frontier. Taking China as an example, if total factor productivity growth follows the typical convergence process, starting from the country's current level of income, it may decline in the medium term by about ¾ percentage point compared with its precrisis rates (Nabar and N'Diaye 2013).[27] Furthermore, the reduction in emerging market total factor productivity growth may be amplified by the reduction in total factor productivity growth in the United States observed since the mid-2000s through technological spillovers. Finally, as for advanced economies, human capital growth is also likely to decline gradually as educational attainment increases toward advanced economies' levels (see Annex Figure 3.5.1, panels 2–3).

Putting It All Together

These scenarios for the components imply that potential growth in advanced and emerging market economies is likely to remain below precrisis rates. In particular, in advanced economies, potential growth is expected to increase only slightly from current rates—from an average of about 1.3 percent during 2008–14 to about 1.6 percent during 2015–20. In emerging market economies, potential growth is likely to decline even further, from an average of about 6.5 percent during 2008–14 to about 5.2 percent during 2015–20. In China, the decline could be even larger because of the rebalancing of growth away from investment and toward consumption (Figure 3.11).[28]

These scenarios are subject to significant uncertainty. In some advanced economies, especially in the euro area and Japan, a protracted period of weak demand could further erode labor supply and investment and thus potential growth. In emerging market economies,

[27]This decline may be partly mitigated if the shift away from investment-led growth leads to a more efficient allocation of resources.

[28]These scenarios are based on the following assumptions:

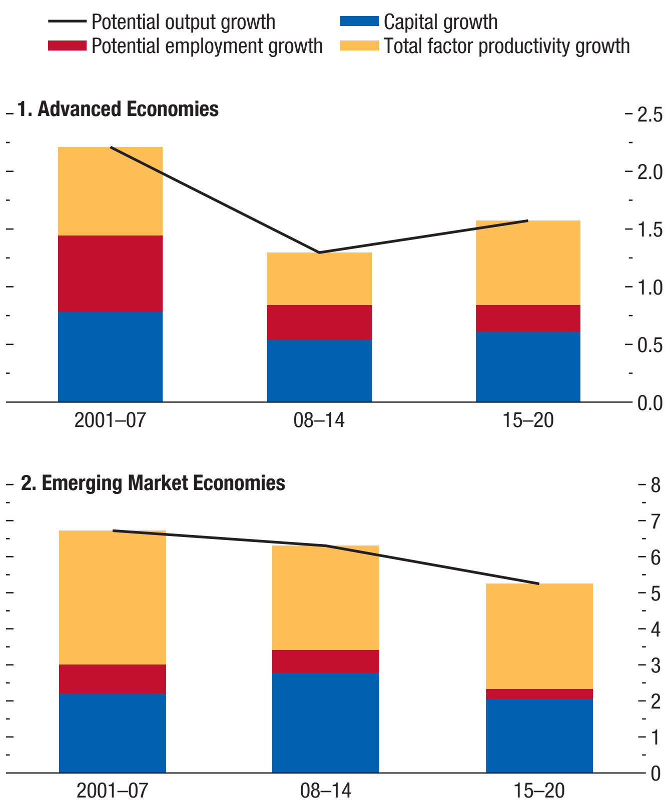
For *advanced economies:* (1) potential employment grows in line with demographic factors, adjusted for medium-term NAIRU estimates obtained using the multivariate filter, which suggest a decline in NAIRU of about 3.3 percentage points by 2020; (2) the investment-to-capital output ratio remains at 2014 rates in the medium term; and (3) total factor productivity growth remains at the precrisis (2003–07) average in the medium term.

For *China:* (1) potential employment grows in line with demographic factors, adjusted for medium-term NAIRU estimates obtained using the multivariate filter, which suggest a decline in the NAIRU of about 1.1 percentage points by 2020; (2) the investment-to-capital output ratio declines by about 1.5 percentage points by 2020 as a result of growth rebalancing, consistent with WEO projections; and (3) total factor productivity growth increases gradually from its 2014 value (by 0.2 percentage point by 2020) because of growth rebalancing—consistent with WEO projections—while remaining below its historical average.

For *other emerging market economies:* (1) potential employment growth is in line with demographic factors, adjusted for medium-term NAIRU estimates obtained using the multivariate filter, which suggest a decline in the NAIRU of about 4.8 percentage points by 2020; (2) the investment-to-capital output ratio remains at 2014 rates in the medium term; and (3) total factor productivity growth converges to historical (2001–14) averages in the medium term (2015–20).

Figure 3.11. Evolution of Potential Output Growth and Its Components
(Percent)

In advanced economies, potential output growth is expected to increase only slightly from current rates as some crisis-related factors wear off, but to remain below precrisis rates. In emerging market economies, potential output growth is expected to decline even further as a result of lower total factor productivity growth and potential employment growth.



Source: IMF staff estimates.
Note: Economy groups are defined in Annex 3.1.

a number of country-specific factors could influence potential growth. In particular, geopolitical risks could affect potential growth in Russia. In addition, potential growth prospects for commodity exporters such as Brazil and Russia depend on the evolution of commodity prices, as the latter is likely to affect investment and capital growth. In China, potential growth prospects will depend crucially on the growth-rebalancing process. And in both advanced and emerging market economies, substantial uncertainty remains about the evolution of total factor productivity growth in the medium term. Finally, these scenarios do not assume policy changes that could boost potential growth in the medium term.

Summary Findings and Policy Implications

From the early 2000s to 2007 (the year before the onset of the global financial crisis), potential output was accelerating strongly in emerging market economies but decelerating in advanced economies.

The crisis was associated with a reduction in potential growth for both groups of economies. The findings of this chapter suggest that potential growth declined in advanced and emerging market economies by ½ and 2 percentage points, respectively, following the crisis.

The chapter's analysis also suggests that in advanced economies, potential growth is likely to increase only slightly from current rates, but to remain below precrisis rates in the medium term. In particular, employment growth has declined and is likely to decline further because of demographic factors, and capital growth is likely to remain below precrisis rates even as output and investment recover from the crisis.

In emerging market economies, potential growth is likely to decline further, as potential employment growth is expected to slow. Because of less favorable external financing conditions and structural constraints, capital accumulation growth is likely to remain below precrisis rates in these economies, especially in China, where it may decline further as growth shifts toward consumption. And without policy changes, the growth of total factor productivity is not likely to return to its high precrisis rates in emerging market economies, given the expected further movement of these economies toward the technological frontier.

Reduced prospects for potential growth in the medium term have important implications for policy. In advanced economies, lower potential growth makes it more difficult to reduce still-high public and private debt. It is also likely to be associated with low equilibrium real interest rates, meaning that monetary policy in advanced economies may again be confronted with the problem of the zero lower bound if adverse growth shocks materialize. In emerging market economies, lower potential growth makes it more challenging to rebuild fiscal buffers. For all economies, a total factor productivity growth rate that remains below precrisis rates will slow the rise in living standards relative to the precrisis years.

These difficulties imply that raising potential output is a priority for policymakers. The reforms needed to achieve this objective vary across countries. In advanced economies, there is a need for continued demand support to boost investment and thus capital growth (Chapter 4) and for adoption of policies and reforms that can permanently boost the level of potential output, as well as its growth rate in the medium term. These policies would involve product market reforms, greater support for research and development—including strengthening patent systems and adopting well-designed tax incentives and subsidies in countries where they are low—and more intensive use of high-skilled labor and information and communications technology capital inputs to tackle low productivity growth (Box 3.5; OECD 2010); infrastructure investment to boost physical capital (Chapter 3 in the October 2014 *World Economic Outlook*); and better designed tax and expenditure policies to boost labor force participation, particularly for women and older workers (IMF 2012).

In emerging market economies, the important structural reforms to improve productivity include removing infrastructure bottlenecks, improving business conditions and product markets, and hastening education reform. In particular, removing excessively restrictive regulatory barriers in product and labor markets, liberalizing foreign direct investment, and improving education quality and secondary and tertiary attainment can have large productivity payoffs in many emerging market economies (Dabla-Norris and others 2013). In addition, in some of these economies, there is scope to address distortions from high labor tax wedges and inefficient pension design (IMF 2012).

Annex 3.1. Data Sources and Country Groupings

Country Groupings

In Figures 3.1 and 3.2, "World" encompasses the 189 economies that form the statistical basis of the World Economic Outlook (WEO) database. "Advanced economies" comprises the 36 economies listed in Table B of the Statistical Appendix. "Emerging market economies" refers to the economies listed in Table E of the Statistical Appendix, excluding those noted there as low-income developing countries.[29]

For the rest of the figures, the members of the advanced and emerging market economy groupings in the chapter's analyses are shown in Annex Table 3.1.1. These include 10 advanced economies and 6 emerging market economies from the Group of Twenty (G20); these 16 economies accounted for about three-fourths of world GDP in 2014. Data limitations preclude the analysis for three G20 economies—Argentina, Indonesia, Saudi Arabia, and South Africa. Estimates for the European Union—the 20th economy in the G20—and the euro area are based on individual country estimates for France, Germany, Italy, and Spain.

Annex Table 3.1.1. Countries Included in the Analysis

Advanced Economies	
Australia	Japan
Canada	Korea
France	Spain
Germany	United Kingdom
Italy	United States
Emerging Market Economies	
Brazil	Mexico
China	Russia
India	Turkey

Data Sources

The primary data sources for the chapter are the WEO database and the Organisation for Economic Co-operation and Development (OECD) database. All data sources used in the analysis are listed in Annex Table 3.1.2.

Annex 3.2. Multivariate Filter Methodology

Baseline Approach

The estimates of potential output presented in this chapter are computed using a small macroeconomic model, referred to as a multivariate filter. The structure of the model is as follows:[30]

The output gap is defined as the deviation of actual (log) real output from (log) potential output ($\bar{Y}$):

$$y = Y - \bar{Y}. \tag{A3.2.1}$$

The stochastic process for output (measured by real GDP) comprises three equations:

$$\bar{Y}_t = \bar{Y}_{t-1} + G_t + \varepsilon_t^{\bar{Y}}, \tag{A3.2.2}$$

$$G_t = \theta G^{SS} + (1 - \theta)G_{t-1} + \varepsilon_t^{G}, \tag{A3.2.3}$$

$$y_t = \phi y_{t-1} + \varepsilon_t^{y}. \tag{A3.2.4}$$

[29]See the Statistical Appendix for further information on the WEO's classification of countries into economy groups.

[30]Further details are available in Blagrave and others 2015.

