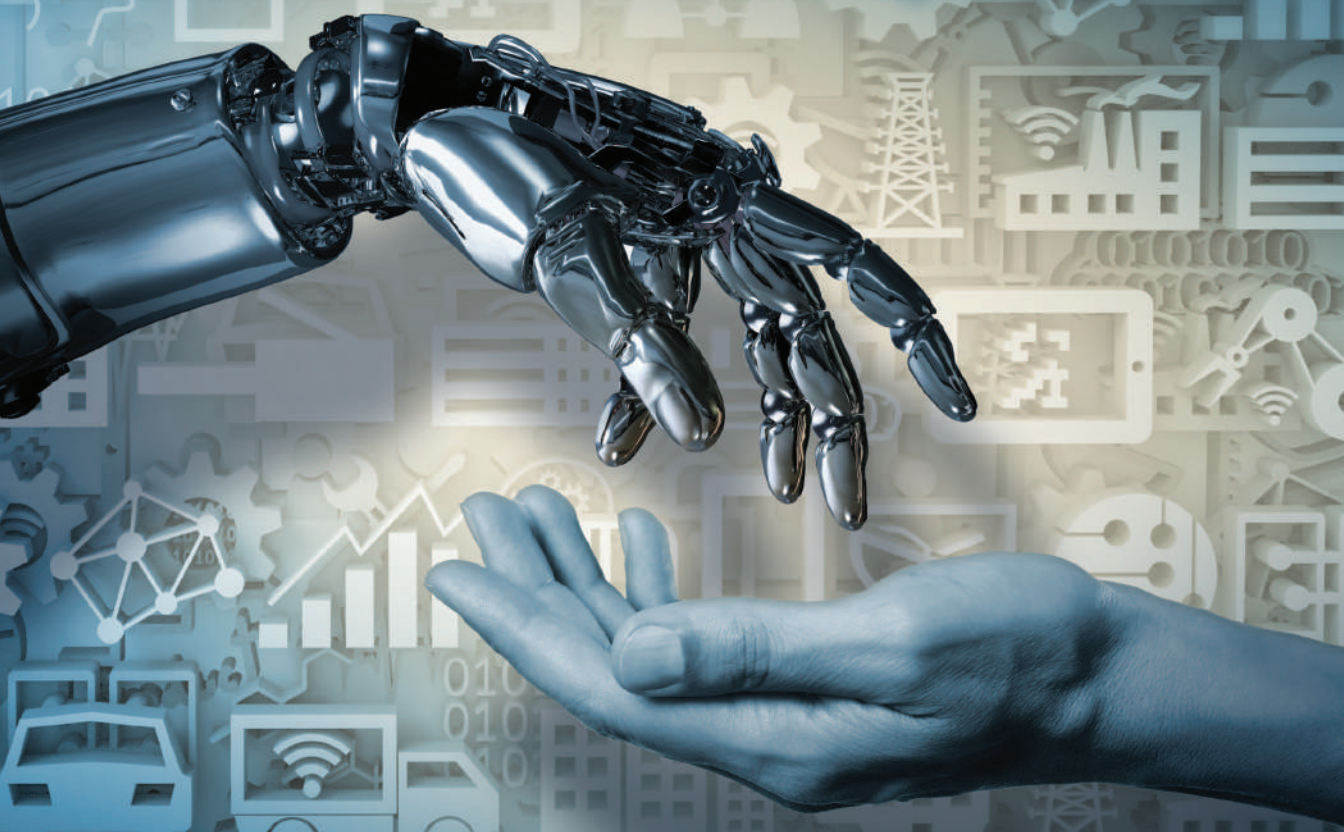
CONFERENCE EDITION

# Trouble in the MAKING?

## The Future of Manufacturing-Led Development



Mary Hallward-Driemeier
Gaurav Nayyar

WORLD BANK GROUP

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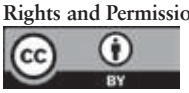
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# Foreword

With the global economy experiencing an era of profound change, building a prosperous society with an equitable distribution of income will require ever-greater ingenuity and stronger strategies. The creation of higher-skilled, higher-wage jobs is essential to achieving the twin goals of the World Bank Group—ending extreme poverty by the year 2030 and promoting shared prosperity—and will require investment and innovation across economic sectors, including agriculture, services, and manufacturing.

The surest way to raise workers' incomes is to create high-quality jobs. Historically, these have been found in manufacturing, but jump-starting job growth in manufacturing is no easy task for policymakers or the private sector. *Trouble in the Making? The Future of Manufacturing-Led Development* aims to help policymakers and business leaders envision new approaches to promoting manufacturing-led development.

Focusing on the impacts of new technologies and shifting patterns of globalization, the book recognizes that "business as usual" will not succeed in promoting manufacturing-led job growth in developing countries. However, it makes the case that wealth-generating, job-creating opportunities can indeed be seized. Success requires new approaches to promoting manufacturing that consider each economy's competitiveness, capabilities, and connectedness, within the context of ever-shifting international trade patterns, marketplace demands and financial strengths.

Society cannot afford to fail in confronting the challenges of the manufacturing sector. Any economy that misses opportunities for job creation—especially in the higher-skilled, higher-wage occupations that are concentrated in the manufacturing sector—is setting itself up for suboptimal growth rates and potentially an unstable society that suffers from a chronic concentration of wealth and poverty.

Designing effective strategies to broaden opportunities in production and related services will call for energetic economic thinking. Policies will be needed to raise education and skill levels, guide public- and private-sector finance to their most promising use, and reduce the barriers that have long hindered cross-border commerce and fair-minded development.

Government officials and private-sector leaders are seeking new ideas about strengthening productivity gains and bolstering job creation. This book offers a range of suggestions to help economic decision makers overcome these dilemmas.

Every economy will be affected by the accelerating change in global trends, and every policymaker and business leader who seeks practical solutions to the job-creation challenge can benefit from the imaginative ideas explored here.

*Jan Walliser*
Vice President, Equitable Growth, Finance and Institutions
The World Bank Group

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# Abbreviations

| | |
|---|---|
| FDI | foreign direct investment |
| GDP | gross domestic product |
| GVC | global value chain |
| HICs | high-income countries |
| ICT | information and communication technology |
| IoT | Internet of Things |
| LMICs | low- and middle-income countries |
| n.e.c. | not elsewhere classified |
| NTMs | nontariff measures |
| R&D | research and development |
| WTO | World Trade Organization |
| 3Cs | competitiveness, capabilities, connectedness |
| 3-D | three-dimensional |

# Introduction

## Motivation and Objectives

In the past, manufacturing-led development typically delivered both productivity gains and job creation for unskilled labor. Underpinning the productivity benefits was the sector's tradability in international markets, which not only reinforced scale economies and technology diffusion, but importantly, also provided greater opportunities to access demand beyond the domestic market and increased competition. The agricultural sector was also tradable but faced demand-side constraints owing to a low income elasticity of demand and productivity improvements that were closely linked to labor-saving technologies. Many low-end services could also absorb surplus labor from agriculture but provided little by way of productivity growth.

Looking ahead, changing technologies and shifting globalization patterns call the feasibility of manufacturing-led development strategies into question. Trade is slowing. Global value chains (GVCs) remain concentrated among a relatively small number of countries. The Internet of Things, advanced robotics, and 3-D printing are shifting the criteria that make locations attractive for production and are threatening significant disruptions in employment, particularly for low-skilled labor. These trends raise fears that manufacturing will no longer offer an accessible pathway for low-income countries to develop and, even if feasible, would no longer provide the same dual benefits of productivity gains and job creation for unskilled labor. As a result, the potential risk of growing inequality across and within countries warrants closer attention to the implications of changing technology and globalization patterns.

Much of the attention on changing technologies and globalization patterns treats "manufacturing" in the aggregate, highlights the downside risks, and focuses on high-income countries. This book, in contrast, looks at changing technology and globalization from the perspective of low- and middle-income countries (LMICs)—with an emphasis on analyzing differences across manufacturing subsectors and identifying policy priorities with an eye toward making the most of new opportunities. Any forward-looking discussion is inherently speculative; the aim here is to identify possible challenges and opportunities for LMICs to help them strengthen their position now.

The book will answer the following questions:

- How has the global manufacturing landscape changed, and why does this matter for development opportunities?
- How are emerging trends in technology and globalization likely to shape the feasibility and desirability of manufacturing-led development in the future?
- If low wages are going to be less important in determining competitiveness, how can less industrialized countries make the most of new opportunities that shifting technologies and globalization patterns may bring?

## Scope

When analyzing shifts in technology, the focus is on the use of new industrial process technologies to produce traditional manufactured goods, which can change conventional patterns of comparative advantage. The Internet of Things, advanced robotics, and 3-D printing are among the most emphasized process technologies in the Industry 4.0 literature and are expected to affect the relative competitiveness of firms across countries.

In looking at globalization patterns, the focus is on trends in international trade and foreign direct investment (FDI). In manufacturing, compared with other sectors, it is far more likely that capital, know-how, and intermediate goods flow to where the labor is than the other way around, with final goods then flowing again to where consumers are. These flows of goods and capital, with technology embedded, are therefore central to developing a successful manufacturing sector.

Technological advancement and globalization are treated as distinct trends, but the two are not independent. Technology intersects with trade and investment in affecting where and how production happens, where different types of jobs are being created, the extent of productivity growth, and thus the extent of economic opportunities around the world. They need to be understood together when analyzing how the geography of production is likely to change in the future.

The changing geography of production is defined by three outcomes of interest: The first—the distribution of global manufacturing activity—concerns the extent to which LMICs are expanding their global shares in

manufacturing value added, employment, and exports, and how concentrated such activities are among them. The second—the composition of manufacturing within domestic production baskets—pertains to the changing share of manufacturing in GDP and employment within countries, both relative to other sectors and in absolute terms. Examining the prevalence and extent of deindustrialization frames the discussion of implications for productivity and employment. The third—the composition of manufacturing subsectors across countries—examines, using patterns of revealed comparative advantage and changing domestic production baskets, the extent of the evidence for "flying geese," or product cycle migration of production to lower-cost locations. For this, data on two-digit manufacturing subsectors at the country level are used; these are widely available, allow a range of dimensions to be explored, and keep the analysis general enough to identify the potential for spillovers.

## Structure

### Part I: The Global Manufacturing Landscape

Before discussing the future of manufacturing-led development, understanding the historical comparison with other sectors provides needed context about why manufacturing is important and why the prospects for greater deindustrialization may be a cause for concern. The comparison with agriculture and services in the past is to highlight the mix of pro-development characteristics of manufacturing: the sector's opportunities for scale, tradability, innovation, and employment brought a combination of spillovers and dynamic growth gains with job creation for unskilled workers. It is precisely this combination that is shifting, potentially dramatically, depending on how labor-saving new technologies are, how much more efficient they are at producing goods, and how widely they are adopted.

While much of the literature has focused on "manufacturing," there is enormous heterogeneity between subsectors, across countries, and over time that affects the potential for development impact. Taking this heterogeneity into account provides important nuances as to where the various desirable, pro-development characteristics can be found. Which goods a country makes matters, not because some goods are inherently superior but because of their potential to provide spillovers, dynamic growth gains, and job creation—and because production processes across subsectors are likely to be differentially affected by changes in technology and globalization patterns in the future.

The changing distribution of manufacturing output, employment, and productivity therefore matters. Chapter 2 summarizes these recent changes in the global manufacturing landscape within three categories of stylized facts:

- *Distribution of global shares of manufacturing.* High-income countries still account for most of global manufacturing value added and remain the big exporters, although China has become the single

largest producer of manufactured goods. At the same time, LMICs' shares of global manufacturing employment are higher than their shares of value added, reinforcing productivity differences between the dominant and smaller players.

- *Manufacturing as a share of domestic production and employment.* The vast majority of countries are seeing declines in the manufacturing share of gross domestic product (GDP) and total employment, but these seldom translate into absolute declines, instead reflecting faster growth of the services sector. Further, the manufacturing shares of both total value added and employment are peaking at lower levels, and at lower levels of per capita income, than in the past.
- *Composition of manufacturing subsectors across countries.* While high-income countries are deindustrializing across the manufacturing sector, the changing composition of production and export baskets shows some evidence of the "flying geese" paradigm—moving from labor-intensive to higher-skill manufactured goods—among upper-middle-income industrializers. Few lower-income countries have a revealed comparative advantage in anything but labor-intensive tradables or commodity-based regional processing, although not all have even passed these thresholds.

These specialization patterns in the manufacturing sector across low- and lower-middle-income economies have implications for potential positive spillovers and dynamic growth and development gains. Looking ahead, a concern is whether new technologies and shifting patterns of globalization will make it harder for LMICs to have a significant role in manufacturing, including in sectors that define their curent production baskets.

### Part II: Technology, Globalization, and the Future of Manufacturing-Led Development

While urbanization, demographic change, and climate change will affect the demand for manufacturing, the two trends with the biggest impact on how and where goods will get made are advancing technology and changing globalization patterns. Technology has the potential to introduce radically labor-saving processes, disrupt traditional scale economies, change the required skill mix of workers, and increase the need for complex, firm ecosystems to support production. The resulting possibility of reshoring to high-income countries could limit the production opportunities coming to lower-income countries. Further, trade is slowing for both cyclical and structural reasons as some global value chains become more concentrated, China rebalances from investment to consumption, and new threats of protectionism arise. Manufacturing represents a significantly decreasing share of greenfield FDI, although evidence indicates diversification in the destination countries. Together, these trends raise the prospect of significant disruptions for less industrialized countries that are already part of GVCs or are seeking to expand their manufacturing base in the future.

Therefore, emerging technologies and changing patterns of globalization are likely to affect both the feasibility and desirability of manufacturing-led development. For one thing, the bar is rising for a location to be an attractive production site. For another, the very desirability of manufacturing activities may be eroding, owing to new manufacturing process technologies—both if the sector's job creation potential declines and if shortened GVCs diminish the productivity benefits associated with international trade in manufactured goods.

However, focusing only on production misses the broader sources of value, employment, and innovation through which the manufacturing process can contribute to development. The growing synergies with services, which are increasingly either embodied or embedded in goods, are important hallmarks of the future of manufacturing. Services are not only increasingly intertwined in driving the value and success of manufacturing, but are also expanding their own contributions in the employment-trade-productivity space. Several professional services share the productivity characteristics associated with being traded, a source of innovation and technology diffusion. And to the extent that services can provide growth opportunities independent of a manufacturing core—particularly as demand for services rises with income—they offer a potential alternative strategy for development. These "stand-alone" services, however, are unlikely to deliver the dual benefits of productivity growth and large-scale jobs for unskilled workers.

## Part III: Preparing for Change: Refocusing the Manufacturing-Led Development Agenda

Strengthening competitiveness, capabilities, and connectedness (the 3Cs) becomes increasingly important given heightened global competition, but the agenda needs some reconceptualization in the face of coming changes. Technological advances and changing globalization patterns reinforce the urgency in some elements of the traditional reform agenda. But they also introduce a new understanding of why each of the 3Cs is important and thus why new agenda items need to be added, as follows:

- *Ensuring competitiveness* will increase the urgency of reforms that lower unit labor costs, but also put more emphasis on ensuring that institutional frameworks support new business models, new contracting relationships to use technology, and new ways that manufacturing goods deliver services.
- *Building capabilities* will add to workers' skills, strengthen firms' abilities to absorb new technologies, and provide the new infrastructure and rules needed to use them.
- *Strengthening connectedness* will continue to encompass openness to trade in goods and logistics performance, but also will raise the importance of accessing the growing synergies of services as embodied and embedded features of goods.

The identification of policy priorities within this reform agenda will also benefit from some customization across countries. Countries vary in their levels of competitiveness, capabilities, and connectedness. There may even be differences across countries within the constituent components of each of the 3Cs. For example, within connectedness, while restrictions on services trade might be particularly problematic for some countries, they might be a strength among others. Further, given existing patterns of specialization across different manufacturing subsectors, countries may need to emphasize certain parts of the 3Cs agenda, depending on how changing technology and globalization patterns differentially affect certain subsectors. For example, if a subsector is expected to need higher capabilities, countries that are active in this sector should likely prioritize strengthening their capabilities to maintain or expand their position in this subsector.

Given the new reform priorities, countries will need to explore complementarities between "horizontal" (economywide) and more "targeted" (sector- or location-specific) industrial policies. As reform priorities become more demanding because of new technologies and changing globalization patterns, it may be more feasible to achieve a globally competitive manufacturing sector by targeting reforms to locations and sectors. One debate gaining attention is about technological leapfrogging: if using newer technologies will not be possible without having first developed traditional manufacturing processes, then *not* intervening to catalyze production could include dynamic costs of closing off important opportunities in the future. At the same time, given the increasing importance of interfirm and intersectoral spillovers and the growing uncertainty about the pace of technological change, countries will need to focus on establishing linkages *throughout* the economy and developing transferable skills to reduce future risks. Intervening in isolation is not likely to be effective.

PART I

# THE GLOBAL MANUFACTURING LANDSCAPE

*Manufacturing-led development—the hitherto dominant development paradigm—has been associated with some of the biggest development gains in history. Those economies that led the Industrial Revolution are now among the richest in the world, and the "East Asian Miracle" provides a more recent example of the success of the manufacturing export-led model—the benefits being manifested in the absorption of unskilled labor at a productivity premium and positive spillovers associated with trade in international markets.*

*Yet, not all countries that attempted industrialization were successful in climbing up the income ladder, a disparity that emphasizes the "how" rather than the "what" of production. Historically, the geography of global production has been shaped by the intertwining of changes in technology and globalization. Perhaps what is different now is that the pace of change is accelerating, and the extent to which new technologies may be labor saving could be unprecedented.*

*Before turning to the Fourth Industrial Revolution that is now under way—which part II of this book addresses—part I looks at some of the impacts of earlier waves of new technology and globalization on key patterns in today's manufacturing landscape, including across subsectors. The nature of these impacts has implications for development opportunities because manufacturing subsectors vary in the magnitude of associated pro-development characteristics. Therefore, as patterns of specialization change, so do the potential benefits of a manufacturing-led development strategy.*

CHAPTER 1

# Why Manufacturing Is Important for Development

## Introduction

Industrialization has been synonymous with development because most high-income countries (HICs) achieved that level of prosperity through manufacturing export-led strategies. Economic history demonstrates that countries at the forefront of the Industrial Revolution in the 18th century are now among the richest economies in the world. Almost all of today's HICs have industrialized with manufacturing, at its peak, accounting for 25–35 percent of gross domestic product (GDP). More recently, the rise of successive waves of East Asian countries to the upper-middle-income and high-income ranks on the strength of export-led manufacturing reinforces the development community's attention to the potential of manufacturing to foster development. Few countries have reached high-income levels without developing a manufacturing base—in such cases, doing so through either natural resource extraction or the exploitation of specific locational or other advantages.

The development benefits associated with manufacturing historically resulted from the absorption of unskilled workers at a productivity premium and the positive spillover effects of international trade. The manufacturing sector has typically absorbed a substantial part of the economy's lowskilled labor and placed that labor on a productivity path that rises up to the global frontier. This productivity boost for large numbers of unskilled workers is attributable to the manufacturing sector's production of tradable goods—facilitating scale economies, technology diffusion, greater competition, and other spillover effects. Although agricultural commodities were also traded internationally, the demand-side dynamics resulting from a relatively low income elasticity of demand meant that countries specializing in

primary production did not benefit as much as manufacturing-based economies from the expansion of world markets.

Nor did all countries benefit equally from industrialization, demonstrating the importance of the "how" rather than the "what" of production. Some countries saw progress stall after a transitory pickup of economic growth, such as in Latin America. Other countries, including those in Sub-Saharan Africa and South Asia, never managed to break into manufacturing production to a significant extent. In many of these countries, efforts to industrialize without openness—for example, through import substitution—led to many costly failures. Similarly, the adoption of capital-intensive production techniques in heavy industries did not result in the large-scale absorption of unskilled labor.

## The Stakes: Manufacturing's Historical Desirability Revisited

*Key message: The manufacturing sector's role in supporting economic growth and development has been underpinned by a range of pro-development characteristics with the potential for spillovers and dynamic productivity gains: scale, tradability, innovation, learning by doing, and job creation. It has played a unique role in development by raising the productivity of large, unskilled workforces.*

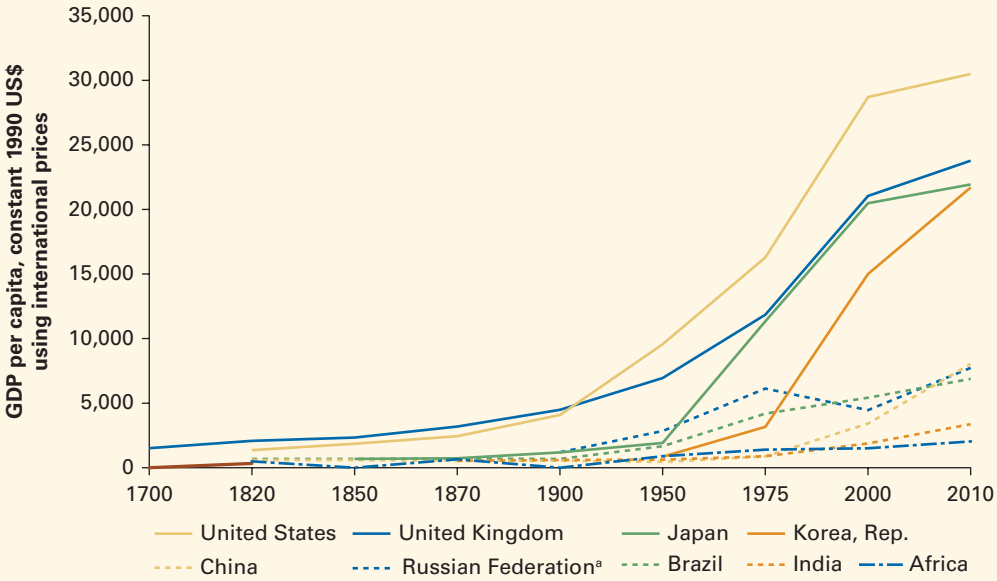
Some of the biggest development gains in history have been associated with industrialization.[1] Annual growth in global GDP per capita was below 0.1 percent until the early 19th century, yet technological change from the late 1700s to the mid-1800s spurred a manufacturing-based, fossil-energy-fueled Industrial Revolution, leading to a significant boost in growth among early industrializers.[2] In Western Europe's earliest industrializers and in the United States, average annual per capita income growth sped up to 1.0 and 1.3 percent, respectively, over the 1820–70 period, compared with close to zero in other regions such as East Asia and Latin America (figure 1.1). It was industrialization again that drove other countries to catch up to these early industrializers, starting in the late 19th century with Japan.

More recently, the economic take-off circa 1960 that resulted in East Asia's growth miracle coincided with the rapid export growth of manufactures (Leipziger 1997; Rodrik 1994; Stiglitz and Yusuf 2001; World Bank 1993).[3] Those few countries that have reached high income levels through other means have done so through natural resource extraction[4] or the exploitation of specific locational or other advantages.[5]

Empirical evidence documents a robust association between the growth of manufacturing activity and overall economic growth. "Kaldor's growth laws," based on data from now-high-income economies, proposed that economic growth is related to three positive associations: (a) between growth of manufacturing output and average GDP growth, (b) between growth of manufacturing output and manufacturing productivity, and (c) between

**Figure 1.1 Development Has Historically Been Associated with Industrialization**

*Per Capita GDP Growth of Selected Industrializing Economies, 1700–2010*




*Source:* Bolt and van Zanden 2014.
*a.* Russian Federation, 1991–present; Union of Soviet Socialist Republics, 1922–91.

growth of manufacturing output and the overall productivity of the economy Kaldor (1966).

More-recent evidence based on data from low- and middle-income countries (LMICs) also reveals a positive relationship between the growth of manufacturing output and overall GDP growth (Fagerberg and Verspagen 1999; Szirmai and Verspagen 2015).[6] Between 1970 and 2010, China, the Republic of Korea, and Thailand had significant increases in the share of manufacturing in employment and value added, combined with some of the highest per capita income growth rates in the world (Cruz and Nayyar 2017). However, these relationships in the data represent correlations, not causality, which is hard to establish.[7]

Integral to these dynamics was the movement of surplus labor from (rural) agriculture to (urban) manufacturing and capital accumulation in the latter (Lewis 1954). This structural transformation was productivity-enhancing, owing to large and systematic differences in labor productivity between the agricultural and manufacturing sectors, and these intersectoral labor productivity gaps are wider in the poorest countries (Caselli 2005; Herrendorf, Rogerson, and Valentinyi 2013; Restuccia, Yang, and Zhu 2008). For example, across a sample of 11 African economies, agriculture (at 35 percent of average productivity) has the lowest

productivity by far; manufacturing productivity is 1.7 times as high (Diao, McMillan, and Rodrik 2017). In East Asian countries, the movement of labor from low-productivity agriculture to modern manufacturing industries played a critical role in boosting productivity growth (World Bank 1993).

While many economists have emphasized structural transformation from agriculture to manufacturing as the central dynamic to understanding productivity growth, others suggest that opportunities to enhance productivity growth may also be occurring within sectors. For example, Herrendorf, Rogerson, and Valentinyi (2013) show that for most high-income and transitioning economies, productivity growth has largely occurred within sectors, with occasional reallocations across sectors. Diao, McMillan, and Rodrik (2017) also support this finding, concluding that recent growth accelerations in Latin American countries were based on rapid within-sector labor productivity growth. In particular, reallocation of resources within sectors has become an important source of productivity gains, with evidence of large heterogeneity in productivity across firms (Bloom et al. 2010; Caballero et al. 2004; McMillan and Rodrik 2011).[8] Analyzing the contributions of manufacturing is not to claim that it alone drives productivity growth.

