3. The "New Mediocre" and the Outlook for Productivity in Asia

Introduction and Main Findings

Nearly 10 years after the global financial crisis, the prospect of mediocre future growth is still a concern. In part, the cause for this concern is the recent slowdown in productivity growth in many advanced economies—a slowdown that is widely expected to continue. Another related reason is the weakness in business investment, which is one channel through which new technology and innovation—the fundamental underpinnings of productivity growth—influence economies.

Asia is no exception. Indeed, in some countries lower productivity growth since the global financial crisis already is a reality, especially in the advanced economies in the region. They face some of the same challenges as other advanced economies across the world, including coping with the sectoral move toward services, where high productivity growth is more difficult to achieve, and population aging, which tends to lower productivity (Chapter 2).[1] For its part, China faces its own productivity challenges with the rebalancing of the economy. In other economies in the region, productivity spillovers are more pertinent: productivity developments at home tend to be influenced by those elsewhere.

The prospect of low productivity growth is worrisome for policymakers in Asia. Sustained improvements in welfare and living standards ultimately require productivity growth. "Extensive growth" driven by capital accumulation is possible for a while. But over long periods of time, only productivity growth—or "intensive growth"—can overcome decreasing returns to capital and lower investment. Intensive growth is especially important for economies already close to the technological frontier, as extensive growth can lead to the accumulation of too much capital. And for middle-income economies seeking to converge toward high-income-economy income levels, productivity growth can help offset the slowdown in investment.

Against this backdrop, this chapter reviews recent productivity developments in Asia and evaluates the implications of a more adverse external environment for productivity growth. Specifically, the chapter will explore the following questions:

- Has there been a productivity slowdown in Asia similar to that in advanced economies? If so, how large and extensive has it been? What have been the implications for convergence? What is the outlook for productivity?
- How much of the slowdown can plausibly be attributed to external factors? How does it compare to the extent to which the slowdown can be attributed to domestic factors?
- Is there an investment malaise in Asia and can it be related to that in advanced economies elsewhere? How important is foreign direct investment (FDI) as a driver of business investment?

To answer these questions, the chapter presents stylized facts on productivity developments since the global financial crisis, putting them in context with experiences prior to the crisis, as well as stylized facts on developments in underlying drivers, including research and development (R&D) spending. The chapter will also present empirical analyses on the role of external and domestic factors in productivity growth.

The analysis confirms that Asia has also experienced a productivity growth slowdown since the global financial crisis. The productivity slowdown has been most severe in the advanced

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[1]See, for example, Dabla-Norris and others (2015) on advanced economies, and Adler and others (2017), section on "Driving Forces – Long Term Forces" on emerging economies, plus demographics in general.

economies of the region and in China, and the drivers seem similar to those in other advanced economies, including less favorable demographics and a smaller impetus from trade integration. On the other hand, in other emerging market economies and some developing economies of the region, the decline in productivity growth since the global financial crisis has been small.

While the magnitude and nature of the slowdown differ across economies in the region, a common theme emerges: reforms to strengthen domestic sources of productivity growth should be high on the policy agenda in Asia for at least three reasons. First, looking forward, external factors seem less likely to contribute as much to productivity growth as they have in the past, when, as the chapter highlights, they were a major driving force. Second, as was discussed in Chapter 2, demographics will increasingly weigh on productivity growth in a number of economies. Third, Asian countries face the challenge to maintain high productivity growth in parallel with the sectoral change toward services, where productivity growth has been substantially lower than in manufacturing (Baumol, Blackman, and Wolff 1985).

There are positive features upon which policies can build. R&D activity in the advanced economies of the region remains strong, and one policy challenge is to strengthen the effectiveness of R&D spending in boosting productivity. In many of the emerging market and developing economies, the issue is how to strengthen productivity by capitalizing on recent achievements and favorable external factors such as increased FDI, as well as improve on their (sometimes mixed) records for educational achievements, infrastructure spending, and private domestic investment. Finally, building new momentum in trade liberalization and integration would also benefit productivity.

The Productivity Picture in Asia and the Pacific

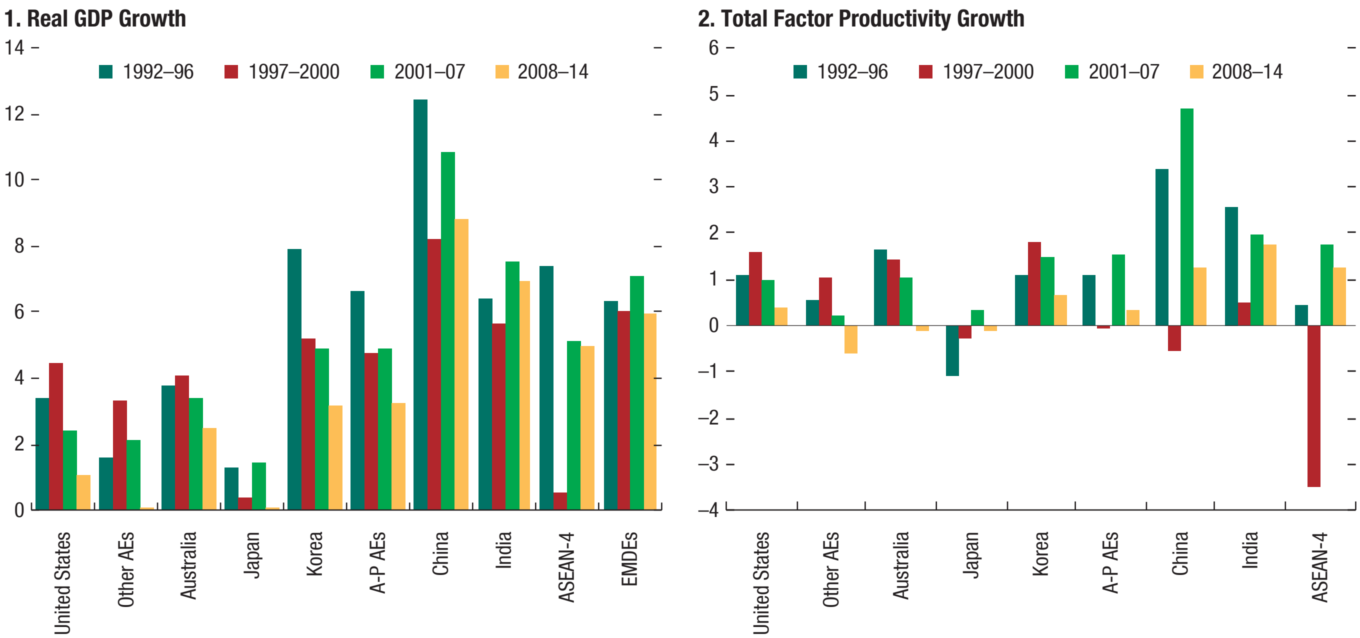
Productivity measures how effectively production inputs are used. This chapter considers two concepts of productivity: total factor (or multi-factor) productivity, typically referred to as total factor productivity (TFP), and labor productivity.

Increasing TFP implies that a given set of factors of production—capital and labor—can produce more output over time. The key role of TFP in economic growth has long been highlighted in the literature on economic growth.[2] Labor productivity measures the output per worker or per hour worked. It increases with TFP, but can also increase with capital deepening—an increase in the amount of capital per worker or per hour worked. Hence, one would expect TFP and labor productivity growth to be positively, but not necessarily strongly correlated.

There are two ways to assess productivity growth on a country by country basis—either against past performance, or relative to the technological frontier. The rationale for the latter is that there should be a tendency toward convergence or catching up, that is, for output in countries further away from the frontier to grow faster than those on the frontier. Countries on the frontier, including the United States, lead in the development of new technologies and have the highest productivity levels. If there is convergence, countries over time should close productivity gaps with the frontier as technology and knowledge diffusion should, over time, enable countries to catch up.[3] This chapter presents measures of productivity gaps relative to the United States. While there are other countries on or close to the frontier, depending on the sector, a single point of comparison has the merit of simplicity.

[2]For example, Solow (1956), Jorgenson and Griliches (1967), Lucas (1988), and Cooley and Prescott (1995).
[3]See, among others, Wolff (2014).

Figure 3.1. Real GDP Growth and Total Factor Productivity Growth
(Percent)



Sources: IMF, World Economic Outlook database; Penn World Tables 9.0; and IMF staff calculations.
Note: GDP growth rates are weighted by purchasing power parity GDP. Other advanced economies (AEs) are Canada and the European Union. Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand; emerging market and developing economies (EMDEs) are Bangladesh, Bhutan, Cambodia, Fiji, Lao P.D.R., Myanmar, Nepal, Sri Lanka, and Vietnam.

Aggregate Total Factor Productivity

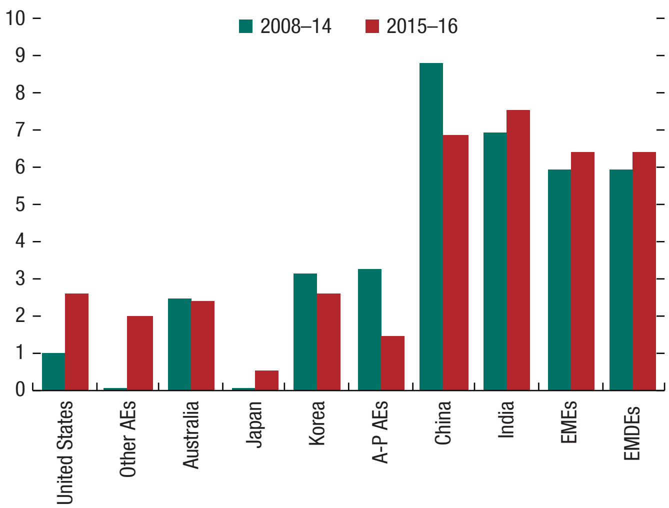
Figure 3.1 juxtaposes a regional overview of real GDP growth and aggregate TFP growth in four groups within the Asia region and compares them to developments in the United States. Both charts show average rates of growth over four periods in order to highlight trends and abstract from cyclical fluctuations.

The broad picture that emerges is that economic growth has generally held up well in Asia since the global financial crisis, both when compared to the precrisis period (2001–07) and to other advanced economies. The difference between real GDP and TFP growth could suggest that growth after the crisis has been relatively more extensive, that is, driven more by factor accumulation than by TFP improvements.

Within this broad picture, however, there is considerable variation across the major country groups.

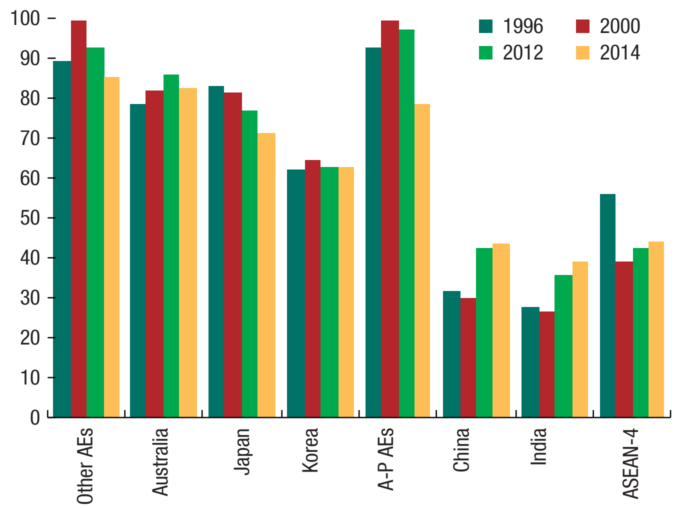
- In the *Asia-Pacific advanced economies* (Australia, Japan, Korea, Hong Kong SAR, New Zealand, and Singapore) growth was about 1 percentage point lower on average after the global financial crisis, roughly comparable to the outcome in the United States but better in comparison with other advanced economies as a group. The decline in TFP growth after the global financial crisis, however, is broadly comparable to that in other advanced economies.
- In the two large emerging economies in Asia—*China and India*—the decline in average growth has been smaller since the global financial crisis. Average growth is close to 8 percent, although it has declined more recently in China. This is also reflected in TFP growth in India, although the decline in China's TFP growth is more substantial than that of its real GDP.