Annex Table 3.1.2. Data Sources

Indicator	Source
Potential Output Growth and Its Components	
Potential output growth	IMF staff estimates using multivariate filter
Capital	OECD, Economic Outlook: Statistics and Projections database
Working-age population	UN, *World Population Prospects: The 2012 Revision*
Labor force participation	OECD, Labour Force Statistics database; and International Labour Organization, Key Indicators of the Labour Market database
Nonaccelerating inflation rate of unemployment	IMF staff estimates using multivariate filter
Indicators Used in the Potential Output Growth and Cohort Model Estimations	
Inflation expectations	Consensus Economics
Gross domestic product growth expectations (constant prices)	Consensus Economics
Life expectancy	UN, *World Population Prospects: The 2012 Revision*
Fertility	UN, *World Population Prospects: The 2012 Revision*
Years of schooling	Barro and Lee 2010
Investment	OECD, Economic Outlook: Statistics and Projections database
Depreciation rate	OECD, Economic Outlook: Statistics and Projections database
Others	
Gross domestic product (constant prices)	IMF, World Economic Outlook database
Inflation	IMF, World Economic Outlook database
Unemployment	IMF, World Economic Outlook database
Human capital accumulation	Barro and Lee 2010
Financial crises	Laeven and Valencia 2014

Note: OECD = Organisation for Economic Co-operation and Development; UN = United Nations.

The level of potential output ($\bar{Y}_t$) evolves according to potential growth (G_t) and a level-shock term ($\varepsilon_t^{\bar{Y}}$), which can be interpreted as supply-side shocks. Potential growth is also subject to shocks (ε_t^{G}), with their impact fading gradually according to the parameter θ (with lower values entailing a slower reversion to the steady-state growth rate following a shock). Finally, the output gap is also subject to shocks (ε_t^{y}), which are effectively demand shocks.

To help identify the three aforementioned output shock terms ($\varepsilon_t^{\bar{Y}}$, ε_t^{G}, and ε_t^{y}), a Phillips curve equation for inflation is added, which links the evolution of the output gap (an unobservable variable) to observable data on inflation. In this way, the filter's estimates of the output gap are, in part, determined by inflation outcomes:[31]

$$\pi_t = \lambda\pi_{t+1} + (1 - \lambda)\pi_{t-1} + \beta y_t + \varepsilon_t^{\pi}. \qquad \text{(A3.2.5)}$$

In addition, equations describing the evolution of unemployment are included to provide further identifying information for the estimation of the aforementioned output shocks and output gap:

$$\bar{U}_t = \tau_4 \bar{U}^{SS} + (1 - \tau_4)\bar{U}_{t-1} + g\bar{U}_t + \varepsilon_t^{\bar{U}}, \qquad \text{(A3.2.6)}$$

$$g\bar{U}_t = (1 - \tau_3)g\bar{U}_{t-1} + \varepsilon_t^{g\bar{U}}, \qquad \text{(A3.2.7)}$$

$$u_t = \tau_2 u_{t-1} + \tau_1 y_t + \varepsilon_t^{u}, \qquad \text{(A3.2.8)}$$

$$u_t = \bar{U}_t - U_t. \qquad \text{(A3.2.9)}$$

In these equations, $\bar{U}_t$ is the equilibrium value of the nonaccelerating inflation rate of unemployment (NAIRU), which is time varying and subject to shocks ($\varepsilon_t^{\bar{U}}$) and variation in the trend ($g\bar{U}_t$), which is itself also subject to shocks ($\varepsilon_t^{g\bar{U}}$)—this specification allows for persistent deviations of the NAIRU from its steady-state value. Most important, equation (A3.2.8) is an Okun's (1970) law relationship, in which the gap between actual unemployment (U_t) and its equilibrium process ($\bar{U}_t$) is a function of the amount of slack in the economy (y_t). As such, this equation behaves in much the same way as equation (A3.2.5): it dictates that estimates of the output gap are, in part, determined by deviations of the unemployment rate from the NAIRU.

The empirical implementation of the filter requires data on just three observable variables: real GDP growth, consumer price index inflation, and the unemployment rate. Annual data are used for these variables for the 16 countries considered. Parameter values and

[31]The degree to which inflation outcomes influence estimates of the output gap in a given country depends on the estimated strength of the relationship between the two (β) and the persistence of any deviation of inflation from target (since a short-lived deviation of inflation from target tends, all else equal, to be interpreted by the filter as an inflation shock rather than being associated with an output gap). Recent evidence (see Chapter 3 in the April 2013 WEO) suggests that there has been considerable flattening in the Phillips curve during the past several decades, but that much of this flattening took place before the start of the sample period, which begins in 1996.

the standard errors for the variances of shock terms for these equations are estimated using Bayesian estimation techniques.[32]

Data on growth and inflation expectations are added to the model's core structure, in part to help identify shocks during the sample period, but mainly to improve the accuracy of estimates at the end of the sample period:

$$\pi^C_{t+j} = \pi_{t+j} + \varepsilon^{\pi^C}_{t+j},\ j = 0, 1, \qquad \text{(A3.2.10)}$$

$$GROWTH^C_{t+j} = GROWTH_{t+j} + \varepsilon^{GROWTH^C}_{t+j}, \quad j = 0, \ldots, 5, \qquad \text{(A3.2.11)}$$

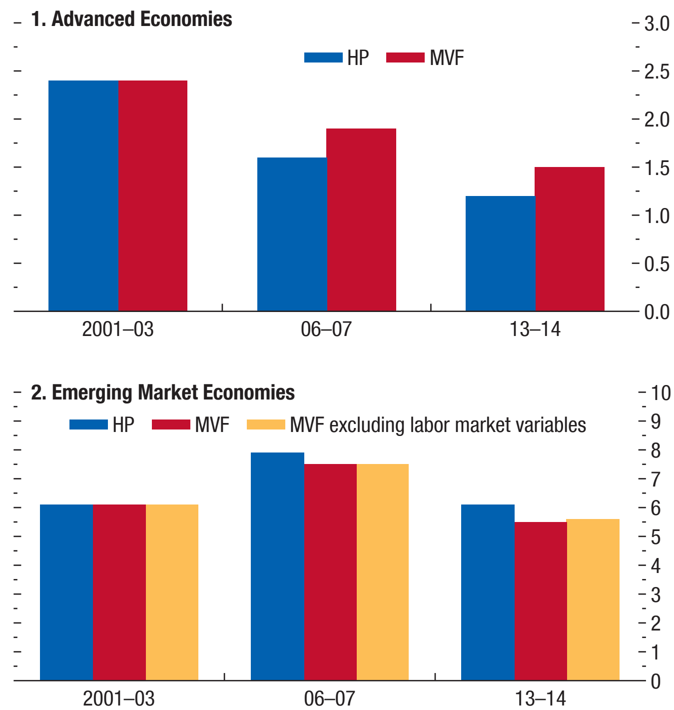
in which π^C_{t+j} and $GROWTH^C_{t+j}$ are Consensus Economics forecasts of inflation and GDP growth, respectively. The addition of these equations imparts some additional stability to the filter's model-consistent growth and inflation expectations estimates. In particular, the inclusion of the $\varepsilon^{\pi^C}_{t+j}$ and $\varepsilon^{GROWTH^C}_{t+j}$ terms allows Consensus Economics forecasts to influence, but not override, the model's own expectations process (which is dictated by the model's estimates of slack in the economy) when potential output is being estimated.

Alternative Approaches

Estimates of potential output are inherently uncertain—because this variable is not observable—and may vary across different estimation methodologies. To illustrate the possible sensitivity of estimates of potential output to different statistical techniques, this section compares the baseline results with those obtained using (1) the Hodrick-Prescott statistical filter, and (2) for emerging market economies, a modified version of the multivariate filter excluding the Okun's (1970) law relationship (that is, equations A3.2.6–A3.2.9). This second alternative approach seeks to reduce possible measurement errors stemming from limited unemployment data quality.

The results in Annex Figure 3.2.1 suggest that these alternative methodologies produce qualitatively similar findings to those presented in the chapter text. In particular, in advanced economies, the decline in potential growth started in the early 2000s and was worsened by the global financial crisis. In emerging market economies, in contrast, it began only after the crisis.

Annex Figure 3.2.1. Potential Output Growth
(Percent)



Source: IMF staff estimates.
Note: Economy groups are defined in Annex 3.1. HP = Hodrick-Prescott filter with smoothing parameter equal to 6.25; MVF = multivariate filter.

Annex 3.3. Estimating Trend Labor Force Participation Rates

This annex describes the methodology used to estimate trend labor force participation rates for the 16 advanced and emerging market economies considered in the chapter (see Annex 3.1) from 1980 to 2013. The methodology relies on a cohort-based model—as, for example, in Aaronson and others 2014 and Balleer, Gomez-Salvador, and Turunen 2014—to decompose the aggregate participation rate into the participation rates of disaggregated age-gender groups and estimate their determinants.

Model

For each age group *a*, gender *g*, in year *t*, the time series of group-wise labor force participation rates

[32]See Hamilton 1994 for a general discussion of the Kalman filter, which is used to obtain estimates of the unobservable variables as part of the estimation process. Estimates for each country are available in Blagrave and others 2015.

(in logs) is estimated according to the following specification:[33]

$$\log LFP_{a,g,t} = \alpha_{a,g} + \frac{1}{n_a} \sum_{b=1920}^{1988} \beta_{b,g}\, I_{a,t}(t - a = b)$$

$$+ \sum_{l=0}^{2} \gamma^{l}_{a,g} cycle_{t-l} + \lambda_{a,g} X_{a,g,t} + \varepsilon_{a,g,t}. \quad \text{(A3.3.1)}$$

This specification is estimated separately for each country. Group-specific labor force participation rates have four main categories of determinants:

- An *age-gender-specific intercept* captures the average labor force participation rate for each age group to reflect the life cycle (bell-shaped) pattern of labor supply: low for youth, increasing and flattening during prime age, and decreasing as retirement age approaches. This life cycle pattern can differ for men and women.
- Slowly evolving cultural and behavioral changes can shift the whole life cycle participation profile up or down, depending on the birth year of an entire cohort. Such *unobservable cohort effects* have been widely documented for women born during the baby boom years in the United States (for example, Aaronson and others 2014), and similar evolutions are taking place in many European and Asian countries. These cohort effects are captured by a fixed effect (I) for each birth year b (depending on data availability for a particular country; the analysis accounts for cohorts born between 1920 and 1988). To obtain the average cohort effect for a given age group, the cohort coefficient is divided by the number of cohorts included in an age group n_a.
- The *business cycle* can have a different effect on the participation decisions of different age-gender groups. For example, the labor supply of young people is often more sensitive to cyclical conditions than is that of mature prime-age workers. The coefficient γ captures the cyclical sensitivity of each group's labor force participation rate while allowing for a partially delayed response of participation rates to cyclical conditions, consistent with existing evidence (see, for example, Balakrishnan and others 2015). The cyclical position is proxied by the employment gap (that is, the deviation of current employment from its trend).
- The model includes *structural factors* that can have an impact on the trend labor force participation rate of particular age groups (vector X). For young people, the participation decision depends on education enrollment status. For women, the participation decision is positively related to educational attainment and, during early prime working age, negatively correlated with fertility and marriage status. For workers close to statutory retirement age, increasing life expectancy is expected to lead to higher participation rates.