Another fundamental question involves whether *how* a good is produced has as important a potential impact on development—if not more so—than *what* is produced. Baldwin (1969), de Ferranti et al. (2002), Lederman and Maloney (2010), and Rodríguez Clare (2007) caution that expanding a sector with potential positive spillovers does not necessarily imply that the spillovers will automatically occur if the sector is not organized appropriately. For example, at the beginning of the 20th century, copper mining in the United States led to a knowledge network in chemistry and metallurgy that laid the foundations for subsequent diversification and industrialization, while in Chile the same industry nearly died (Maloney and Valencia 2016). Likewise, although Nigeria has arguably underperformed economically, Norway has created an innovative oil and gas industry with substantial links and become one of the richest countries of the world, creating a Norwegian Petroleum Directorate as well as accelerating a manufacturing industry supporting the sector (Cappelen, Eika, and Holm 2000; Fagerberg, Mowery, and Verspagen 2009). Within manufacturing, although both the Republic of Korea and Mexico began assembling electronics in the early 1980s, only Korea has produced a truly indigenous electronic device: the Samsung Galaxy smartphone line.

The production process in the manufacturing sector has typically absorbed large numbers of relatively unskilled workers from other sectors at a substantial productivity premium: it is comparatively easy to turn a rice farmer into a garment factory worker without significant investment in human capital and with manageable investment in physical capital. In contrast, the mining sector—whose productivity also is significantly higher than in agriculture (16.8 times higher among a sample of 11 countries in

Sub-Saharan Africa [McMillan and Rodrik 2011])—is capital-intensive and thus cannot absorb as much of the unskilled labor supply as the manufacturing sector. Nor can the education, health, and professional services sector (where high-value-added, high-productivity services are typically skill-intensive), whereas many low-end services that *could* absorb surplus labor from agriculture provide little productivity growth. This latter point illustrates Baumol's (1967) "cost disease" hypothesis, which emphasized that productivity in labor-intensive services cannot be readily increased through capital accumulation, innovation, or economies of scale.[9]

Furthermore, unlike evidence on per capita income levels or aggregate labor productivity, Rodrik (2011) shows that labor productivity in (formal) manufacturing exhibits "unconditional convergence" across countries.[10] Therefore, labor productivity in lagging manufacturing sectors, such as those in low- and middle-income economies, tends to rise and eventually converge with the global technological frontier regardless of policy and institutional determinants.[11] More recent evidence suggests that high productivity growth in the manufacturing sector explains about 50 percent of the catch-up in relative aggregate productivity across countries (Duarte and Restuccia 2010). This convergence may be attributable to the manufacturing sectors' production of tradable goods, thus facilitating scale economies, technology diffusion, and greater competition, among other spillover effects. It is therefore not surprising that countries that have reached high income levels did so through manufacturing export-led strategies rather than import substitution approaches (Agénor and Canuto 2015).

The contrast between export-oriented industrialization in East Asia and import substitution industrialization in Latin America also shows that *how* an economy produces and not just *that* it produces matters for its growth outcomes. Between 1965 and 1986, manufacturing output in the Republic of Korea and Taiwan, China, grew twice as much as in the fastest-growing Latin American economies. Korea's production was growing at 16.1 percent per year and that of Taiwan, China, at nearly 12.2 percent per year, while Mexico's growth was a mere 5.2 percent and Brazil's was 7.1 percent (Jenkins 1991). At the same time, between the 1960s and the 1990s, Asian economies such as Indonesia; Korea; Malaysia; Singapore; Taiwan, China; and Thailand started leaping past Latin American countries in the growth ranks (Devlin and Moguillansky 2011). These Asian economies also sharply and sustainably reduced poverty, while Latin America did not (Devlin, Estevadeordal, and Rodríguez-Clare 2006). The success of East Asian economies is often attributed to export-oriented industrialization, which integrated the countries with world markets, enabling them to achieve scale, face competition, and acquire foreign technology. In contrast, import substitution industrialization in Latin American countries—an inward-oriented strategy that used trade barriers to strengthen local producers in sectors that did not conform to the country's comparative advantage—did not deliver similar growth benefits (Gereffi and Wyman 2014).

In sum, more so than the agriculture and services sectors, manufacturing combined tradedness and other productivity-enhancing characteristics with large-scale job creation for the relatively unskilled. Although the agricultural sector was also traded it faced price volatility in international markets, and productivity improvements were closely linked to labor-saving technologies.[12] Demand-side dynamics also play a role: as per capita incomes rise, the share of agricultural products in total expenditure declines, while the share of manufactured goods increases in accordance with a hierarchy of needs.[13] As a result, countries specializing in agricultural production do not benefit from the global expansion of markets for manufactured goods (Szirmai 2012). As for the services sector, as noted earlier, high-end services have typically been skill-intensive and were largely not tradable in the past. Although many low-end services could absorb surplus labor from agriculture, they provided little by way of productivity growth. Of late, productivity-enhancing structural change in Africa has been attributed to an expansion in low-end services, but this expansion appears to be largely unsustainable owing to limited demand beyond the domestic market (McMillan, Rodrik, and Sepulveda 2017).

### Indicators of Pro-Development Characteristics

This uniqueness of manufacturing-led development can be summarized in the combination of five variables that are indicative of these pro-development characteristics:

- *Scope to employ unskilled workers:* The share of blue-collar workers in a sector's employment is used, taken from census data for selected high-income and low- and middle-income economies.[14]
- *Sector's share of labor in the overall economy:* Beyond the share of a sector's labor that is unskilled, the sector's share of total employment (world total) is of direct interest.
- *Labor productivity:* The sector's output per worker (world total) proxies for its extent of labor intensity and labor productivity.
- *Tradedness:* The sector's export-to-output ratio measures trade in international markets (world total).[15] Although all goods have the potential to be traded, in practice, sectors vary considerably in the extent to which their goods are traded.
- *Scope for innovation and diffusion:* The ratio of research and development (R&D) spending to value added, based on U.S. data, captures technology development. That sectors are R&D-intensive in HICs does not mean that R&D activities are also being conducted in LMICs. Rather, there is more scope for technology diffusing in the more innovative sectors.

The combination of these variables indicates a sector's relative pro-development potential. Specifically, *employment creation for unskilled labor* can be assessed by looking at a sector's share of total labor employed

in the economy and the share of unskilled labor among those employed in the sector. Whether this unskilled labor is employed at a *productivity* premium can then be further assessed by also looking at the level of value added per worker. A sector's *tradedness* in international markets, which is easily measured, indicates the potential for spillovers through learning by doing, scale economies, technology diffusion, and greater competition. Finally, assessing a sector's tradedness alongside its extent of *innovation* can provide a more complete picture of the scope for knowledge spillovers.

Table 1.1 shows a historical example of data for comparative sector assessment. The manufacturing sector's absorption of unskilled labor at a productivity premium, combined with its tradedness in international markets and scope for technology diffusion, is compared with the same measures of the agriculture, services, and natural resources and mining sectors.

Why the focus on identifying pro-development characteristics associated with manufacturing? Because they can help generate spillovers and provide dynamic gains to growth and development. For instance, on-the-job learning by doing increases human capital and productivity as gains beyond what workers earn in wages. Employment can also have social benefits, with workers' sense of social cohesion strengthened through their labor alongside others (World Bank 2012).[16] Trade can facilitate technology diffusion and increase competitive pressures to improve

**Table 1.1 The Extent of Pro-Development Characteristics Is Historically Seen Across Sectors**

*Sectoral Comparison of Pro-Development Characteristics, Selected Countries, 1994*

| Sector | Export-to-output ratio (world, %) | Share of total employment (world, %) | Value added per worker (world, current US$, 2011) | Ratio of R&D expenditure to value added (U.S., %) | Share of blue-collar workers in total sector employment (selected countries, avg. %) |
|---|---|---|---|---|---|
| Agriculture | 13.97 | 35.03 | 1,860.42 | n.a. | 90.86 |
| Manufacturing | 67.60 | 11.90 | 25,911.85 | 14.44 | 73.83 |
| Services | 5.62 | 39.68 | 26,927.51 | 1.07 | 30.68 |

*Source:* World Development Indicators database.
*Note:* Data taken from across all countries in 1994. LDCs = least-developed countries. n.a. = not applicable.
a. The export-to-output ratio indicates a sector's potential for positive spillovers through learning by doing, scale economies, technology diffusion, and greater competition.
b. Value added per worker, or output per worker, measures labor productivity.
c. The ratio of R&D spending to value added indicates the sector's scope for technology diffusion. Ratios calculated from U.S. data only.
d. The share of blue-collar workers in a sector's total employment indicates the sector's job creation potential for unskilled workers. These shares are calculated from Integrated Public Use Microdata Series (IPUMS) data from 19 selected countries, using the most recent years available from 2008 onward.

efficiency, in turn increasing productivity growth. Innovation and the expansion of knowledge can also lead to dynamic growth and productivity gains. Beyond the potential for spillovers, these characteristics can also be understood as being pro-development more broadly if policy makers see expanding employment—and providing a more open, competitive business operating environment—as goals in themselves.

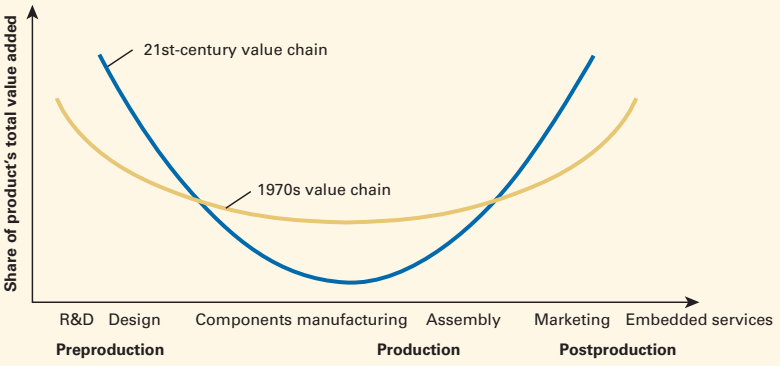
It is important to distinguish between "spillovers" and the broader term—"pro-development characteristics"—because spillovers will not necessarily be realized in all manufacturing activities.[17] Rather, these pro-development characteristics of manufacturing indicate that the *potential* for the spillovers is there. In other words, *how* goods are produced will determine whether the spillovers are realized in practice.

## The Increasing Role of Services in Manufacturing

Notably, the boundaries between sectors are blurring, and "manufacturing" increasingly represents the entire value chain of producing goods. Services are often embodied in goods (as part of the manufacturing process), and more services are being embedded in goods during postproduction (such as after-sales support and other add-on services). As the "smile curve" illustrates (figure 1.2), service inputs into manufacturing make up a growing source of value added over time. Agro-based manufactures are increasingly being processed, and here, too, services matter.

Although this volume is about "manufacturing," a key message is that what matters is manufacturing as a whole, which goes beyond production to include the whole value chain, including the services embodied

**Figure 1.2 Value Added of Services in Manufacturing, 1970s versus 21st Century**




*Note:* Figure adapts the "smile curve" depiction of how value added changes across different stages of bringing a manufactured product to market, as first proposed circa 1992 by Acer Inc. founder Stan Shih; for a more detailed discussion, see Baldwin (2012). R&D = research and development. "Embedded services" refers to services delivered through the manufactured good (for example, apps on a mobile phone).

and embedded in the final product. As such, the development impact of manufacturing comes not only from "production" per se but also from making and adding value at every stage—from raw materials to design and production, and all the way to sales and follow-on services.

## Variations in Pro-Development Characteristics across Manufacturing Subsectors

*Key message: The manufacturing sector is not monolithic. Its constituent industries vary in the extent to which they share different pro-development characteristics. In addition, these characteristics are not fixed or innate to a manufacturing subsector, but vary across countries and over time. When thinking about development impact, what matters is these characteristics and not the particular industry per se.*

The case for why manufacturing has been special has so far has examined the sector in the aggregate, but there are important variations across subsectors. Furthermore, looking at this variation across countries and over time adds nuance to the subsectors' potential for realizing these pro-development characteristics. This more granular understanding will also help set the scene for the discussion in Part II on the impacts of new technologies and globalization, which are expected to have differential impacts across subsectors and thus on the nature and prevalence of these pro-development characteristics.

The manufacturing sector is not monolithic and subsectors vary in the extent to which they combine the five dimensions of pro-development characteristics described earlier. There is heterogeneity in this employment-productivity-trade space and thus the potential for dynamic gains across manufacturing industries. It is not that any one subsector or product embodies all five dimensions; they combine varying degrees of different dimensions—which is why it is important to look at manufacturing in more disaggregated terms.

The 16 two-digit manufacturing subsectors can be grouped into five categories based on the clustering of these five pro-development characteristics (table 1.2). Within each characteristic, the subsectors are also grouped based on the distribution of values (indicated by the shading within each column based on threshold values that are reported below the columns). The sectors are then sorted based on the common sets of rankings across the dimensions.

Among these results, the share of unskilled (blue-collar) workers and trade intensity (the export value-to-output ratio) demonstrated the greatest variation, so those measures form the two axes of figure 1.3. R&D intensity stood out in only a few subsectors, which the figure indicates with blue shading. And because of the significant deviation in labor productivity from other subsectors, the bubbles for the textiles and apparel, as well as for manufacturing "not otherwise classified" (n.e.c.), are colored in green.

**Table 1.2 Grouping of Manufacturing Subsectors, by Global Pro-Development Characteristics**

| Grouping | Sector | Industry code | Export-to-output ratio (world 2011, %) | Blue-collar share[a] (avg. after 2008, selected countries, %) | Value added per worker (world 2011, current US$) | U.S. R&D intensity[b] (U.S. 2013, %) | Sector share of manufacturing employment[c] (world 2011, %) |
|---|---|---|---|---|---|---|---|
| Commodity-based regional processing | Manufacture of food, beverages, and tobacco products | 15 | 18.4 | 69.6 | 51,791 | 2.2 | 13.3 |
| Commodity-based regional processing | Manufacture of wood and of products of wood and cork, except furniture | 20 | 19.3 | 83.3 | 42,506 | 0.8 | 2.2 |
| Commodity-based regional processing | Manufacture of other nonmetallic mineral products | 26 | 12.5 | 76.3 | 48,458 | 3.0 | 4.6 |
| Commodity-based regional processing | Manufacture of fabricated metal | 28 | 19.4 | 82.0 | 55,373 | 1.3 | 5.7 |
| Commodity-based regional processing | Manufacture of paper and paper products; printing and publishing | 21 | 24.2 | 60.9 | 53,813 | 1.2 | 3.8 |
| Commodity-based regional processing | Manufacture of rubber and plastics products | 25 | 31.4 | 69.7 | 56,386 | 4.9 | 3.5 |

*(Table continues on next page)*

**Table 1.2 Grouping of Manufacturing Subsectors, by Global Pro-Development Characteristics** *(continued)*

| Grouping | Sector | Industry code | Export-to-output ratio (world 2011, %) | Blue-collar share[a] (avg. after 2008, selected countries, %) | Value added per worker (world 2011, current US$) | U.S. R&D intensity[b] (U.S. 2013, %) | Sector share of manufacturing employment[c] (world 2011, %) |
|---|---|---|---|---|---|---|---|
| Commodity-based regional processing | Manufacture of basic metals | 27 | 30.9 | 72.0 | 48,921 | 0.7 | 7.0 |
| Capital-intensive regional processing | Manufacturing of coke, refined petroleum products, and nuclear fuel | 23 | 31.4 | 46.0 | 259,271 | 0.2 | 0.9 |
| Capital-intensive regional processing | Manufacture of chemicals and chemical products* | 24 | 38.8 | 48.6 | 83,038 | 19.3[d] | 5.0 |
| Low-skill labor-intensive tradables | Manufacture of textiles, wearing apparel, and leather products | 17 | 49.0 | 83.0 | 14,243 | 2.3 | 15.9 |
| Low-skill labor-intensive tradables | Manufacture of furniture; manufacturing n.e.c. | 36 | 51.4 | 78.7 | 36,680 | 2.5 | 4.7 |
| Medium-skill global innovators | Manufacture of machinery and equipment n.e.c. | 29 | 47.9 | 62.3 | 49,937 | 8.5 | 9.3 |
| Medium-skill global innovators | Manufacture of transport equipment | 34 | 46.1 | 69.4 | 54,322 | 20.3 | 9.6 |

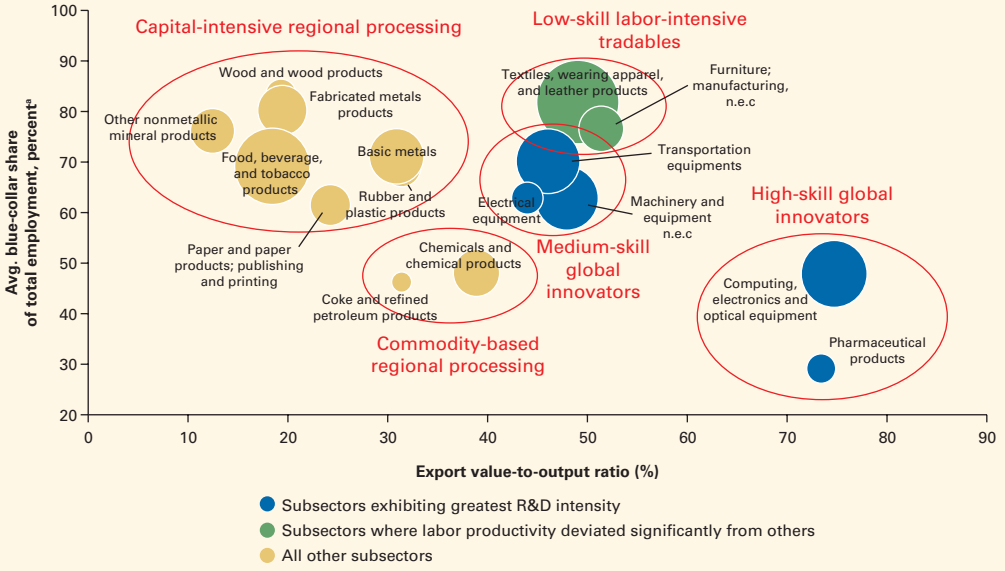
*(Table continues on next page)*

**Table 1.2 Grouping of Manufacturing Subsectors, by Global Pro-Development Characteristics** *(continued)*

| Grouping | Sector | Industry code | Export-to-output ratio (world 2011, %) | Blue-collar share[a] (avg. after 2008, selected countries, %) | Value added per worker (world 2011, current US$) | U.S. R&D intensity[b] (U.S. 2013, %) | Sector share of manufacturing employment[c] (world 2011, %) |
|---|---|---|---|---|---|---|---|
| Medium-skill global innovators | Electrical machinery and equipment | 31 | 44.0 | 61.7 | 84,200 | 24.1 | 2.3 |
| High-skill global innovators | Computer, electronics, and optical equipment | 30 | 74.7 | 46.6 | 38,727 | 150.1 | 10.2 |
| High-skill global innovators | Manufacture of pharmaceutical products[d] | 2423 | 73.4 | 30.4 | 96,907 | 19.3 | 2.0 |
| | | | <40 | <50 | <20,000 | >7.5 | |
| | | | 40–60 | 50–75 | 20,000–60,000 | | |
| | | | >60 | >75 | >60,000 | | |

*Sources:* Calculations from the United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database; UN Comtrade database; and University of Minnesota's Integrated Public Use Microdata Series (IPUMS) International database.
*Note:* n.e.c. = not elsewhere classified. R&D = research and development.
a. Blue-collar occupations are those classified as International Standard Classification of Occupations (ISCO) groups 5, 7, 8, and 9. Blue-collar shares are calculated at sector-by-country level using country census data harmonized by IPUMS International.
b. "U.S. R&D intensity" refers to the ratio of R&D spending to value added in that sector in the United States.
c. Total number of sector employees includes occupations classified as ISCO groups 1, 2, 3, 4, 5, 7, 8, and 9.
d. Includes pharmaceutical products.

**Figure 1.3 Manufacturing Subsectors, Grouped by Pro-Development Characteristics, 2013**




*Sources:* Calculations based on United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database; UN Comtrade database; University of Minnesota's Integrated Public Use Microdata Series (IPUMS) International database.
*Note:* Bubbles colored blue indicate the five subsectors exhibiting the greatest R&D intensity. Bubbles colored green indicate subsectors that deviated significantly from others in terms of labor productivity. Bubble size indicates each manufacturing subsector's share of total manufacturing employment. n.e.c. = not elsewhere classified.
a. For blue-collar shares, occupations classified as International Standard Classification of Occupations (ISCO) groups 5, 7, 8, and 9 are labeled as blue-collar occupations. Total number of sector employees includes occupations classified as ISCO groups 1, 2, 3, 4, 5, 7, 8, and 9. Blue-collar shares are calculated at sector-by-country level for selected countries using census data harmonized by IPUMS International.

The extent to which sectors provide employment is ultimately one of the development outcomes of interest and so is represented by the size of the bubbles in the figure rather than being used as a way of categorizing the subsectors. Taking the clustering of these characteristics together, the five groups are high-skill global innovators, medium-skill global innovators, low-skill labor-intensive tradables, capital-intensive processing, and commodity-based regional processing (figure 1.3). The comparison of trends within this sector typology can indicate ways in which countries may be able to benefit from producing in these subsectors.

It is important to recognize that there will likely be considerable heterogeneity in these pro-development characteristics across products within these manufacturing subsectors. For example, Deason and Ferrantino (2009) show that electronic and optical products vary greatly in terms of whether they are revealed to be technology-intensive: for example, doped wafers and semiconductor-manufacturing equipment are "high-tech," whereas

computers and computer peripherals are "low-tech" in final assembly. Recent studies also find vast differences in productivity (Bartelsman, Haltiwanger, and Scarpetta 2013; Foster et al. 2017; Herrendorf, Rogerson, and Valentinyi 2013; Muendler 2004; Syverson 2004) and quality (Khandelwal 2010; Schott 2008) within very disaggregated goods categories across countries. Another challenge arises from the recent literature, which emphasizes that manufacturing export success is less about sectoral growth than about a few "big hits"—which account for most of the export value and may include matches between a very disaggregated product and a particular geographical market (Easterly, Reshef, and Schwenkenberg 2009).

Further, even within highly disaggregated industries or products, firms might be the relevant unit of analysis. Recent research, using firm-level data for high-income economies and low- and middle-income economies, has documented large within-industry differences in labor productivity. Within a narrowly defined industry (for example, saw blade manufacturing, sporting goods stores, or direct mail advertising), it is not unusual to find that one firm can produce and sell three times as much output as another with the same measured use of labor input (Syverson 2011). Similarly, a series of papers based on census data from countries across regions and income groups show that output, jobs, and exporting across industries is dominated by a group of very large firms (Bernard et al. 2012; Freund and Pierola 2015; Hallward-Driemeier and Aterido 2015).[18]

The greatest scope for innovation, productivity growth, and job creation is thus concentrated among a relatively small number of firms. How well managed they are; their strategies for interacting with smaller suppliers; and their own choices on adopting technology, quality upgrading, and pricing can have disproportionate effects on how the sector performs in a country.[19] While recognizing firms' heterogeneity within subsectors, viewing them through a subsector lens reveals broader patterns of changes facing multiple countries that manufacture similar products and highlights key trends in technology, trade, and investment that operate across firms. The interest here is not in highlighting very disaggregated products or particular types of firms to support, but rather in broader activities that are likely to bring positive spillovers and contribute to growth and job creation as part of a country's development strategy.

### Combinations of Pro-Development Characteristics, by Sector Type

As figure 1.3 illustrates, subsectors within manufacturing share combinations of these pro-development characteristics, making it possible to analyze them in terms of five groups. The group names reflect the key dimensions of these characteristics that differentiate one from the other. The groups sort into three levels of tradedness but are further differentiated within each level by low-skill labor intensity, R&D intensity, or capital intensity.

**Low-skill labor-intensive tradables.** Among the manufacturing sectors that are more traded internationally, one group employs a relatively high

share of blue-collar workers with distinctly high employment-to-output ratios: "low-skill labor-intensive tradables." Textiles, garments, and leather products as well as furniture and manufacturing n.e.c. are highly traded in international markets, and the large majority of employees in these industries are blue-collar workers. Strikingly, they also have the lowest output per worker among all manufacturing sectors (as depicted in figure 1.3 by the green bubbles). This is not surprising, because light manufacturing—comprising goods such as apparel, toys, jewelry, and sports equipment—has typically required labor-intensive assembly and, with limited fixed capital investments, has been seen as "footloose," that is, ready to move to new, lower-cost locations. These sectors, however, are not R&D-intensive. Therefore, although their goods are traded internationally, these sectors have limited scope for technology diffusion.

**Medium-skill global innovators and high-skill global innovators.** Two groups of R&D-intensive sectors vary by degree of tradedness and share of blue-collar workers. The "medium-skill global innovators"—manufacturers of transportation equipment and other machinery and equipment as well as electrical machinery and apparatus n.e.c.—are as highly traded in international markets as the low-skill labor-intensive tradables, but their workforces comprise lower shares of blue-collar workers. The "high-skill global innovators"—manufacturers of electronics, computing and optical instruments, and pharmaceutical products—have a distinctly higher export-to-output ratio but a distinctly lower share of blue-collar workers than the medium-skill innovators.

Collectively, these five manufacturing industries are R&D-intensive[20] (and thus similarly shaded in figure 1.3), although their R&D-related activities are carried out primarily in high-income economies, whereas low- and middle-income economies are home to the labor-intensive assembly in globally fragmented production chains. This higher rate of R&D and more constant stream of product upgrading open up a host of opportunities for technology diffusion, as reflected in Rodrik's (2015) finding of labor productivity convergence across countries, which is least rapid in textiles and clothing and most rapid in machinery and equipment.