Figure 3.2. Real GDP Growth after the Global Financial Crisis
(Percent)



Sources: IMF, World Economic Outlook database; and IMF staff calculations.
Note: All GDP growth rates are weighted by purchasing power parity GDP. Other advanced economies (AEs) are Canada and the European Union; Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand; emerging market and developing economies (EMDEs) are Bangladesh, Bhutan, Cambodia, Fiji, Lao P.D.R., Myanmar, Nepal, Sri Lanka, and Vietnam.

Figure 3.3. Total Factor Productivity Gaps
(Current purchasing power parity, United States = 100)



Sources: Penn World Tables 9.0; and IMF staff calculations.
Note: All total factor productivity is weighted by purchasing power parity GDP. Other advanced economies (AEs) are Canada and the European Union; Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand; emerging market and developing economies (EMDEs) are Bangladesh, Bhutan, Cambodia, Fiji, Lao P.D.R., Myanmar, Nepal, Sri Lanka, and Vietnam.

- In the *ASEAN-4* economies (Indonesia, Malaysia, the Philippines, and Thailand), real GDP and TFP growth after the global financial crisis remained relatively close to precrisis growth, with only a minor decline in both.
- Growth in other *Asia-Pacific emerging market and developing economies* remained high and stable, with only a minor reduction in growth after the global financial crisis.[4] TFP data are not available for all countries in the group, but some have TFP patterns similar to real GDP growth.

The data presented so far end in 2014. What has happened to productivity since? Over longer periods, TFP growth tends to be strongly procyclical. Since real GDP growth broadly held up in 2015–16 compared to 2008–14 (Figure 3.2), one would expect that TFP trends in 2008–14 would still be broadly representative for the more recent period.

Productivity growth has not been high enough everywhere for a strong convergence in TFP levels. Figure 3.3 uses TFP data from the Penn World Tables to construct relative indices for selected Asia-Pacific countries and regions against the United States as the frontier country.[5] It suggests relatively weak TFP convergence in China and India and in the ASEAN-4. Furthermore, the Asia-Pacific advanced economies have lost some ground against the United States, like other advanced economies.

Productivity Developments by Sector

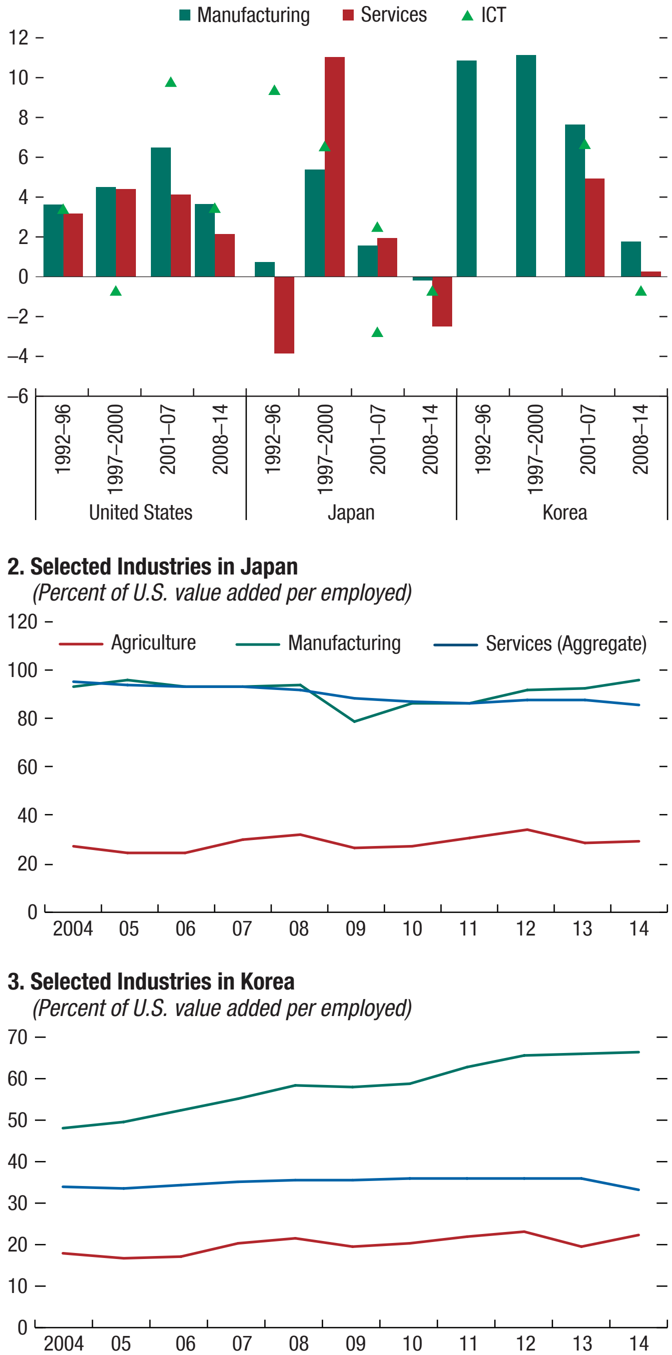
Aggregate productivity reflects developments at the sectoral and, ultimately, firm level. Data at the sectoral level should thus be more informative

[4]The Asia-Pacific emerging market and developing economies include Bangladesh, Bhutan, Brunei Darussalam, Cambodia, Fiji, Lao P.D.R., Maldives, Myanmar, Nepal, Solomon Islands, Timor Leste, Vanuatu, Vietnam and the other small Pacific island nations.

[5]This is the level of TFP at current PPP prices, indexed to the United States equal to 100. See Inklaar and Timmer (2013) on the construction of the TFP measures.

Figure 3.4. Sector-Level Labor Productivity Growth

1. Period Averages for Selected Industries in the United States, Japan, and Korea
(Percent change in GDP per hour)



Sources: CEIC database; Haver Analytics; Organisation for Economic Co-operation and Development, Productivity and ULC by Main Economic Activity (ISIC Rev.4) database; and IMF staff calculations.
Note: The growth rates in the top chart are geometric averages over the periods. For the 1992–96 period, only 1994–96 is available for Japan. Data for Korea cover 2001–14 only for services and information and communication technology (ICT). Services also include ICT.

about the underlying dynamics in productivity, showing, for example, the sectors that are the engines of productivity growth (typically manufacturing sectors) as well as sectors where growth is below average (typically services sectors).

Given data availability issues, sectoral level analysis relies on measurements of labor productivity rather than TFP. In practice, looking at labor productivity is complementary to looking at TFP, given their positive correlation. That said, one caveat to keep in mind is that magnitudes of labor productivity growth are not directly comparable to those of TFP.

Figure 3.4 highlights the considerable difference in labor productivity growth in the manufacturing sectors relative to the services sectors for Japan, Korea, and the United States. Four developments stand out. First, labor productivity growth in the services sectors has been much lower than in the manufacturing sectors. While labor productivity growth in the services sectors has improved in Korea since the global financial crisis, it has remained weak in Japan. Second, in Korea, labor productivity growth in manufacturing has been broadly similar to or stronger than in the United States. In both countries, labor productivity growth in manufacturing declined after the global financial crisis. Third, in information and communication technology (ICT) sectors, labor productivity growth in both Korea and Japan has been relatively weak compared to the United States. To the extent that the ICT sectors are likely to remain important drivers of economy-wide labor productivity gains, this lagging performance could be a concern. Fourth, reflecting relatively low growth compared to the United States, productivity convergence in services broadly stalled in Korea, while some earlier gains started to be reversed in Japan.

What sectors have been the engines of labor productivity growth in Asia? To answer this question, Figure 3.5 provides details on sector-level labor productivity growth in China, India, Japan, and Korea, plus a comparison with the United States. The panels in the figure incorporate

Figure 3.5. Contribution of "Within" and "Structural Change" Effects on Sectoral Labor Productivity Growth
(In constant prices)

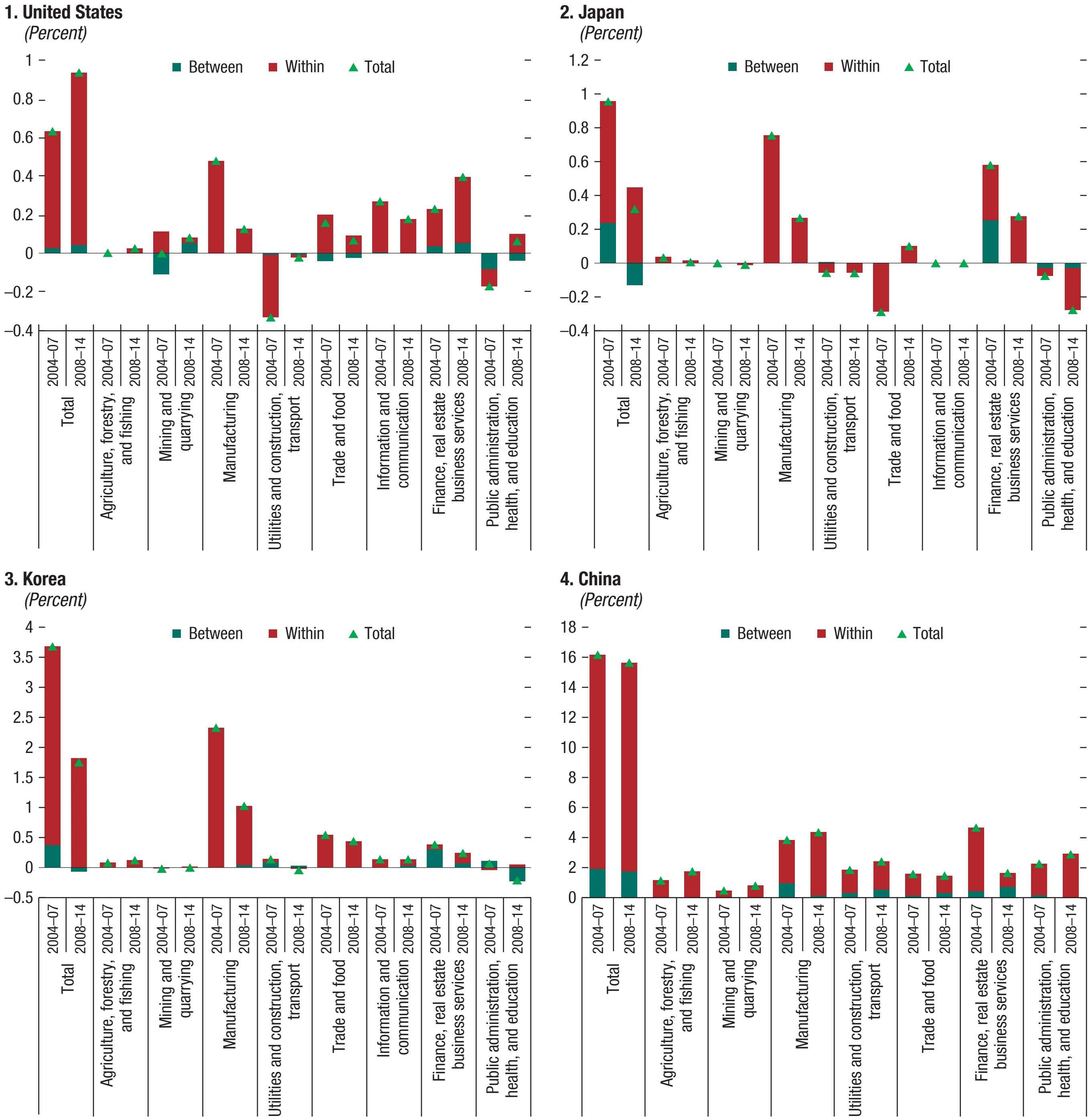
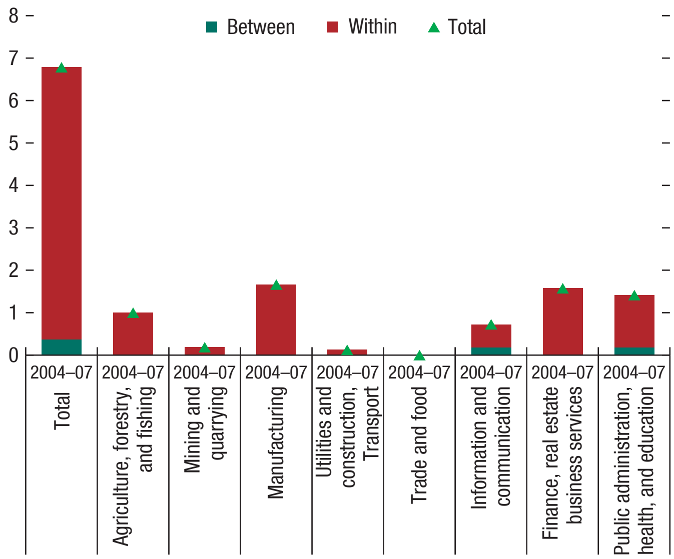