Data and Estimation

For advanced economies, the sample consists of 11 age groups (with four-year intervals), separated by gender, from 1980 to 2013; hence there are 11 equations that are jointly estimated for each gender using cross-equation equality restrictions on the cohort coefficients. For emerging market economies, data availability is reduced by both age group granularity (only five age groups for each gender) and period coverage (1990–2013).

Not all cohorts are observed for the same number of years, and in fact, no cohort is observed for the whole life cycle. In particular, cohorts born after 1990 entered the labor force only during or after the global financial crisis, making it hard to distinguish the negative effect of the crisis (beyond the average cyclical impact) from any potential cohort-specific trends. To mitigate this end-point problem (and a similar starting-point problem for the oldest cohorts), no cohort effect is estimated beyond 1988 or before 1920. An alternative version of the model is also estimated that allows the cohort effect of those born after 1988 and before 1920 to equal the average of that for the adjacent five cohorts. The results are robust to this alternative specification.

The effects of the other structural determinants for women, young people, and workers older than 54 are explicitly estimated for advanced economies for which such data are available. It is well documented that the labor force participation rate for prime-age men in advanced economies has been trending down for the past several decades (see, for example, Aaronson and others 2014 and Balleer, Gomez-Salvador, and Turunen 2014), but there is no clear explanation regarding the factors behind this decline. This trend is captured by allowing for linear and quadratic deterministic trends in the labor force participation rate

[33]The model is estimated in logs to ensure that the level labor force participation rate is bounded between zero and one.

equation for prime-age men. For emerging market economies, because of data restrictions, the group trends are obtained by estimating a linear and quadratic trend separately for each group.

The analysis then evaluates each age-gender group's labor force participation rate at the predicted trend rate with a zero cyclical gap and then weights each group by its respective population share to obtain the aggregate trend rate in each year. For the medium-term projection, existing cohorts are allowed to transition through the age distribution according to the estimated cohort age profile, with the assumption that entering cohorts do not experience any systematic shifts in their lifetime participation profiles relative to the last estimated cohort. Future values for structural variables in X are obtained by using life expectancy, fertility, and population projections from the UN Population and Development Database (medium-fertility scenario), linearly extrapolating the educational attainment variables, and keeping all other deterministic trends flat at the last observed level.

Finally, these estimates are then combined with data on demographic distributions to compute the aggregate trend labor force participation rate (Annex Figure 3.3.1).

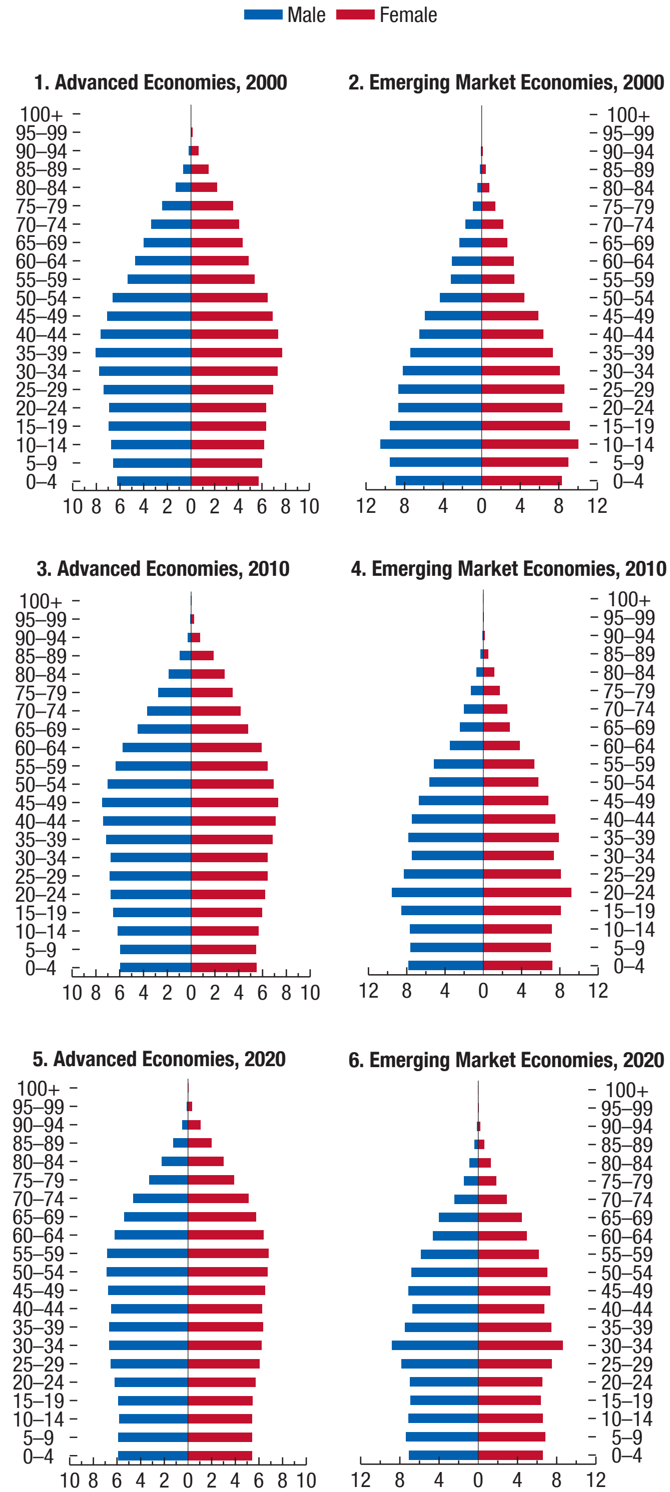
Annex 3.4. Potential Output in the Aftermath of the Global Financial Crisis

The analysis presented in the chapter text shows that potential growth has declined in both advanced and emerging market economies in the aftermath of the global financial crisis. The factors behind this decline are a reduction in capital growth and demographic trends in advanced economies and lower total factor productivity growth in emerging market economies. This annex tries to identify the effect of the crisis on the level and the growth rate of potential output using an econometric framework that controls for precrisis trends, common factors affecting the evolution of potential output in the aftermath of the crisis, and lagged potential output growth.[34]

The analysis follows the approach proposed by Jordà (2005) and expanded by Teulings and Zubanov (2014) by tracing out potential output's evolution in the aftermath of the crisis (identified with a dummy

[34]Although including lagged potential output helps control for various country-specific factors that influence potential output in the near term—since determinants affecting potential output are typically serially correlated—the methodology is not able to control for medium-term country-specific factors.

Annex Figure 3.3.1. Population Share Distributions by Age
(Percent)



Sources: United Nations, *World Population Prospects: The 2012 Revision*; and IMF staff calculations.
Note: Economy groups are defined in Annex 3.1.

that takes the value of 1 for 2008 and 0 otherwise). This approach has been advocated by Stock and Watson (2007) and Auerbach and Gorodnichenko (2013), among others, as a flexible alternative that does not impose dynamic restrictions embedded in vector autoregression (autoregressive distributed lag) specifications.

Specifically, the method consists of estimating separate regressions for potential output at different horizons. More formally, the following econometric specification is estimated:

$$
\begin{aligned}
y_{i,t+k} - y_{i,t-1} = {} & \alpha_i^k + \gamma_t^k + \Sigma_{j=1}^{l}\ \delta_j^k \Delta y_{i,t-j} \\
& + \beta_k D_t + \Sigma_{j=1}^{l}\ \theta_j^k D_{t-j} \\
& + \Sigma_{j=0}^{k-1}\ \rho_j^k D_{t+k-j} + \varepsilon_{i,t+k}^k, \qquad \text{(A3.4.1)}
\end{aligned}
$$

in which the i subscripts index countries, the t subscripts index time, and k denotes the horizon (years after time t) being considered; y denotes the (log) level of potential output; D is a crisis dummy that takes the value of 1 for 2008 and 0 otherwise; and α_i and γ_t are country and time dummies, respectively.[35] As suggested by Teulings and Zubanov (2014), the specification includes the forward leads of the crisis dummy between time 0 and the end of the forecast horizon to correct the impulse response bias inherent in local projection methods. The effects of the crisis on potential output growth are estimated by expressing the left side of equation (A3.4.1) in first differences $(y_{i,t+k} - y_{i,t+k-1})$.

The model is estimated for each k. Impulse response functions are computed using the estimated coefficients β_k. The confidence bands associated with the estimated impulse response functions are obtained using the estimated standard deviations of the coefficients β_k. The lag length (l) for potential output and the crisis variable is determined to be equal to two years using standard selection criteria. Equation (A3.4.1) is estimated using heteroscedasticity- and autocorrelation-robust standard errors. A possible concern in the estimation of equation (A3.4.1) is reverse causality, because changes in potential output may affect the probability of occurrence of the global financial crisis. However, this empirical strategy partly addresses this concern by estimating changes in potential output in the aftermath of the crisis. Moreover, robustness checks for reverse causality confirm the validity of the results.[36]

Advanced Economies

The econometric estimates suggest that the global financial crisis was associated with a reduction in potential output in advanced economies of about 6½ percent, on average (Annex Figure 3.4.1, panel 1). The reduction in the euro area economies was about 7¾ percent, that in the United States about 7 percent, and that in the other advanced economies about 5½ percent, although these differences from the average are not statistically significant. These findings are consistent with those of previous studies on the global financial crisis (for example, Ball 2014). In addition, the results suggest that six years after the crisis, about 60 percent of the cumulative loss of actual output in advanced economies, on average, can be attributed to a decline in potential output—this share holds for most of the economies in the group—while the remaining part can be imputed to the cumulative loss in output gaps. In particular, by 2014, output gaps remain negative for most advanced economies.[37]

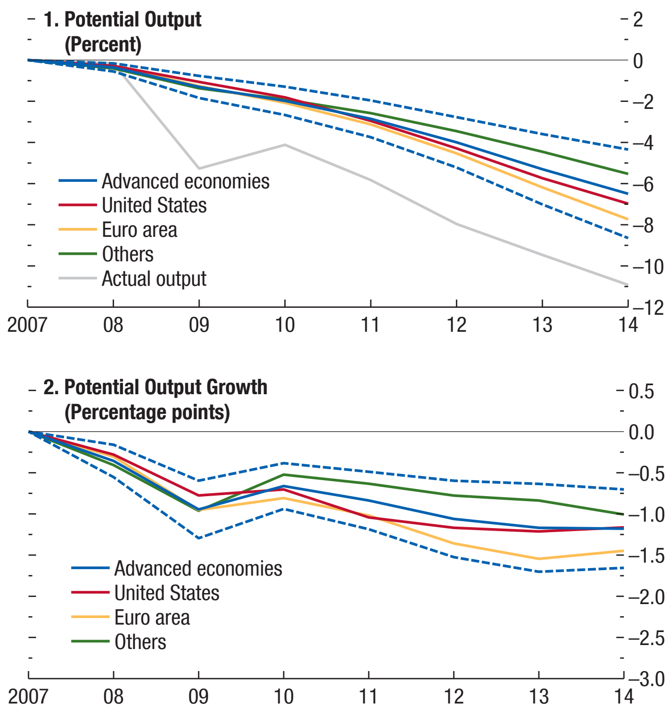
The persistent and increasing decline in the level of potential output also implies a reduction in its growth rate, of about 1.2 percentage points, on average (Annex Figure 3.4.1, panel 2). The differences in the loss of potential growth within the group mirror those for the level of potential output: for euro area economies, potential growth dropped by about 1.4 percentage points, that for the United States by about 1.2 percentage points, and that for the other advanced economies by about 1 percentage point, and again the differences are not statistically significant. These estimates are lower than those presented in the chapter text, as they capture the reduction in potential growth compared with precrisis averages rather than deviations from the 2006–07 period, when potential growth was already declining.