**Commodity-based regional processing and capital-intensive regional processing.** Among the manufacturing sectors that are less traded internationally, there are again two groups that vary in their shares of blue-collar workers and, to some extent, their tradedness. "Commodity-based regional processing"—encompassing food processing, wood products, paper products, basic metals, fabricated metal products, nonmetallic mineral products, and rubber and plastic products—is closely linked to the use of agricultural raw materials or mining products. These goods are typically less traded internationally, either because they are bulky to transport (such as cement, within the nonmetallic minerals sector) or because they require proximity to raw materials (for example, food processing industries). Among these sectors, food processing stands out in its high share of total manufacturing

employment, second only to textiles, garments, and leather products (as depicted by the relative size of the bubbles in figure 1.3). In contrast, "capital-intensive regional processing" includes two manufacturing sectors that are somewhat more traded internationally but employ lower shares of blue-collar workers: chemical products and refined petroleum products.

These groupings of sectors are reinforced by differences in how they are traded and thus the potential entry points for low- and middle-income countries (LMICs). The high-skill global innovator industries are not only the most traded but also the most global value chain (GVC)-intensive, followed by medium-skill global innovators and low-skill labor-intensive tradables. These sectors have both more production stages and higher rates of these stages being performed abroad. Therefore, they can provide more opportunities for LMICs to participate, albeit most likely in narrow sets of activities or tasks. On the other hand, commodity processing sectors are the least GVC-intensive, ranking the lowest in terms of both GVC length and the share of stages located abroad. With less complex production processes, the requirements to enter may be less demanding even as the upside potential on trade and innovation may be lower.

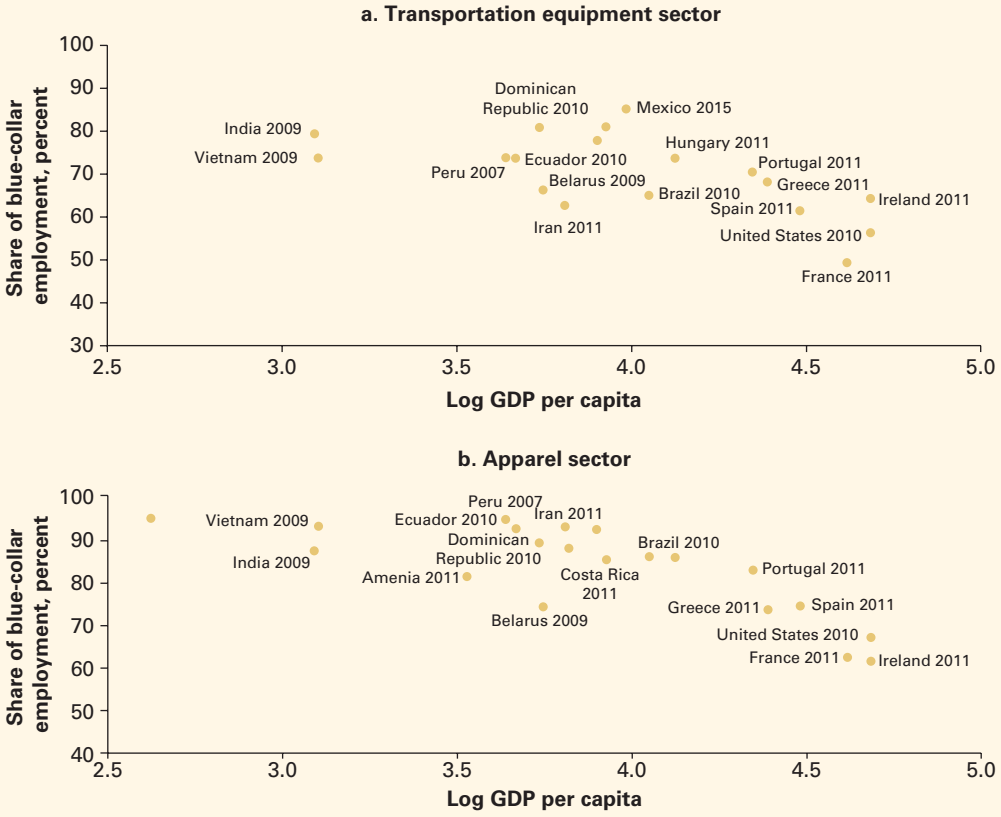
### Heterogeneity of Pro-Development Characteristics across Countries and over Time

The pro-development characteristics associated with a particular manufacturing subsector vary across countries, often reflecting the relative position of high-income economies and low- and middle-income economies within GVCs. Take, for example, the transportation equipment industry, which employs a much higher share of blue-collar workers in middle-income countries such as India, Mexico, and Vietnam than in HICs such as France, Spain, and the United States (figure 1.4, panel a). The same holds true for other manufacturing sectors such as apparel (figure 1.4, panel b). This distribution of tasks and skills conforms to the smile curve analogy, whereby LMICs add value in the low-skill labor-intensive assembly component of producing a good, while higher-income economies add more value by occupying more skill-intensive parts of the chain, such as upstream and downstream services.

That the nature of tasks to produce the same manufactured good varies across countries, particularly by labor intensity, is also reflected in levels of output per worker, which are positively correlated with levels of GDP per capita in the same manufacturing sectors. The case of computers, electronics, and optical equipment provides an illustrative example (figure 1.5). In thinking about what the potential scope for spillovers and pro-development characteristics associated with a subsector, it is important to keep in mind which part of the manufacturing process will be done in a particular country—and *how* it will be produced.[21]

The magnitude of pro-development characteristics across manufacturing subsectors have also changed over time, albeit not dramatically. The rise in

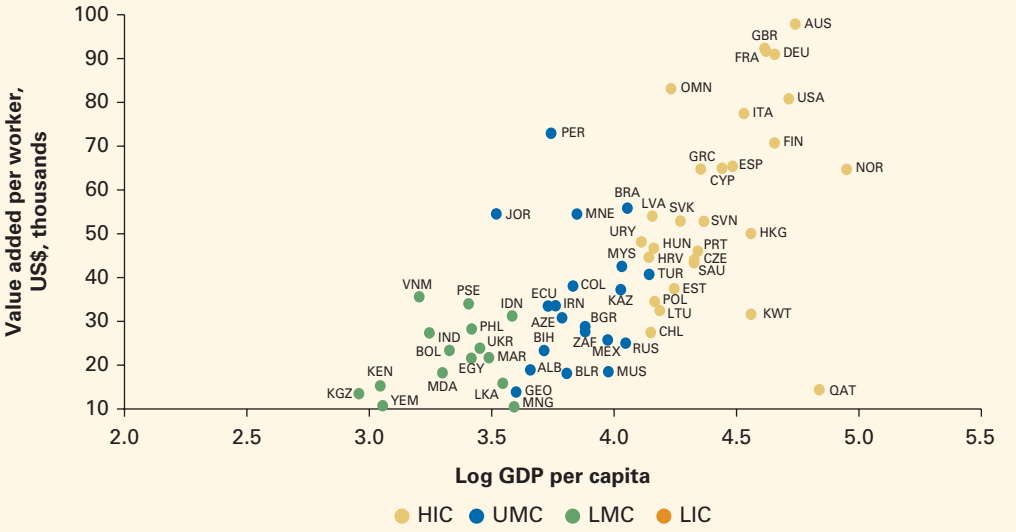
**Figure 1.4 Share of Blue-Collar Workers in Selected Manufacturing Sectors and Countries, by GDP per Capita, circa 2010**




*Source:* Calculations based on Integrated Public Use Microdata Series (IPUMS) International database, Minnesota Population Center, University of Minnesota.
*Note:* Selected countries based on year of data availability.

pharmaceuticals' export-to-output (tradedness) share is one of the more significant changes, followed by a similar rise for coke and petroleum products (figure 1.6, panel a). Other than nonmetallic minerals and wood products, all of the subsectors increased their export shares in output globally. Almost all sectors saw the blue-collar share of employment decline (figure 1.6, panel b). Computers and electronics saw a decline in relative productivity, while chemicals' relative productivity increased (figure 1.6, panel c). As for job creation between 1994 and 2013, more jobs have been added in computers and electronics, while they have decreased in textiles and apparel (figure 1.6, panel d). By 2013, food processing just eked out textiles and garments for employing the greatest number of workers.

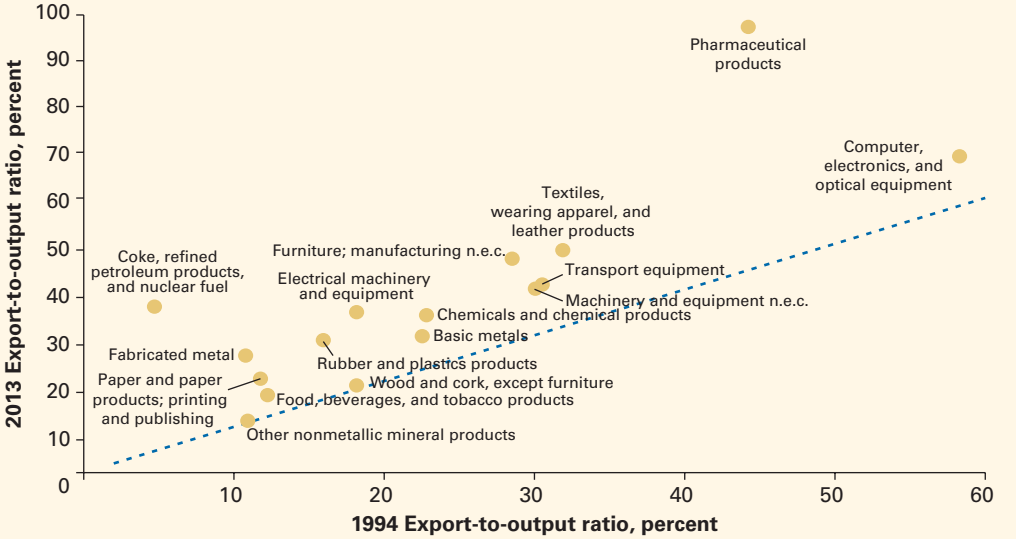
**Figure 1.5 Value Added per Worker and GDP per Capita, Computers and Electronics Sector, by Country Income Level, circa 2015**




*Sources:* Calculations based on United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database; World Development Indicators database.
*Note:* Data from 2015 or most recent year available. HIC = high-income country. UMC = upper-middle-income country. LMC = lower-middle-income country. LIC = lower-income country.

**Figure 1.6 Changes in Pro-Development Characteristics of Manufacturing Subsectors, 1990s–2010s**

**a. Change in tradedness, by subsector, 1994–2014**

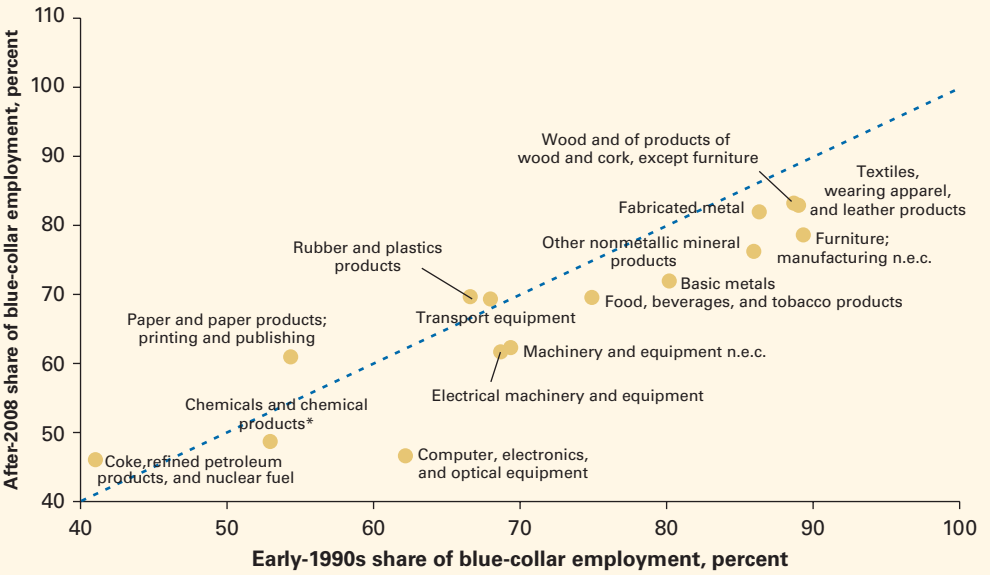



*Sources:* Calculations based on World Development Indicators and United Nations Comtrade databases.
*Note:* n.e.c. = not otherwise classified.

*(Figure continues on next page)*

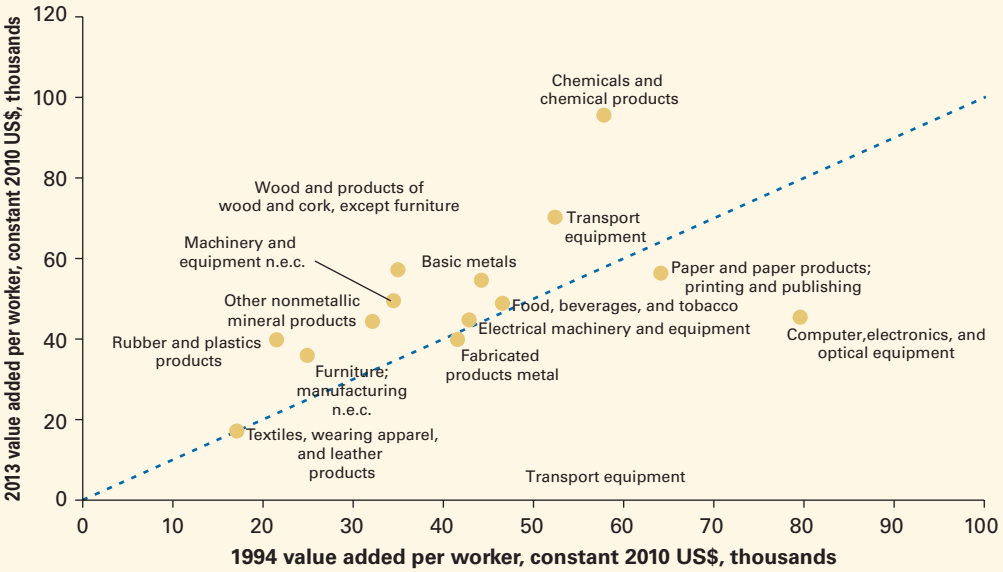
**Figure 1.6 Changes in Pro-Development Characteristics of Manufacturing Subsectors, 1990s–2010s** *(continued)*

**b. Change in share of blue-collar employment, by subsector, early 1990s–2010s**




*Sources:* Calculations based on Integrated Public Use Microdata Series (IPUMS) International, Minnesota Population Center, University of Minnesota.
*Note:* Data are for 20 selected countries based on years of data availability. n.e.c. = not otherwise classified.

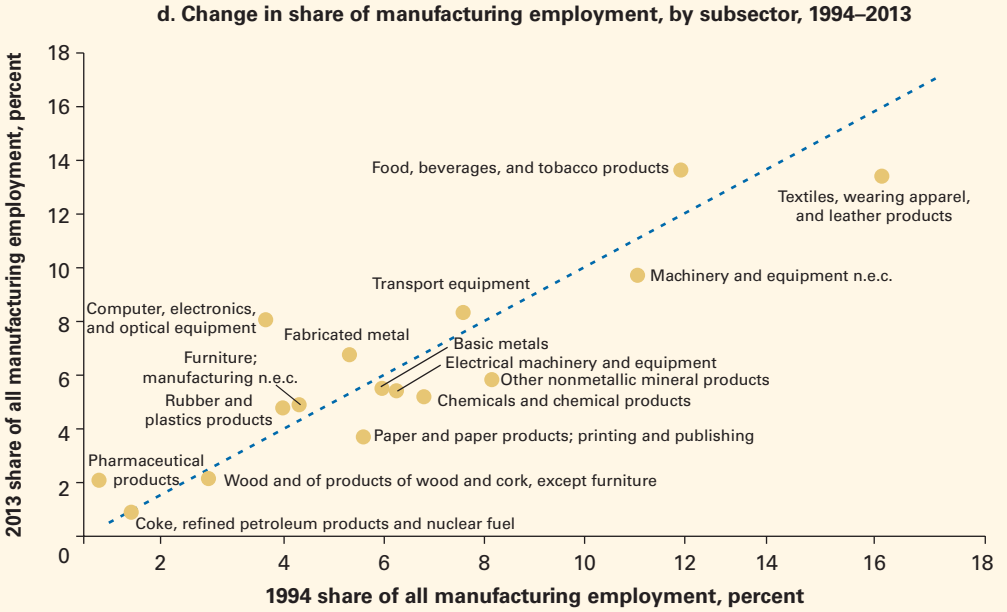
**c. Change in labor productivity, by subsector, 1994–2013**




*Sources:* Calculations based on United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database; World Development Indicators database.
*Note:* Data are for 1994 and 2013, or the closest years available. n.e.c. = not otherwise classified.

*(Figure continues on next page)*

**Figure 1.6 Changes in Pro-Development Characteristics of Manufacturing Subsectors, 1990s–2010s** *(continued)*

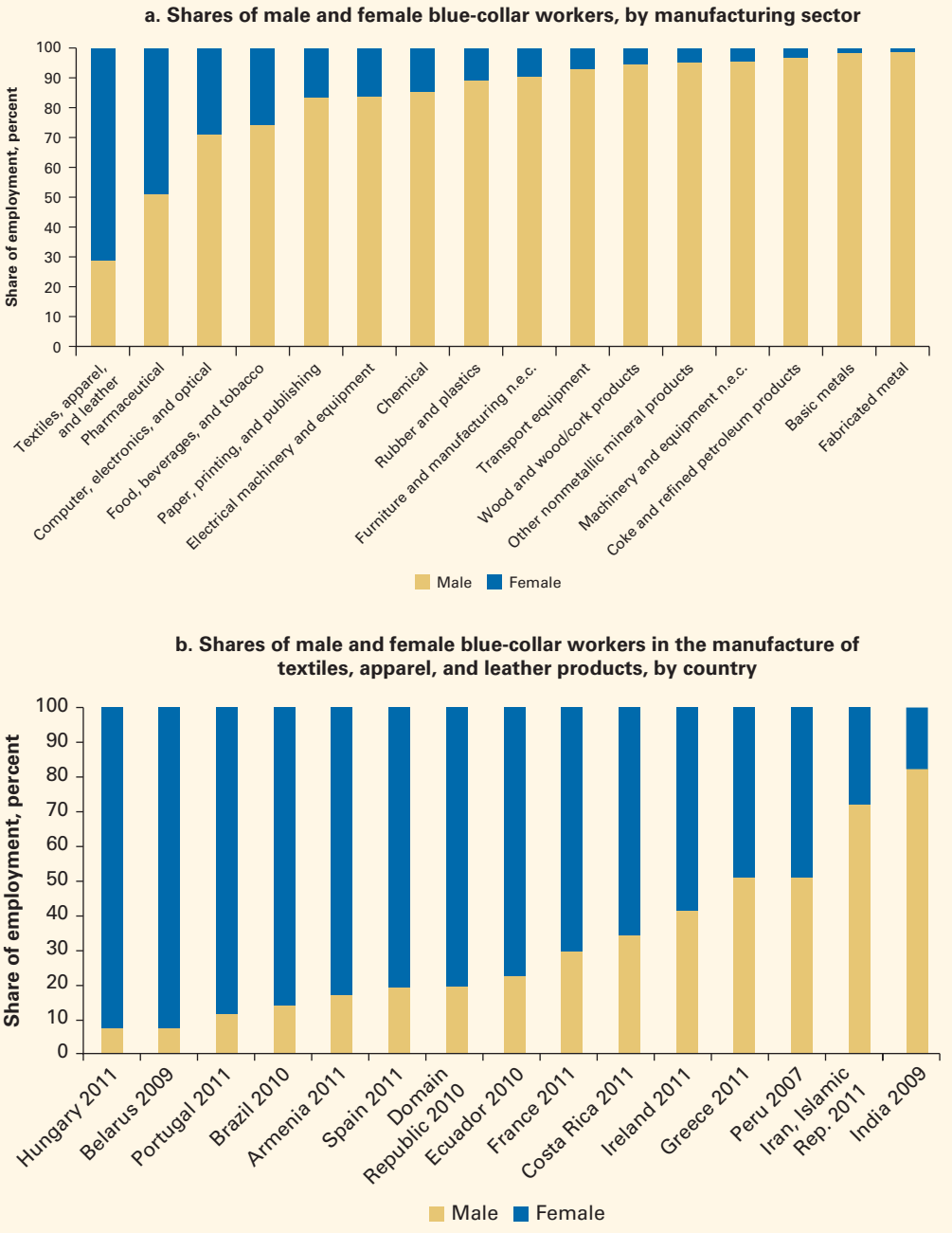



*Sources:* Calculations based on United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database; World Development Indicators database.
*Note:* Data are for 1994 and 2013, or the closest years available. n.e.c. = not otherwise classified.

In addition, there are differences across manufacturing subsectors in the gender composition of their workforces (figure 1.7, panel a). The garment (figure 1.7, panel b) and electronic assembly subsectors disproportionately hire women. In countries where the garment sector has taken off (as in Bangladesh, Cambodia, and Vietnam), it has noticeably shifted women's economic prospects—so much so that they have cascaded into increasing girls' school enrollment; with better prospects for employment, more investments are being made in daughters (Hallward-Driemeier 2013; World Bank 2011). Although subsectors that tend to be more capital-intensive or use heavier goods or machines tend to hire more men (figure 1.7, panel c), assembly jobs of smaller items tend to hire more women. Therefore, there can be an added inclusivity agenda when looking across subsectors.

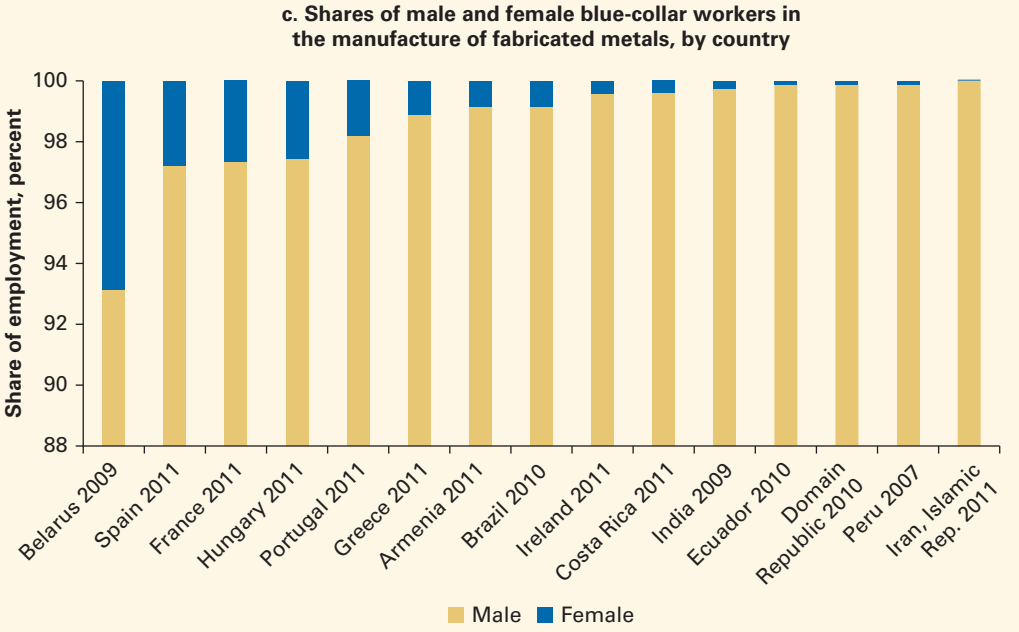
**Figure 1.7 The Share of Male and Female Blue-Collar Workers Varies Significantly Across Sectors on Average—and Within the Same Sector Across Countries**

*Shares of Male and Female Blue-Collar Workers in Manufacturing, by Sector and Selected Countries, circa 2007–11*




*(Figure continues on next page)*

**Figure 1.7 The Share of Male and Female Blue-Collar Workers Varies Significantly Across Sectors on Average—and Within the Same Sector Across Countries** *(continued)*




*Source:* Calculations based on Integrated Public Use Microdata Series (IPUMS) International database, Minnesota Population Center, University of Minnesota.
*Note:* Years of country data vary, from 2007 to 2011; n.e.c. = not elsewhere classified.

## Conclusion

Overall, the variations within manufacturing subsectors imply that rather than aiming to produce a product per se, the attention should be on expanding the activities that deliver the desirable characteristics in a given country context. *What* a country manufactures is indicative of the set of pro-development characteristics likely to be experienced; there is a common clustering of characteristics among groups of subsectors. However, *how* goods are manufactured—as seen in the variations in production processes and nature of tasks performed in the same subsector across countries and over time—reinforces the message that to assess a subsector's desirability, the focus should be on the combination of likely pro-development characteristics in the specific country context. Part II discusses in detail the impacts of new technologies and globalization on the nature, prevalence, and combinations of these pro-development characteristics. Because these changes are expected to have differential impacts across subsectors of manufacturing, the relevant groupings of subsectors may also need to be adjusted going forward.