Figure 3.5. *(continued)*

5. India
(Percent)



Sources: Groningen Growth and Development Centre 10-Sector database; Organisation for Economic Co-operation and Development national accounts statistics; national authorities; and IMF staff calculations.
Note: No data available for India after 2007.

the results from a shift-share analysis, where real labor productivity growth (or its contribution), in aggregate or a sector, is decomposed into "within" and "structural change" effects, for the period prior to the global financial crisis (2004–07) and the period following the crisis (2008–14).[6] The within effects are changes in productivity growth generated in the sector itself, while structural change effects arise from the changing share of a sector in the economy over time, presumably from reforms or shifts in preferences. The highlights are as follows:

- The sectoral labor productivity growth rates generally confirm that productivity growth in Asia slowed after the global financial crisis.
- The manufacturing sectors accounted for about half of aggregate labor productivity growth (less in China, with a broader spread across sectors). A slowdown in these sectors was an important reason for the overall productivity slowdown following the global financial crisis, although labor productivity has also slowed in other sectors, including financial services.
- While labor productivity growth in the services sectors generally is lower than in manufacturing, finance, real estate, and business services sectors also contributed substantially to aggregate labor productivity growth, accounting for between one-fifth and one-third of that growth.[7] Still, labor productivity growth in these services sectors slowed compared to the period prior to the global financial crisis. These sectors also accounted for most of the structural change

[6]"Structural change effects" are measured by comparing labor productivity in industries with expanding employment relative to average labor productivity in shrinking industries. Thus, structural change effects would be more positive for those industries with relatively higher labor productivity than for shrinking industries, and more negative for those expanding industries with lower labor productivity. Timmer and de Vries (2009) provide details on the methodology.

[7]This is affirmed by a much broader sample of emerging market economies (including Asian economies) before the global financial crisis, in McMillan and Rodrik (2011).

effects in aggregate labor productivity growth. The growing share of these sectors in the economy generally has, in fact, lifted aggregate labor productivity growth, all else being equal.

- In China and India, the labor productivity gains were in part generated by continuing reallocation from agriculture to other sectors—a phenomenon that is common for many developing economies.

Domestic and External Factors in Productivity Growth

To understand the factors behind the slowdown in productivity established in the previous section, this section turns to the drivers and determinants of productivity and provides empirical evidence on the role of external and internal factors in productivity growth.

Drivers of Productivity Growth

Fundamentally, productivity improvements are driven by new technologies—technological progress—or new ways of organizing production processes. There is broad agreement that both drivers depend on economic incentives and on preconditions that create an enabling environment.

There is also broad agreement that economic integration and openness can boost productivity through a number of channels (Grossman and Helpman 1991), ranging from technology and knowledge diffusion through information-sharing to increased competition from foreign firms that can force domestic firms to adapt and raise their productivity.[8] In addition, trade creates larger markets that enable greater specialization and higher productivity or facilitate more productive supply chain arrangements.

Assessing the state of the drivers of productivity is notoriously difficult. Economic incentives and enabling factors are concepts that are difficult to measure in practice because they involve many dimensions. This chapter focuses on three primary concepts to assess the current environment for productivity in Asia. One relates to a domestic factor (measures of R&D investment) and two are related to international factors (international trade and FDI).[9] These factors seem particularly relevant, given the focus on spillovers.

Other factors influencing productivity relate to the enabling environment. This includes an economy's absorptive capacity, along with other features that facilitate productivity growth. Absorptive capacity can be defined as the ability of one factor to enrich the ability of another factor to stimulate productivity growth. For example, high-quality R&D or high-quality infrastructure (often a result of public capital investment) may interact with FDI to further increase productivity. Other contributing factors to absorptive capacity, such as human capital, as well as financial depth and the role of institutions, can also be considered.[10]

[8]Imports of intermediate goods can provide technology from exporting countries (forward spillovers), for example in the form of capital goods. Conversely, exports of intermediate goods to more technologically advanced importers can encourage the importers to transfer technology to the exporters (backward spillovers). At the same time, opportunities from greater openness can also encourage exporters to adapt and compete with exporters elsewhere, leading to greater sophistication and productivity. Greater import penetration can increase competition for local firms in domestic markets (horizontal spillovers), which should lead to greater efforts to improve their productivity, or enable access to new or better intermediate goods, thereby increasing productivity (vertical spillovers). Havránek and Iršová (2011) find evidence for vertical spillovers. Estimates for horizontal spillovers range from none (Iršová and Havránek 2013) to positive (usually in low-income countries where foreign firms operate in markets separate from domestic firms and do not crowd out domestic firms) (Meyer and Sinani 2009).

[9]Studies on the roles of the three concepts for emerging market economies can be found in Ciruelos and Wang (2005), Crispolti and Marconi (2005), and Krammer (2010). Blomström and Kokko (1998) and Keller (2004) provide surveys of the sector-level literature.

[10]See Aghion and others (2010), Aghion, Hemous, and Kharroubi (2014), Delgado and McCloud (2016), Farla, De Crombrugghe, and Verspagen (2016), Filippetti, Frenz, and Ietto-Gillies (2017), and Krammer (2015).

Domestic and External Drivers of Productivity Growth

This section presents empirical evidence based on the role of R&D, trade openness, and FDI inflows in productivity growth, building on the approach by Griffith and others (2004). The approach uses sectoral data and, as above, is based on labor productivity growth. The sectoral data are only available for a cross-section of advanced economies, including three Asian advanced economies (Japan, Korea, and Taiwan Province of China) for the sample period 1995–2007. While this data sample does not cover the period after the global financial crisis, it should nevertheless provide representative evidence on the role of domestic and external factors in driving productivity growth.

The analysis is based on a panel regression that relates labor productivity growth in 24 sectors to the productivity gap and other determinants in 19 advanced economies (see Annex 3.1 for details of the specification, results, and data set). The productivity gap captures the idea of convergence. This productivity gap is interacted with other explanatory variables to see whether these variables influence the speed of convergence. Since the dependent variable is labor productivity growth, the regression also controls for the changes in the capital-labor ratio.

The five explanatory variables of interest are (1) R&D expenditure, (2) exports, (3) imports, (4) inward FDI, and (5) outward FDI. All variables are scaled by the value added or gross output in the sector. As such, the assumption is that, within the variation encountered in the sample, the relationship between labor productivity growth and these variables is broadly proportional.

The results are broadly in line with the conceptual framework discussed previously. Labor productivity grows faster in the industries with larger labor productivity gaps, indicating more catch-up growth, or a transfer of productivity from abroad. This relationship is statistically significant.

Higher R&D spending raises labor productivity. It is noteworthy, however, that the impact of R&D spending is greater in sectors where labor productivity levels are already close to U.S. levels. Interestingly, the analysis does not find substantial differences between manufacturing and services sectors as far as the magnitude of the productivity impact of R&D. This is consistent with the view that technological progress (for example, the provision of business services reliant on new telecommunications systems) has also become important for services. That said, in the sample used in the analysis, R&D spending has been small in the services sectors compared to that in manufacturing sectors.

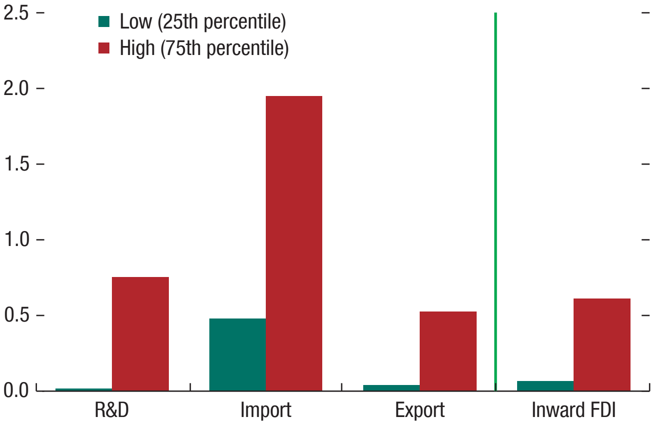
Higher trade openness also has a positive and significant impact on labor productivity growth, as expected. The results suggest that there is a larger positive impact if import openness increases by 1 percentage point than if export openness increases by the same amount. They also confirm the finding of other studies that imports of intermediate inputs are an important channel through which imports can raise labor productivity.[11]

The impact of FDI on labor productivity growth also matters at the sectoral level. Inward FDI shows a statistically significant positive impact. In contrast, outward FDI has a negative impact. It may be that firms invest abroad in more productive markets, crowding out some domestic investment, leading to weaker-than-otherwise domestic labor productivity growth.

What do the results imply for the relative role of external versus internal factors in productivity growth? To answer this question, consider a thought experiment that asks what would happen to labor productivity growth if the main productivity drivers (R&D, imports, exports, and FDI) increased from the low end (25th

[11]Ahn and others (2016) document that imports can promote productivity by increasing competitive pressure on domestic firms (competition channel) and by enhancing the quality of their intermediate goods (input channel), while exports can increase productivity via learning from foreign markets and through increased competition abroad.

Figure 3.6. Estimated Impact on Sectoral Labor Productivity Growth
(Percent)



Source: IMF staff calculations.
Note: The 25th and 75th percentiles are calculated based on research and development (R&D) expenditure, imports and exports from the United States, and inward foreign direct investment (FDI) for all industries and countries in the sample.

percentile) to the high end (75th percentile) of the sample, that is, an economy or industry shifting from being a "low" to a "high performer."[12] The differences between the blue and red bars in Figure 3.6 show the marginal benefit of this shift and suggest that policies aimed at increased trade integration or greater import competition and inward FDI would generate substantial productivity increases.[13]

The thought experiment highlights the potentially strong impact of greater openness and trade integration on productivity growth. Higher productivity growth can also enable firms to compete better in international markets, increasing openness. The flip side is that productivity growth with stagnating global trade and cross-country investment flows becomes more difficult to achieve. As a caveat, it should be noted, however, that the relationship between external factors and labor productivity growth is a complex one and that the analysis does not establish causality definitively. There is a possibility of reverse causality and omitted variable bias. Moreover, the experiment does not capture the effects of all domestic factors, many of which are captured by country-industry fixed effects in the regressions that cannot be recovered for an economic interpretation.