[35]The year dummy for 2008 is not included as a control.

[36]Empirical tests suggest that the probability of the occurrence of the global financial crisis is not affected by past evolution of potential output. Similar results are also obtained using a two-step generalized-method-of-moments system estimator.

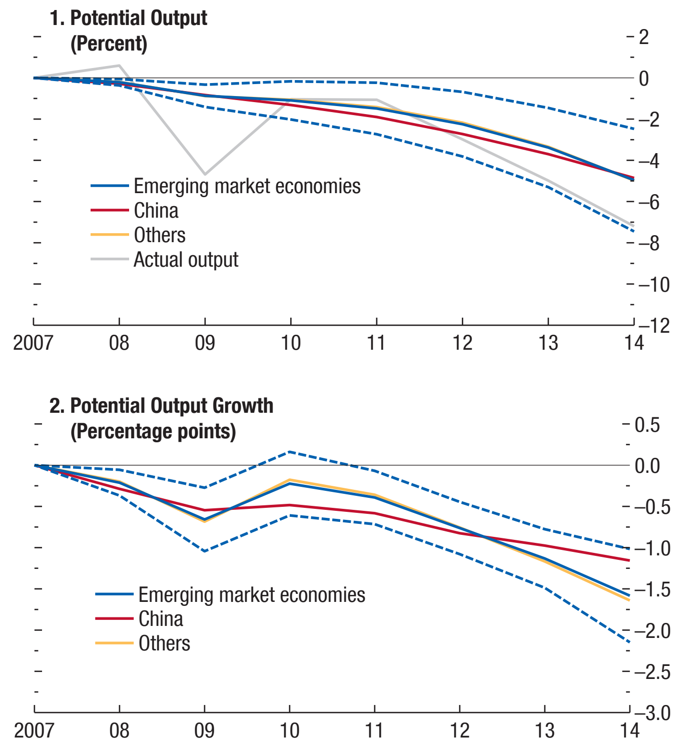
[37]The average output gap for the sample of advanced economies in 2014 is about –1.8 percent.

Annex Figure 3.4.1. Aftermath of the Global Financial Crisis in Advanced Economies



Source: IMF staff estimates.
Note: Dashed lines denote 90 percent confidence bands. Advanced economies are defined in Annex 3.1.

Annex Figure 3.4.2. Aftermath of the Global Financial Crisis in Emerging Market Economies



Source: IMF staff estimates.
Note: Dashed lines denote 90 percent confidence bands. Emerging market economies are defined in Annex 3.1.

Emerging Market Economies

Results suggest that the global financial crisis was associated with a reduction in potential output in emerging market economies of about 5 percent, on average (Annex Figure 3.4.2, panel 1). As was observed for advanced economies, the results also suggest that much (about 70 percent) of the cumulative loss of actual output across emerging market economies can be attributed to a decline in potential output, with only small differences among these economies, while the remaining part can be imputed to the cumulative loss in output gaps. In particular, by 2014, output gaps remain slightly negative for most emerging market economies.[38]

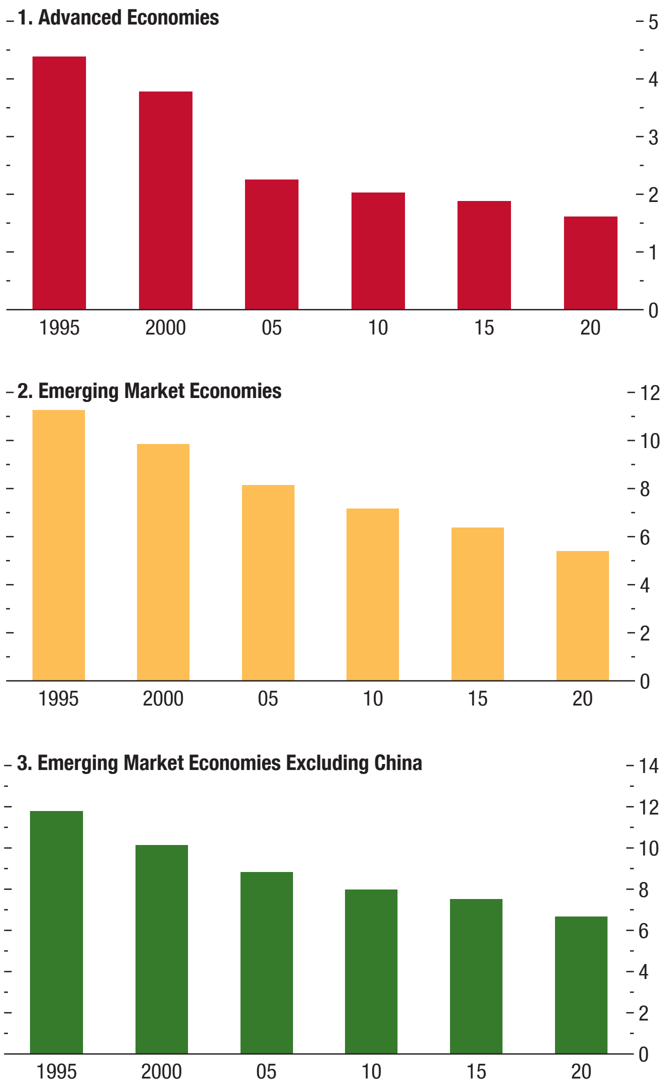
The crisis was also associated with a reduction in potential growth of about 1.6 percentage points (Annex Figure 3.4.2, panel 2), with a smaller decline for China (1.2 percentage points) than for other emerging market economies (1.6 percentage points). Although these results are similar to those presented in the chapter text, the econometric estimates presented here identify deviations from precrisis averages, whereas the analysis presented in the chapter is based on deviations of potential growth from the record-high growth rates in 2006 and 2007.

[38]The average output gap for the sample of emerging market economies is about –0.7 percent.

Annex 3.5. Human Capital Growth Projections

Human capital growth assumptions are based on the educational attainment projections using a cohort model by KC and others (2010). These projections are based on estimates of fertility and mortality rates and net migration flows, as well as education transition dynamics by five-year age groups. This last variable is projected on the assumption that the country's future educational attainment expands based on global historical trends.

Annex Figure 3.5.1. Human Capital Growth Projections
(Percent)



Sources: KC and others 2010; and IMF staff estimates.
Note: Human capital is measured as the percentage of people in the population over 15 years old who have secondary education or higher. Economy groups are defined in Annex 3.1.

Based on these assumptions, human capital growth is expected to decline in the medium term in both advanced and emerging market economies (Annex Figure 3.5.1). In particular, in advanced economies human capital growth is projected to decline by about ¼ percentage point by 2020. The projected decline is larger in emerging market economies, from about 6½ percent in 2015 to about 5½ percent in 2020.

Box 3.1. Steady As She Goes: Estimating Sustainable Output

Sustainable output is a theoretical benchmark intended to estimate an economy's position in the absence of imbalances. Defined in this way, it seeks to identify financial or other macroeconomic imbalances and thereby signal the risk of a future disorderly adjustment. Recent examples of such imbalances are the credit and house price booms experienced by some of Europe's crisis-hit economies. With the introduction of the euro, investor risk appetite rose and risk premiums fell, boosting credit, house prices, and growth. In hindsight it seems clear that GDP growth rates were above their sustainable levels and a correction was likely. The opposite held when the boom went bust during the Great Recession.

Assessing sustainable output is crucial for policymakers. From a fiscal sustainability point of view, a reliable estimate of sustainable fiscal positions that are not perturbed by large shocks such as financial booms and busts will help prevent debt bias. For example, if the revenue flows linked to a booming housing sector can be correctly identified in real time as temporary, government spending is less likely to be adjusted upward, and fiscal buffers can be built. In addition, a robust measure of sustainable output will also make it easier to assess the impact of structural reform on medium- and long-term growth. Policymakers aiming to avoid sudden ups and downs of the economy—and the accompanying periods of high unemployment—might draw on sustainable output as another indicator to signal the need for stabilization through fiscal or monetary policy.

In this context, a measure of sustainable output incorporating financial variables may be particularly useful in formulating macroprudential policy. For instance, if taking into account financial variables would lead policymakers to believe that credit and house price growth was associated with a higher degree of overheating than suggested by conventional measures based on consumer price inflation, monetary policy might not be the most effective instrument to address the boom. Although higher interest rates can help, they can also be harmful for the rest of the economy. In such a case, more stringent macroprudential policy measures might be even more useful and should, therefore, be launched first.[1]

A multivariate filter augmented with financial variables may help identify episodes of particularly high or low GDP growth that are unlikely to last. Whereas conventional measures rely solely on the relationship between output and prices, these approaches add financial (and other) variables—in the model used here, the deviations of credit, house prices, and inflation from their own longer-term trends. The approach lets the data speak. If wide swings in output tend to occur along with wide swings in credit (or another variable), the filter's estimates of sustainable output will ignore the former when determining the finance-neutral sustainable output. However, if credit provides little additional information, the model will produce results in line with conventional approaches.

For multivariate filter models augmented with financial variables to work and reduce the risk of misinterpreting permanent shifts as temporary, it is important to exclude credit expansions associated with sound economic fundamentals (for example, a higher level of credit growth due to financial deepening). The admittedly crude approach taken here is to restrict the information from financial variables to business cycle and higher frequencies.[2] Another challenge with such approaches is properly identifying episodes of unsustainable growth in real time. At the beginning of a credit expansion, it is extremely difficult for policymakers to diagnose whether the episode is associated with sound economic fundamentals or will develop into an unsustainable boom. In practice, while this methodology is capable of signaling possible risks of future disorderly adjustments, it is best used as a "fire alarm": when the finance-neutral gap deviates from a conventional output gap, policymakers should scrutinize the underlying reasons to reach a more conclusive diagnosis.