## Notes

1. Throughout this volume, the term "industrialization" refers to manufacturing only.
2. Data for this paragraph are based on the Maddison project, a collaborative research project that seeks comparable historical national accounts data for as many countries as possible (Bolt and Van Zanden 2014).
3. The "East Asia growth miracle" here refers to the following economies: Hong Kong SAR, China; the Republic of Korea; Singapore; and Taiwan, China.
4. Norway, for example, has created an innovative oil and gas industry with substantial links and become one of the richest countries of the world (Cappelen, Eika, and Holm 2000; Fagerberg, Mowery, and Verspagen 2009). This is consistent with empirical tests of the "resource curse" (Sachs and Warner 2001), which have proven unrobust (Lederman and Maloney 2010), and some of the more robust empirical tests even find a positive impact of subsoil wealth on economic growth (Brunnschweiler and Bulte 2008; Manzano and Rigobon 2001; Sala-i-Matin 1997).
5. For example, Singapore's location in key shipping lanes and its deep natural port have made it an important transshipment point. A few small economies have adopted specific tax or financial regulations to attract large numbers of multinationals, but much of the wealth reflects accounting practices rather than wealth-generating activities in the country.
6. Fagerberg and Verspagen (1999) regress real GDP growth rates on growth rates of manufacturing. If the coefficient of manufacturing growth is higher than the share of manufacturing in GDP, this is interpreted as supporting the engine-of-growth hypothesis. Szirmai and Verspagen (2015) regress average five-year growth rates on the share of manufacturing at the beginning of a given five-year period and a set of control variables for a sample of 90 countries between 1950 and 2005.
7. This relationship may suffer from an omitted variable bias or reverse causality, which usually are not satisfactorily addressed in most of the empirical work. Therefore, the interpretation of the relationship between manufacturing, structural change, and growth should be viewed with caution.
8. Hsieh and Klenow (2009), for example, find that between a third and half of the differences in manufacturing total factor productivity between China, India, and the United States can be explained by the large number of inefficient firms. Similarly, Söderbom (2012) finds that two-thirds of the value-added gap between large and small firms in Ethiopia can be explained by differences in labor productivity. Labor mobility within sectors may also affect firm productivity

through knowledge spillover effects. These gains can be particularly relevant for skilled workers in management positions (Cruz, Bussolo, and Iacovone 2016) or for workers with previous experience in multinational firms (Balsvik 2011).

9. Based on data from present-day high-income economies, Rowthorn and Wells (1987) showed that real services output did not rise significantly faster than manufacturing output, but that output per worker increased faster in the latter. This implies that labor-saving technological progress led to productivity gains in the manufacturing sector, and labor-intensive service activities absorbed an even greater fraction of the workforce to keep notional output rising parallel to manufacturing.
10. Similarly, Hwang (2007) documented a tendency for catch-up in export unit values: the lower the average unit values of a country's manufactured exports, the faster the country's subsequent growth, unconditionally.
11. Of course, the better the environment, the more rapid the convergence—that is, conditional convergence is even more rapid (Rodrik 2013).
12. The introduction of high-yield seed varieties, irrigation infrastructure, and agricultural education, among other factors, also played an important role.
13. This pattern of shifting expenditure shares with income is traditionally referred to in the literature as Engel's law. Engel's law refers to the empirical observation that as income rises, the proportion of income spent on food or agricultural products falls (even if the absolute expenditure on food rises). The share of expenditures on manufactured goods is expected to rise and then fall as incomes rise further and the share spent on services is expected to rise with income.
14. The share of blue-collar workers in a sector's total employment draws on the University of Minnesota's Integrated Public Use Microdata Series (IPUMS) data from 20 selected countries, using the most recent years available. In this dataset, "blue-collar workers" comprise the following major groups as defined in the International Standard Classification of Occupations (ISCO): sales and service workers, craft and related trades workers, plant and machine operators and assemblers, and elementary occupations.
15. The export-to-output ratio follows closely the weight-to-value ratio. It also corresponds to the extent of complex global value chains in the sector.
16. For a more in-depth analysis of "good jobs for development," see *World Development Report 2013: Jobs* (World Bank 2012).
17. The product space literature has suggested that technologically sophisticated or more complex goods—those produced by few and diversified countries—generate knowledge spillovers that encourage economic growth (Hausmann and Hidalgo 2011; Hausmann, Hwang,

and Rodrik 2007). But little can be inferred about the characteristics of these goods other than they are correlated with per capita income. Further, the analysis uses final goods export data, which do not capture the tasks a country is really undertaking (Maloney and Nayyar 2017).

18. For example, of the 5.5 million firms operating in the United States in 2000, just 4 percent were exporters, and among these exporting firms, the top 10 percent accounted for 96 percent of total exports (Bernard et al. 2012).
19. The heterogeneity of firm performance and its implications for policies seeking to encourage innovation and productivity growth are currently being explored in other World Bank studies—for example, *The Innovation Paradox: Developing Country Capabilities and the Unrealized Promise of Technological Catch-Up* (Cirera and Maloney, forthcoming) and *High Growth Entrepreneurship in Developing Countries* (Cruz et al., forthcoming).
20. Within the manufacturing sector, more than 90 percent of R&D investments occur in just four industries: pharmaceutical products, electrical machinery, nonelectrical machinery (covering information and communication technology), and transportation equipment.
21. Looking at tasks rather than sectors or products provides additional insights, but such analysis is constrained by the dearth of data, particularly when looking beyond trade numbers. For example, Hausmann and Klinger (2007) and Hidalgo et al. (2007) explore the spillovers associated with producing a good by arguing that goods in the dense part of a country's product space allow an easier transition to other goods and hence a continuing dynamic growth process. However, analyzing the density of the product space using data on goods rather than tasks appears problematic. For example, countries might find it relatively easy to jump from the assembly of apparel to the assembly of electronics, but the two products might be quite far apart in the product space.

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CHAPTER 2

# The Changing Manufacturing Landscape: Trouble Already Brewing?

## Introduction

Historically, changes at the intersection of technology and globalization have had an important association with evolving comparative advantage and, therefore, with patterns of specialization in the manufacturing sector. The initial Industrial Revolution, powered by steam engines, enabled the separation of production and consumption and resulted in an international division of labor whereby low- and middle-income countries (LMICs) exported agricultural products and industrial raw materials to high-income economies in exchange for manufactured goods. With the second Industrial Revolution and the introduction of electrical machinery and assembly line production, the production of commoditized or technologically simple, labor-intensive manufactured goods moved to lower-income economies as per the "flying geese" paradigm.[1] More recently, the information and communication technology (ICT) revolution of the 1990s and 2000s combined with falling transportation costs and more open trade policies to support the global fragmentation of production, enabling more countries to participate in manufacturing trade. It is also the period when China engaged more fully with the global economy.

Understanding how the extent and composition of manufacturing across countries and subsectors have evolved—following dynamic comparative advantage—provides an important context for further changes that evolving technology and globalization patterns may bring. Given the spillovers and dynamic gains associated with manufacturing and the heterogeneity within, as described in chapter 1, relevant trends that describe the changing global manufacturing landscape provide an indication of the benefits associated with production patterns.

This chapter presents these trends as a set of 12 stylized facts to summarize changes in the global manufacturing landscape, particularly over the

past two decades. In doing so, it looks at manufacturing in the aggregate as well as across disaggregated manufacturing sector groups. The stylized facts fall into three categories of change:

- *Distribution of global shares of manufacturing*. The first four stylized facts look at shifting patterns in global manufacturing in terms of value added, employment, productivity, and exports to shed light on whether high-income economies continue to dominate global manufacturing production and the extent to which low- and middle-income countries (LMICs) have emerged as global players.
- *Manufacturing as a share of gross domestic product (GDP) and employment*. Five stylized facts examine the evolving size of manufacturing relative to other sectors in the economy as well as in absolute terms. This discussion distinguishes between value added and employment, with implications for productivity.
- *Composition of manufacturing subsectors across countries*. Using revealed comparative advantage and changing domestic production baskets, three stylized facts examine the extent of evidence for the product cycle and/or "flying geese" paradigm.

The pro-development characteristics used to develop chapter 1's manufacturing sector typology distinguish between factor intensity and other dimensions that offer the potential for spillovers and thus dynamic gains. The characteristics related to factor intensity (overall labor share, share of unskilled labor in total labor, capital intensity as reflected in output per worker, R&D-intensity, and the link to commodities) complement theories of comparative advantage based on endowments. Further, the five resulting groups of manufacturing subsectors lend themselves to looking for the prevalence of product cycle or flying-geese dynamics: "commodity-based regional processing," "capital-intensive processing," "low-skill labor-intensive tradables," "medium-skill global innovators," and "high-skill global innovators." For example, are countries with large pools of unskilled labor active in "low-skill labor-intensive tradables"? Because a recent concern involves whether what is now unskilled-labor-intensive manufacturing may not be migrating to unskilled-labor-intensive countries as much as in the past, knowing the recent trends will be useful. The manufacturing sector typology developed in chapter 1 therefore will be used as a simplifying framework to analyze trends in manufacturing at a disaggregated level.

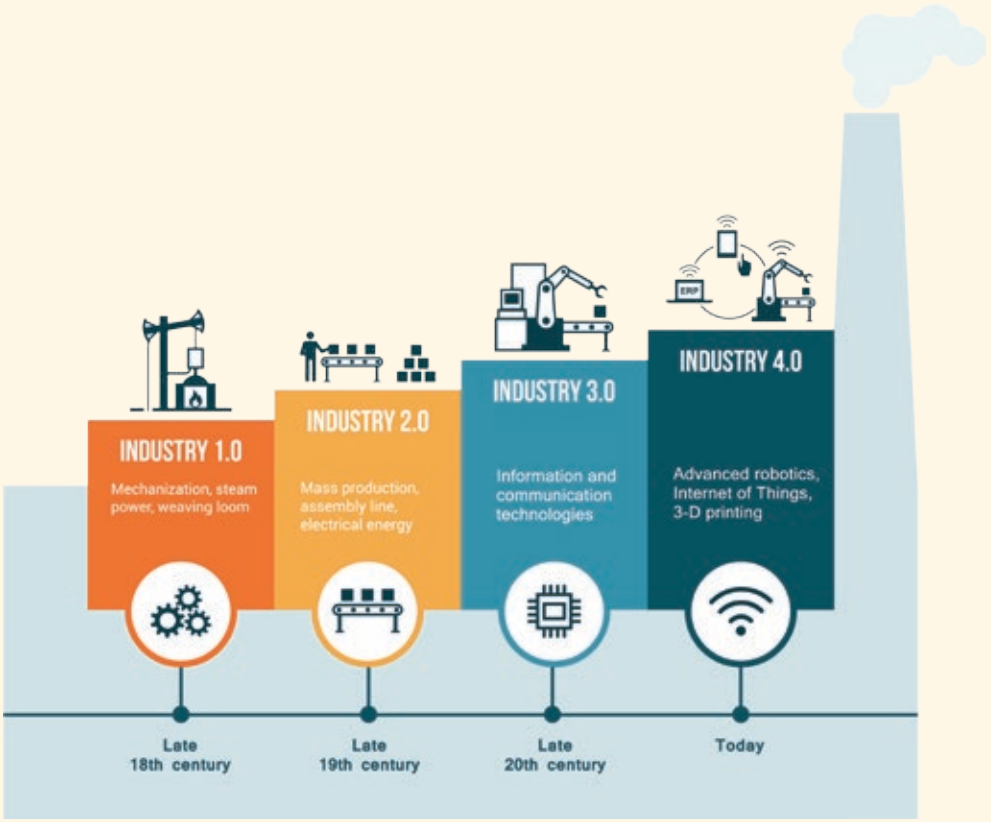
## Setting the Stage: Industry 1.0, Industry 2.0, Industry 3.0, and Drivers of Global Manufacturing Production

*Key message: Historically, changes at the intersection of technology and globalization—from the first Industrial Revolution in the late 18th century to the ICT revolution in the 1990s—have had an important association with evolving comparative advantage and therefore patterns of specialization in the manufacturing sector.*

Over time, industrial revolutions have been shaped by changes at the intersection of technology and globalization—starting with steam power, which revolutionized transportation and enabled international trade in Industry 1.0 during the late 18th century; through electrical machinery and assembly line production, which altered specialization patterns in Industry 2.0 during the late 19th century; to the ICT revolution, which enabled global production fragmentation in Industry 3.0 at the end of the 20th century (figure 2.1). With the first Industrial Revolution, steam-powered engines greatly reduced transportation costs and times. The vast expansion of international trade that followed enabled countries to specialize in the products at which they were most efficient, thereby accelerating the international division of labor. A new global economic landscape—defined by an advanced industrial "core" and a raw-material-supplying "periphery"—gradually took shape over the course of the 19th century (Findlay and O'Rourke 2007). Artisanal and craft producers in low- and middle-income countries (LMICs) could not compete with capital- and technology-intensive manufactures from the

**Figure 2.1 Each Industrial Revolution Shifts the Manufacturing Opportunities and Patterns of Specialization**

*Industrial revolutions and shifts in manufacturing specialization, 1784–present*




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fast-industrializing countries in Western Europe (Ravenhill 2011). Between World War I and World War II, the trade patterns differed little from those of the previous century: they were largely dominated by the export of agricultural products and industrial raw materials from low- and middle-income economies to high-income economies in exchange for manufactured goods (Bairoch and Kozul-Wright 1996).

As the second Industrial Revolution introduced electrical machinery and assembly line production, dynamic comparative advantage changed specialization patterns and created new production opportunities in less-industrialized economies. As high-income economies became richer, they accumulated capital and improved their production technologies, which shifted the export structure toward more skill- and capital-intensive industries (Carrere et al. 2009). At the same time, the production of commoditized or technologically simple manufactured goods moved to countries with lower production costs, as per the "flying geese" paradigm (Akamatsu 1962). For example, Japan started out specializing in unskilled-labor-intensive industries such as apparel and leather. As it transformed itself into a leading exporter of capital- and technology-intensive manufactures, the labor-intensive industries moved to lower-wage countries in the East Asia and Pacific region (Balassa and Noland 1989; Heller 1976). This pattern of initial specialization in labor- or resource-intensive activities, followed by a move up the ladder of comparative advantage as relative resource endowments change, is also precisely the sequence envisaged in the "stages of comparative advantage" set out many years ago by Balassa (1977).

The concept of a product cycle also maps a similar pattern (Vernon 1966). In its most idealized form, new goods would be innovated and produced in the highest-income large economies (in the 1960s, the United States) owing to innovative capacity and "demand-push" innovation to satisfy the tastes of high-income consumers. The good would diffuse, eventually being exported from economies other than the original innovator. When the technology of production became sufficiently mature, the good would be produced in low-wage economies. However, such a product cycle was not the typical pattern for all goods: patterns of comparative advantage for a range of high-income economies have shown a good deal of persistence over time, at least in the two decades between 1970 and 1990 (Proudman and Redding 2000).

The ICT revolution in the 1990s marked a third industrial revolution, which created a new wave of manufacturing export-led growth. Vast absolute differences in unskilled labor wages between high-income economies and low- and middle-income economies, driven by differences in factor endowments, made cross-border production sharing profitable. And the ICT revolution made it feasible to exploit the potential benefit of international production fragmentation, enabling the remote coordination of complex tasks at a relatively low cost (Batra and Casas 1973; Dixit and Grossman 1982; Jones and Kierzkowski 1990, 2001). This trade in tasks was often facilitated by efficiency-seeking foreign direct investment (FDI) by multinational firms,

which established operations under their ownership and managerial control in LMICs (Helpman 1984). With the departure from the "Fordist" production systems (whereby entire goods were produced in one firm), the spread of global value chains (GVCs) provided LMICs with the opportunity to industrialize rapidly because offshore production diffused technology that took other countries decades to develop domestically—multinational firms combined high-tech ideas with low-wage workers in developing nations (Baldwin 2011, 2016; Feenstra 1998).

The integration of LMICs into GVCs and the spread of FDI were also associated with reductions in transportation costs and lower tariffs on goods trade (Amiti and Konings 2007; Baldwin 2012; Damuri 2012). The building blocks of East Asia's participation in GVCs, for example, were laid by tariff liberalization (at a time when industry relocation from Japan gained momentum) and were supported by the spread of container transportation systems that significantly lowered costs. Many countries in the region unilaterally cut their effective tariff rates through duty-drawback schemes and duty-free treatment for unskilled-labor-intensive firms in export processing zones (Baldwin 2006). Exempting exporting firms from import duties on their inputs enhanced their cost advantage in the world market and induced foreign firms to locate production in those firms' locations (Engman, Onodera, and Pinali 2007). Improving trade facilitation programs and logistics also played a part. Subsequently, policy changes to attract FDI flows also took center stage (Kimura 2006).

This advent of global production fragmentation shifted the importance of economies in global manufacturing production. The resulting international division of labor, defined as "task trade" by Grossman and Rossi-Hansberg (2008), meant that a low- or middle-income economy that was relatively abundant in unskilled labor would complete and export the relatively unskilled-labor-intensive tasks involved in the manufacturing process, typically final assembly. At the same time, a relatively capital- or skilled-labor-intensive country would export intermediate products (such as capital goods) and services (such as design and research and development [R&D]). Over time, countries can move into different parts of the value chain based on their changing comparative advantage, thereby reinforcing the "flying geese" paradigm: that is, the "lead goose" sheds its low-productivity production to countries further down in the hierarchy, in a pattern that then reproduces itself among the countries in the lower tiers as comparative advantage evolves.

Emerging opportunities in export-led manufacturing may have also been associated with changes in comparative advantage resulting from China's rapid expansion in global markets. China's particularly abundant labor supply, deep economic reforms in the 1980s and 1990s, and accession to the World Trade Organization (WTO) in 2001 enabled it to vastly expand its exports, which are concentrated in low-skill labor-intensive tradables. Evidence suggests that, had China's export supply capacity remained constant between 1995 and 2005, the demand for exports

from 10 other LMICs that specialized in manufacturing[2] would have been 0.8–1.6 percent higher; hence, China's export expansion constituted a modest negative shock to those countries (Hanson and Robertson 2010). Further China's manufacturing-led demand surge for commodities (Devlin, Estevadeordal, and Rodríguez-Clare 2006) lowered other LMICs' share of all labor-intensive manufacturing in the sum of labor-intensive manufacturing and primary output by 1–3.5 percentage points, and their corresponding export share by 1–5 points, during the 1990s compared with the 1980s (Wood and Mayer 2011).[3] Therefore, China's export expansion constituted a modest negative shock to the export of manufactures from other LMICs.

The issue going forward is whether these specialization patterns may fundamentally shift. If new advanced technology requires production and R&D to be performed in the same place, opportunities for offshoring production to lower-cost locations may slow down. Similarly, with an emphasis on customization and time-to-market, technologies such as three-dimensional (3-D) printing could disrupt scale economies, and democratize production (with more goods being produced in more locations). Because these new technologies are only starting to be used, it is too soon to see data that reflect much of their impacts. What the past 20 years—with the rolling out of ICT, trade liberalization, reduced transportation costs, and GVCs—*can* show, however, is the extent to which production has been shifting to lower-cost locations (enabling low- and middle-income countries to enter or expand their participation) and how this can vary by subsector. This will provide the context for understanding how the next waves of technology may affect the current geography of production.

## The Changing Manufacturing Landscape: 12 Stylized Facts

*Key message: High-income countries still account for most of global manufacturing value added, but China has become the single largest producer of manufactured goods and lower-income countries are realizing greater opportunities in labor-intensive tradables and commodity-based regional processing.*

### Patterns of Global Shares across Countries

**Stylized Fact 1:** *High-income countries still account for most of global manufacturing value added, even as their share declines and China has become the single largest producer of manufactured goods.*

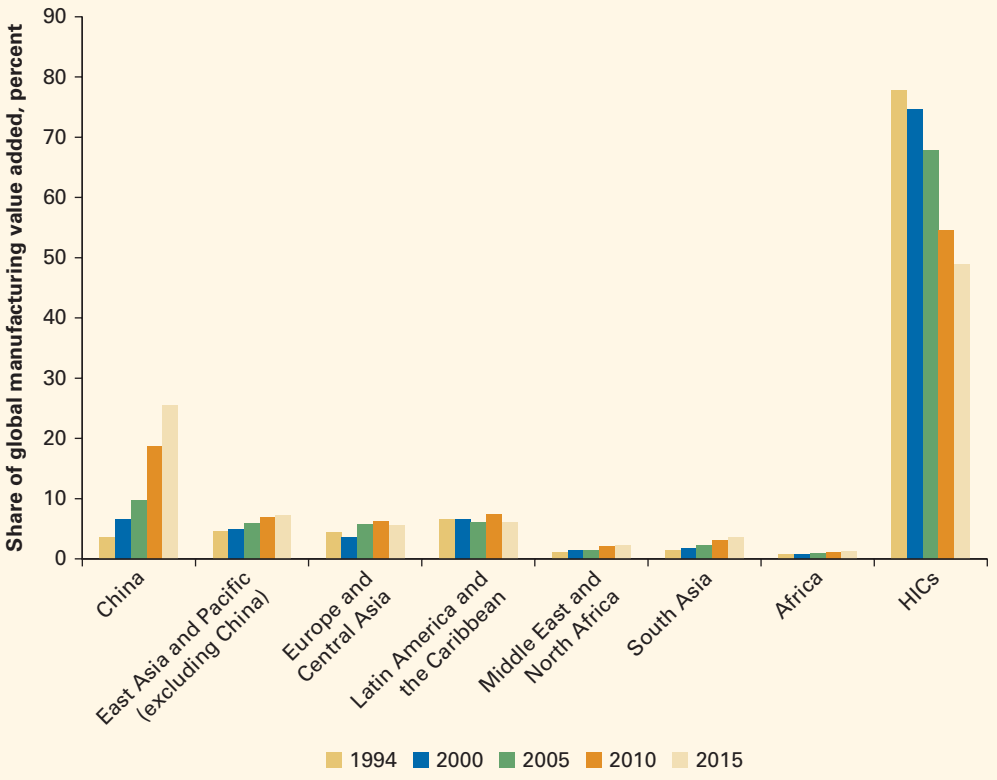
That the share of high-income countries (HICs) in global manufacturing value added has declined over the last two decades largely reflects the offshoring of production by their multinational companies, which either set up subsidiaries as export platforms in lower-cost locations or produce goods overseas to serve local markets. Figure 2.2 shows the trends from 1994 to 2015, but the decline in the HICs' share was apparent for decades before that. Among the HICs with declining shares, the United States stands out:

its share of global manufacturing value added declined from 27 percent in 1994 to 17 percent in 2015. The HIC category in figure 2.2 is defined by countries' 1994 gross national income per capita. If we were to use current income levels, the share accounted for by today's HICs would be higher, at 60 percent. This reflects that many countries that have joined the HIC ranks have been significant industrializers.[4] It also explains why industrialization is often seen as synonymous with being an HIC.

Much of the decline of production in HICs coincides with a strong move toward production in Asia, particularly China. China's share of global manufacturing value added increased from being negligible in 1970 to 25 percent in 2015. Even since 1990, it has grown fivefold, from less than 5 percent to 25 percent. China's accession to the WTO in 2001 helped catalyze its development as the "world's factory," with multinational corporations drawn to its low-cost labor and extensive

**Figure 2.2 Although Still Significant, High-Income Countries' Global Share of Manufacturing Value Added Has Been Declining Since 1994, as China Stands Out as an Expanding Producer**

*Share of global manufacturing value added in China, global regions, and high-income countries*




*Source:* World Development Indicators database.
*Note:* High-income countries (HICs), as defined in 1994, are those whose gross national income per capita was at least US$8,955.

transportation infrastructure—and the lure of being able to access its growing domestic market over time. The extent of technology transfer China has benefited from in the process continues to help fuel the country's ability to move into higher-value-added goods.

Several regions have seen their global share rise by significant proportions, albeit from a low base. However, this growing importance of East Asia, South Asia, and Eastern Europe in global manufacturing production has been concentrated among a handful of emerging economies: India, Indonesia, the Republic of Korea, Poland, Thailand, and Turkey. For example, between 1994 and 2015, India doubled its share of global manufacturing value added, from 1.1 percent to 2.8 percent, while the Republic of Korea's share increased from 2.1 percent to 3.3 percent. These examples highlight the fact that large emerging economies have been more successful at increasing their share of the global manufacturing value added pie, compared to smaller low- and middle-income countries.

**Stylized Fact 2:** *Low- and middle-income countries' shares of manufacturing employment are higher than their shares of value added—with China employing more than twice the workers of all high-income countries combined.*

Although data on manufacturing employment were available for only 67 countries, the differences between employment shares and value added shares are striking. These 67 countries include the largest economies and so capture the vast majority of global manufacturing, but smaller and lower-income countries are not as well represented. Among the 67 countries, China accounted for more than 40 percent of the employment in 2010,[5] while it had 18 percent of the value added. HICs together accounted for 17 percent of employment and 69 percent of value added (figure 2.3).