Broader Evidence of Domestic and External Drivers of Productivity Growth

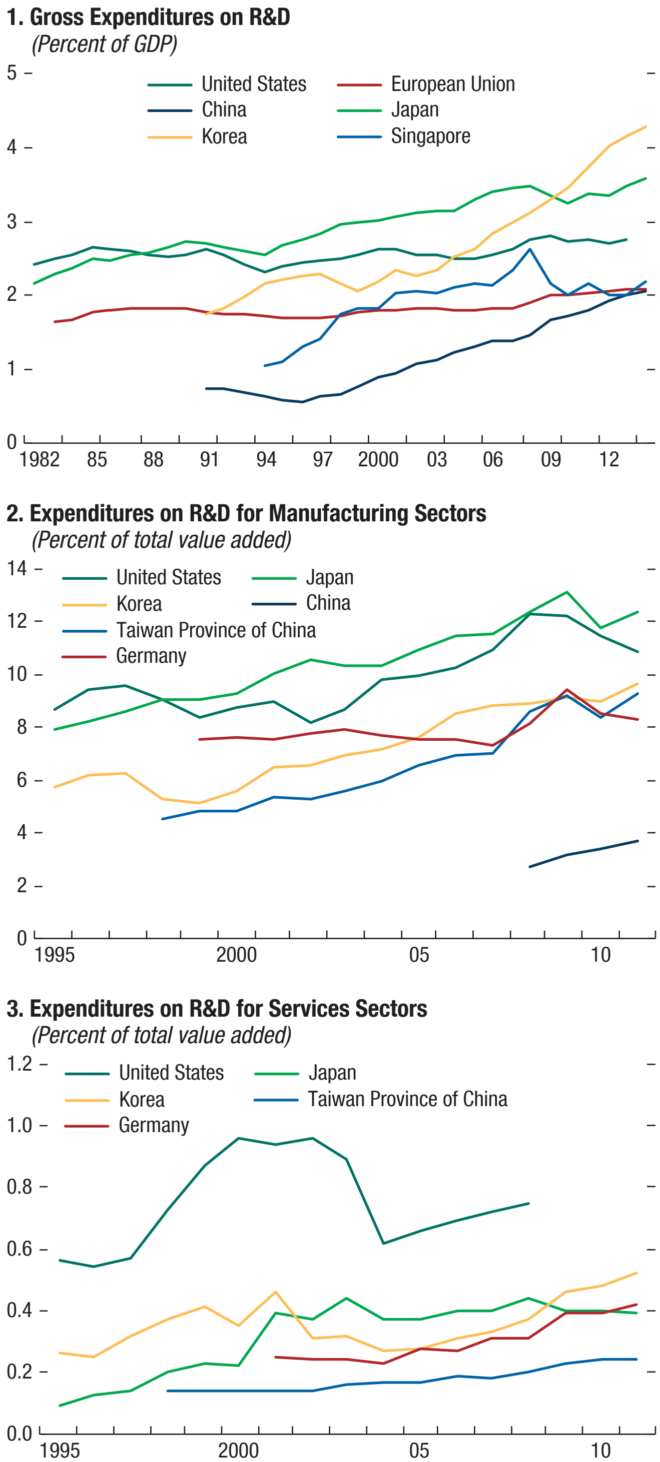
As a cross-check, we now complement the sectoral analysis in the previous section with country evidence on aggregate TFP growth for a more recent sample period 1980–2014 and for a broader set of Asia-Pacific countries, including the Asian advanced economies, China, India, the ASEAN-4, and some Asia-Pacific emerging market and developing economies. The analysis is based on three different panel regressions that relate country-level TFP levels to a broadly similar set of explanatory variables (see Annex 3.2 for details of the specifications, results, robustness checks, and the data set).

The country-level evidence also suggests that, in general, domestic factors (such as R&D) have less of an impact than external factors (such as FDI). That said, there is some evidence that the sources of TFP growth have shifted in favor of domestic factors (also including financial development and absorptive capacity) since the global financial crisis. This will be key if advanced economies continue to slow and provide a weaker impetus to Asia-Pacific productivity. By looking at the recent trends in the factors used in this analysis, the next section will further elucidate the possibilities for productivity growth going forward.

[12]The estimated impacts are calculated as the product of the estimated coefficients on explanatory variables (see Annex 3.1 for the estimation results) and the 25th and 75th percentiles of the variables, which show the implied difference in average labor productivity growth between low and high explanatory variables (for example, R&D expenditure, import/export openness, and inward FDI).

[13]It should be noted that the results of inward FDI are based on a regression with a smaller sample of countries because of data availability issues. See Annex 3.1 for more details.

Figure 3.7. Expenditures on Research and Development



Sources: National Science Foundation; National Center for Science and Engineering Statistics, National Patterns of R&D Resource (Annual Series); Organisation for Economic Co-operation and Development, Main Science and Technology Indicators (2015/1); UNESCO Institute for Statistics Data Centre.

Understanding Productivity Developments and Prospects in Asia: A Narrative Approach

This section drills down deeper and reviews recent developments in the main productivity drivers (R&D, investment, trade, and FDI) before and after the global financial crisis and discusses their likely impact, drawing on the analysis from the previous section.

Research & Development Investment

R&D is the means through which firms and countries more broadly innovate and develop new technologies. R&D can also be a means to promote technology transfer, or adaptation and imitation.[14]

Overall R&D spending has increased notably among Asian countries since the global financial crisis, converging toward United States and other advanced economy levels. Korea has even become a leader in R&D spending (Figure 3.7). As of 2014, after more than a decade of sustained increases, China was at par with the average R&D spending in the European Union and with spending in Singapore.

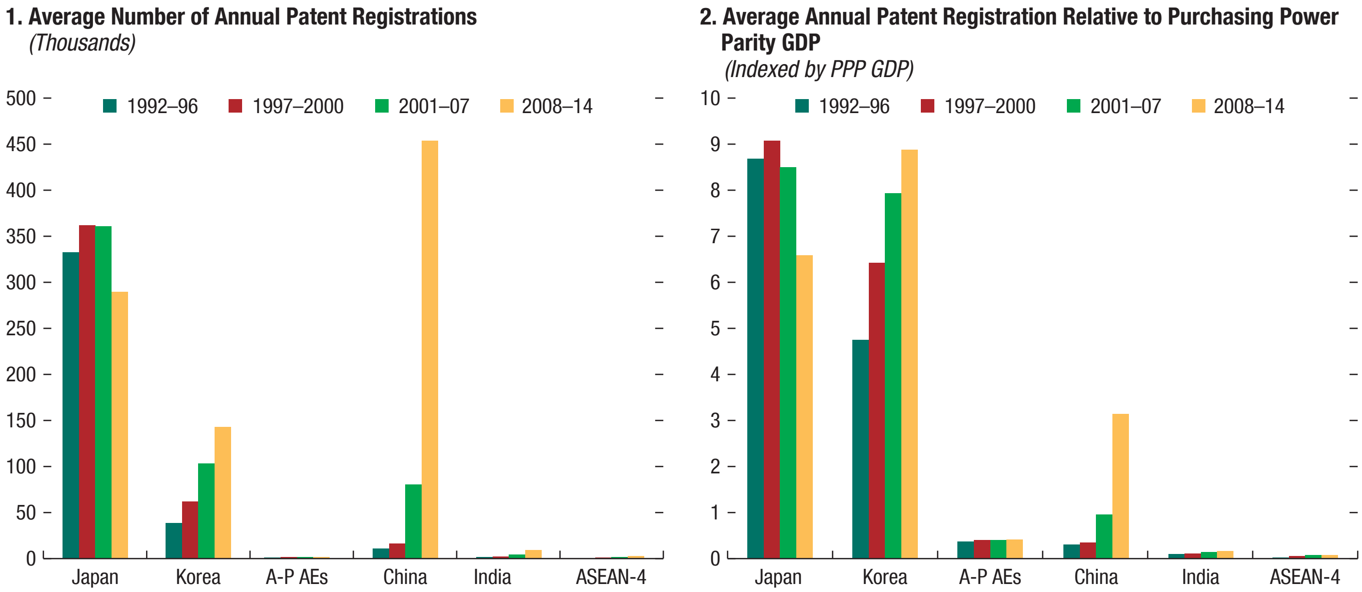
Data on the number of patent applications filed by residents in their own country, in absolute numbers and per unit of GDP (Figure 3.8), corroborate the picture provided by R&D spending.[15] The strong increases in the number of patents in China and Korea stand out.

The increase in R&D spending since the global financial crisis in some Asian economies would, all else being equal, imply that productivity growth in these economies should have increased noticeably, based on the benchmarks provided by the previous empirical analysis. The fact that it did not suggests either that other factors more than offset the beneficial impact, or that the

[14]See Griffith, Redding, and van Reenen (2004), Acemoglu, Aghion and Zilibotti (2006), and Madsen and Timol (2011).

[15]See Kao, Chiang, and Chen (1999) and Lee (2006) at the country level, and Branstetter and Nakamura (2003) at the sectoral level.

Figure 3.8. Average Annual Registration of Patents

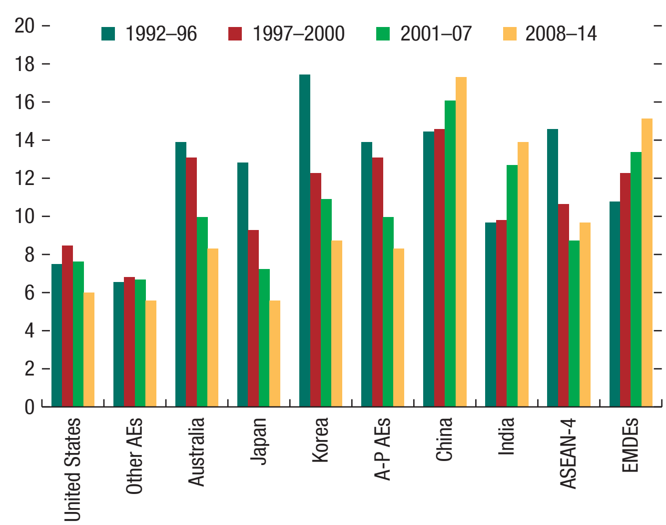


Sources: World Intellectual Property Organization; and IMF staff calculations.
Note: Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, and Singapore. The ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand. PPP = purchasing power parity.

increased spending has not yet translated fully into marketable innovation and productivity gains because of problems of effectiveness. For some sectors, there is indeed some evidence that there have been such problems (Branstetter and Nakamura 2003). Another reason could be that the diffusion from R&D-related spending by leading firms, which likely accounts for much of the increase in R&D spending, might have slowed. There is indeed evidence that much of the R&D spending in Asia is undertaken by large companies, especially multinational ones.

The closing of the gap with or even surpassing the United States in R&D spending in a growing number of Asian economies primarily reflects developments in manufacturing sectors, rather than services (Figure 3.7, second and third panels). In the services sectors, R&D spending in the same economies is still lagging, which could plausibly be one of the factors explaining relatively lower productivity growth in these sectors.

Figure 3.9. Gross Fixed Capital Formation
(Percent of previous year's capital stock)



Sources: IMF, World Economic Outlook database; Penn World Tables 9.0; and IMF staff calculations.
Note: Regional aggregates for gross fixed capital formation are weighted by purchasing power parity GDP. Other advanced economies (AEs) are Canada and the European Union; Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand; emerging market and developing economies (EMDEs) are Bangladesh, Bhutan, Cambodia, Fiji, Lao P.D.R., Myanmar, Nepal, Sri Lanka, and Vietnam.

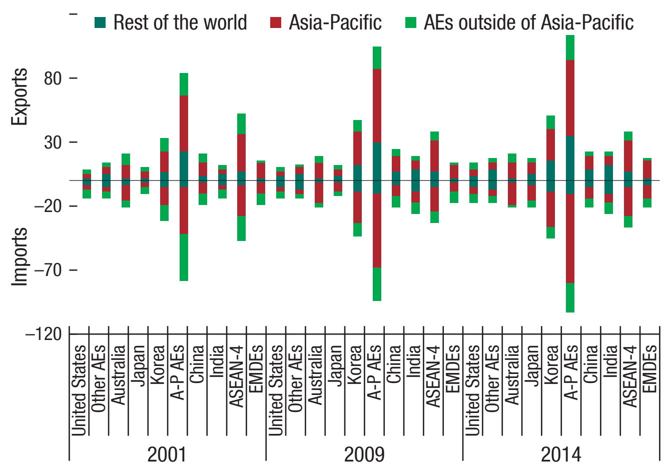
Fixed Investment

Fixed investment can also contribute to productivity growth. The traditional channel is through increased capital intensity, which lifts labor productivity for a given amount of labor. Another channel operates through the new technologies embodied in new capital. There is also a case to be made that there is a bias toward capital affecting the measurement of productivity, so this channel may be more important than often thought (Box 3.1). This would imply that a downshift in the investment path—say, relative to pre-global-financial-crisis trends—would lower TFP.