The results of analysis employing the multivariate filter augmented with financial variables suggest that conventional estimates may overestimate sustainable output during credit and housing booms and underestimate it during busts. For example, in the case of some euro area economies with high borrowing spreads during the 2010–11 sovereign debt crisis (notably Greece, Ireland, and Spain), the difference between actual and sustainable output when credit dynamics are taken into account—the finance-neutral output gap—tends to be higher (lower) than the output gap derived from the relationship of inflation and

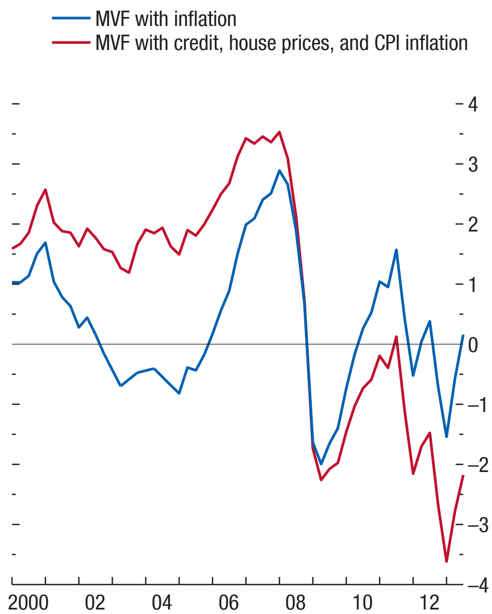
The authors of this box are Helge Berger, Mico Mrkaic, Pau Rabanal, and Marzie Taheri Sanjani. The analysis presented here draws on Berger and others, forthcoming.

[1]See, for example, Benes, Kumhof, and Laxton 2014, which assesses vulnerabilities associated with excessive credit expansions and asset price bubbles and the consequences of various macroprudential policies. Quint and Rabanal (2014) study the role of country-specific macroprudential policies in a currency union.

[2]The approach is close to that of Borio, Disyatat, and Juselius (2013) but differs in its estimation approach and the treatment of longer-term trends. See Berger and others, forthcoming, for details.

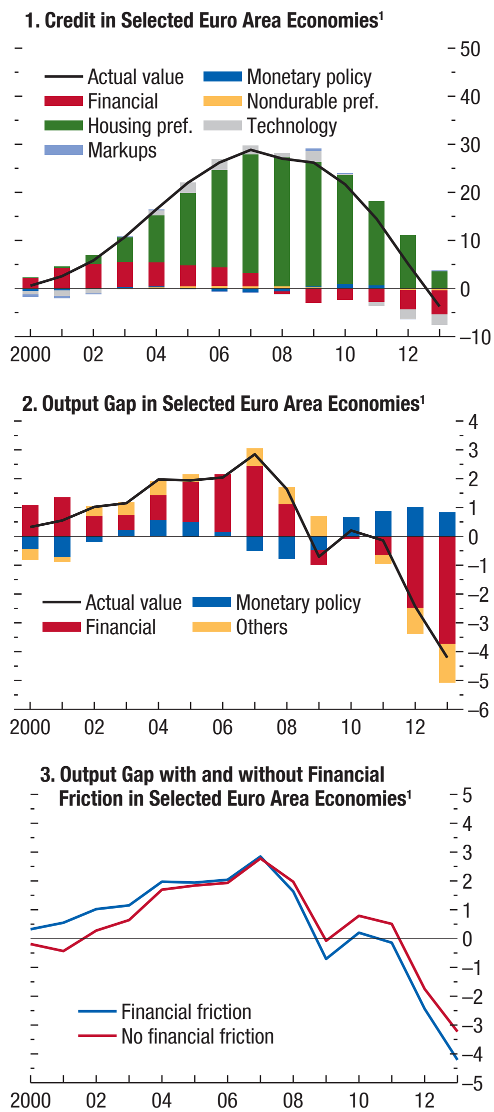
Box 3.1 *(continued)*

Figure 3.1.1. Output Gap in Selected Euro Area Economies:[1] Multivariate Filter Augmented with Financial Variables versus That with Inflation Only
(Percent)



Source: IMF staff estimates.
Note: CPI = consumer price index; MVF = multivariate filter.
[1]Euro area economies (Greece, Ireland, Italy, Portugal, Spain) with high borrowing spreads during the 2010–11 sovereign debt crisis.

Figure 3.1.2. Credit and Output Gaps Implied by the Dynamic Stochastic General Equilibrium Model
(Percent deviation from potential, unless noted otherwise)



Source: IMF staff estimates.
Note: Credit is in percent deviation from trend. In panel 2, "Others" includes nondurable preference, housing preference, technology, and markups. Pref. = preference.
[1]Euro area economies (Greece, Ireland, Italy, Portugal, Spain) with high borrowing spreads during the 2010–11 sovereign debt crisis.

output alone during episodes of high (low) credit growth (Figure 3.1.1).

A two-region dynamic stochastic general equilibrium model with financial frictions at the household level and housing can be used to further assess the findings of the augmented multivariate filter for the euro area.[3] The model incorporates an explicit role for leverage and credit risk. In this setting, it is possible to distinguish sustainable changes in output linked to a reduction in financial friction from credit-fueled growth. Seen through the lens of the model, the introduction of the euro led to a persistent decline in risk premiums, reduced financial friction, and lifted

[3]See Rabanal and Taheri Sanjani, forthcoming, for details. The work builds on Furlanetto, Gelain, and Taheri Sanjani 2014 and Quint and Rabanal 2014.

Box 3.1 *(continued)*

both GDP and sustainable output in the euro area economies with high borrowing spreads during the 2010–11 sovereign debt crisis (Figure 3.1.2). However, by the mid-2000s, a housing and credit boom had taken hold in some euro area economies with high borrowing spreads during the 2010–11 sovereign debt crisis (notably Greece, Ireland, and Spain) that let actual GDP rise significantly above sustainable output. The crisis reversed most of this expansion after 2007, leading to an increase in country and housing risk premiums, a credit bust, and a large output contraction.

Overall, the evidence discussed here suggests that financial variables can inform estimates of sustainable output—but more work is needed. The augmented multivariate filter approach lets the data speak but still requires numerous practical decisions that affect findings and deserve further scrutiny. Real-time identification of sustainable output also remains a challenge. Although dynamic stochastic general equilibrium models may help identify the drivers of sustainable and potential output in a coherent way, their underlying structural assumptions also affect the results. Finally, more work is needed to link augmented multivariate filter estimates of sustainable output more rigorously to the flexible-price concept of potential output used in dynamic stochastic general equilibrium models.

Box 3.2. U.S. Total Factor Productivity Spillovers

The growth in total factor productivity in the United States—whose technological development is commonly regarded as representing the world frontier—started to decline in 2003 as the exceptional growth effects of information and communications technology as a general-purpose technology observed in the late 1990s to the early 2000s began to wane (Fernald 2014a). Did the decline in U.S. total factor productivity spill over to other advanced economies? To answer this question, this box uses a novel approach to compute total factor productivity and takes an empirical look at spillovers from the United States to other advanced economies.

Measuring total factor productivity growth is challenging. Typical measures of such growth are commonly estimated using the so-called Solow residual, or the part of actual output growth that is not accounted for by growth in factor inputs such as labor and capital. Unfortunately, these residual-based measures tend to include unobserved input utilization, which is highly procyclical. As a result, spillover analysis based on the Solow residual measure is likely to capture business cycle comovements rather than true total factor productivity spillovers. In the analysis presented in this box, a refined measure of total factor productivity is constructed using the procedure proposed by Basu, Fernald, and Kimball (2006) and Fernald (2014a, 2014b) to control for unobserved utilization in capital and labor.[1] Adjusted total factor productivity series are constructed using industry-level data for an unbalanced panel of 16 advanced economies, for the period 1970–2007.[2]

In particular, the following production function is estimated for each industry i for each country:

$$dy_{i,t} = \gamma_i\, dx_{i,t} + \beta_j\, du_{i,t} + dtfp_{i,t}, \qquad (3.2.1)$$

in which dy is output growth; dx is growth in observed input, defined as a linear combination of growth in capital, labor, and material input; du is growth in unobserved inputs measured by hours worked; and $dtfp$ is total factor productivity growth.[3]

The aggregate total factor productivity measure is then computed as the difference between the aggregate Solow residual and the aggregate utilization measure:[4]

$$dtfp = dtfp_{solow} - du. \qquad (3.2.2)$$

As discussed in Basu, Fernald, and Kimball 2006, adjusted total factor productivity has three noteworthy features compared with the simple Solow residual: (1) there is limited contemporaneous comovement between output and adjusted total factor productivity growth, (2) hours worked is more negatively correlated with adjusted total factor productivity, and (3) the estimated factor utilization is negatively correlated with adjusted total factor productivity (Table 3.2.1).

Two econometric specifications are used to assess total factor productivity spillovers. The first establishes whether total factor productivity shocks in the United States materially affect total factor productivity in other advanced economies and is estimated as follows:

$$tfp_{i,t+k} - tfp_{i,t-1}$$
$$= \alpha_i + \beta_k dtfp_{US,t} + \delta(L) dtfp_{it} + \varepsilon_{it}, \quad (3.2.3)$$

Table 3.2.1. Properties of Adjusted Total Factor Productivity Compared with Solow Residual, Advanced Economies, 1970–2007

	Solow Residual	Utilization-Adjusted TFP
Correlation with Output Growth	0.70	0.34
Correlation with Hours Worked	–0.07	–0.15
Correlation with Factor Utilization	0.13	–0.39

Source: IMF staff estimates.
Note: TFP = total factor productivity.

The authors of this box are Davide Furceri, Sinem Kilic Celik, and Annika Schnücker.

[1]Basu, Fernald, and Kimball (2006) show that unobserved input utilization (labor effort and workweek of capital) can be proxied by observed input utilization (hours per worker).

[2]The included countries are Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Poland, Portugal, Spain, the United Kingdom, and the United States for an unbalanced period between 1970 and 2007. Data availability limitations preclude the analysis for recent years. The data sources are EU KLEMS and World KLEMS.

[3]Specifically, growth in observed input is computed as $dx_{i,t} = s_{Li}dl_i + s_{Ki}dk_i + s_{Mi}dm_i$, in which dl, dk, and dm are growth in employment, capital, and material input, respectively, and s_A is the ratio of payments to input A in total cost.

The industries are grouped into three main sectors: nondurable manufacturing, durable manufacturing, and nonmanufacturing.

[4]The aggregate Solow residual and input utilization are computed as $dtfp_{solow} = \Sigma_i \frac{w_i}{(1 - sm_i)}(dy_i - dx_i)$ and $du = \Sigma_i \frac{w_i}{(1 - sm_i)} \gamma_i dtfp_i$, in which w_i is the value-added share of each industry in aggregate output.

Box 3.2 *(continued)*

in which *tfp* is the log of adjusted total factor productivity, α_i are country fixed effects, and *dtfp* is the growth rate of adjusted total factor productivity. The coefficient β_k measures the spillover effect of a 1 percent change in the U.S. adjusted total factor productivity growth.