**Stylized Fact 3:** *Productivity differences across countries remain substantial and have been rising over the past 20 years between the dominant and smaller producing countries.*

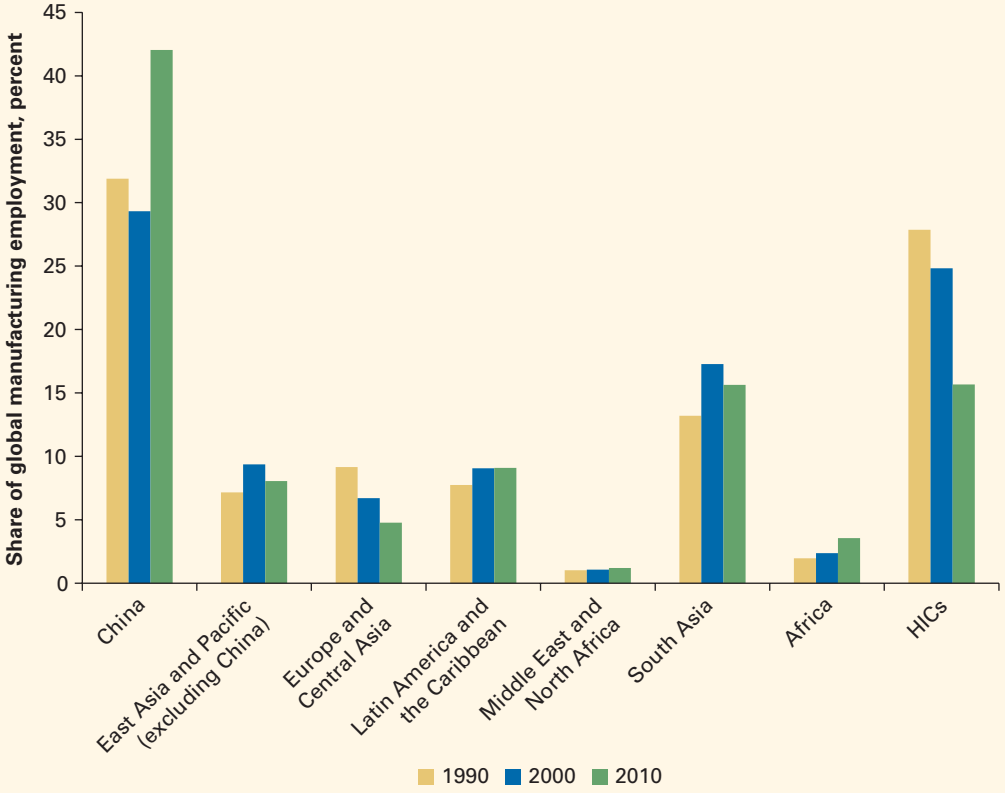
Consistent with the first two stylized facts, labor productivity in HICs has been increasing in recent decades, while labor productivity growth has been more mixed among the nondominant producing countries, widening the productivity gaps among countries. China has been able to expand its productivity substantially, although still at a fairly low level (figure 2.4).[6]

**Stylized Fact 4:** *High-income countries remain dominant players in terms of exports, too—and across the five manufacturing sector groups—with China joining their ranks in four of the five.*

HICs remain important global players in each manufacturing segment, including those where they did not have a revealed comparative advantage. Across the five major manufacturing sector groups, the large majority of the top 10 exporting countries (as measured by domestic value added in share of gross exports [in US$]) are high-income economies (figure 2.5).

**Figure 2.3 Shares of Global Manufacturing Employment (Percentages) Are Significantly Higher in Low- and Middle-Income Countries Than Their Shares of Value Added**

*Share of global manufacturing employment in China, global regions, and high-income countries, 1990–2010*



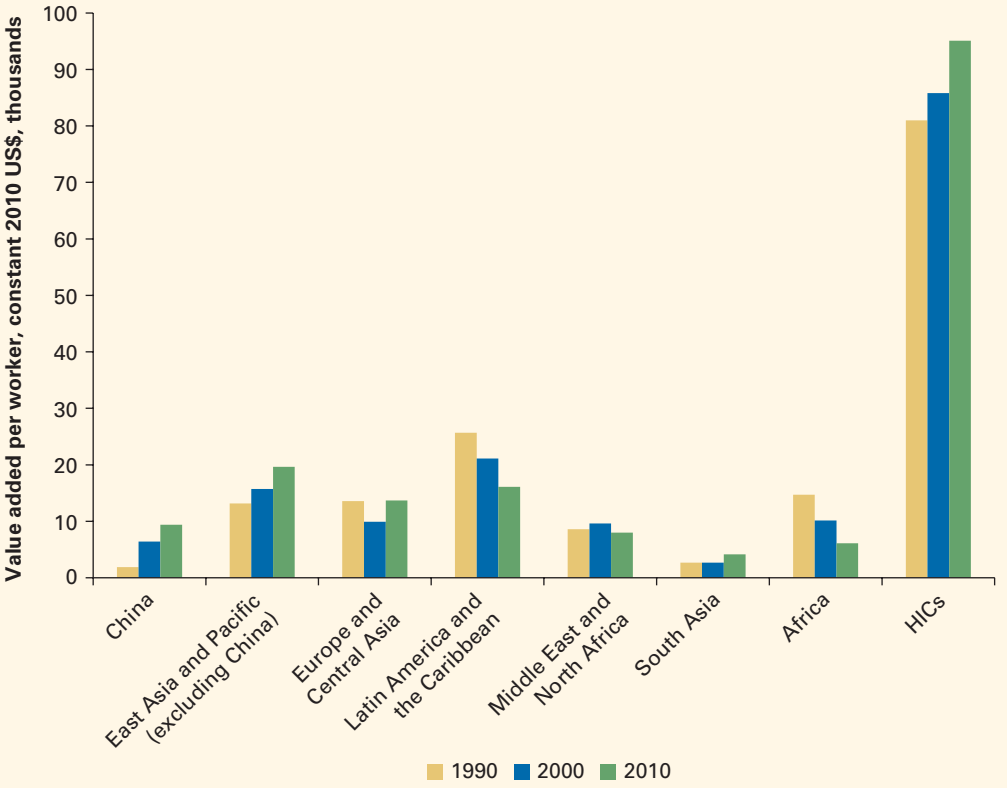

*Sources:* ILOSTAT database, International Labour Organization (ILO); Key Indicators of the Labour Market (KILM) database, ILO; Groningen Growth and Development Centre (GGDC) 10-sector database, University of Groningen, Netherlands.

*Note:* The figure includes only the 67 economies with data for 1995, 2000, and 2010. (Germany's missing 1990 data was replaced by data for 1995). The high-income countries (HICs) as defined in 1990 are those whose gross national income per capita was at least US$7,620. Europe and Central Asia includes only five countries (Azerbaijan, Poland, the Russian Federation, Slovenia, and Ukraine). South Asia includes only India. Middle East and North Africa includes only the Arab Republic of Egypt and Morocco. Latin America and the Caribbean includes 20 countries.

Among the medium-skill global innovator industries, Germany occupied the top position in 1995 and remained the largest exporter in 2011. For the group of high-skill global innovators, Japan and the United States were, respectively, in second and third position, in both 2007 and 2011. In 2011, Germany and the United States were the two largest exporters of capital-intensive processing manufactures, while four of the top five exporters of commodity-based regional processing manufactures in addition to China were (in this order) the United States, Germany, Japan, and Italy. Even in low-skill labor-intensive tradables, 7 of the top 10 exporters in 2011 were high-income economies—France, Germany, Italy, Japan,

**Figure 2.4 Labor Productivity is Rising Among the Dominant Manufacturing Countries—as is the Productivity Gap With Smaller Producing Countries**

*Manufacturing labor productivity in China, global regions, and high-income countries 1990–2010*

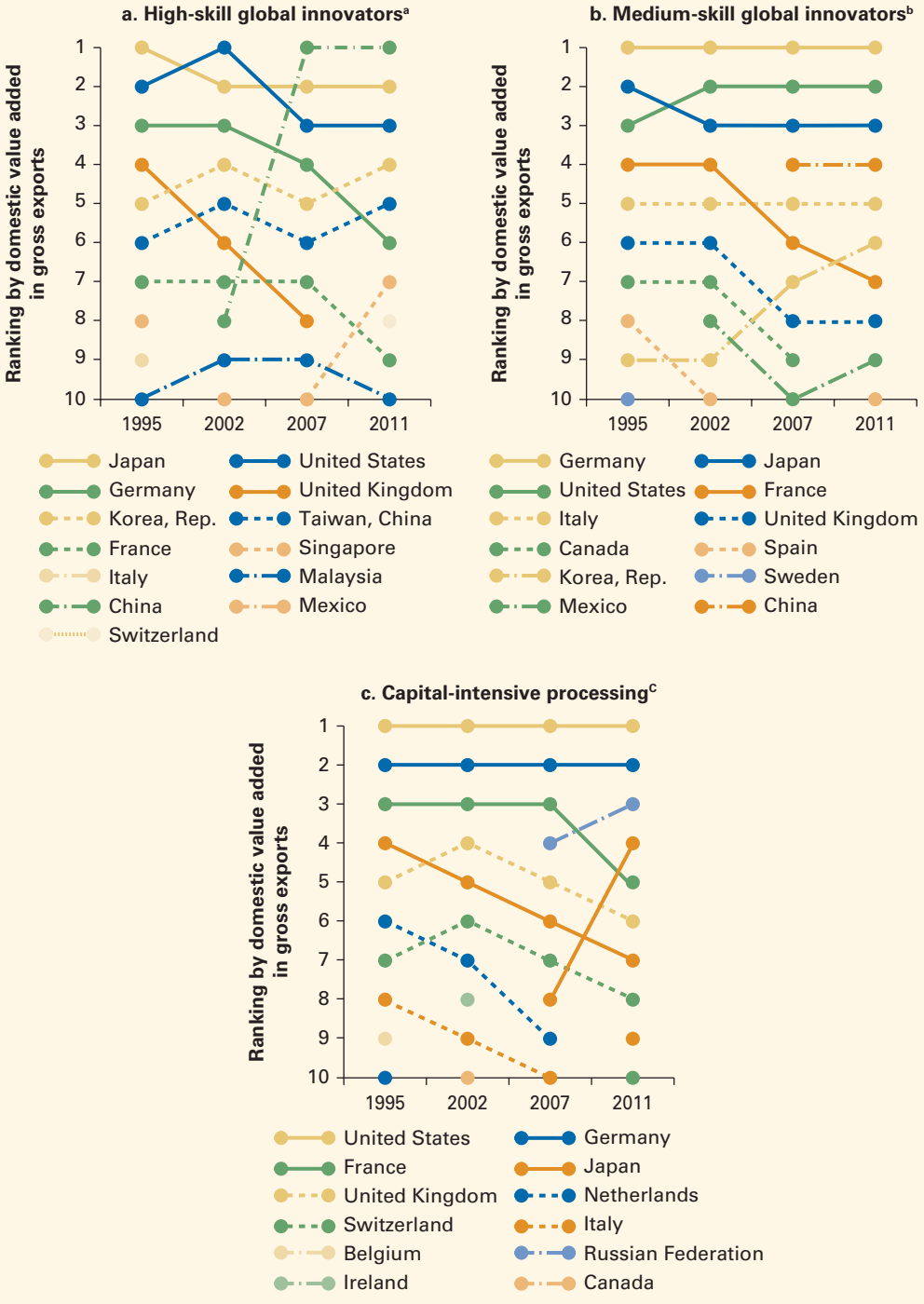



*Source:* ILOSTAT database, International Labour Organization (ILO); Key Indicators of the Labour Market (KILM) database, ILO; Groningen Growth and Development Centre (GGDC) 10-sector database, University of Groningen, Netherlands; United Nations (UN) National Accounts database.
*Note:* Figure includes only 66 economies (instead of the 67 economies in figure 2.3, owing to the lack of data on value added for Taiwan, China (Germany's missing 1990 data were replaced by data for 1995). High-income countries (HICs) as defined in 1990 are those whose gross national income per capita was at least US$7,620. "Europe and Central Asia" includes only five countries (Azerbaijan, Poland, the Russian Federation, Slovenia, and Ukraine); "South Asia" includes only India; "Middle East and North Africa" includes only the Arab Republic of Egypt and Morocco; and "Latin America and the Caribbean" includes 20 countries.

Spain, the United Kingdom, and the United States—despite not having a revealed comparative advantage in these industries.

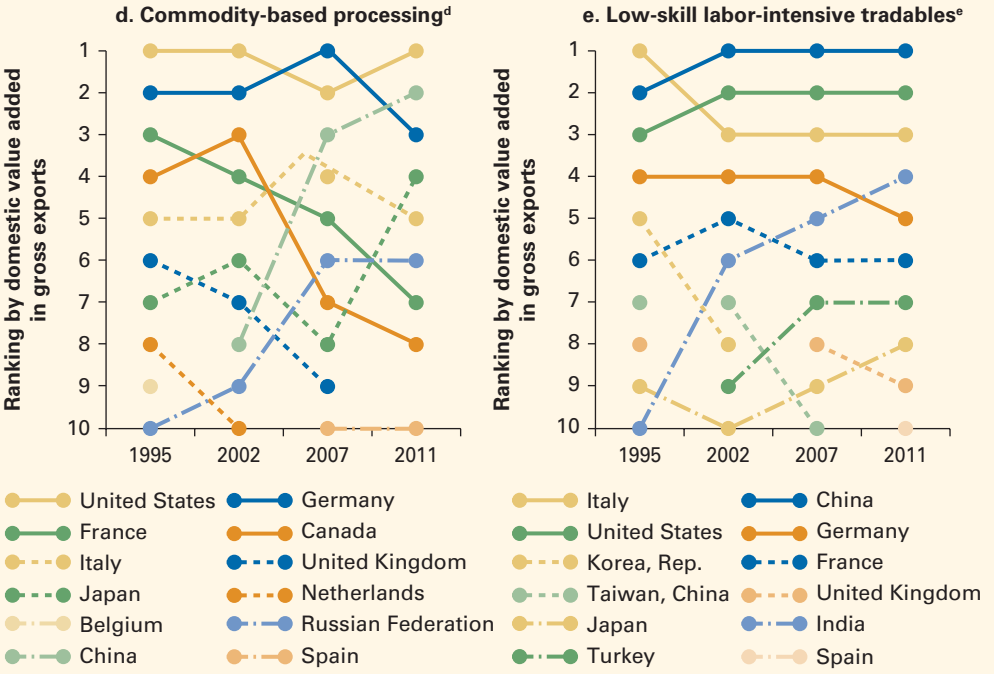
The shifting importance of export locations—as measured by domestic value added in gross exports—across each manufacturing group highlights the rise of China, which by 2011 had a revealed comparative advantage in four of five groups. China in 1995 already occupied the second position behind Italy in the export of labor-intensive manufactures, and has been the largest exporter in 2002, 2007, and 2011. The rise of China as a manufacturing powerhouse between 1995 and 2011 is particularly evident through

**Figure 2.5** **Top 10 Exporting Economies, by Manufacturing Sector Group, 1995–2011**




*(Figure continues on next page)*

**Figure 2.5 Top 10 Exporting Economies, by Manufacturing Sector Group, 1995–2011** *(continued)*




*Source:* OECD-WTO Trade in Value Added (TiVA) dataset.
*Note:* The top 10 exporting economies (as measured by domestic value added in gross exports) use trade in value added (TiVA) rather than total trade to highlight the domestic contributions to the exports. The TiVA data are available for 1995, 2002, 2007, and 2011.
a. "High-skill global innovators" include computing, electronics, and optical instruments, as well as pharmaceutical products.
b. "Medium-skill global innovators" include transportation equipment, electrical equipment, and other machinery and equipment n.e.c. (not elsewhere classified).
c. "Capital-intensive processing" includes chemical products and refined petroleum products.
d. "Commodity-based processing" includes food processing, wood products, paper products, basic metals, fabricated metal products, nonmetallic mineral products, and rubber and plastic products.
e. "Low-skill labor-intensive tradables" includes textiles, apparel, and leather products as well as furniture and manufacturing n.e.c.

its rising importance as an export location for the high-skill and medium-skill global innovator industries. For example, China in 1995 was outside the top 10 exporting countries for the high-skill global innovators. By 2002, it reached the eighth position and quickly became the top exporter in this manufacturing sector group by 2007, a position that it retained in 2011. Similarly, among the medium-skill global innovators, China was outside the top 10 exporting countries in 2002, but became the fourth largest exporter in 2007 and remained so in 2011.

The share of the top 10 exporting countries across the five manufacturing sector groups has remained high between 1995 and 2011, with the concentration higher in some than others. As much as 81 percent of all

global exports of the high-skill global innovator industries in 1995 came from the top 10 exporting countries, a share that declined only marginally to 78 percent in 2011. Similarly, the top 10 countries exported 80 percent of total exports of medium-skill global innovator industries in 1995 and were still exporting 75 percent of those manufactures in 2011. Exports of labor-intensive tradable manufactures were much less concentrated geographically, with the top 10 countries accounting for only 58 percent of total exports in 1995, but this share increased to 69 percent in 2011, primarily on account of China. The share of the top 10 exporters in commodity-based manufactures was also 58 percent in 1995, but their share declined to 52 percent in 2011. Export concentration similarly declined in the capital-intensive regional processing industries, with the top 10 exporters accounting for 65 percent of total exports in 1995, compared with 57 percent in 2011.

Beyond the high-income economies and China, a group of about 15 large emerging markets formed the next tier of big players across the manufacturing groups, with a few making it to the top 10 exporters in each by 2011. They included Argentina, Brazil, Colombia, Costa Rica, India, Indonesia, Malaysia, Mexico, the Philippines, Romania, the Russian Federation, South Africa, Thailand, Turkey, and Vietnam. The composition of these countries did not change much between 1995 and 2011. Making the top 10 exporting countries were India and Turkey in labor-intensive tradables, Malaysia in high-skill global innovators, Mexico in medium-skill global innovators, India and Russia in capital-intensive regional processing, and Brazil and Russia in commodity-based regional processing.

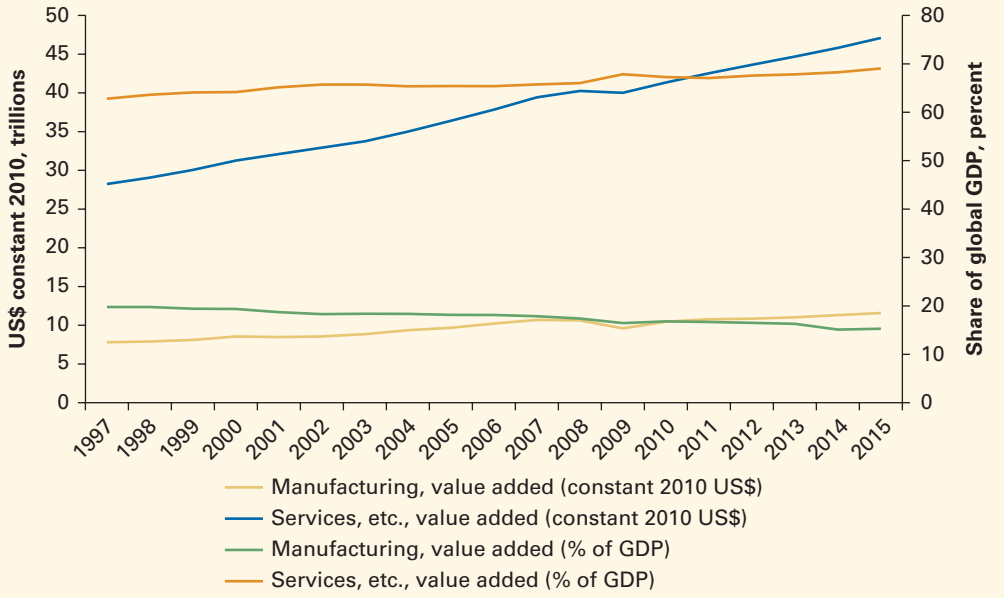
## Patterns of Manufacturing in GDP and Employment: Industrialization and Deindustrialization

**Stylized Fact 5:** *The share of manufacturing value added in global GDP has been declining for decades, as services have grown relatively faster.*

The declining share of manufacturing in global GDP is relative but not absolute—a seeming "deindustrialization" that indicates that services have simply grown faster. Global manufacturing value added as a share of global GDP fell from just under 19.7 percent in 1997 to 15.3 percent in 2015. The decline has been steady, with some accelerations during recessions. However, although the share has declined, the level of global manufacturing value added rose from US$7.8 trillion (constant 2010 prices) in 1997 to US$11.6 trillion in 2015—a 49 percent increase in real terms over the 18–year period, or an annual average of 2.3 percent (figure 2.6). At the same time, the services sector's increasing share of global GDP—from 62.8 percent in 1997 (US$28.2 trillion) to 69 percent (US$47.1 trillion) in 2015—reflects its relatively faster growth, averaging 2.8 percent per year. This is perhaps indicative of income growth around the world and the higher income elasticity of demand for services: as people's incomes rise, they disproportionately demand more services, in accordance with Engel's law concerning the hierarchy of needs.

**Figure 2.6 Real Global Manufacturing Value Added is Growing, but Not as Fast as Services, So Its Share of GDP is Falling**

*Global manufacturing share of GDP and absolute value relative to services, 1997–2015*




*Source:* World Development Indicators database.

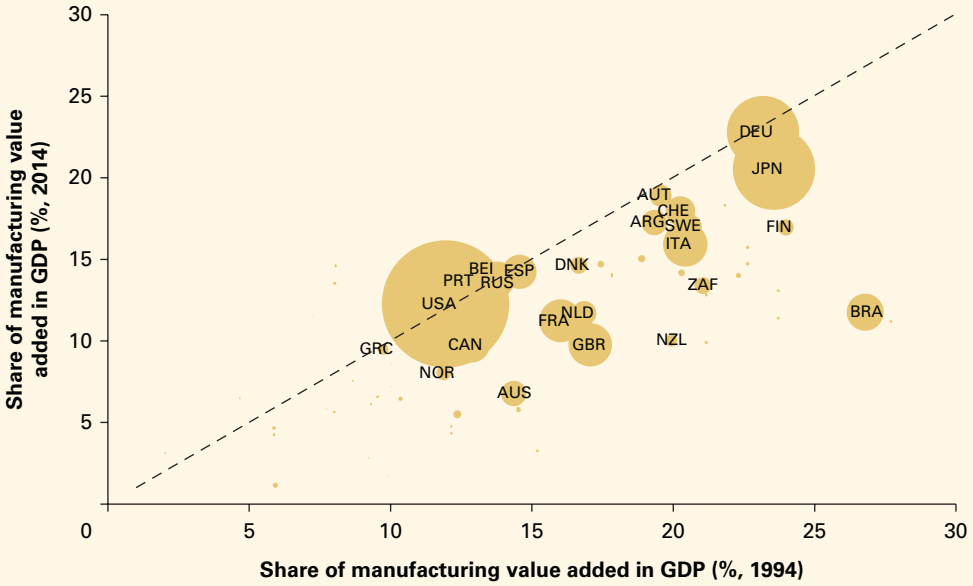
**Stylized Fact 6:** *Three-quarters of countries—including China—are experiencing a decline in the share of manufacturing in GDP.*

Falling shares of manufacturing value added in GDP is a widespread phenomenon. All of the countries that were high income in 1994 are experiencing a domestic decline in the share of value added accounted for by manufacturing—as well as virtually all of the 107 countries whose *global* shares of manufacturing production are also declining. (Almost all countries shown in figure 2.7 are below the 45-degree line.) What is striking is that a domestic decline also characterizes half of the 92 countries whose global shares of manufacturing production are *rising*. (Forty-six of the countries shown in figure 2.8 are above the 45-degree line.) This would indicate that services are rising even faster than manufacturing in these countries.

Of the 20 countries with the largest 1994–2015 declines in the manufacturing share of GDP, almost all were HICs (figure 2.7). This deindustrialization trend among high-income economies, which conforms to the conventional structural change process, was not limited to labor-intensive tradables and commodity-based regional processors; it was largely uniform across the five major manufacturing sector groups, each of which represented a lower share of GDP in 2014 than in 1994. These economies

**Figure 2.7 Countries With Shrinking Global Shares in Manufacturing Value Added Include Almost All Countries That Were High Income in 1994, And Almost All Are Deindustrializing Domestically**

*Change in manufacturing value added as a share of domestic GDP among countries with contracting global shares, 1994–2014*



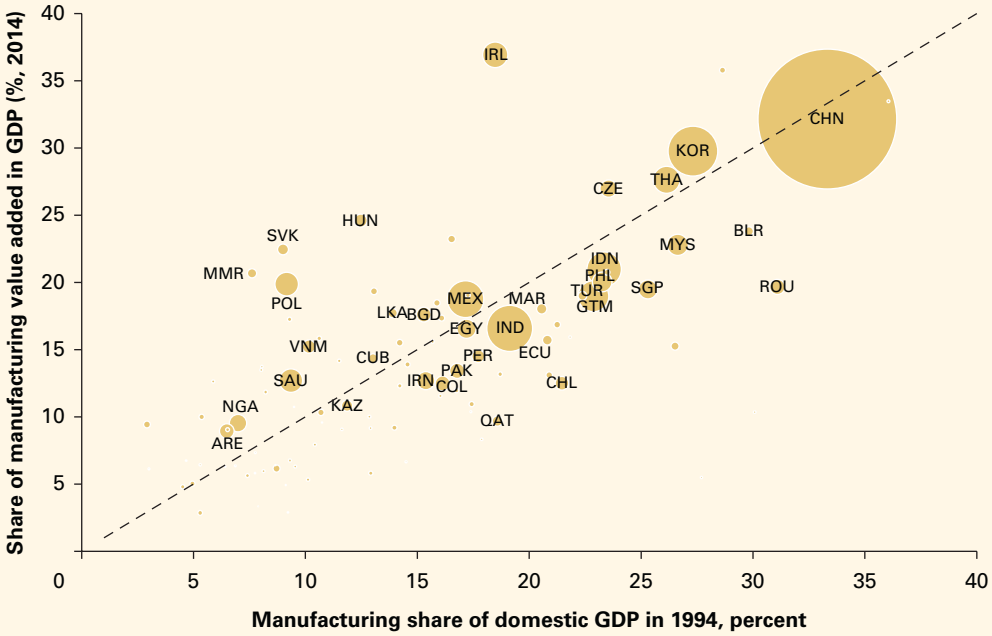

*Sources:* World Development Indicators database; United Nations Industrial Development Organization (UNIDO) Manufacturing Value Added (MVA) 2017 database; U.S. Bureau of Economic Analysis National Economic Accounts database.
*Note:* The dotted 45-degree line separates countries that are industrializing (above the line) from those that are deindustrializing (below the line) over time. Bubble size represents a country's global share of manufacturing value added in 2014.

include Canada, Denmark, Finland, France, Spain, the United Kingdom, and the United States.[7]

The larger emerging global players show a split as to whether they are also experiencing a rise in manufacturing in their domestic shares of GDP. Those showing an increase included the Czech Republic, India, the Republic of Korea, Poland, and Thailand. This increase in the manufacturing's share of GDP was most notable in Korea and Poland, where it rose, respectively, from 27 percent in 1994 to 29 percent in 2014 and from 9 percent in 1994 to 20 percent in 2014. Although Korea's share peaked around 2010 and has now begun declining, it remains above the 45-degree line because it is still above the 1994 level. At the same time, Indonesia and Turkey—countries with expanding shares of global manufacturing value added from relatively large bases—experienced a decline in the GDP share of manufacturing between 1994 and 2014. Strikingly, China is also on this list of countries that is expanding its global share even as its domestic share starts to decline.