Figure 3.9 shows that the rate of fixed investment, as a percent of the stock of physical capital, slowed in Asia-Pacific advanced economies to rates that are broadly at par with those in other advanced economies after the global financial crisis. This slowdown is perhaps the clearest reflection that elements of the new mediocre have also been present in the advanced economies in the region. Estimates by Adler and others (2017) would suggest that such declines in investment rates could explain a sizable reduction in TFP growth, on the order of ¼ to ½ of a percentage point. In the ASEAN-4 countries, in contrast, investment rates were broadly unchanged before and after the global financial crisis. In a number of countries in the region, however, investment rates increased and have supported productivity, including in China, India, and other emerging market and developing economies in the region.

Prospects are that fixed investment will remain relatively weak for some time and is unlikely to contribute to productivity in the economies where investment rates slowed after the global financial crisis. Furthermore, in China, with the economic rebalancing toward consumption, investment rates are likely to slow, which, in the absence of offsetting measures, could weigh on productivity.

Figure 3.10. Developments in Trade Openness
(Percent of GDP)



Sources: IMF, *Direction of Trade Statistics*; IMF, World Economic Outlook database; and IMF staff calculations.
Note: Values for trade are approximations because of incompatibilities between different data sources. Measures of GDP for the regional aggregates include intraregional trade; the corresponding measures of trade exclude it. Other advanced economies (AEs) are Canada and the European Union; Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand; emerging market and developing economies (EMDEs) are Bangladesh, Bhutan, Cambodia, Fiji, Lao P.D.R., Myanmar, Nepal, Sri Lanka, and Vietnam.

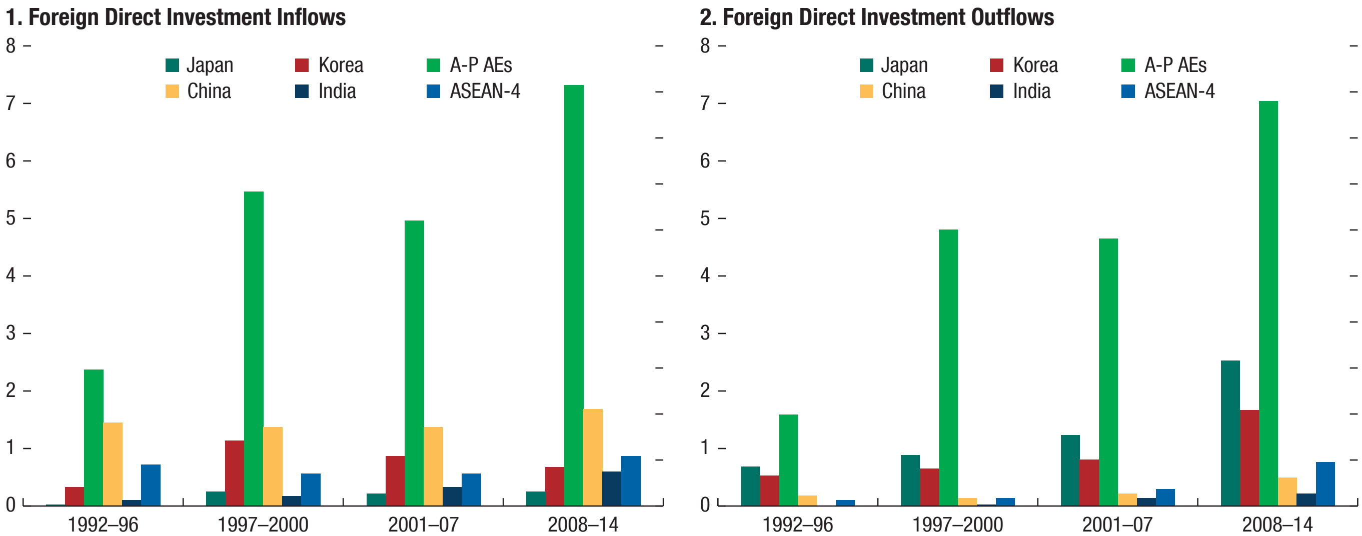
International Trade

International trade is an important channel of technology transfer, as discussed above.[16] Figure 3.10 shows that, overall, trade openness involving both exports and imports has generally moved sideways or declined since the global financial crisis. Trade, therefore, is unlikely to have supported productivity. Going forward, prospects are for continued moderate trade growth, with little change in export or import ratios. A trade-related boost to productivity overall thus seems unlikely (Constantinescu, Mattoo, and Ruta 2016).

There have been exceptions to these broad trends, however. Trade openness increased after the global financial crisis in Asia-Pacific advanced economies and in other emerging market and developing economies in the region. The increase is particularly prominent in intra-Asia-Pacific

[16]See, for example, Ahn and others (2016), Frankel and Romer (1999), and IMF (2016).

Figure 3.11. Foreign Direct Investment
(Percent of GDP)



Sources: Financial Flows Analytics Database; and IMF staff calculations.
Note: Foreign direct investment inflows and outflows are the average during the period. Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand.

trade and partly reflects further outsourcing of manufacturing activity from advanced economies to emerging market and developing economies in the region and the continued building of supply chains between these economies. This lengthening of supply chains is consistent with developments seen in Europe. There is evidence of such a lengthening in the chains between Germany and central European countries (Aiyar and others 2013). While patterns in trade openness since the global financial crisis do not suggest that the lengthening of cross-border supply chains involved China or India, there is a possibility that supply chains could have intensified within these two countries, generating their own productivity improvements. If so, however, other factors would have offset these gains.

Foreign Direct Investment

FDI can also be an engine of productivity growth, with effects depending in part on whether it is inward FDI[17] or outward FDI.[18] Figure 3.11 shows that, as a percent of GDP, FDI inflows increased in China, India, and the ASEAN-4 after the global financial crisis. In Japan and Korea, FDI inflows remained broadly stable, although the two countries registered a noticeable increase in FDI outflows. China also saw some increase in FDI. The implication is that FDI likely contributed to productivity increases only in emerging and developing Asia-Pacific economies after the global financial crisis. FDI inflows into many emerging market and developing economies in the region are expected to remain strong, which should support further productivity increases. That said, there are risks from increased protectionism, which could slow or reverse the building of supply chains and offshoring.

The empirical analysis associated with the country-level work presented above also suggests that FDI

[17]Inward FDI can be a channel for technology diffusion. Bitzer and Kerekes (2008) offer supporting evidence. Van Pottelsberghe de la Potterie and Lichtenberg (2001) offer an opposing view.

[18]Based on German data, Onaran, Stockhammer, and Zwickl (2013) find that outward FDI to high-wage countries crowds in domestic investment, whereas FDI to low-wage countries crowds out investment.

Table 3.1. Levels of Enrollment in Tertiary Education
(Percent of the official tertiary education cohort population)

	1992[1]	1997[2]	2001	2008	2014[3]
European Union	32.5	44.8	52.3	62.6	67.7
United States	77.1	70.6	69.0	85.0	86.7
Japan	30.0	45.1	49.9	57.6	62.4
Korea	39.5	64.5	82.5	95.3	95.3
Indonesia	9.4	13.4	14.2	20.7	31.1
Malaysia	9.1	21.8	25.0	33.7	38.5
Philippines	25.8	27.5	30.3	29.4	35.8
Thailand	19.3	23.0	39.0	47.9	52.5
China	2.8	5.5	10.0	20.9	39.4
India	6.0	6.6	9.7	15.1	23.9
Bangladesh	—	5.5	6.4	8.6	13.4
Nepal	5.4	4.8	4.5	11.3	15.8

Source: World Bank, World Development Indicators.
[1]For 1992, Bangladesh = not available; India = 1991; Thailand = 1993.
[2]For 1997, Bangladesh = 1999; Japan, Malaysia, the Philippines, and the United States = 1998; Nepal = 1996.
[3]For 2014, India, Japan, Korea, Malaysia = 2013.

supports domestic fixed investment within Asia as a whole, which can be another channel through which increased FDI could raise productivity. In fact, the role of FDI has become increasingly important over time, particularly since the global financial crisis.[19]

Absorptive Capacity

Absorptive capacity refers to factors that enable the domestic economy to absorb the positive influences of other factors such as R&D or technology transfer.[20] Human capital, in particular, has long been identified as an important factor in this regard. The higher it is, the better the workforce can adapt to new technology or contribute to innovation. Absorptive capacity has risen across Asia, albeit with variation across countries.

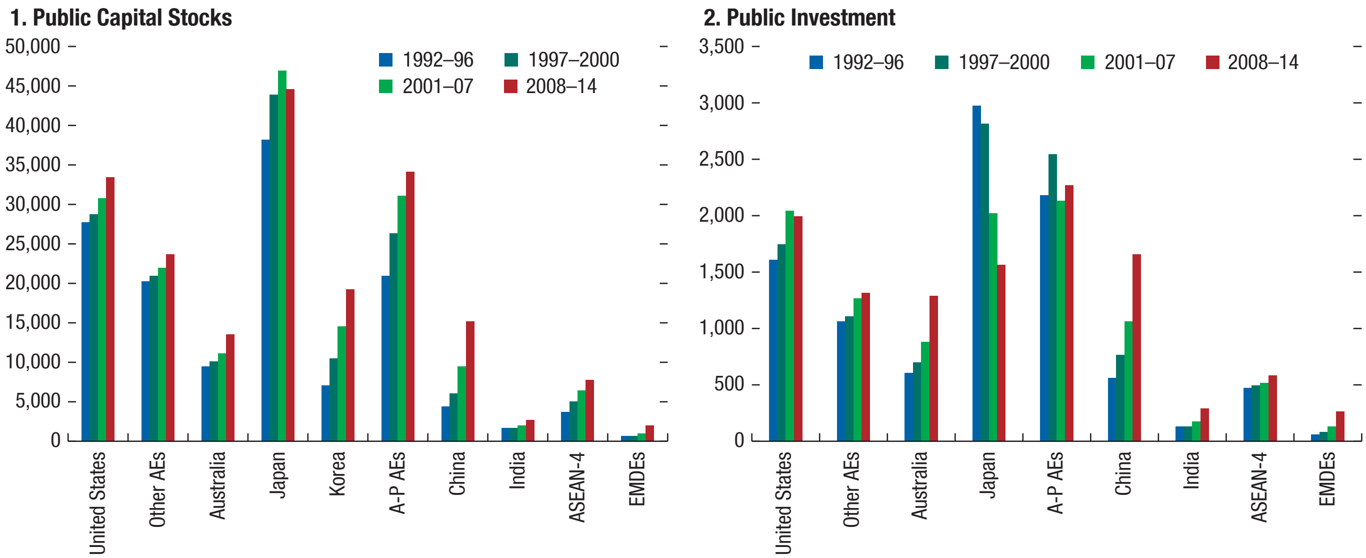
The number of enrollees in tertiary education programs as a share of their age cohort is a standard measure—even if not comprehensive—of human capital. A country's human capital stock would, all else being equal, increase if this share increases. Table 3.1 shows how the tertiary enrollment share has broadly increased across Asian economies over the past few decades. In the advanced economies, where initial levels were already high, the rate of increase has slowed since the global financial crisis, including compared to the precrisis boom period of the early to mid-2000s. This slowdown in the building of human capital is seen as one of the contributing factors to the productivity slowdown in the advanced economies in recent years (Adler and others 2017). In other countries, however, the share of tertiary education increased rapidly after the global financial crisis. In China, for example, the share doubled between 2008 and 2014.

Another dimension of absorptive capacity is public infrastructure. Bom and Ligthart (2014) suggest related investment can substantially increase an economy's output in the short and long term. With higher infrastructure capital, firms can more easily produce goods and ship them to domestic and foreign markets, and they can hire workers who are better educated and healthier (IMF 2014). Figure 3.12 shows that public capital stocks are high in most Asia-Pacific advanced economies and China compared to other advanced economies and the United States. Therefore, initial conditions seem favorable. In China and the ASEAN-4, the public-capital per capita ratio accelerated after the global financial crisis, reflecting increasing investment shares.