The second specification assesses the transmission channels of spillovers by allowing the response to vary with country-specific characteristics and the strength of trade linkages between each country and the United States and is estimated as follows:

$$tfp_{i,t+k} - tfp_{i,t-1} = \alpha_i + \gamma_t + \beta_k\, dtfp_{\mathrm{US},t}\, \bar{X}_{i\text{–US}} + \delta(L) dtfp_{it} + \varepsilon_{it}, \qquad (3.2.4)$$

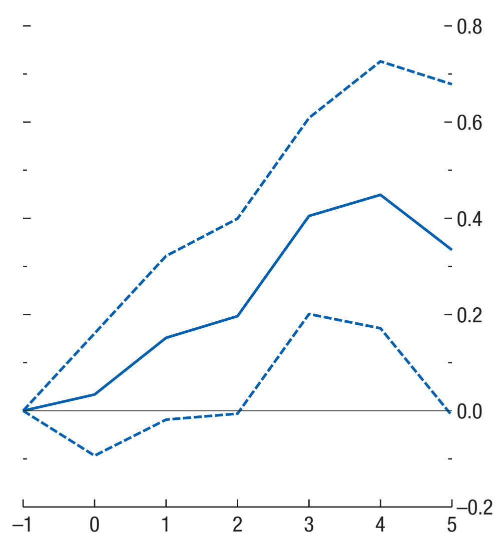
in which γ_t are time fixed effects; $\bar{X}_{i\text{–US}}$ are country-specific characteristics including the country's relative distance from the technological frontier—defined as the gap between its total factor productivity and that of the United States—and its trade and financial openness vis-à-vis the United States.[5]

The results suggest that changes in U.S. total factor productivity growth tend to spill over to other advanced economies. In particular, the econometric estimates imply that a 1 percent change in (shock to) U.S. total factor productivity growth leads to a 0.4 percentage point increase in total factor productivity growth in other advanced economies in the medium term (Figure 3.2.1), with the effect reaching a peak four years after the shock.[6]

The results also suggest that total factor productivity spillovers are larger in countries with higher foreign direct investment (FDI) inflows from the United States and in countries that are technologically more removed from the United States (Table 3.2.2).[7] In particular, the increase in total factor productivity growth in a country that is relatively strongly linked with the United States as measured by FDI flows (at the 75th percentile) is about 0.09–0.14 percentage point higher than in a country that has relatively low linkages (at the 25th percentile). The differential spillover effect on a country that is technologically more distant from the United States (at the 75th percentile) compared with a country that is less distant (at the 25th percentile) is about 0.13 percentage point. Other variables, such as trade openness, human capital accumulation, the stock of FDI, and research and development spending as a share of GDP, are found not to have statistically significant effects.

Figure 3.2.1. U.S. Total Factor Productivity Spillovers to Other Advanced Economies

(Percentage points; years on x-axis)



Source: IMF staff estimates.
Note: $t = 0$ is the year of the shock. Dashed lines denote 90 percent confidence intervals. Impulse response functions are estimated using local projection and bias correction following Teulings and Zubanov 2014 with an unbalanced sample between 1970 and 2007.

[5]These variables have been typically found in the literature to be key transmission channels (for example, Coe and Helpman 1995; Coe, Helpman, and Hoffmaister 2009; Rondeau and Pommier 2012).

[6]As a robustness check, and to disentangle the spillover effects from U.S. total factor productivity growth from those associated with global factors affecting world total factor productivity growth, the average world (excluding the United States) total factor productivity was included in the analysis. The results, not reported here, are qualitatively similar and not statistically different from those shown in Figure 3.2.1.

[7]Openness is measured by FDI (FDI inflows received by a country from the United States as a share of total FDI outflows from the United States) and distance from the technological frontier by its total factor productivity gap with respect to the United States ($(dtfp_{i,t} - dtfp_{\mathrm{US},t})/dtfp_{\mathrm{US},t}$).

Box 3.2 *(continued)*

Table 3.2.2. Transmission Channels

Linkages	(1)	(2)	(3)
FDI to the United States	0.02***		0.03***
	(3.18)		(3.29)
TFP Gap with Respect to the United States		0.01*	0.01***
		(1.92)	(4.04)
R^2	0.18	0.19	0.19
Number of Observations	365	365	365
FDI—Differential in TFP (percentage points)	0.09		0.14
TFP Gap—Differential in TFP (percentage points)		0.13	0.13

Source: IMF staff estimates.

Note: *t*-statistics are in parentheses. Standard errors are robust for heteroscedasticity and serial correlation within panels. All regressions include country and time fixed effects. The differential in TFP (in percentage points) measures the TFP effect of the shock in a country at the 75th percentile level of the variable examined compared with a country at the 25th percentile level. FDI = foreign direct investment; TFP = total factor productivity.

*$p < .10$; ***$p < .01$.

Box 3.3. Total Factor Productivity Growth in Advanced Economies: A Look into Sectoral Patterns

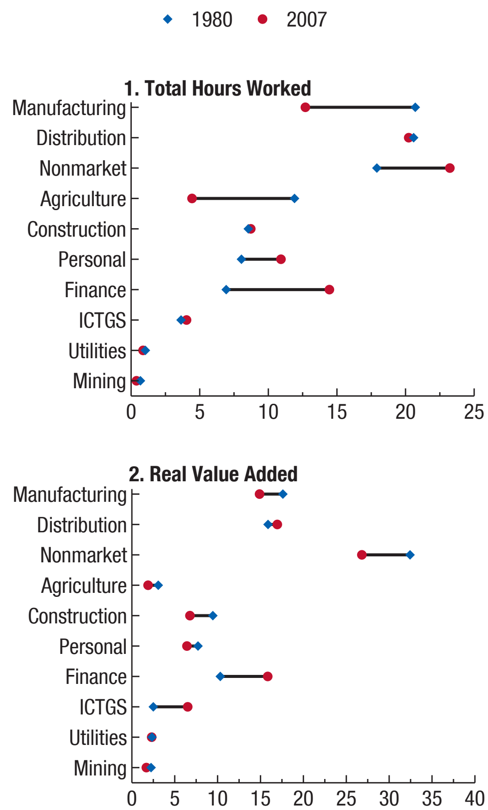
Patterns of total factor productivity growth at the aggregate (economy-wide) level can be indicative of structural changes, a falling pace of sector-specific innovation, and waning impact of past reforms. This box examines sectoral patterns of total factor productivity growth to assess the drivers of aggregate performance in the years leading up to the global financial crisis.

The three decades leading up to the crisis saw the continued reallocation of factors out of agriculture and manufacturing and into services: indeed, by 2007, more than 75 percent of employment (by hours worked) in advanced economies was in services (Figure 3.3.1). This trend reflected technological change within industries, changes in domestic demand, and international trade that drove a process of structural transformation in which labor, capital, and intermediate inputs were reallocated toward services (Herrendorf, Rogerson, and Valentinyi 2013). Labor shares fell in fast-growing sectors such as manufacturing and information and communications technology (ICT) goods and services and rose in slower-growing sectors such as finance, personal services (for example, hotels and restaurants), nonmarket services (for example, government administration, health, and education), and construction. This structural transformation also led to lower economy-wide total factor productivity growth: in many service sectors, productivity growth is much lower than in the rest of the economy because of limited scope for innovation and technical change (Baumol, Blackman, and Wolff 1985) (Figure 3.3.2, panels 1 and 2). Indeed, sectoral reallocation contributed to a decline in economy-wide total factor productivity from about 0.11 during the 1990–2007 period (Figure 3.3.2, panel 3).[1]

During the 1990s and early 2000s, the ICT goods and services sector was a particularly bright spot in an otherwise gloomy landscape of declining total factor productivity growth. Indeed, the explosion in total factor productivity growth in ICT-producing sectors in the United States spilled over into ICT-intensive sectors, fueling greater ICT capital deepening and a rise in total factor productivity in these sectors as well (Fernald 2014a, 2014b). However, by the early to mid-2000s, elevated total factor productivity growth in ICT production appeared to have run its course. Production and capital deepening in the sector declined markedly in the years leading up to the global financial crisis, and total factor productivity growth in ICT-intensive sectors followed suit, albeit with a slight lag (Figure 3.3.3). These dynamics may partly explain the

Figure 3.3.1. Employment and Value Added, 1980–2007

(Percent; PPP weighted)



Sources: EU KLEMS; World KLEMS; and IMF staff calculations.
Note: ICTGS = information and communications technology goods and services; PPP = purchasing power parity.

The authors of this box are Era Dabla-Norris and Kevin Wiseman. The analysis draws from Dabla-Norris and others, forthcoming.

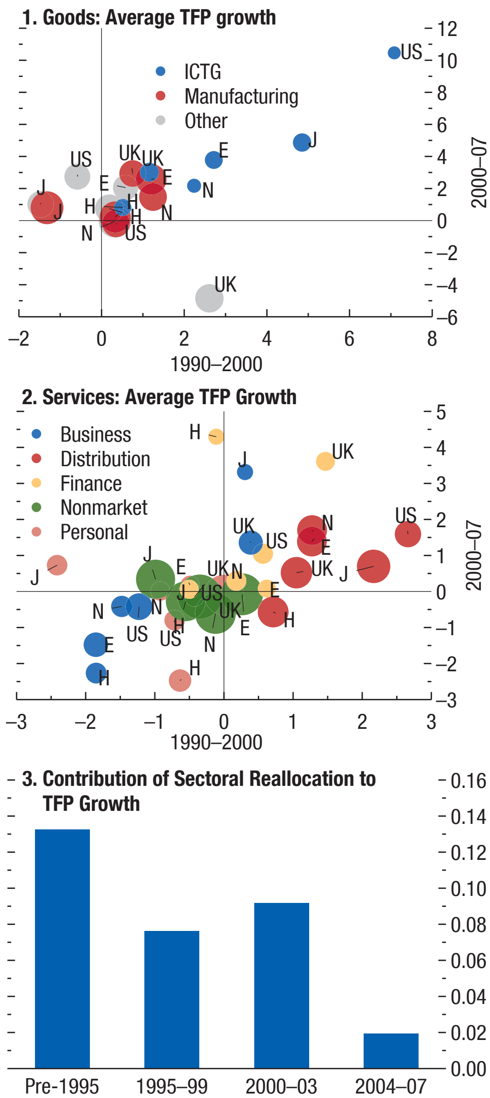
[1]The contribution of sectoral reallocation to total factor productivity is estimated by disaggregating total factor productivity growth into *within* and *between* sectoral total factor productivity changes applying the methodology by McMillan and Rodrik (2011) using the following specification:

$$tfp_t - tfp_{t-1} = \Sigma_i \omega_{i,t-1}(tfp_{i,t} - tfp_{i,t-1}) + \Sigma_i\, tfp_{i,t}\,(\omega_{i,t} - \omega_{i,t-1}),$$

in which tfp and tfp_i refer to economy-wide and sectoral total factor productivity, respectively, and ω_i is the value-added share of sector i in aggregate output. The contribution of sectoral reallocation is then measured by *between* sectoral total factor productivity changes, which correspond to the second term in the equation.