**Figure 2.8 Among Countries With Expanding Global Shares in Manufacturing Value Added, Half Are Deindustrializing Domestically**

*Change in manufacturing value added as a share of domestic GDP among countries with expanding global shares, 1994–2014*




*Sources:* World Development Indicators database; United Nations Industrial Development Organization (UNIDO) Manufacturing Value Added (MVA) 2017 database; U.S. Bureau of Economic Analysis National Economic Accounts database.
*Note:* The dotted 45-degree line separates countries that are industrializing (above the line) from those that are deindustrializing (below the line) over time. Bubble size represents a country's global share of manufacturing value added in 2014. Ireland's outlier position reflects in part the tax advantages it offers to multinational corporations that locate headquarters there.

Many smaller countries, although small in terms of their share in global manufacturing, have seen the share of manufacturing in GDP increase over time. Among the small global players that industrialized between 1994 and 2014, Myanmar, the Slovak Republic, and Hungary experienced the largest percentage point increases in the GDP share of manufacturing—from 8 percent to 21 percent, 9 percent to 22 percent, and 12 percent to 25 percent, respectively. Cambodia and Sri Lanka also made marked strides in the industrialization process, with the 1994–2014 share of manufacturing in GDP increasing from 9 percent to 17 percent and from 14 percent to 18 percent, respectively. Bangladesh experienced a more modest increase, with its share of manufacturing rising from 15 percent of GDP in 1994 to 18 percent in 2014. In Sub-Saharan Africa, Botswana, Lesotho, Nigeria, and Uganda were the biggest gainers, with 2–4 percentage point increases

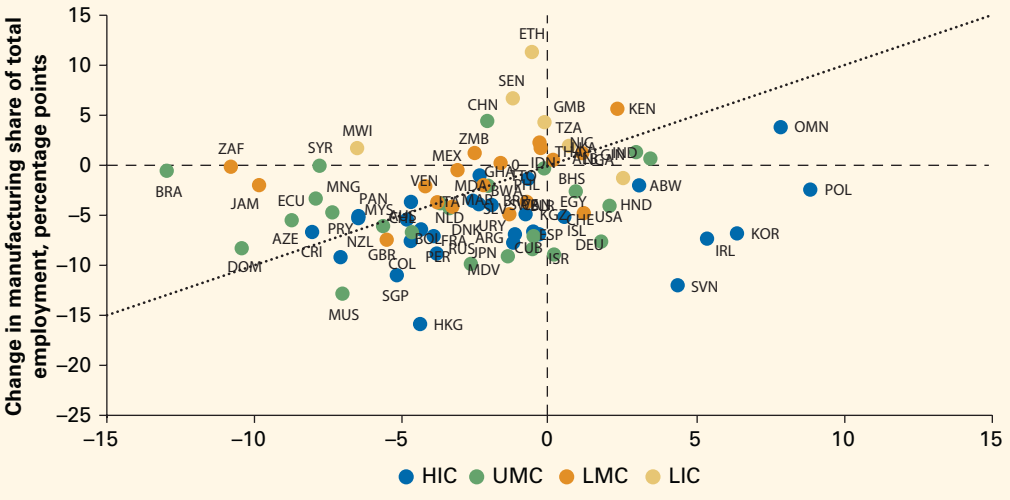
in the GDP share of manufacturing between 1994 and 2014, albeit from lower base shares.

**Stylized Fact 7:** *Changes in the manufacturing share of total employment overlap with those of value added in most countries—but often are bigger.*

The share of manufacturing in total employment declined between 1990 and 2011 in 55 of the 79 countries for which data are available, including a few with rising shares of manufacturing value added in GDP. In most countries, the share of the manufacturing sector in total employment has declined between 1994 and 2011—and changed more than value added. This includes many countries characterized by an expanding manufacturing sector, relative to GDP, over the same period (that is, those in the bottom right quadrant include several of the top industrializers). These results are indicative of productivity gains. However, the productivity gains can threaten the sustainability of demand for manufactured goods and growth if new employment opportunities are not found.

**Figure 2.9 The Changes in Manufacturing Employment Are Often Greater Than Those in Value Added, 1994–2011**

*Change in manufacturing shares of employment and GDP, by country income level, 1994–2011*



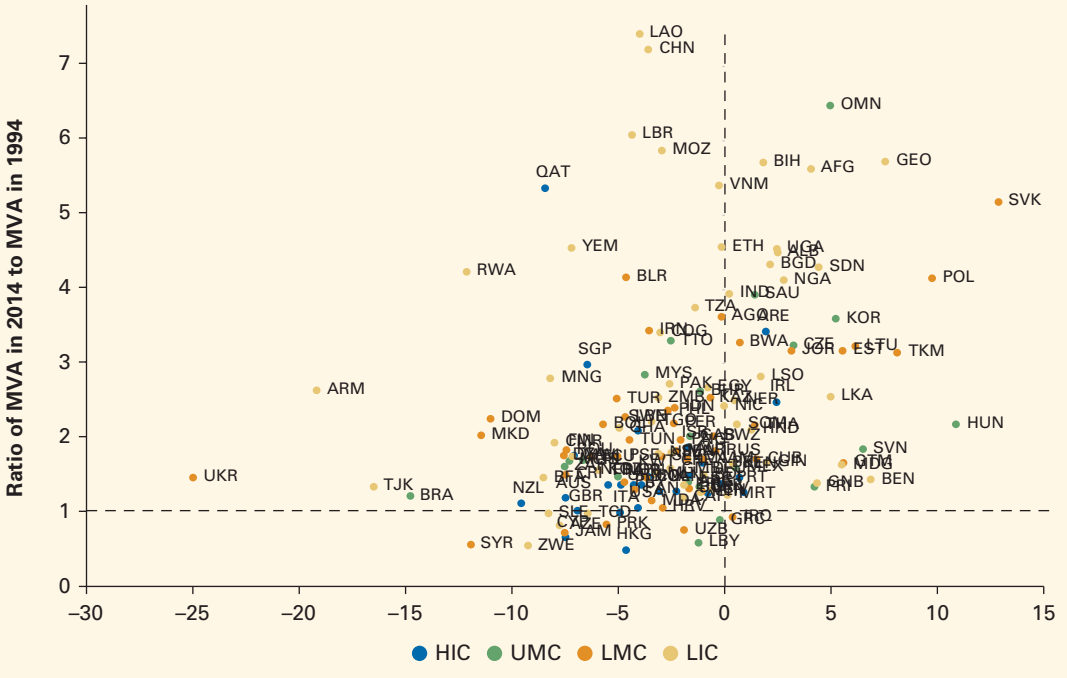

*Sources:* ILOSTAT database, International Labour Organization (ILO); Key Indicators of the Labour Market (KILM) database, ILO; Groningen Growth and Development Centre (GGDC) database, University of Groningen, Netherlands; World Development Indicators database; United Nations Industrial Development Organization (UNIDO) Manufacturing Value Added (MVA) database 2017.
*Note:* HIC = high-income country; LIC = lower-income country; LMC = lower-middle-income country; UMC = upper-middle-income country.

**Stylized Fact 8:** *In few cases did these relative declines of the manufacturing sector in GDP or employment translate into absolute declines.*

Defining deindustrialization as declining *shares* does not necessarily mean that manufacturing employment or value added has declined in *absolute* terms over time. Despite the reduction in the share of jobs in manufacturing, the absolute number of jobs in manufacturing has more than doubled in the past four decades—from about 150 million jobs in 1970 to more than 347 million jobs in 2010—without taking into consideration indirect jobs. Yet, a global comparison across countries and sectors is limited, owing to lack of comparable data available. Among the 66 countries for which we have data, 12 experienced an absolute decline in real manufacturing value added in the past 20 years, many of which had conflict situations (figure 2.10). Some HICs have had only marginal increases over the past 20 years (such as Italy, the United Kingdom, and the United States),

**Figure 2.10 Although the Share of Value Added in GDP Declined in 3 Out of 4 Countries between 1994 and 2014, It Only Declined in Absolute Terms in 12 Countries, Many of Them Being Conflict-Afflicted States**

*Change in manufacturing share of GDP relative to change in absolute value, by country income level, 1994–2014*




*Source:* World Development Indicators database.
*Note:* Countries below the dotted horizontal line experienced an absolute decline in manufacturing value added. All but one of these countries lie to the left of the dashed vertical line, that is, they also experienced a decline in the manufacturing share of total value added. MVA = manufacturing value added. HIC = high-income country. UMC = upper-middle-income country. LMC = lower-middle-income country. LIC = lower-income country.

but many countries have seen significant growth, more than doubling and tripling their real manufacturing value added.

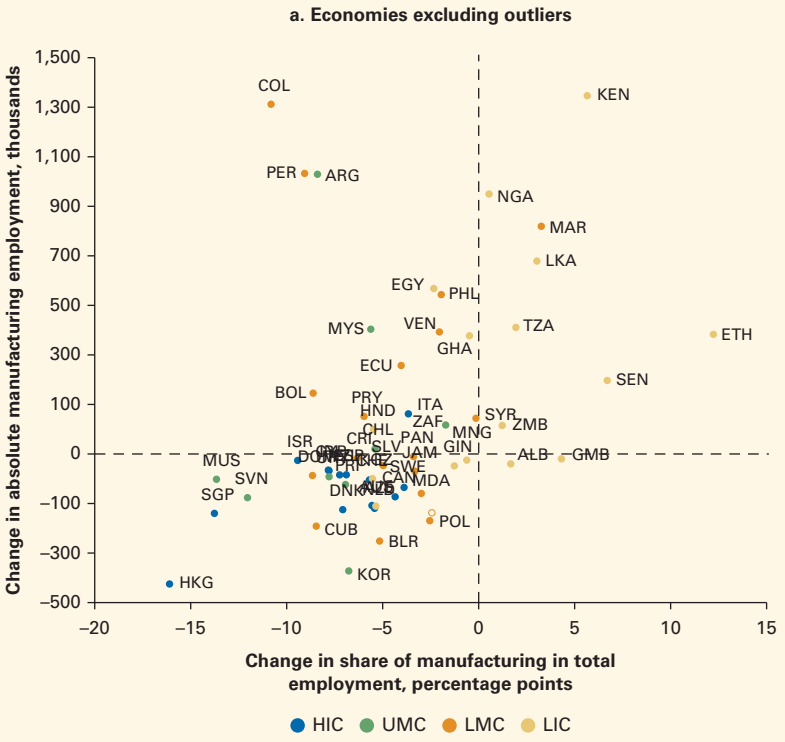
As for employment, a somewhat larger share of countries experienced an absolute decline in jobs, reflecting that the percentage employment declines have been larger than those for value added, too (figure 2.11). Seven countries stand out for having lost close to 1 million manufacturing jobs or more, while China is the extreme positive outlier, gaining 48 million manufacturing jobs over the period 1994–2011.

**Stylized Fact 9:** *The manufacturing shares of both total value added and employment are peaking at lower levels and at lower levels of per capita income than in the past.*

In many low- and middle-income countries (LMICs), the peak shares of manufacturing in value added and employment were both lower and

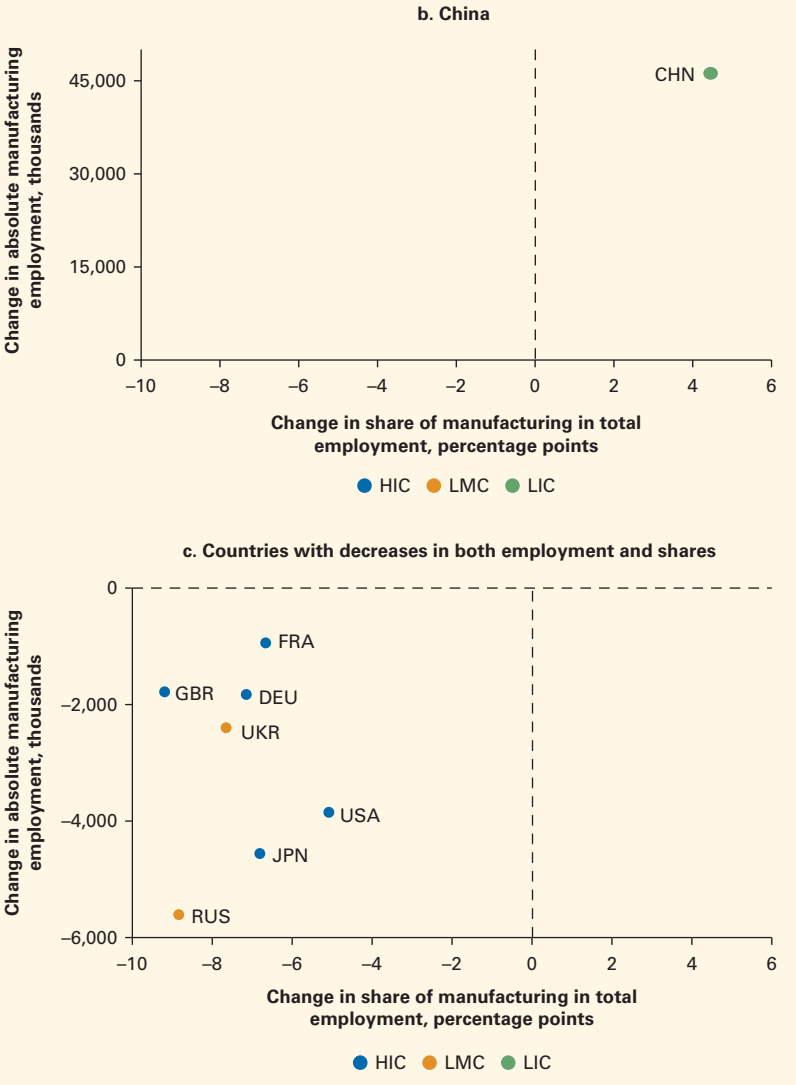
**Figure 2.11 Seven Countries (Mostly Highly Industrialized HICs) Had Significant Reductions in the Number of Jobs, but Most Countries Increased Manufacturing Employment, Even as the Sector Fell as a Share of GDP. China's Manufacturing Employment Soared, Both in Total Numbers and as a Share of Employment**

*Change in manufacturing employment relative to change in share of total employment, by country income level, 1994–2014*




*(Figure continues on next page)*

**Figure 2.11 Seven Countries (Mostly Highly Industrialized HICs) Had Significant Reductions in the Number of Jobs, but Most Countries Increased Manufacturing Employment, Even as the Sector Fell as a Share of GDP. China's Manufacturing Employment Soared, Both in Total Numbers and as a Share of Employment** *(continued)*



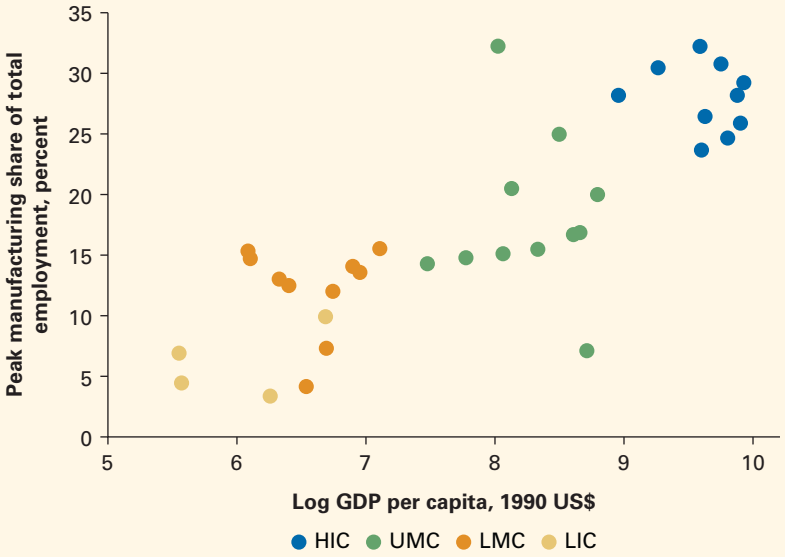

*Source:* World Development Indicators database.
*Note:* Data available for only 66 countries. HIC = high-income country. UMC = upper-middle-income country. LMC = lower-middle-income country. LIC = lower-income country.

occurred at lower levels of development than in the past. Rodrik (2016) reveals this finding for a sample of 42 countries between 1950 and 2012 (figure 2.12) and also shows that this process has more been more rapid in successive decades since the 1960s.[8] This stylized fact has been referred to in the literature as "premature deindustrialization" (Dasgupta and Singh 2007; Rodrik 2016). Although the share of manufacturing jobs and value added is shrinking in many LMICs at lower levels of per capita income than among their high-income, early-industrializer precursors, there is less consensus about this phenomenon being "premature" (box 2.1). One interpretation is that countries are running out of industrialization opportunities sooner and at much lower levels of income than did the early industrializers. Others have argued that "premature deindustrialization" could be an artifact of the fact that activities once classified as "manufacturing" are now "services," but the evidence for this is limited (box 2.2).

This trend of "premature deindustrialization," however, is not necessarily uniform across manufacturing subsectors. Among the low- and

**Figure 2.12 Low- and Middle-Income Countries Are Seeing Lower Peak Shares of Manufacturing in Total Employment and at Lower Levels of Per Capita Income Than Early Industrializers (High-Income Countries)**

*Peak manufacturing share of total employment (1950–2012), by country income level*




*Source:* Groningen Growth and Development Centre (GGDC) 10-sector database, University of Groningen, Netherlands.
*Note:* The sample observations of peak manufacturing share of employment are from 42 economies and periods, 1950–2012. LIC = lower-income country. LMC = lower-middle-income country. UMC = upper-middle-income country. HIC = high-income country.

### Box 2.1 How Deindustrialization Limits Structural Transformation through Manufacturing—and Its Impact on Development

The contribution of manufacturing to productivity growth through an intersectoral reallocation of resources has been lower than expected in many countries. Traditionally, structural transformation involves the movement out of agriculture—first into manufacturing and then into higher value added services. Two factors can lower the contribution of structural transformation: First, in moving to other jobs, people are actually going into lower- rather than higher-productivity ones. Second, the movement into higher-productivity sectors may be limited. With manufacturing generally exhibiting higher productivity than agriculture, if people are not moving, fewer productivity gains are being realized, and if people are moving instead from agriculture to low-end services, structural transformation could actually be associated with a decline in aggregate productivity.

Evidence suggests that the bulk of the difference in productivity performance between Asian countries and most countries in Sub-Saharan Africa and Latin America is accounted for by differences in the pattern of structural change—with labor moving from low- to high-productivity sectors in Asia but in the opposite direction in Latin America and Africa (McMillan, Rodrik, and Verduzco-Gallo 2014). After 2000, however, structural change contributed positively to Africa's overall productivity growth, accounting for about 40 percent of the total, on average, across the 19 African countries in the sample. In contrast, Latin American countries have seen structural transformation contribute little to growth; most of the gains have been within-sector productivity gains.

It should be noted, however, that much of the gain from structural change in Africa stems from movements out of agriculture and into services; the positive contributions of structural transformation have largely bypassed manufacturing. Although this raises concerns about the feasibility of expanding manufacturing in the region, it is also encouraging that the services sector is playing a positive role (Diao, McMillan, and Rodrik 2017; Paci et al., forthcoming).

### Box 2.2 Premature Deindustrialization and Contracting Out of Services from Manufacturing

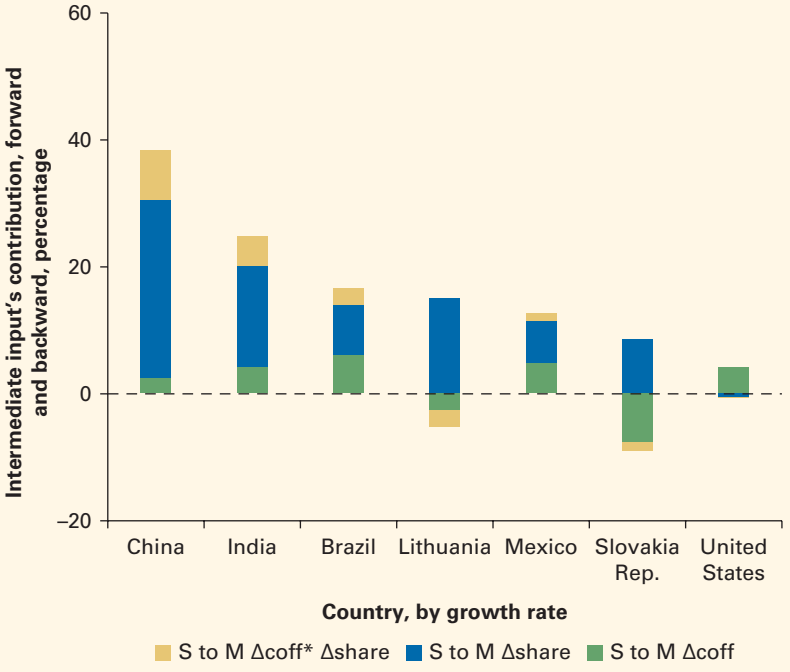
Premature deindustrialization may be attributable, at least in part, to the fact that activities that were earlier classified as "manufacturing" are now "services." Arguably, the growth of the services sector is notional rather than real. This refers to a statistical artifice whereby what was earlier subsumed in manufacturing or agriculture value added is now accounted for as service sector contributions to GDP. It results from the fact that firms in the manufacturing (and agricultural) sector may find it more profitable to "contract out" service activities to specialist providers than to produce them in-house (a process that Bhagwati [1984] refers to as "splintering"). For instance, firms in the industrial sector may make greater use of specialist subcontractors to provide legal, accounting, and R&D services that the firms had previously provided themselves. Similarly, households in the agricultural sector may make greater use of specialist transport and distribution service providers for activities they previously carried out themselves.

Increased contracting out from the manufacturing to the service sector explains about 10 percent of annual services value added growth between 2000 and 2014 in major low- and middle-income economies. The importance of increased contracting out is explored through a decomposition exercise[a] based on national "use" (input-output) tables for more than 40 countries included in the World Input-Output Database (WIOD), which extends the analysis in Gordon and Gupta (2004) and Nayyar (2010).

*(Box continues on next page)*

**Box 2.2 Premature Deindustrialization and Contracting Out of Services from Manufacturing** *(continued)*

**Figure B2.1.1 Percentage Contribution of Demand from the Manufacturing Sector to Annual Services Value Added Growth, Selected Countries, 2000–14**




*Source:* Cruz and Nayyar 2017.
*Note:* "S to M Δcoff" is the change in the input usage of services in manufacturing between 2000 and 2014 for a given level of manufacturing value added; "S to M Δshare" is the change in manufacturing value added between 2000 and 2014 for a given use of services input in the manufacturing sector in 2000; "S to M Δcoff * Δshare" is the product of the first two changes.

The increased use of services input into manufacturing is measured by (a) the change in the input usage of services in manufacturing between 2000 and 2014 for a given level of manufacturing value added; (b) the change in manufacturing value added between 2000 and 2014 for a given use of services input in the manufacturing sector in 2000; and (c) the product of the two changes. Increased splintering from the manufacturing sector is captured by components (a) and (c) and explained 10 percent of annual average services value added growth in China between 2000 and 2014. The corresponding number for Brazil and India was 9 percent over the same period. Yet, the growth of services value added in these low- and middle-income economies was closely linked to the growth of the manufacturing sector as reflected in component (b), which accounted for nearly 30 percent of the average annual growth in China's services value added. The corresponding numbers for Brazil and India were somewhat lower, at 8 percent and 16 percent, respectively.

These estimates, however, do not account for the growing "servicification" of manufacturing within firm boundaries. Even as manufacturing firms are purchasing more services from specialist

*(Box continues on next page)*

**Box 2.2 Premature Deindustrialization and Contracting Out of Services from Manufacturing** *(continued)*

service providers, they are employing more workers in services occupations within the boundaries of the firm. This increased service intensity of manufacturers, as it takes place within firms, is not reflected in input-output tables.

*Source:* Cruz and Nayyar 2017.
a. The growth in services value added is decomposed into intermediate and final demand. Final demand consists of consumption, investment, and net exports. The first part of intermediate demand refers to services input into other sectors in the economy and has nine components: (1) the change in the input usage of services in agriculture; (2) the change in agriculture value added given the initial input usage of services in agriculture; (3) the product of these two changes; (4) the change in the input usage of services in manufacturing; (5) the change in manufacturing value added given the initial input usage of services in manufacturing; (6) the product of these two changes; (7) the change in the input usage of services in other industry (mining, construction, and utilities); (8) the change in other industry value added given the initial input usage of services in other industry; and (9) the product of these changes. The second part of intermediate demand refers to input from other sectors into services and has the analogous nine components.

lower-middle-income countries in Sub-Saharan Africa that experienced a decline in the manufacturing share of GDP between 1994 and 2015 and are in the larger sample (figures 2.7 and 2.8), the share of commodity-based processing manufactures such as food, beverages, and tobacco typically expanded. Tanzania is one example. Among upper-middle-income countries in Latin America—where the manufacturing share of GDP declined between 1994 and 2015—Peru and Ecuador experienced an increase in the GDP share of commodity-based processing manufactures, while Brazil, Colombia, Mexico, and Uruguay experienced an increase in the share of high-skill global innovators in GDP over the same period, albeit from a low base.