[19]See Annex Table 3.2.5. For support in the literature, see Al-Sadig (2013), Farla, Crombrugghe, and Verspagen (2016), and Hejazi and Pauly (2003).

[20]See Crispolti and Marconi (2005) and Filippetti, Frenz, and Ietto-Gillies (2017). At the sectoral level, see Blalock and Gertler (2009) and Blalock and Simon (2009) for Indonesia and Özer and Böke (forthcoming) for Turkey.

Figure 3.12. Public Capital Stocks and Investment
(Constant 2011 dollars, per capita)



Sources: IMF, Investment and Capital Stock Dataset; and IMF staff calculations.
Note: All flows are in real terms, weighted by purchasing power parity real GDP. Other advanced economies (AEs) are Canada and the European Union; Asia-Pacific advanced economies (A-P AEs) are Hong Kong SAR, New Zealand, Singapore, and Taiwan Province of China; the ASEAN-4 are Indonesia, Malaysia, the Philippines, and Thailand; emerging market and developing economies (EMDEs) are Bangladesh, Bhutan, Cambodia, Fiji, Lao P.D.R., Myanmar, Nepal, Sri Lanka, and Vietnam.

In sum, a number of factors can explain the recent slowdown in productivity growth in many economies in the Asia-Pacific region after the global financial crisis, including lower investment rates, less impetus from international trade integration, and slowing growth in human capital. That said, in emerging market and developing economies in the region, many of these forces have continued to contribute to productivity growth.

Conclusions and Policy Implications

The analysis presented in this chapter suggests that Asia experienced a productivity growth slowdown after the global financial crisis. It also suggests that, in terms of productivity, there has been little, if any, convergence to the technological frontier. The likelihood is that productivity growth will remain low for some time, including, increasingly, because of demographics. Raising productivity growth should therefore be a priority on the economic policy agenda in Asia. Within this broad picture, however, the magnitude and nature of the slowdown differ across economies in the region.

In terms of magnitude, the slowdown has been most severe in the advanced Asia-Pacific economies and in China. In terms of the nature of the problem, many of the factors behind the slowdown identified elsewhere apply to the advanced economies of the region, including slowing investment, little impetus from trade (as reflected in broadly unchanged trade openness), slowing human capital formation, reallocation of resources to less productive sectors, and, as discussed in Chapter 2, an aging population. Another common theme is that the performance in some services sectors in the region has been lagging relative to other countries, notably with respect to the United States. On the positive side, however, R&D activity in the advanced economies of the region remains strong or has increased.

In China, a number of underlying drivers of productivity have improved further since the global financial crisis, including increased R&D spending and rapid progress in educational attainment. On the other hand, trade openness has declined after some increases immediately following China's accession to the World Trade Organization, suggesting that the related gains in productivity levels have largely been absorbed. And resource misallocation (reflected in sectoral overcapacity, for example) and distortions in economic incentives appear to be holding back productivity.

In emerging markets and some low-income economies of the region, including India and the ASEAN-4, the decline in productivity growth since the global financial crisis has been small. That said, there has been little progress in productivity convergence toward the high-productivity countries at the technology frontier.

Looking forward, the main policy issue is how to raise productivity growth when external factors might not be as supportive as they were before the global financial crisis. In particular, further trade liberalization might be more difficult to achieve. While policies can also strengthen domestic sources of productivity growth, the analysis highlights that increases in trade openness come with strong productivity benefits. Efforts toward further trade liberalization should thus continue to be pursued. Turning to domestically oriented policies, priorities differ across countries in Asia. In advanced economies, the focus should be on strengthening the effectiveness of R&D spending and measures to raise productivity in the services sectors (see Box 3.2 for the cases of Australia and Singapore). Increased competition in these sectors would spur innovation and adaption. The empirical analysis has shown that these mechanisms have contributed to higher productivity growth not just in manufacturing but also in services.

In India, improving productivity in the agriculture sector, which is the most labor-intensive sector and employs about half of Indian workers, remains a key challenge. More needs to be done to address long-standing structural bottlenecks and enhance market efficiency, including from liberalizing commodity markets to giving farmers more flexibility in the distribution and marketing of their produce, which will help raise competitiveness, efficiency, and transparency in state agriculture markets. In addition, input subsidies to farmers should be administered through direct cash transfers rather than underpricing of agricultural inputs, as such subsidies to the agriculture sector have had large negative impacts on agricultural output.[21]

In other emerging market and developing economies in the region, the priority should be to capitalize on recent achievements, including the rise in FDI inflows, by increasing the related productivity spillovers through further increases in absorptive capacity and domestic investment. Japan and Korea have proved to be leaders in the field of human capital formation. The ASEAN-4 countries have begun to follow this model and should continue, including by strengthening the quality and flexibility of domestic education systems. In some economies, there is a need to expand public infrastructure, as noticeable gaps remain.

[21]For example, cheap or free water, electricity and fertilizers have had a large negative impact on ground-water levels, soil fertility and production efficiency for both inputs and outputs in agriculture (IMF 2017).

Box 3.1. Biased Technical Change and Productivity

The issue of biased technical change has gained prominence recently as progress in automation in manufacturing and services has led to increased substitution away from labor to automated processes. Understanding technical bias helps with assessing future directions in productivity, factor compensation, and employment (Amtz, Gregory, and Zierahn 2016; Autor 2015). A particularly important question for policymakers is how to combine increased labor savings in sectors undergoing rapid automation with the ability of the economy to employ the labor resources productively elsewhere.

This box investigates whether the issue of technical bias is relevant for China, Japan, and Korea (and the United States, for the sake of comparison) and discusses some implications for productivity. It suggests that there is indeed a bias toward capital equipment and high-skilled labor away from low-skilled labor in a number of industries.

The framework for measuring factor bias is based on the multi-factor cost approach (as in Binswanger 1974), which looks at the change in factor shares used for production, using five input factors (capital goods, high-skilled labor, medium-skilled labor, low-skilled labor, and intermediate goods) across four broadly defined industries (agriculture; food, textiles, and leather; machinery and equipment; and finance).

Following this approach, a bias toward a particular factor, $B_i(t)$, is defined as a change in share $S_i(t)$ of this factor for any given set of relative prices. A positive value for $B_i(t)$ indicates a shift toward an increasing use of the factor, while a negative value means a shift toward the reduced use of the factor. For the capital stock, K, the bias, $B_K(t)$, is measured as:

$$B_K(t) \approx (s_{Kt+1} - s_{Kt})/s_{Kt} \mid \rho_K, w, \rho_I,$$

given the cost of capital, p_K, the wage, w, and the price of intermediate goods, p_I.

The biases are computed from 1995 to 2009 over four periods: prior to the Asian crisis (1995–96), during the Asian crisis (1997–2000), after China's accession to the World Trade Organization (2001–07), and during the global financial crisis (2008–09). Figure 3.1.1 suggests several trends and tendencies.

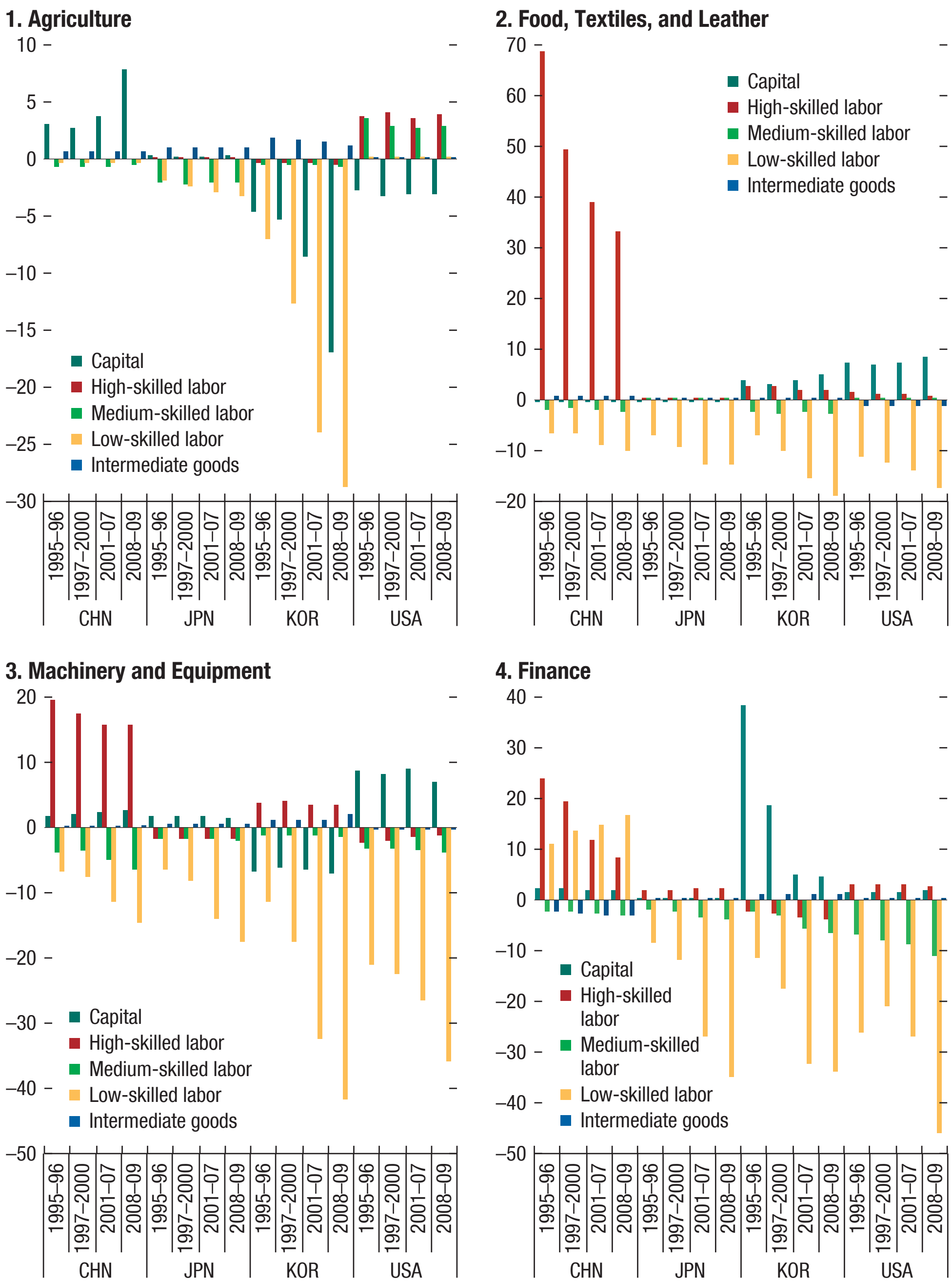
There is a general tendency toward a positive bias in capital goods and a negative bias against low-skilled labor in all countries under consideration. The capital bias is stronger in China, which is consistent with the notion that this country is relatively capital scarce, although the bias is declining over time. There appears to be a mild bias toward high-skilled labor in more research-intensive industries (such as machinery and equipment) and high-knowledge service industries (such as finance). Not surprisingly, those industries exhibit a strong negative bias against low-skilled labor, with the strongest negative bias in the most technically advanced country (the United States) and the least negative bias in China. Furthermore, in China, as an emerging market economy, the bias toward high-skilled labor is also observed in other industries, consistent with its relative scarcity.

These trends suggest that the impact of biased technical change on productivity may be unclear. Industries with a positive bias toward capital goods should generally demonstrate higher labor productivity. The impact on aggregate productivity, however, will depend on the productivity sectors where labor is reallocated and the ability of the economy to redeploy workers without increasing unemployment. Therefore, policymakers should take into account that increasing productivity in separate industries needs to be combined with inclusive growth. In addition, the widespread and often strong negative bias toward low-skilled labor and the positive bias toward high-skilled labor suggest that the benefits from increasing human capital and economic environment could help mitigate the economic effects from the ongoing transition implied by strong technical bias.

This box was prepared by Sergei Dodzin and Xinhao Han.