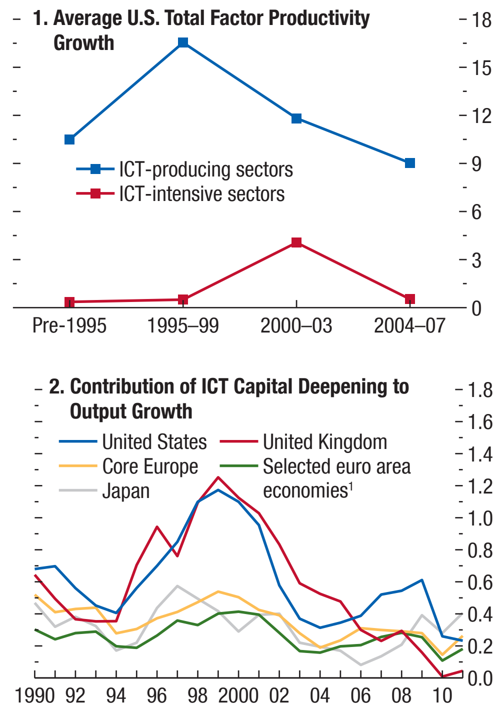
Box 3.3 *(continued)*

Figure 3.3.2. Selected Country Groups: Total Factor Productivity Growth in Goods and Services Sectors
(Percent; PPP weighted)



Sources: EU KLEMS; World KLEMS; Organisation for Economic Co-operation and Development; and IMF staff calculations.
Note: Bubble size denotes sectoral share in value added. In panel 1, "Other" refers to the agricultural, utilities, construction, and mining sectors. E = core Europe; H = euro area economies (Greece, Ireland, Italy, Portugal, Spain) with high borrowing spreads during the 2010–11 sovereign debt crisis; ICTG = information and communications technology goods; J = Japan; N = natural resource producers; PPP = purchasing power parity; TFP = total factor productivity; UK = United Kingdom; US = United States.

Figure 3.3.3. Information and Communications Technology Productivity Growth and Spillovers
(Percent)



Sources: Corrado and others 2012; Fernald 2014a; Research Institute of Economy, Trade and Industry, Japan Industrial Productivity Database; and IMF staff calculations.
Note: ICT = information and communications technology.
[1]Euro area economies (Greece, Ireland, Italy, Portugal, Spain) with high borrowing spreads during the 2010–11 sovereign debt crisis.

estimated slowdown in U.S. total factor productivity growth in the years leading up to the crisis. In other advanced economies, ICT capital deepening played a smaller role, but the dynamics and timing were similar, with a comparable rise through the 1990s giving way to a subsequent slowdown.

Evidence from the distribution sector, which has seen the highest rate of total factor productivity growth within the services sectors, supports this view. Cumulative advances in ICT were diffused through the sector, with the rise of firms such as Walmart and Amazon (Lewis 2005) catalyzing high sectoral

Box 3.3 *(continued)*

productivity growth. Some commentators have noted that these advances had been largely exploited by the precrisis 2000s and that productivity growth in the distribution sector was slowing across advanced economies (Figure 3.3.2, panel 2). The losses in productivity growth were partially offset by gains in "euphoric" sectors such as finance in some economies; the postcrisis durability of these sectors remains to be seen.

Box 3.4. The Effects of Financial Crises on Labor Productivity: The Role of Sectoral Reallocation

Financial crises can affect economy-wide labor productivity in two ways: (1) through their impact on labor productivity within each economic sector and (2) by inducing sectoral reallocations of labor. The effect of financial crises through the second channel (sectoral reallocation) is ambiguous, because labor can be reallocated between various high- and low-productivity sectors, with an unclear net effect on aggregate labor productivity.

This box examines empirically the effect of financial crises on labor productivity, by estimating the role of each of these two transmission channels. Since data availability limitations do not allow an examination of these channels for the global financial crisis, the analysis presented here is based on past financial crises.

The approach used to decompose aggregate productivity into *within*- and *between*-sector productivity effects follows the methodology proposed by McMillan and Rodrik (2011):

$$y_{t+k} - y_{t-1} = \sum_{i=1}^{I} \omega_{i,t-1}(y_{i,t+k} - y_{i,t-1}) + \sum_{i=1}^{I} y_{i,t+k}(\omega_{i,t+k} - \omega_{i,t-1}), \qquad (3.4.1)$$

in which y_t and $y_{i,t}$ refer to economy-wide and sectoral labor productivity levels, respectively, and $\omega_{i,t}$ is the share of employment in sector i. The first term in the decomposition is the weighted sum of productivity growth within each sector, in which the weights are the employment share of each sector at time t. This term captures the *within* component of productivity growth. The second term is the part of labor productivity resulting from the reallocation of resources across different sectors and captures the *between* component of productivity growth.

The analysis follows the approach proposed by Jordà (2005) by tracing the evolution of productivity growth in the aftermath of a financial crisis. It controls for precrisis trends, common factors affecting the evolution of productivity growth in the aftermath of the crisis, and lagged productivity growth. In particular, the following econometric specification is estimated:

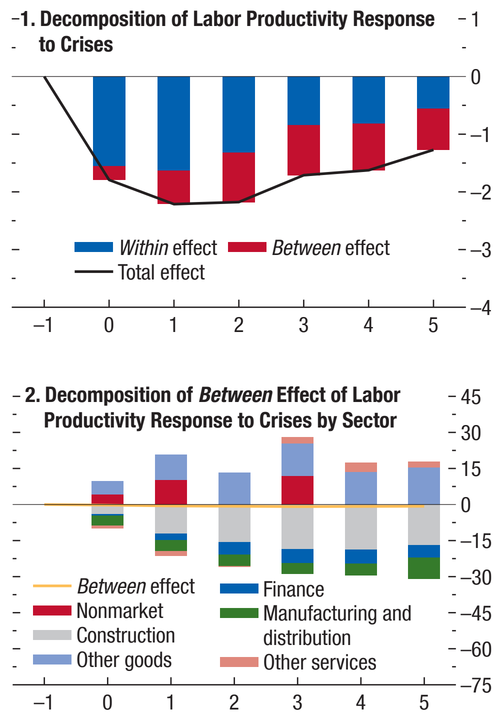
$$x_{i,t+k} - x_{i,t-1} = \alpha_c^k + \gamma_t^k + \sum_{j=1}^{2} \delta_j^k \Delta y_{t-j} + \beta_k D_t + \sum_{j=1}^{2} \theta_j^k D_{t-j} + \sum_{j=0}^{k-1} \rho_j^k D_{t+k-j} + \varepsilon_{i,t+k}^k, \qquad (3.4.2)$$

in which $x_{i,t}$ denotes either the *within* or *between* effect of sectoral productivity growth for sector i at time t; y is economy-wide productivity growth; D is a crisis dummy that takes a value of 1 for crisis years, as identified by Laeven and Valencia (2014); and α_c and γ_t are country and time fixed effects, respectively. The econometric specification also controls for lagged crisis effects and includes the bias correction suggested by Teulings and Zubanov (2014).

Equation (3.4.2) is estimated for eight sectors in 24 advanced economies during 1970–2007 for $k = 0, \ldots 5$. The econometric estimates imply that financial crises typically have a statistically significant negative effect on labor productivity (Figure 3.4.1, panel 1). Specifically, labor productivity is estimated to decline on impact by about 2 percent, on average, and remain about 1½ percent below its precrisis rate five years after the crisis. Sectoral reallocation (the *between*

The author of this box is Juan Yépez Albornoz.

Figure 3.4.1. Response of Labor Productivity to Crises
(Percent; years on x-axis)



Source: IMF staff estimates.
Note: $t = 0$ is the year of the shock.

Box 3.4 *(continued)*

effect) explains roughly half of the medium-term decline in labor productivity. This is because displaced labor in relatively high-productivity sectors—such as manufacturing and finance, and to a lesser extent construction—tends to move to low-productivity sectors—such as personal services and nonmarket services (Figure 3.4.1, panel 2).

These results are consistent with empirical evidence in previous studies (for example, Aaronson, Rissman, and Sullivan 2004) suggesting that finance and manufacturing tend to contract more than other sectors during downturns, while employment in nonmarket services tends to be more resilient to changes in economic activity (for example, Kopelman and Rosen 2014).

Box 3.5. The Effects of Structural Reforms on Total Factor Productivity

This box examines the impact of structural reforms on sectoral total factor productivity. It relies on the conceptual framework of "distance from the technological frontier" (Aghion and Howitt 2006, 2009; Acemoglu, Zilibotti, and Aghion 2006) to assess empirically the relative importance of a range of policy and structural factors across different industries and countries. According to this framework, the set of policies aimed at sustaining productivity growth in different industries and sectors can vary depending on the industry or sector's distance from the technological frontier.

Two econometric specifications are used to assess the effect of structural reforms on total factor productivity. The first establishes whether changes in structural indicators have a material impact on total factor productivity and whether the impact depends on the distance from the technological frontier. This specification controls for country- and industry-specific characteristics and common factors affecting total factor productivity, as well as for the total factor productivity *gap* with respect to the "global frontier"—defined as the highest level of total factor productivity in the particular industry in a given year.[1]

Because policy reforms and structural shocks can result in adjustment costs, particularly in a weak-demand environment, it is useful to assess their productivity impacts *over time*. Consequently, the second specification focuses on assessing the dynamic (short- and medium-term) impact of structural shocks—identified by episodes of large changes in structural indicators—on total factor productivity.[2] The analysis follows the approach proposed by Jordà (2005) by tracing the response of total factor productivity in the aftermath of these reforms. This is done by controlling for precrisis trends as well as for country- and industry-specific characteristics and common factors affecting the evolution of total factor productivity in the aftermath of the reforms.[3] For both specifications, the sample consists of industry-level annual data from EU KLEMS, covering 23 market industries in 11 advanced economies during 1970–2007.

This box examines how institutional and product and labor market regulations affect efficiency and convergence to the frontier,[4] which is important because more stringent regulations could curb total factor productivity growth by hindering efficient reallocation of resources across plants, firms, and industries. The regressions also include other industry-specific factors that drive expansion of the technological frontier and facilitate technology adoption, such as education (share of high-skilled labor in total labor), innovation (research and development [R&D] expenditure as a share of industry value added), and information and communications technology (ICT) use (ICT capital share of total capital), all from the EU KLEMS data set.

Econometric estimates obtained using the first specification suggest that lower product market regulation and more intense use of high-skilled labor and ICT capital

The authors of this box are Minsuk Kim and Aleksandra Zdzienicka. The analysis presented here draws on Dabla-Norris and others, forthcoming.

[1]In particular, the econometric specification is estimated as follows:

$$\Delta y_{ijt} = \beta_0 + \beta_1 \Delta y_{Ljt} + \beta_2 (y_{ijt-1} - y_{Ljt-1}) + \beta_k \textstyle\sum_k X^k_{ijt-1}$$
$$+ \beta_l \textstyle\sum_k X^l_{ijt-1} (y_{ijt-1} - y_{Ljt-1}) + \alpha_1 D_i + \alpha_2 D_j$$
$$+ \alpha_3 D_t + \varepsilon_{ijt},$$

in which subscripts i, j, and t denote country, industry, and year, respectively; subscript L denotes the country with the highest level of total factor productivity in industry j in a given year t (the global frontier); and Δy_{ijt} is total factor productivity growth, which is regressed on the following explanatory variables: (1) the total factor productivity growth in the global frontier (Δy_{Ljt}); (2) the total factor productivity level gap with respect to the global frontier, measured by ($y_{ijt-1} - y_{Ljt-1}$); (3) a set of policy and structural variables (X^k_{ijt-1}) and the interaction terms with the total factor productivity gap; and (4) country, industry, and year dummy variables. See Dabla-Norris and others, forthcoming, for details.