## Patterns of Subsector Specialization across Countries

**Stylized Fact 10:** *High-income countries are deindustrializing across the five sector groupings.*

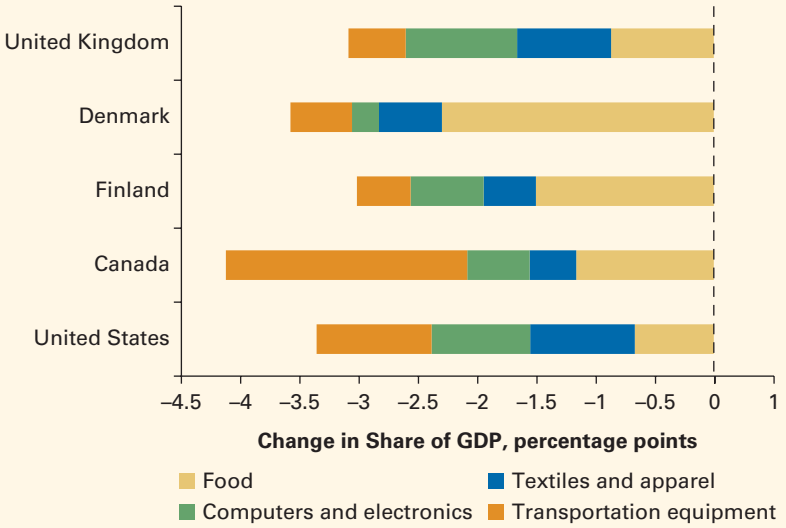
In large HICs, the declining share of manufacturing value added in GDP has been uniform across the five manufacturing sector groups. This trend can be seen in figure 2.13, where four of the five manufacturing sector groups, as represented by sample industries from those sector groups, have shrunk as a share of GDP in the sample of HICs.

**Stylized Fact 11:** *Upper-middle-income industrializers show evidence of "flying geese"—moving from labor-intensive to higher-skill manufactured goods—except for China, which remains a big player in the labor-intensive sectors, too.*

As mentioned earlier, there is evidence of "flying geese"—or product cycle dynamics—among middle-income industrializers that are becoming high-income. A set of upper-middle-income industrializing countries (as defined in 1994) (for example, Hungary, Republic of Korea, Malaysia, Czech Republic and Slovak Republic) are changing the composition of their

**Figure 2.13 Declines in Manufacturing Value Added as a Share of GDP Confirm That Large HICs Are Deindustrializing Across Most Sector Groupings**

*Percentage point change in GDP share from representative manufactures, selected high-income countries, 1994–2014*




*Source:* United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database.

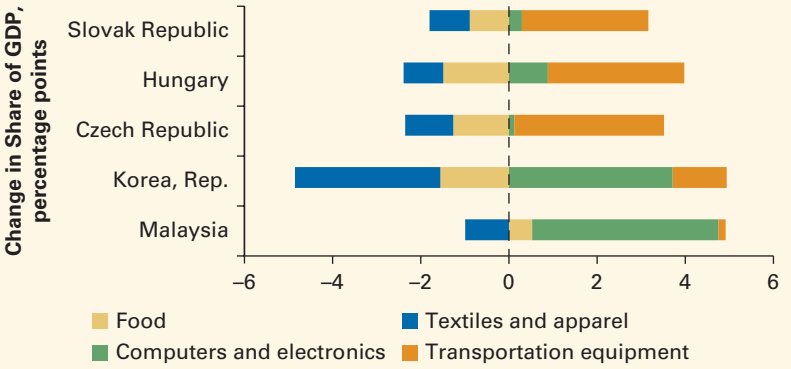
production and exports away from low-skill labor-intensive goods to more skill-intensive goods. This change is reflected in a declining share of food and beverages and textiles and apparel in GDP alongside an increasing share of transportation equipment and computers and electronics in GDP between 1994 and 2014 (figure 2.14).

Based on export baskets, some of these countries, such as Hungary and the Republic of Korea, did not have a revealed comparative advantage in high-skill global innovator industries in 1993–95, but they developed it by 2011–13. Similarly, a larger set of countries switched from a revealed comparative advantage of less than 1 to greater than 1 between 1993–95 and 2011–13 in medium-skill global innovator industries. These countries include the Czech Republic, Hungary, Korea, Morocco, Poland, the Slovak Republic, Thailand, Tunisia, and Turkey. At the same time, countries such as the Czech Republic, Hungary, Korea, and Thailand lost their revealed comparative advantage in labor-intensive tradables between 1993–95 and 2011–13.

The largest industrializing country that is not following this trend is China. As chapter 3 discusses in more detail, China is entering higher value added sectors while also maintaining and expanding its production and exports in four of the five sector groups. Petrochemicals is the one

**Figure 2.14 Several Industrializing Upper-Middle-Income Countries Exhibit Shifts in Sector Composition, as Predicted by the Product Cycle, or "Flying Geese," Pattern**

*Percentage point change in GDP share from representative manufactures, selected upper-middle-income countries, 1994–2014*




*Source:* United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database.

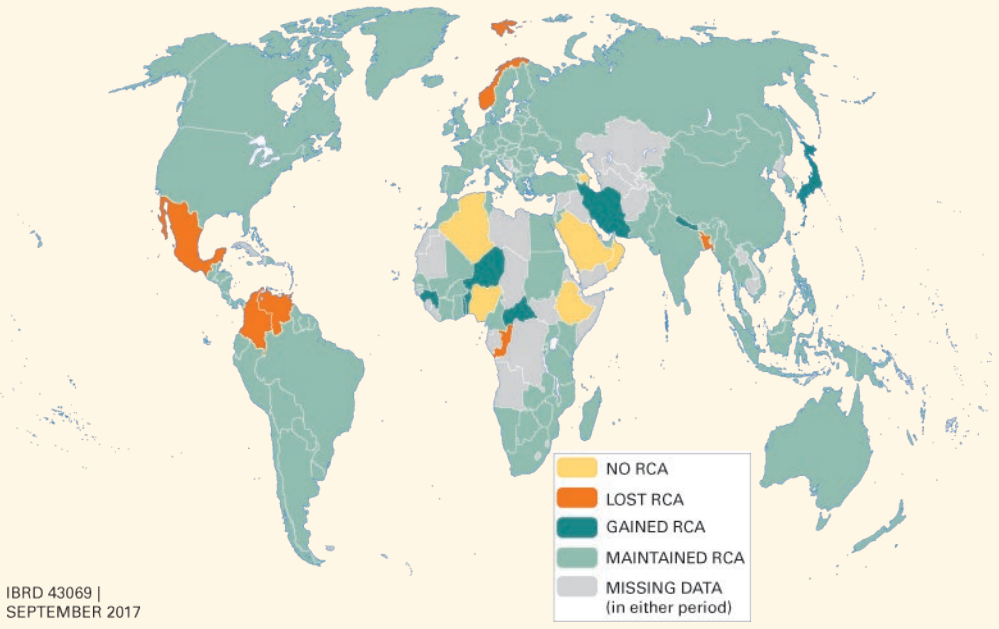
sector in which it does not have a revealed comparative advantage and is not one of the four global leaders in terms of exports. As noted earlier (figure 2.5), China is the largest exporter (in terms of value added in exports) of labor-intensive tradables, the second-largest exporter of commodity-based processing, the fourth-largest exporter of medium-skill global innovators, and the top exporter of high-skill global innovators.

**Stylized Fact 12:** *Few lower-income countries outside of Asia have a revealed comparative advantage in anything but labor-intensive tradables or commodity-based regional processing—although not all have passed even these thresholds.*

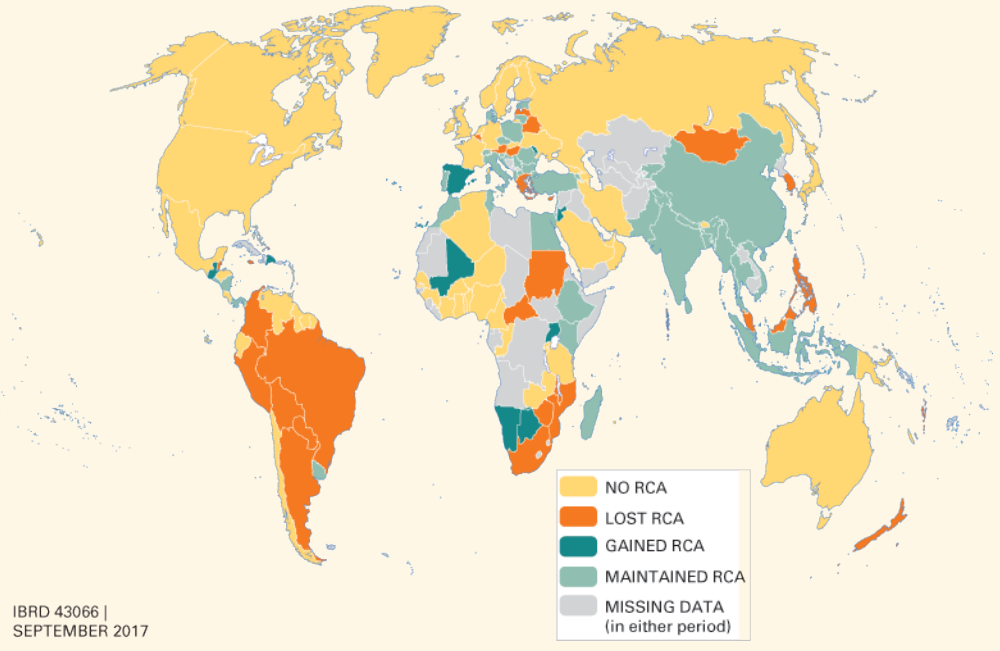
Data on production baskets by disaggregated manufacturing sectors are scarce, particularly for lower-income countries; therefore, the following patterns rely on trends in export baskets. All low-income countries and a large majority of middle-income countries lacked a revealed comparative advantage in the high-skill global innovator industries in 1993–95 and did not acquire one by 2012–14. Similarly, among all low- and lower-middle-income countries, only three developed a comparative advantage in medium-skill global innovators between 1993–95 and 2012–14: Honduras in Latin America and Morocco and Tunisia in the Middle East and North Africa region. The same holds true for a small handful of low- and lower-middle-income countries in the case of capital-intensive regional processing: Côte d'Ivoire, the Arab Republic of Egypt, India, Morocco, and Niger.

**Map 2.1 Changing Patterns of Revealed Comparative Advantage (RCA), by Manufacturing Sector Group, 1993-95 and 2012-2014**

a. Commodity-based regional processing



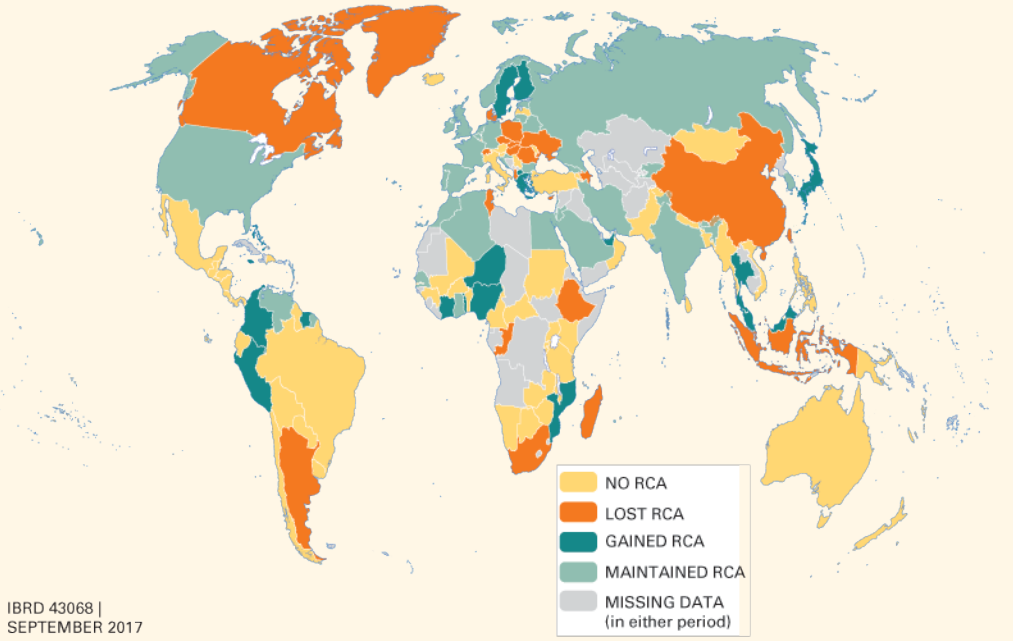

b. Low-skill labor-intensive tradables




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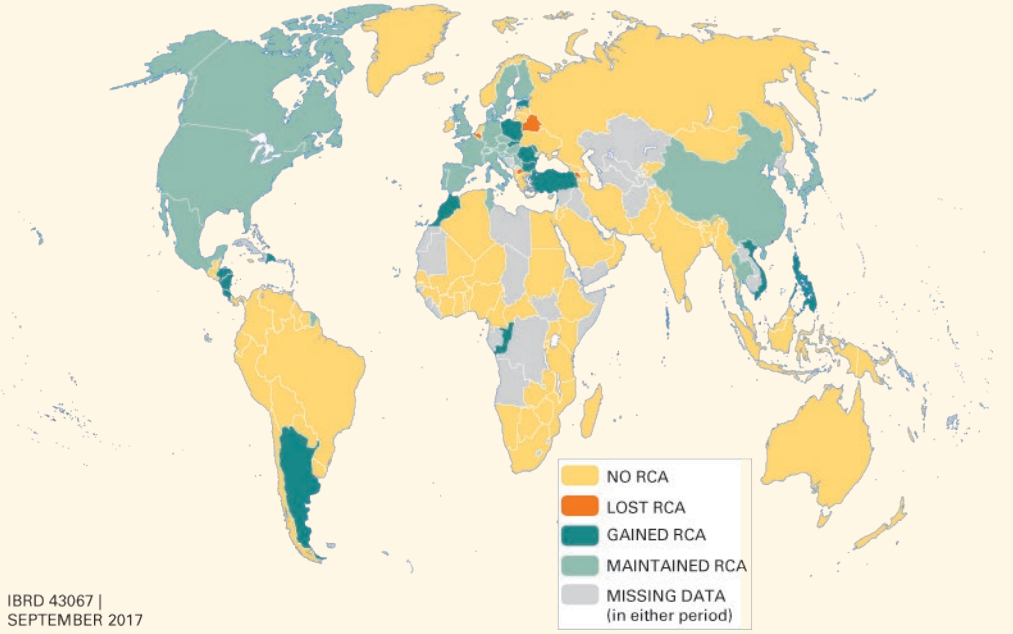
**Map 2.1 Changing Patterns of Revealed Comparative Advantage (RCA), by Manufacturing Sector Group, 1993-95 and 2012-2014** *(continued)*

c. Capital-intensive regional processing




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SEPTEMBER 2017

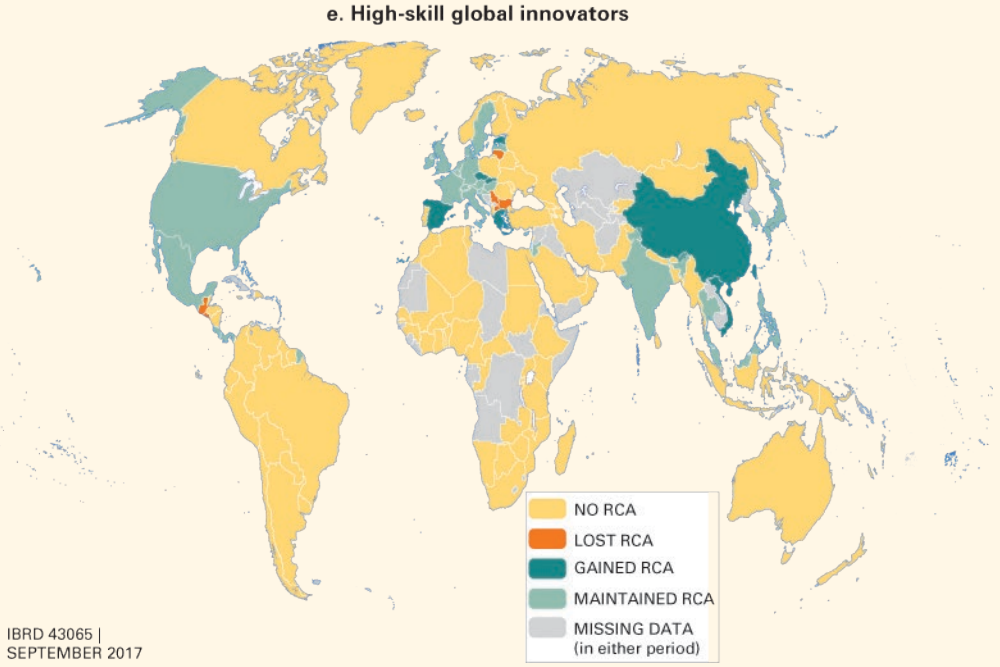
d. Medium-skill global innovators




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*(Map continues on next page)*

**Map 2.1 Changing Patterns of Revealed Comparative Advantage (RCA), by Manufacturing Sector Group, 1993-95 and 2012-2014** *(continued)*




*Source:* Calculations based on UN Comtrade.
*Note:* If data between 1993-1995 are missing, then 1993 is replaced by 1992 (going back to 1991 or 1990 if needed) and 1995 is replaced by 1996 (going up to 1999 if needed). Similarly, if data between 2012 and 2014 are missing, then 2012 is replaced by 2011 (going back to 2010 if needed) and 2014 is replaced by 2015 (going up to 2016 if needed).

At the same time, several low- and lower-middle-income countries in South Asia and Southeast Asia maintained their revealed comparative advantage in labor-intensive tradables between 1993–95 and 2011–13: Bangladesh, Cambodia, India, Indonesia, Pakistan, Sri Lanka, and Vietnam. Myanmar acquired one over the same period. However, China and recently India are the only two middle-income countries on the list of top 10 exporters of labor-intensive tradables (as shown earlier in figure 2.5). In contrast, most low- and lower-middle-income countries in Sub-Saharan Africa lacked a revealed comparative advantage in labor-intensive tradables, both in 1993–95 and in 2012–14. This divergence between Southeast Asia and Sub-Saharan Africa is indicative of the fact that beyond the consideration of low unit labor costs, value chains in labor-intensive tradables such as wearing apparel and other light manufacturing (for example, furniture, joys, jewelry, sporting goods) have developed along regional lines. In other words, suppliers in these countries, unlike those in Sub-Saharan Africa, have benefited from being in close proximity to big players in the industry.

Countries across the income spectrum, including low- and lower-middle-income economies in Sub-Saharan Africa, either developed or maintained their revealed comparative advantage in commodity-based regional processing between 1993–95 and 2012–14. In Sub-Saharan Africa, the countries that maintained it throughout the period include Burkina Faso, the Central African Republic, The Gambia, Guinea, Mauritius, Madagascar, Togo, and Uganda. Those that had acquired it by 2012–14 include Burundi, Cameroon, Côte d'Ivoire, Zambia, and Zimbabwe.

## Conclusion

Although lower-income countries are less likely than upper-middle- or high-income countries to have revealed comparative advantages across more than one manufacturing sector group, those that do tend to be in commodity-based processing and/or labor-intensive tradables. Several South Asian countries have a comparative advantage in labor-intensive tradables. For low- or lower-middle-income countries in Sub-Saharan Africa, however, only the commodity-based processing manufactures are expanding in GDP and where many of these countries have a revealed comparative advantage. Few low- or lower-middle-income economies have a presence in the medium-skill and high-skill global innovator industries.

These specialization patterns in the manufacturing sector across low- and lower-middle-income economies have implications for potential positive spillovers and dynamic growth and development gains. For those with a presence in the global market for labor-intensive tradables, the sector brings together the benefits of international trade—scale, technology diffusion, and competition—with large-scale employment creation for unskilled workers. Although commodity-based regional processing comprises industries that are less traded internationally and therefore benefit less from related productivity benefits, there is still scope for job creation for unskilled labor. The lack of presence in GVCs for high-skill global innovators and medium-skill global innovators means that few lower-income countries have successfully combined unskilled jobs in labor-intensive assembly with the highest scope for technology diffusion, owing to R&D being carried out in high-income economies.

Looking ahead, a concern is whether new technologies and shifting patterns of globalization will make it harder for LMICs to have a significant role in manufacturing, including in sectors that define their current production baskets. To date, new technologies and changing trade patterns have tended to widen the circle of countries benefiting from expanding production. Not all countries have benefited equally, but there has been a pattern over time of additional lower-income countries using manufacturing as a central driver of their development. To the extent that big global players continue to account for large shares of manufacturing,

agglomeration economies might make hitherto less-industrialized countries less competitive in export markets. Further, to the degree that new technologies associated with Industry 4.0—such as robotics, the Internet of Things, and 3-D printing—may be labor-saving, they potentially narrow the paths for less-developed countries to realize the pro-development characteristics that manufacturing has traditionally offered.

Part II of this book explores these questions, even if definitive answers cannot be provided, as many of the new technologies being discussed are only starting to spread. The specialization patterns presented here are important to keep in mind when chapters 3 and 4 look at which sectors are likely to face more disruptions and therefore what the likely scope will be for lower-income countries to maintain or expand their manufacturing activities.

## Notes

1. The "flying geese" paradigm is a model for the international division of labor based on dynamic comparative advantage, where the main driver is the "leader's imperative for internal restructuring" because of increasing labor costs (Akamatsu 1962). As the comparative advantages (on a global scale) of the "lead goose" cause it to shift further and further away from labor-intensive production to more capital-intensive activities, it sheds its low-productivity production to countries further down in the hierarchy in a pattern that then reproduces itself among the countries in the lower tiers. The East Asian experience is usually cited to typify this pattern.
2. These countries, where manufacturing represented more than 75 percent of merchandise exports, included Hungary, Malaysia, Mexico, Pakistan, the Philippines, Poland, Romania, Sri Lanka, Thailand, and Turkey.
3. While not trivial, these results suggest that China's opening during the 1990s did not, on average, have a large effect on the broad sectoral structures of other countries. Other recent evidence linking China's manufacturing-led demand surge for commodities to "Dutch disease" in resource-abundant low- and middle-income countries across Sub-Saharan Africa and Latin America is also inconclusive (Meyersson, Miquel, and Qian 2008; Su et al. 2016).
4. "Industry" strictly includes manufacturing, mining, construction, and utilities. However, the term is also used as an alternative to "manufacturing." In this report, particularly when discussing "deindustrialization," the term "industry" refers to manufacturing and not to the full set of activities under "industry."
5. China's 2000 decline in manufacturing employment share is largely accounted for by the closing of many state-owned enterprises during this period.

6. Note that data were available for only a subset of countries, with lower- income countries only sparsely covered; the differences in productivity would likely be all the larger if the country coverage could be expanded.
7. In Israel, Japan, Malaysia, the Philippines, and Switzerland, the overall share of manufacturing in GDP declined but the share of some high-skill innovator industries—computers, electronics, and optical equipment—increased.
8. The magnitude of coefficients on each decadal dummy variable are mostly negative and are becoming larger over time.

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PART II

# TECHNOLOGY, GLOBALIZATION, AND THE FUTURE OF MANUFACTURING-LED DEVELOPMENT

*Trends in technology and globalization will continue to profoundly affect what is made, how, and where—and what the development impacts will be. They have been the basis for the changing distribution of manufacturing activity over time and across space, as discussed in chapter 2. Chapter 3 now looks ahead at how technology and globalization trends themselves are expected to change. It discusses key developments within these trends, setting up the discussion in chapter 4 on how these will affect the feasibility of manufacturing-led development across different subsectors. Chapter 4 also revisits how new technologies and shifting globalization patterns might affect the desirability of manufacturing—that is, the characteristics of manufacturing that have historically driven dynamic gains (as discussed in chapter 1): scale, tradedness, employment, innovation, and productivity growth. Chapter 5 notes that services increasingly make up a larger source of value in the broader manufacturing process and therefore expand the range of productive activities that countries can participate in. Many stand-alone service activities also increasingly share a range of pro-development characteristics traditionally associated with manufacturing. Yet, many of these services are skill-intensive; the potential, therefore, for the services sector to absorb unskilled labor and then place it on a high-productivity trajectory may be more limited.*

CHAPTER 3

# Trends Shaping Opportunities for Future Production

## Introduction

Given their past importance, new technologies and changing globalization patterns will likely profoundly affect the future of manufacturing-led development. Historically, changes at the intersection of technology and globalization through the first, second, and third industrial revolutions have been associated with changing patterns of specialization, over time and across space, in the global manufacturing landscape. Global production fragmentation—enabled by the information and communication technology (ICT) revolution and Industry 3.0, as documented in chapter 2—was associated with a shift in global manufacturing production from high-income countries to Asia, particularly China. At the same time, there was a slowing pace of structural change and industrialization as well as even deindustrialization in many low- and middle-income countries (LMICs).

Looking ahead, the technology and globalization trends themselves are expected to be subject to considerable change. A key question will be whether new trends in technology and globalization—Industry 4.0 and the continued rollout of Industry 3.0—will weaken the industrialization prospects across a broad range of LMICs or whether they will create new potential to boost manufacturing output and exports and leverage them for growth.

Emerging technologies and their increasing rates of adoption are transforming manufacturing processes, and these are being rolled out in an evolving global setting. Industrial automation and advanced robotics, digitalization and Internet-based systems integration (factory Internet of Things [IoT]), and additive manufacturing (3-D printing) could significantly shift which locations are attractive for production, not only in advanced goods but also in the production of more traditional manufactured goods.

Although not all of these technologies are new (robots and 3-D printing have been around for decades, and the IoT builds on ICT legacy technologies), cost innovation, software advances, and evolving business formats and consumer preferences are fueling adoption.