Box 3.1 *(continued)*

Figure 3.1.1. Technical Biases in Major Sectors
(Percent)



Sources: World Input Output Database; and IMF staff calculations.
Note: Data labels in the figure use International Organization for Standardization (ISO) country codes.

Box 3.2. The Roles of Government in Productivity: Case Studies of Australia and Singapore

In Asia, government could play a greater role in most economies to augment productivity growth. For example, as discussed in the text, government can also play a role by increasing education and health spending. Productivity growth can be stimulated through a variety of channels, often focused on macroeconomic and structural tax and expenditure policy (see IMF 2015). However, here, the focus is more narrow. This is not a call for governments to intervene in industrial policy, but rather to improve their role through engaging with the private sector, using a three-pronged approach:

1. Providing infrastructure through public investment, or by facilitating private efforts;
2. Putting in place a strong regulatory environment and secure legal framework in which to conduct business, have ownership, and engage smoothly with capital and labor; and
3. Establishing public institutions that can serve as public goods for the private sector and provide quality information

This is not to say there is no role for industrial policy, as demonstrated in the past by many of the Asia-Pacific advanced economies. However, to maintain productivity growth, private involvement is also important, and it can be facilitated by governments in their role as a central coordinator in their country for public goods. A good example is a leader in best practices, Australia, an advanced economy with vital links to Asia.

In Australia, several public institutions play the role of public good by sending strong signals to the private sector about the need for improved productivity, providing comprehensive sources of information, and validating private sector initiatives. Initiatives include Infrastructure Australia, which identifies infrastructure needs and evaluates plans to meet those needs from governments and the private sector, and the Productivity Commission, which provides analysis on the state of productivity growth and advice on legislation, but as an arm's-length observer.

The public sector then supplements these activities with its legislative work and direct spending. Through special studies, such as the Competition Policy Review (Harper and others 2015), the government works to strengthen the legal and regulatory environment in order to simplify conducting business. The government also actively engages in trade policy in an innovative fashion, such as through intellectual property protections under the now-defunct Trans-Pacific Partnership agreement.

On the spending side, the public sector leads large-scale infrastructure projects, but also encourages private sector involvement. Some modestly budgeted programs such as the National Innovation and Science Agenda (NISA) have ambitious aims. The NISA incubates industries perceived as future leaders in productivity (for example, information and communication technology), and facilitates research and development and industry collaboration through a three-pronged approach: increasing public spending on many smaller initiatives over five years; addressing perceived gaps in critical science capabilities and access to quality private funding; and simplifying business regulation and interaction with the public sector.

Some segments of Australia's approach are still new, and their effectiveness has yet to be evaluated (especially the new public initiatives and the NISA). However, the hope is that the three-pronged approach is a viable way forward to increase productivity in an economy with slowing productivity, such as Australia.

Australia's approach could be replicated in other Asia-Pacific economies by using limited government funds more efficiently, but avoiding being dependent on the public sector to "mandate" productivity growth. However, some countries, such as Singapore, are adapting Australia's approach to also include a more active

This box was prepared by Dirk Muir.

Box 3.2 *(continued)*

role for government.

In Singapore, the most recent vehicle is the report by the Committee on the Future Economy (2017). It recommends a framework to encourage productivity through economic development using seven strategies focused on five key concepts: consolidating international connections, deepening human capital, encouraging innovation, building a strong modern and digital infrastructure, and supporting industrial transformation. The main thrust of the resulting recommendations is new regulations and public funding that foster or work with the private sector. Some current government programs are consistent with this approach, such as on-the-job training and education (Skills Future) and the science and technology incubator program (Agency for Science Technology and Research, A*Star), which enables small and medium-sized enterprises to commercialize their research and development findings.

Singapore's approach—as seen, for example, in the Committee on the Future Economy and its recommendations—has more elements of a top-down strategy to improve productivity, but using the private sector as a vehicle. In Australia, the government plays more of a support role, providing institutional frameworks and information but little direct government funding. The distinction is not large, but Singapore's approach, at this early juncture, appears to give the government more engagement and control in the process.

Overall, the most useful parts of the push for productivity, as typified by both Australia and Singapore, will mostly likely be those that are also public goods—that is, clear and enforceable regulations and laws, institutions that could serve to evaluate the use of public money, and efforts to incubate commercially viable firms and industries.

Annex 3.1. Methodology and Data for the Sector-Level Productivity Analysis

This annex describes the regression approach underlying the results discussed in the section in this chapter on "Domestic and External Factors in Productivity Growth." It is based on Griffith, Redding, and van Reenen (2004) and Lee (2016). The dependent variable, labor productivity growth, is related to capital deepening, the labor productivity gap vis-à-vis the United States, research and development (R&D) investment, and trade. Using this baseline regression, two further channels—intra- and inter-industry trade, and foreign direct investment (FDI)—are considered individually.

The detailed construction and sources of the data used in the analysis are presented in Annex Table 3.1.1. The sample period is 1995 to 2007, as reported, and covers three Asian advanced economies[1] and 16 other advanced economies[2] for 24 industries (14 in manufacturing, six in services, and four in other sectors, as defined in Annex Table 3.1.2).

The general form of the regression equations (with lagged explanatory variables to mitigate endogeneity concerns) is:

$$\Delta logLP_{ijt} = \alpha_1 \Delta log(K/L)_{ijt} + \alpha_2 GAP_{ijt-1} + \alpha_3 RD_{ijt-1} + \alpha_4 RD_{ijt-1} \cdot GAP_{ijt-1} + \beta_1 Z_{ijt} + \mu_{ij} + \mu_t + \varepsilon_{ijt},$$

where the subscripts i, j, and t represent country, industry, and year, respectively; LP_{ijt} is labor productivity, which is real value added divided by the product of the number of engaged persons and the relevant purchasing-power-parity exchange rate; $(K/L)_{ijt}$ is the capital-labor ratio (real capital stock divided by the number of engaged persons and the relevant purchasing-power-parity exchange rate); GAP_{ijt} is the labor productivity gap via-à-vis the United States, which can be further defined as $(log(LP_{Fjt}) - log(LP_{ijt}))$; RD_{ijt} is R&D intensity (spending scaled by the industry's value added); μ_{ij} and μ_t are country-industry and year fixed effects, respectively; and ε_{ijt} is a stochastic error term.

Note that Z_{ijt} denotes extra channel variables. The first set of regressions in Annex Table 3.1.3—the columns under (1)—uses lagged imports to output (IM_{ijt}), which is the ratio of imports from the United States to country-industry output, and lagged exports to output (EX_{ijt}), the ratio of exports to the United States to country-industry output. Regression (2) further subdivides the measures of exports and imports to intra-industry and inter-industry flows for four extra channel variables. Regression (3) has FDI^{in}_{ijt}, the ratio of inward FDI to country-industry output, and

Annex Table 3.1.1. Variables and Their Data Sources

Variable	Description	Sources
Labor Productivity (*LP*)	Real value added/(number of engaged × PPP exchange rate)	World Input-Output database 2013; Inklaar and Diewert 2016
Capital/Labor Ratio (*K/L*)	Real capital stock/(number of engaged × PPP exchange rate)	World Input-Output database 2013; Inklaar and Diewert 2016
Productivity Gap (*GAP*)	Labor productivity gap from the U.S. ($ln(LP_F)$-$ln(LP_i)$)	World Input-Output database 2013; Inklaar and Diewert 2016
R&D Intensity (*RD*)	R&D expenditure/value added	OECD STAN database
Import Ratio (*IM*)	Imports from the U.S./output	World Input-Output database 2013
Export Ratio (*EX*)	Exports to the U.S./output	World Input-Output database 2013
Inward FDI Ratio (FDI^{in})	Inward FDI position/output	OECD Statistics; World Input-Output database 2013
Outward FDI Ratio (FDI^{out})	Outward FDI position/output	OECD Statistics; World Input-Output database 2013

Note: "FDI position" includes equities and inter-company loans, but excludes investment income flows and financial flows. FDI = foreign direct investment; OECD = Organisation for Economic Co-operation and Development; PPP = purchasing power parity; R&D = research and development.

Annex authored by Dongyeol Lee.

[1]Japan, Korea and Taiwan Province of China.

[2]Australia, Austria, Belgium, Canada, the Czech Republic, Finland, Germany, Hungary, Italy, Mexico, Poland, Portugal, Romania, Slovenia, Spain, and Turkey.

Annex Table 3.1.2. Industries

Sector	Industry Code	Description
Manufacturing (14)	15–16	Food, beverages, and tobacco
	17–18	Textiles and textile products
	19	Leather, leather products, and footwear
	20	Wood and products of wood and cork
	21–22	Pulp, paper, paper products, printing, and publishing
	23	Coke, refined petroleum, and nuclear fuel
	24	Chemicals and chemical products
	25	Rubber and plastics products
	26	Other nonmetallic mineral products
	27–28	Basic metals and fabricated metal products
	29	Machinery and equipment not elsewhere classified
	30–33	Electrical and optical equipment
	34–35	Transport equipment
	36–37	Manufacturing not elsewhere classified and recycling
Services (6)	50–52	Wholesale and retail trade, repair of motor vehicles and motorcycles
	H	Hotels and restaurants
	60–63	Transport and storage
	64	Post and telecommunications
	J	Financial intermediation
	71–74	Renting of machinery and equipment and other business activities
Other (4)	A–B	Agriculture, hunting, forestry, and fishing
	C	Mining and quarrying
	E	Electricity, gas, and water supply
	F	Construction

Source: United Nations International Standard Industry Classification, Revision 3.
Note: Industry codes are from the International Standard Industrial Classification, Revision 3 (ISIC, Rev. 3).

FDI^{out}_{ijt}, the ratio of outward FDI to country-industry output. In this regression, the R&D terms are dropped to avoid potential endogeneity problems between R&D and FDI.

The estimation of the impact of trade and FDI productivity faces identification issues, in particular reverse causality and omitted variables bias. Our econometric specification tried to address the reverse causality issue by using lagged variables as explanatory variables, an approach that has been widely used in the growth literature (for example, Griffith, Redding, and van Reenen 2004; Woo and Kumar 2015; Ahn and others 2016). The omitted variables bias is addressed through country-industry and year fixed effects. While these steps cannot fully resolve the identification issues, other studies found that ordinary least squares (or fixed effects) estimates do not appear to overstate the trade effects on income/productivity compared to instrumental variables (IV) estimates (for example, Frankel and Romer 1999; Ahn and Duval 2017). Moreover, our econometric specification may be less vulnerable to reverse causality issues than some other country-level estimation in the growth literature as we use industry-level productivity growth and bilateral industry-level trade with the United States (technology frontier). In this setup, the external influences are more likely to be transmitted from the technological frontier to non-frontier countries, not vice versa.

Annex Table 3.1.3. Sectoral Productivity Growth: Domestic and External Factors

	(1)					(2)	(3)
	All	Asian AEs	Other AEs	Manufacturing	Services	All	All
Capital/Labor Growth	0.301***	0.205***	0.321***	0.302***	0.235***	0.300***	0.187***
	(0.067)	(0.051)	(0.074)	(0.088)	(0.044)	(0.068)	(0.048)
Lagged LP Gap	0.127***	0.091***	0.126***	0.119***	0.167***	0.125***	0.288***
	(0.020)	(0.031)	(0.021)	(0.026)	(0.016)	(0.020)	(0.052)
Lagged R&D Intensity	0.256	0.310**	0.116	0.216	2.053*	0.252	
	(0.157)	(0.126)	(0.420)	(0.150)	(1.119)	(0.155)	
Interaction of Lagged R&D	−0.277**	0.307	−0.286	−0.191	−0.703	−0.257*	
and LP Gap	(0.132)	(0.327)	(0.200)	(0.142)	(1.412)	(0.140)	
Lagged Imports to Output	1.279***	1.454	1.258***	1.192***	1.793		
	(0.304)	(1.411)	(0.315)	(0.337)	(1.219)		
Lagged Exports to Output	0.347**	0.248	0.373**	0.441***	−0.988		
	(0.141)	(0.329)	(0.159)	(0.158)	(0.675)		
Lagged Imports to Output						1.336***	
(intraindustry)						(0.381)	
Lagged Imports to Output						1.160**	
(interindustry)						(0.486)	
Lagged Exports to Output						0.403	
(intraindustry)						(0.556)	
Lagged Exports to Output						0.337	
(interindustry)						(0.251)	
Lagged FDI to Output							0.029*
(inward)							(0.016)
Lagged FDI to Output (Outward)							−0.023*
							(0.013)
Country-Industry	403	67	336	249	81	401	182
Observations	4,233	672	3,561	2,723	710	4,211	1,434
R^2—within	0.305	0.233	0.321	0.264	0.561	0.296	0.202

Source: IMF staff calculations.