[2]See Dabla-Norris and others, forthcoming, for details. Moreover, the overall productivity gains are likely to depend on the magnitude of reforms and structural shocks.

[3]In particular, the econometric specification is estimated as follows:

$$tfp_{i,j,t+k} - tfp_{i,j,t} = \beta^k_0 + \beta^k_1 S_{i,j,t} + \beta^k_2 S_{i,j,t} tfpgap_{i,j,t} + \beta^k_3\, tfpgap_{i,j,t}$$
$$+ \beta^k_4 \Delta tfp_{L,j,t} + \beta^{k\prime}_5 X_{it} + \alpha^k_1 D_i + \alpha^k_2 D_j$$
$$+ \alpha^k_3 D_t + \varepsilon_{i,j,t},$$

in which tfp_{ijt} is the log of real total factor productivity in country i, industry j, and year t and S_{ijt} denotes reform dummies; the log of real total factor productivity at frontier industry j and the technological gap with respect to the frontier are indicated by tfp_{Ljt} and $tfpgap_{ijt}$, respectively; D_i, D_j, and D_t are country, industry, and time dummies, respectively; X_{it} is a set of control variables, including recession and financial crisis dummies and GDP growth; and the estimated coefficients β_1 and β_2 capture the unconditional and conditional (given technological gaps) effects of reform at horizon k. See Dabla-Norris and others, forthcoming, for details.

[4]Both variables are taken from the Organisation for Economic Co-operation and Development (Regimpact indicator and employment protection legislation index).

Box 3.5 *(continued)*

Table 3.5.1. Impact of Product and Labor Market Frictions on Total Factor Productivity Growth

	All Industries		Manufacturing	ICT-Related[1]	Services
	(1)	(2)	(3)	(4)	(5)
Dependent variable: Annual TFP growth rate (Percent)					
TFP Growth Rate at the Frontier	0.053	0.052	0.115	0.025	0.013
	(0.014)***	(0.014)***	(0.031)***	(0.013)*	(0.011)
TFP Gap with Respect to the Frontier	–0.110	–0.099	–0.093	–0.053	–0.060
	(0.023)***	(0.027)***	(0.037)**	(0.029)*	(0.026)**
Product Market Regulation	0.717	0.945	0.892	–0.199	–1.315
	(0.460)	(0.516)*	(0.786)	(0.776)	(0.445)***
Labor Market Regulation	0.825	0.645	0.895	0.395	0.451
	(0.569)	(0.624)	(0.954)	(0.814)	(0.640)
Product Market Regulation		0.006	–0.006	–0.010	–0.017
X TFP Gap		(0.007)	(0.008)	(0.010)	(0.005)***
Labor Market Regulation		–0.008	–0.007	–0.014	–0.012
X TFP Gap		(0.008)	(0.012)	(0.011)	(0.011)
Product Market Regulation	–0.638	–1.255			
X Manufacturing Dummy	(0.424)	(0.536)**			
Product Market Regulation	–0.537	–1.461			
X Service Dummy	(0.192)***	(0.366)***			
Product Market Regulation		–0.014			
X TFP Gap X Manufacturing Dummy		(0.012)			
Product Market Regulation		–0.021			
X TFP Gap X Service Dummy		(0.007)***			
Number of Observations	4,646	4,646	2,424	1,616	1,414
Adjusted R^2	0.20	0.20	0.24	0.29	0.21

Source: IMF staff estimates.
Note: *p*-values are in parentheses. ICT = information and communications technology; TFP = total factor productivity.
[1] Industries that produce ICT goods intensively.
*$p < .10$; **$p < .05$; ***$p < .01$.

inputs, as well as higher spending on R&D activities, contribute positively and with statistical significance to total factor productivity (Tables 3.5.1 and 3.5.2). The effects vary across sectors and are typically larger the closer the sector is to the technological frontier. For example, product market deregulation has larger positive total productivity effects in the services sector, but high-skilled labor and R&D expenditure have the strongest effects in ICT-related sectors. To put these results in economic terms and provide a specific example, the estimates suggest that if Austria were to reduce its services sector regulations to bring them in line with those of the Netherlands, the average total factor productivity growth gain across all industries could amount to about 0.2 percentage point a year, and about 0.6 percentage point in the services sector. In contrast, labor market regulation is not found to have statistically significant effects on total factor productivity, possibly owing to difficulty in measuring the degree of labor market flexibility across countries. Finally, the results from the first specification present evidence of productivity-enhancing knowledge spillovers from the frontier (captured by the coefficient of total factor productivity growth at the frontier) and a catchup convergence effect in "follower" countries (measured by the coefficient on the total factor productivity gap).

The econometric estimates from the second specification confirm the results presented in Tables 3.5.1 and 3.5.2 and suggest that reforms are typically associated with higher total factor productivity in both the short and the medium term (Figure 3.5.1). Overall, the results suggest a cumulative medium-term increase in the average total factor productivity levels across all industries following the implementation of key reforms, with the effect depending on the particular reform.[5] The largest gains in total factor productiv-

[5] These increases represent 0.05 to 2 standard deviations of the average cumulative five-year change in the total factor productivity level in the sample.

Box 3.5 *(continued)*

Table 3.5.2. Impact of Information and Communications Technology, Human Capital, and Research and Development

	All Industries		Manufacturing	ICT-Related[1]	Services
	(1)	(2)	(3)	(4)	(5)
Dependent variable: Annual TFP growth rate (Percent)					
TFP Growth Rate at the Frontier	0.043	0.046	0.089	0.028	0.005
	(0.013)***	(0.013)***	(0.030)***	(0.016)*	(0.012)
TFP Gap with Respect to the Frontier	–0.008	–0.026	–0.043	–0.076	–0.038
	(0.005)	(0.007)***	(0.010)***	(0.016)***	(0.014)***
ICT Capital	0.024	0.023	0.146	0.000	–0.063
	(0.014)**	(0.022)	(0.053)***	(0.037)	(0.037)*
High-Skilled Labor	0.047	0.120	0.077	0.183	0.236
	(0.024)*	(0.028)***	(0.053)	(0.041)***	(0.057)***
R&D Expenditure	0.084	0.195	0.100	0.480	0.387
	(0.048)*	(0.056)***	(0.082)	(0.119)***	(0.731)
ICT Capital		0.000	0.002	0.000	–0.002
X TFP Gap		(0.000)	(0.001)**	(0.001)	(0.001)**
High-Skilled Labor		0.002	0.002	0.003	0.003
X TFP Gap		(0.001)***	(0.001)	(0.001)***	(0.001)***
R&D Expenditure		0.002	0.001	0.006	0.013
X TFP Gap		(0.001)	(0.001)	(0.002)***	(0.013)
Number of Observations	2,685	2,685	1,707	849	487
Adjusted R^2	0.11	0.11	0.15	0.21	0.24

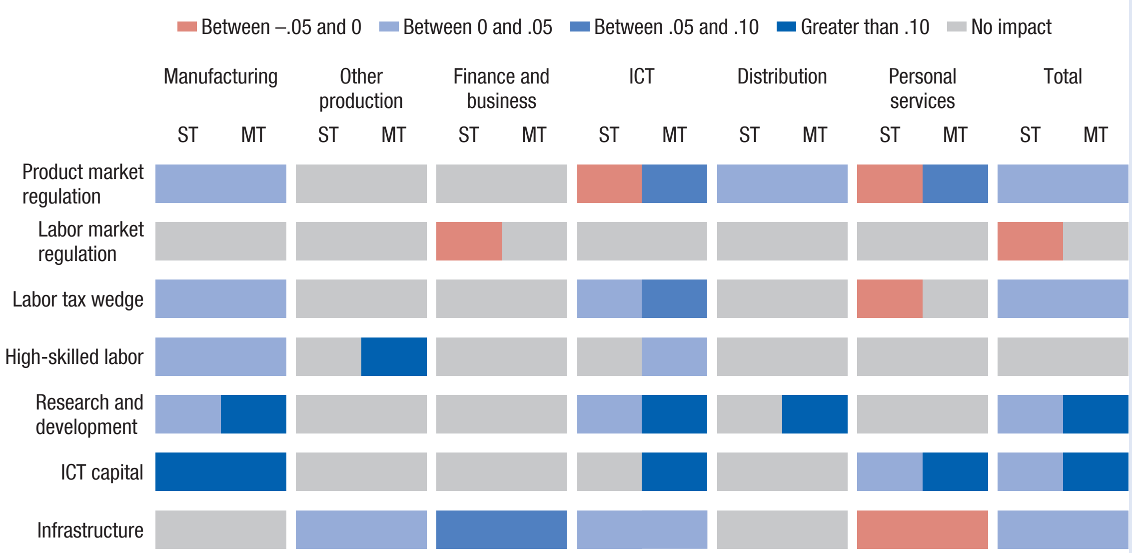
Source: IMF staff estimates

Note: *p*-values are in parentheses. ICT = information and communications technology; R&D = research and development; TFP = total factor productivity.

[1] Industries that produce ICT goods intensively.

$^{*}p < .10$; $^{**}p < .05$; $^{***}p < .01$.

Figure 3.5.1. Short- and Medium-Term Impact of Structural Reforms on Total Factor Productivity Growth
(Percent; average technological gap)



Source: IMF staff estimates.

Note: “Other production” includes agriculture; forestry; fishing; mining; quarrying; and electricity-, gas-, and water-related industries. ICT = information and communications technology; MT = medium term (five years); ST = short term (three years).

Box 3.5 *(continued)*

ity levels are associated with increasing R&D and ICT capital. The results also suggest that an increase in infrastructure capital has a positive impact on productivity over a longer horizon. This is a result of economies of scale, the existence of network externalities, and competition-enhancing mechanisms.

The effects vary across sectors and reforms. For example, total factor productivity gains associated with product market liberalization are highest in the ICT, personal services, and finance and business services sectors, but higher R&D spending and education reforms produce larger effects in the manufacturing and ICT sectors.

The impact of reforms also depends on initial (prereform) settings and business cycle conditions. For example, the effect of product market reforms is greater in highly regulated services sectors (Bourlès and others 2013) and during periods of expansion. Some differences, however, can be gleaned across industries, especially those in ICT and personal services, where productivity gains tend to be higher when initial levels of R&D and ICT capital use are low. Conversely, infrastructure shocks are associated with larger productivity gains during periods of economic downturn (see also Abiad, Furceri, and Topalova, forthcoming).

Finally, reforms can also have short-term negative impacts on total factor productivity (for example, the effect of product market deregulation on total factor productivity in ICT and personal services), possibly reflecting adjustment costs during the reform process (Blanchard and Giavazzi 2003).

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