Note: Numbers in parentheses are robust standard errors clustered at the country-industry level. Constants, country-industry fixed effects, are included but not reported. The sample period is 1995–2007. AEs = advanced economies; FDI = foreign direct investment; LP = labor productivity; R&D = research and development.

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

Annex 3.2. Methodology and Data for the Country-Level Productivity Analysis

This annex relies on estimation at the country level, and is built around a main regression focused on productivity or technology spillovers across borders mainly through two channels—foreign direct investment (FDI) and trade—as well as domestic engines of productivity, best represented by investment in research and development (R&D). It builds on the work of Ang and Madsen (2013).

The regression equation to capture the total factor productivity (TFP) spillovers across countries is defined as:

$$logTFP_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta_1 logR\&D_{it} + \beta_2 logFDI_{it} + \beta_3 Import_{it} + \gamma X_{it} + \varepsilon_{it},$$

where the subscripts i and t represent country and year, respectively; TFP_{it} is total factor productivity; a_0 is the constant term; a_i and a_t are the country and year fixed effects, respectively; $R\&D_{it}$ is a domestic R&D stock constructed from patent data; FDI_{it} is the FDI stock; $Import_{it}$ is the ratio of imports to GDP; X_{it} is the control variables, including financial development and absorptive capacity (interaction terms involving human capital and public capital with FDI); and ε_{it} is a stochastic error term. The tertiary education enrollment rate for men is used as a proxy for human capital because men are the primary workforce in many countries. Stock data on R&D, public capital, and FDI are used rather than flow data, because technology spillovers might occur over the medium to long term. Since the latter are largely predetermined, they alleviate concerns about endogeneity problems, although the issue is not fully resolved because of a lack of suitable instruments. Hence, the results only indicate relationships between productivity and external factors, but not necessarily causality. To avoid problems with multicollinearity, some plausible but highly correlated other control variables are excluded from the set of explanatory variables (for example, the public capital stock is excluded since it is highly correlated with the R&D stock). The detailed construction and sources of the data used in the analysis are presented in Annex Table 3.2.1. This regression forms the basis of the regressions reported in Annex Tables 3.2.2, 3.2.3, and 3.2.4.

The analysis of the relationship between domestic investment and inward FDI considers the following empirical specification:

$$GFCF_{it} = \alpha_0 + \alpha_i + \alpha_t + \beta_1 GFCF_{it-1} + \beta_2 Inward\_FDI_{it} + \beta_3 Growth_{it-1} + \beta_4 i_{it} + \varepsilon_{it},$$

where the subscripts i and t represent country and year, respectively; $GFCF_{it}$ is domestic investment (gross fixed capital formation, both public and private); α_0 is the constant term; α_i and α_t are

Annex Table 3.2.1. Variables and Their Data Sources

Variable	Description	Sources
Total Factor Productivity (TFP)	TFP at constant national prices adjusted at 2011 purchasing power parity (USA = 1)	Penn World Tables 9.0 and Feenstra, Inklaar, and Timmer 2015
Gross Fixed Capital Formation (GFCF)	Gross fixed capital formation (percent of GDP)	IMF World Economic Outlook database
Domestic R&D Stock (R&D)[1]	Estimated using the perpetual inventory method for total patent applications by residents with a 20 percent depreciation rate as in Ang and Madsen 2013	World Intellectual Property Organization
Foreign Direct Investment (FDI)	FDI stock (percent of domestic capital stock)	UNCTAD; Penn World Tables 9.0
Inward FDI (Inward_FDI)	FDI inflow (percent of GDP)	UNCTAD
Public Capital Stock (Public_capital)	General government capital stock (percent of real GDP)	IMF Investment and Capital Stock Dataset
Imports	Imports of goods and services (percent of GDP)	World Development Indicators
Financial Development	Domestic credit to private sector (percent of GDP)	World Development Indicators
Human Capital	Tertiary education enrollment rate for men	World Development Indicators
Interest Rate	Lending interest rate (percent)	World Development Indicators
Real GDP Growth (Real_growth)	Real GDP growth rate	IMF World Economic Outlook database

Note: R&D = research and development; UNCTAD = United Nations Conference on Trade and Development.

[1]To avoid the division by zero problem when taking the log of domestic R&D, the formula log(R&D+0.1^5) is used. The results do not change substantially if we change this specification.

Annex authored by Ryota Nakatani.

Annex Table 3.2.2. Baseline Country-Level Total Factor Productivity Results

	Asia-Pacific	Asian AEs	Other A-P	AEs	EMDEs
R&D Stock	0.005***	0.019***	0.005***	0.008***	0.001
	0.001)	(0.006)	(0.001)	(0.003)	(0.001)
FDI Stock	0.089***	0.067***	0.103***	0.014***	0.046***
	(0.007)	(0.024)	(0.009)	(0.005)	(0.006)
Imports	−0.001***	0.001**	−0.003***	0.001***	−0.002***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Financial Development	0.002***	0.001	0.002***	0.000**	0.001
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)
Countries	14	5	9	36	70
Observations	454	153	301	1052	2074
R-Squared	0.93	0.81	0.90	0.87	0.93

Source: IMF staff calculations.

Note: White's heteroscedasticity robust standard errors are in parentheses. Constants, country fixed effects, and year fixed effects are included but not reported. AEs = advanced economies; A-P = Asia-Pacific; EMDEs = emerging market and developing economies; FDI = foreign direct investment; R&D = research and development.

*$p < .10$; **$p < .05$; ***$p < .01$.

Annex Table 3.2.3. Absorptive Capacity in Asia

	Asia-Pacific	Asia-Pacific	Asia-Pacific
R&D Stock	0.012***	0.005***	0.023***
	(0.004)	(0.001)	(0.005)
FDI Stock	0.118***	0.087***	0.096***
	(0.012)	(0.008)	(0.013)
Imports	−0.001*	−0.001***	−0.002**
	(0.001)	(0.000)	(0.001)
Financial Development	0.001*	0.002***	0.002**
	(0.001)	(0.000)	(0.001)
Interaction of FDI Stock and Human Capital	0.002**		0.002**
	(0.001)		(0.001)
Interaction of FDI Stock and Public Capital		−0.011	−0.099**
		(0.014)	(0.044)
Countries	12	13	11
Observations	203	430	184
R-Squared	0.95	0.93	0.95

Source: IMF staff calculations.

Note: White's heteroscedasticity robust standard errors are in parentheses. Constants, country fixed effects, and year fixed effects are included but not reported. AEs = advanced economies; EMEs = emerging market economies; FDI = foreign direct investment; R&D = research and development.

*$p < .10$; **$p < .05$; ***$p < .01$.

the country and year fixed effects, respectively; $Inward\_FDI_{it}$ is FDI inflows; $Growth_{it}$ is real GDP growth; i_{it} is a nominal interest rate; and ε_{it} is a stochastic error term. $Growth_{it-1}$ is lagged one year to avoid endogeneity problems, whereas contemporaneous $Inward\_FDI_{it}$ is used to estimate the simultaneous relationship between FDI and domestic investment (*GFCF*). The results of this regression are reported in Annex Table 3.2.5.

Panel unit root regression tests were carried out, indicating that most variables are stationary at the 5 percent level of significance, although the financial development, human capital, and public capital variables have unit roots and are stationary in first differences. The sample in this study covers five Asian advanced economies (Asian AEs),[1] nine other Asia-Pacific economies (other A-P),[2] the Asian advanced economies and other Asia-Pacific economies as one group (Asia-Pacific), 36 advanced economies (AEs),[3] and 70 emerging

[1]Japan, Korea, Hong Kong SAR, Macao SAR and Singapore.

[2]China, Fiji, India, Indonesia, Malaysia, Mongolia, the Philippines, Sri Lanka, and Thailand.

[3]Australia, Austria, Belgium, Canada, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, New Zealand, Norway, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the United States plus the five Asian advanced economies.

Annex Table 3.2.4. Asia before and after the Global Financial Crisis

	1980–2007	2008–14
R&D Stock	0.010***	0.090***
	(0.003)	(0.027)
FDI Stock	0.127***	0.107***
	(0.014)	(0.027)
Imports	−0.001	−0.003***
	(0.001)	(0.001)
Financial Development	0.002**	0.001
	(0.001)	(0.001)
Interaction of FDI Stock and Human Capital	0.001	0.002**
	(0.001)	(0.001)
Countries	12	11
Observations	137	66
R-Squared	0.97	0.98

Source: IMF staff calculations.
Note: White's heteroscedasticity robust standard errors are in parentheses. Constants, country fixed effects, and year fixed effects are included but not reported. Excludes Australia and New Zealand. AEs = advanced economies; A-P = Asia-Pacific; EMEs = emerging market economies; FDI = foreign direct investment; R&D = research and development.
$^{*}p < .10$; $^{**}p < .05$; $^{***}p < .01$.

Annex Table 3.2.5. Complementarity between Domestic Investment and Foreign Direct Investment in Emerging and Developing Asia and the Pacific

	1978–2015	1992–2015	1997–2015	2001–15	2008–15
Lagged Investment	0.690***	0.664***	0.571***	0.557***	0.325***
	(0.036)	(0.041)	(0.046)	(0.055)	(0.078)
Inward FDI Flows	0.133**	0.126*	0.146**	0.170***	0.566***
	(0.060)	(0.065)	(0.069)	(0.077)	(0.122)
Lagged Real Growth	0.156**	0.107	0.129	0.111	0.144
	(0.072)	(0.084)	(0.089)	(0.104)	(0.195)
Interest Rate	0.038**	0.036**	0.194**	−0.046	−0.507
	(0.016)	(0.017)	(0.088)	(0.182)	(0.361)
Observations	470	382	330	273	147
R-Squared	0.84	0.83	0.82	0.81	0.83

Source: IMF staff calculations.
Note: Standard errors are in parentheses. Constants, country fixed effects, and year fixed effects are included but not reported. Excludes Australia and New Zealand. FDI = foreign direct investment.
$^{*}p < .10$; $^{**}p < .05$; $^{***}p < .01$.

market and developing economies (EMDEs)[4] for TFP spillover analyses. It also covers 19 emerging and developing Asia and Pacific economies for the analysis examining the complementarity of investment and FDI.[5] The TFP regressions cover the period (or subperiods of) 1980–2014 (Annex Tables 3.2.2 to 3.2.4), while the investment-FDI regressions cover the period (and subperiods of) 1978–2015 (Annex Table 3.2.5).

[4]Argentina, Armenia, Bahrain, Barbados, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Chile, Colombia, Costa Rica, Côte d'Ivoire, Croatia, the Dominican Republic, Ecuador, Egypt, Guatemala, Honduras, Hungary, Iran, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kuwait, the Kyrgyz Republic, Lesotho, Mauritius, Mexico, Moldova, Morocco, Mozambique, Namibia, Nicaragua, Nigeria, Panama, Paraguay, Peru, Poland, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Serbia, Sierra Leone, South Africa, Sudan, Swaziland, Tajikistan, Tanzania, Trinidad and Tobago, Tunisia, Turkey, Ukraine, Uruguay, Venezuela, and Zimbabwe plus the nine other Asia-Pacific economies.

[5]Bangladesh, Bhutan, Brunei Darussalam, China, Fiji, India, Indonesia, Malaysia, Maldives, Mongolia, Myanmar, Nepal, the Philippines, Solomon Islands, Sri Lanka, Thailand, Timor-Leste, Vanuatu, and Vietnam.

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