Further, globalization—as manifested through freer cross-border flows in trade, capital, and ideas and the concomitant growth of global value chains (GVCs)—has been an important driver of export-led manufacturing thus far, but its pace appears to be slowing. Moreover, protectionist forces are on the rise among a wide range of countries seeking to reindustrialize, upgrade, or industrialize their economies and manufacturing sectors. The prospects for export-led manufacturing in the future will depend, in large part, on the confluence of these technology and globalization trends.

## Megatrends That Matter

*Key message: While the focus is on the role of technology and globalization in the changing geography of production, these trends need to be understood in the context of other global megatrends, such as demographic change, urbanization, and climate change.*

The future manufacturing landscape will be influenced by many trends—including demographic change, urbanization, and climate change—that are likely to underpin continued strong global demand for manufactured goods. After countries reach a sufficiently high level of income, the demand for services increases faster than that for manufactures, owing to a higher income elasticity of demand.[1] However, even if the demand for goods declines as incomes rise and the demand for services increases faster, the per capita consumption of manufactured goods is lower in middle-income economies and far less in low-income ones. Thus, we can expect a volume boost on the demand side as low- and middle-income country (LMIC) populations expand and urbanize, incomes rise, and material standards of living continue to converge (Kharas 2010; WEF 2012). Yet there are likely to be broad changes as to *which* manufacturing goods will be in demand. Aging populations, growing middle classes, and urbanizing populations will demand different types of goods. The dematerialization of consumption, due to climate change concerns and the sharing economy, may dampen the demand for some manufactured goods.[2] While this book recognizes that these megatrends will shift the composition, and likely scale, of demand, the focus is on how manufacturing production processes are likely to be affected.

Many of these megatrends may also affect the supply of manufactured goods, especially regarding where production is likely to occur. Low- and middle-income economies will be responsible for much of the growth of the global labor supply in coming years. Further, the new generation of young workers from these economies is more educated than the previous ones, increasing the supply of skilled workers (Ahmed and others 2017).

These demographic changes can potentially improve the competitiveness of less industrialized countries in labor-intensive manufacturing (World Bank 2015a). Urbanization, which is proceeding rapidly in many LMICs, could also boost manufacturing production through agglomeration and localization effects (Beeson 1987; Morosini 2004).[3] Perhaps more important, greater urbanization can foster the exchange of ideas and attract talent since centers of innovation tend to be in urban areas (Malmberg and Maskell 2002; Padmore and Gibson 1998). Last but not least, climate policy—represented by the Paris Agreement and the United Nations (UN) Sustainable Development Goal (SDG) on sustainable industry[4]—will create incentives to produce new products and clean technologies for manufacturing goods (World Bank 2010, 2015b).

At the same time, the bigger trends affecting the geography of production will come from changing globalization dynamics and emerging technologies. Globalization—as manifested through freer cross-border flows in trade, capital, labor, and ideas as well as the concomitant growth of GVCs—has been an important driver of export-led manufacturing. Yet, the pace of globalization appears to be slowing. Following decades of rapid growth, there has been a considerable decline in the trade of parts and components (Constantinescu, Mattoo, and Ruta 2015). The share of foreign direct investment (FDI) going to manufacturing in LMICs has also been declining. Moreover, protectionist sentiments are on the rise among a wide range of countries seeking to reindustrialize, upgrade, or industrialize their economies and manufacturing sectors. The prospects of manufacturing export-led development are further complicated by emerging technologies that can enable firms to "reshore" previously labor-intensive activities back to high-income economies, either in response to the reduced importance of wage costs or increased demand for quick-turnaround customized goods, or to maintain production in LMICs but with much lower levels of employment.

## Globalization Trends: Trade, FDI, Migration

*Key message: While globalization and technological change are deeply intertwined, abstracting from changes in technology, the changing external environment itself provides new opportunities and creates new challenges for export-led manufacturing. Trends in trade and FDI flows could offer new opportunities for a wider set of low- and middle-income countries in manufacturing. In addition, labor flows, while never a large part of the manufacturing agenda, show new relevance among high-skill workers.*

### Flows of Goods: Slowing Trade, China's Changing Role, and New Threats of Protectionism

Five primary changes in the trade landscape, some cyclical and others more structural, will affect the prospects for export-led manufacturing: weak import demand and a lower growth elasticity of trade coming out of the financial crisis of 2008; the end of the commodities super-cycle;[5] the

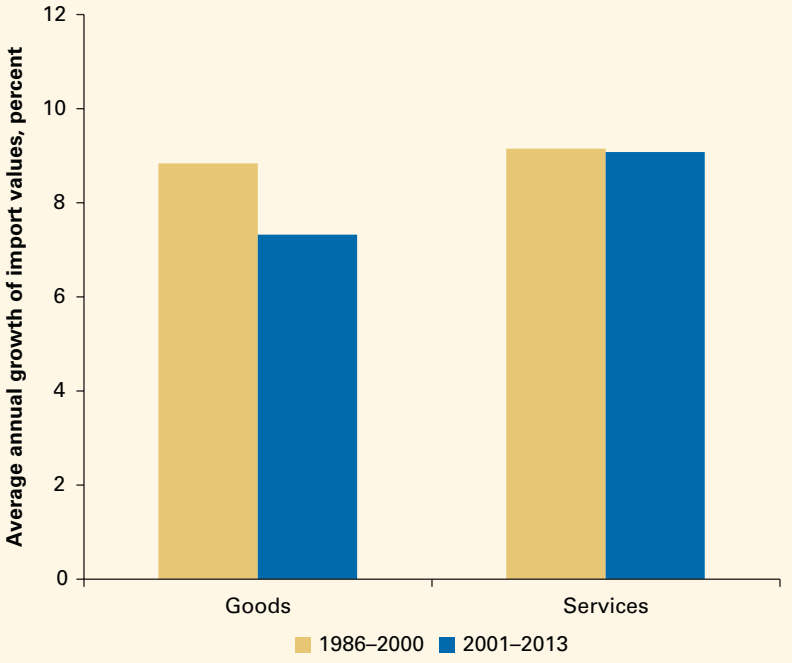
slowdown of trade in intermediates; China's value chain upgrading; and growing calls for protectionism in some countries.

In fact, given its size in manufacturing, China exhibits changes that help to account for each of these phenomena. Specifically, its slowing growth rates contribute to lower import demand abroad too. Its rebalancing helps explain some of the decreased demand for commodities. Its value chain upgrading explains the declining trade in parts and components. Even with some signs of slowing, given both its level of production and that it still continues to have among the highest growth rates in many manufacturing sectors, how China's future production evolves will be a major factor in shaping global production patterns. While many of these trends appear as challenges, they also present opportunities.

## Weak Import Demand

Global trade growth has been strongly subdued in recent years—growing on average by 3 percent per year since 2012, well below the pre-crisis annual average of 7 percent (1987–2007) and somewhat below the growth rate of world gross domestic product (GDP) in real terms, which has hovered slightly above 3 percent. The rapid growth in world trade in value terms in the 1990s and its subsequent slowdown in the 2000s were driven by goods rather than services (figure 3.1). Constantinescu, Matto,

**Figure 3.1 Global Growth of Import Values for Goods and Commercial Services, 1986–2000 and 2001–13**




*Sources:* United Nations (UN) Comtrade database; WTO 2015.

and Ruta (2015) find that, at the world level, the long-run elasticity of manufacturing trade to GDP was 2.4 in the 1990s and fell to 1.9 in the 2000s. In contrast, services trade elasticity and commodity trade elasticity increased over the same period.[6] This pattern confirms that developments within the manufacturing sector are key to understanding the global trade slowdown.

Trade has been growing more slowly not only because economic growth has become less trade-intensive, but also because global growth is slower. Indeed, trade weakness in the aftermath of the 2008 global financial crisis has been most pronounced in the high-income economies at the center of the crisis, notably the euro area and the United States.[7] The resulting weak import demand in these economies epitomizes the Keynesian concern: that weak aggregate demand resulting in subdued world import growth may adversely affect individual countries' economic growth by limiting opportunities for their exports. Although demand from large emerging markets might be stronger looking ahead, China's transition to a new growth path that is less dependent on investment and industrial production may dampen growth in demand and limit other countries' prospects for manufacturing export-led growth.[8] It is worth noting that while not a trend decline, the trade slowdown might be more than cyclical, with the long-term elasticity of trade in goods with respect to income returning in the 2000s to the levels that had preceded the "long 1990s": elasticity was 1.1 between 1970 and 1985, rose to 2.2 in the period 1986–2000, and then declined to 1.6 in the 2000s.

### Other Cyclical Factors

Other cyclical factors driving the trade slowdown, most notably through the end of the commodities super-cycle, might present new opportunities for export-led manufacturing. Prices of commodities, particularly fuels, declined sharply since mid-2014, although prices leveled off in 2016. As a result, commodity exporters in Sub-Saharan Africa, the Middle East and North Africa, Europe and Central Asia, and Latin America experienced a decline in trade values, even though trade volumes did not decline. The deterioration in the terms of trade of commodity producers adversely affected their real incomes and exacerbated recessions in some countries, leading to a further contraction in their import volumes.

Although lower commodity prices have negative effects in the short term, they may favor specialization into manufacturing in the longer term. This is because high commodity prices are associated with "Dutch disease": an appreciation of the real exchange rate and a decline in nonresource exports that may depress growth. The resulting real exchange rate depreciations from a decline in commodity prices may, therefore, represent an opportunity to shift resources toward other, higher-growth manufacturing activities.

### Declining Parts and Components Trade and GVCs

While the trade slowdown in recent years may be explained, in part, by falling commodity prices,[9] the pace of globalization appears to be slowing more structurally with a decline in parts and components trade. The trade

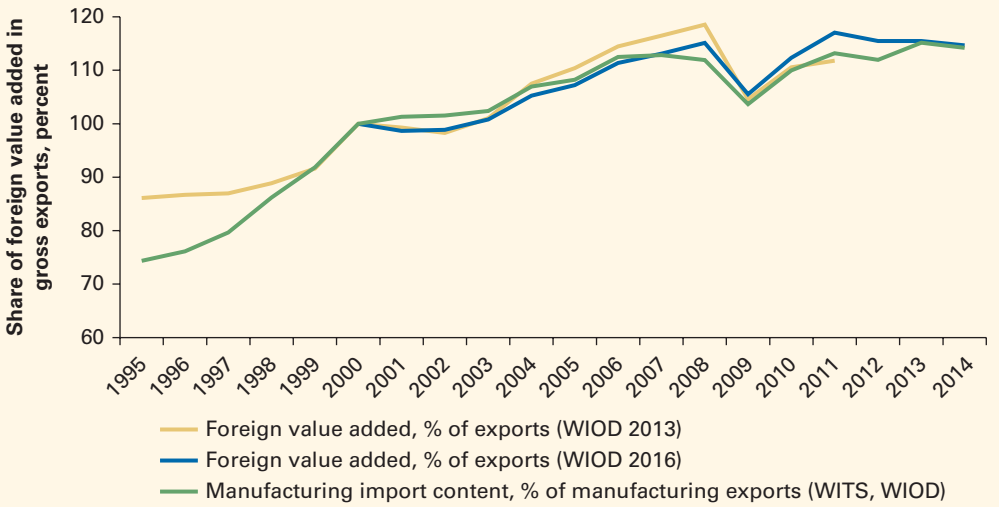
elasticity increased during the 1990s as production fragmented internationally into GVCs, leading to a rapid surge in trade in parts and components, and decreased in the 2000s as this process "matured." In fact, while the share of foreign value added in gross exports of all goods and services had been growing steadily, it fell sharply with the financial crisis in 2008 and has since remained flat. The growth in the import content of manufactures' exports began to decline earlier (figure 3.2). Many studies in the literature document a substantial decline in parts and components trade in recent years (Constantinescu, Mattoo, and Ruta 2017; Haugh, Jin, and Pandiella 2016; Timmer et al. 2015). The diminishing importance of the parts and components imports is reflected most clearly in their falling share of China's manufacturing exports, from the mid-1990s peak of 34 percent to the current share of approximately 22 percent (Constantinescu et al. 2015). This decline in parts and components trade is important because the international fragmentation of production in manufacturing sectors has been associated with faster productivity growth (figure 3.3).[10]

### China's Restructuring and Rebalancing

In the past, China's rapid expansion in global manufacturing may have been associated with changes in comparative advantage in LMICs seeking opportunities for export-led manufacturing growth (as explained

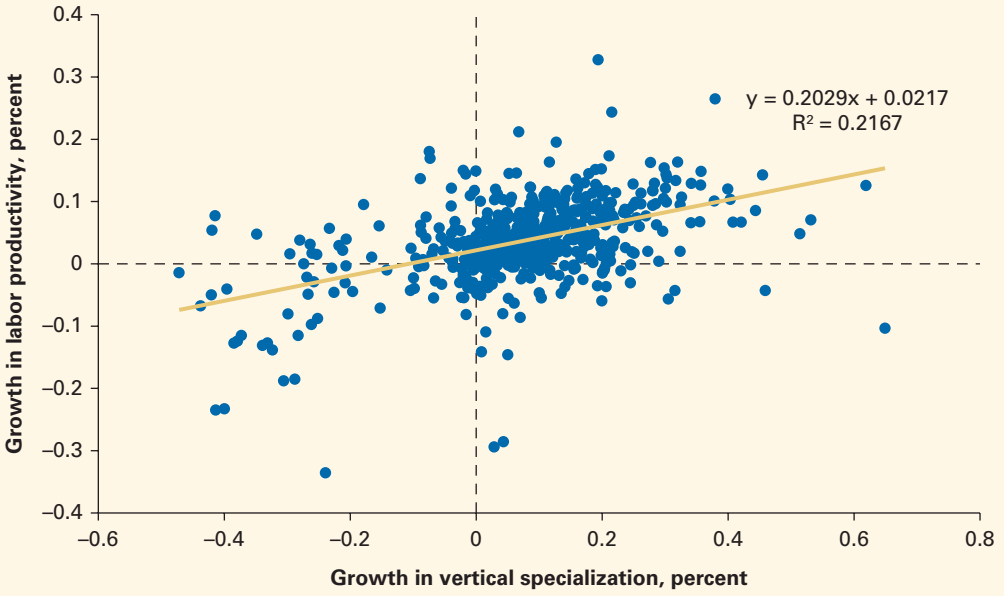
**Figure 3.2 Measures of World Vertical Specialization, Having Risen Until 2008, Have Since Flattened Out**

*Global share of foreign value added in gross exports of goods and services, 1995–2014*




*Sources:* Calculations based on World Input-Output Database (WIOD) (2013 and 2016 releases) and World Integrated Trade Solution (WITS) database.
*Notes:* The measures of vertical specialization based on WIOD 2013 and 2016 data are shares of foreign value added in gross exports of goods and services (2000 = 100 percent). The third measure is based on manufacturing trade data from WITS and on sectoral output from WIOD.

**Figure 3.3 Vertical Specialization Growth in Relation to Labor Productivity Growth, Manufacturing Industries, 1995–2009**

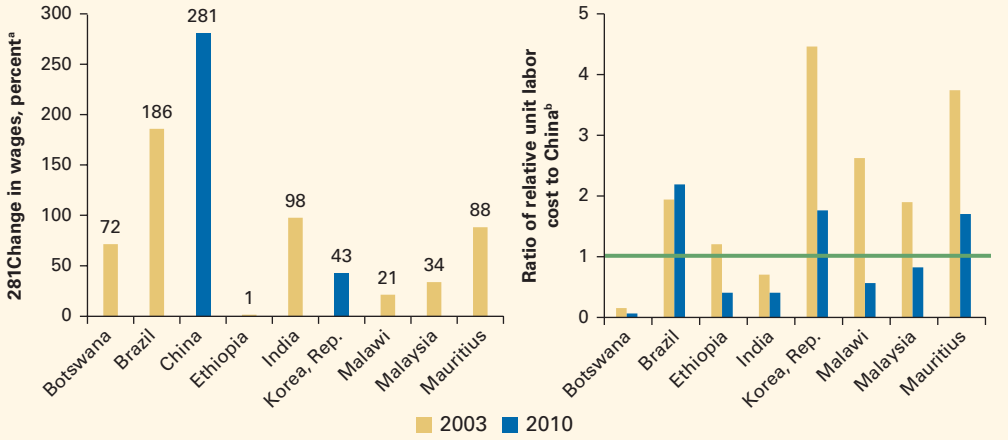



*Sources:* Constantinescu, Mattoo, and Ruta 2017.
*Note:* Each dot represents a country-year combination. Petrochemicals are excluded from the manufacturing aggregate.
a. Labor productivity is computed as the real value added divided by the number of persons employed.
b. Vertical specialization in manufacturing for each country and year includes the foreign value added embodied in exports (backward linkages) as well as the domestic value added that is embodied in exports of other countries (forward linkages).

in chapter 2). Looking ahead, China's rising wages and production upgrading create the possibility for production relocation to low-wage countries. The declining share of imports of parts and components in China's manufacturing exports over the past two decades reflects production upgrading through Chinese firms' substitution of domestic for foreign inputs, a finding corroborated by evidence of increasing domestic value added in Chinese firms (Kee and Tang 2015). At the same time, Chinese manufacturing wages rose by 281 percent between 2003 and 2010, much faster than in many other low- and middle-income economies (figure 3.4, panel a). Even accounting for shifts in real exchange rates, Chinese competitiveness from a unit labor cost perspective appears to have declined over the same period relative to that of many other LMICs (figure 3.4, panel b).[11] This may encourage the relocation of production toward other lower-cost economies. China's gradual rebalancing from investment to consumption is also likely to create opportunities for exporters of final goods.[12]

**Figure 3.4 Rapid Wage Increases in Chinese Manufacturing Have Reduced the Sector's Competitiveness on Labor Costs**

*Change in manufacturing wages and relative unit labor costs, China and selected LMICs, 2003–10*




*Source:* Ahmed and Chen 2017.
*Note:* The choice of LMICs selected for comparison was driven by data availability.
a. Manufacturing wage data from United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database.
b. China = 1 (dark horizontal bar). Relative unit labor cost estimates follow the methodology of Ceglowski et al. (2015) and account for differences in the nominal exchange rate. They are presented as the ratio of a country's relative unit labor cost to China's relative unit labor cost to describe how wage competitiveness relative to China is shifting. A value below the bar suggests that the economy's manufacturing sector should be more competitive than China's based on labor costs.

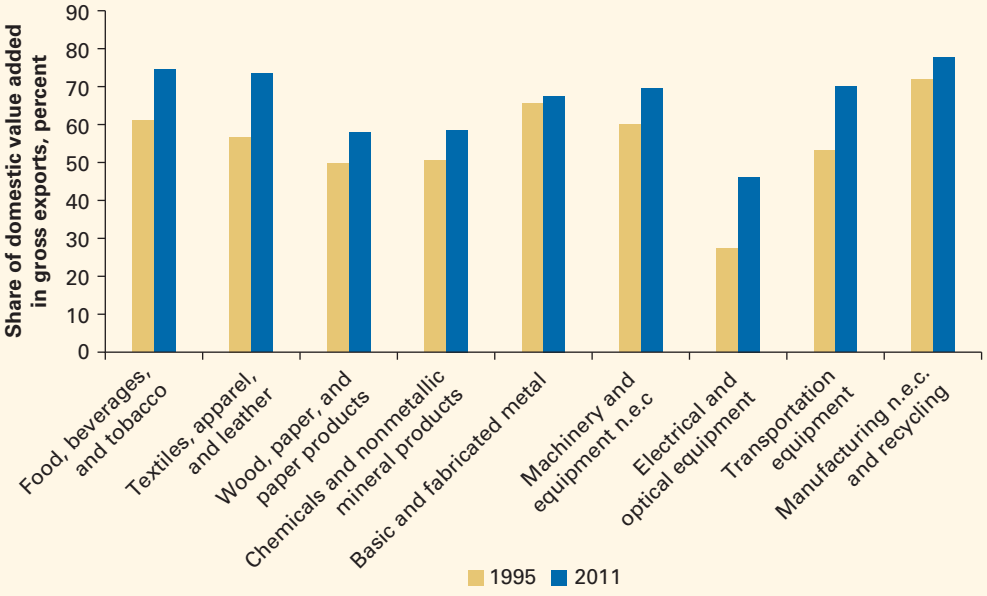
The spillovers from China's upgrading and rebalancing might be most relevant for neighboring countries through regional production networks in which Chinese firms increasingly take a leading role. Evidence shows that in the context of shared international production, China's trading partners benefit if their production structure is complementary to China's, which is the case for many LMICs (Boffa et al. 2017).

At the same time, the potential for less "moving out" of lower-value-added goods from China may affect these prospects of export-led manufacturing in countries hitherto less involved in GVCs. The fact that China is moving up from, yet not moving out of, the lower-value-added end of GVCs is captured by recent evidence that China is increasing its domestic value added in all manufacturing sectors (figure 3.5).

The global dynamics for exports of electrical and optical equipment between 1995 and 2009 further illustrates this point (figure 3.6). The comparison reveals that the "smile curve"—here depicting compensation per hour as it varies across different stages of the production process—has deepened as compensation for U.S. ICT services (USA14) increased from US$25 to US$60 an hour, whereas Chinese wages in the ICT services sector

**Figure 3.5 China Increased Its Domestic Value Added in All Manufacturing Sectors between 1995 and 2011**

*Change in domestic value added of manufacturing sectors in China, 1995–2011*




*Source:* Calculations based on Trade in Value Added (TiVA) database of the Organisation for Economic Co-operation and Development and World Trade Organization.
*Note:* n.e.c. = not elsewhere classified.

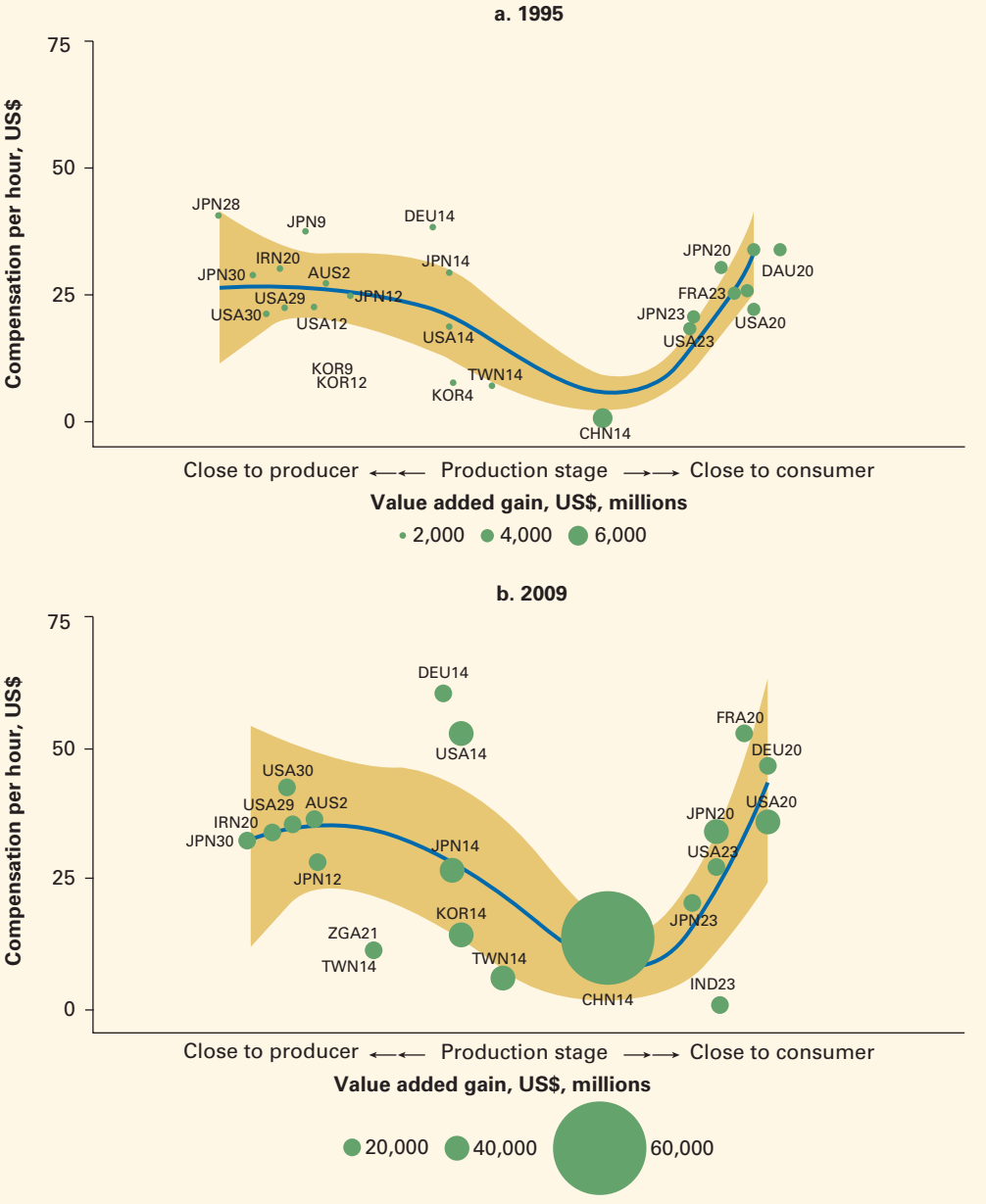
(CHN14)[13] stagnated. This was associated with a dramatic increase in the total value added of the ICT sector in China for GVCs in electrical and optical equipment, as depicted by the size of CHN14 bubble in figure 3.6. Meanwhile, with the exception of some minor gains for the Indian inland transport industry (IND23), no other LMICs have yet been able to "join" the smile curve for this sector, even in the low-end production stages. It perhaps reflects the benefits of agglomeration derived from China's established ecosystem of suppliers, workforce skills, and business culture, which in turn renders the relocation decision based on unit labor costs different from simply looking at wage differentials.

### Potential Rise of Protectionism

Most economies are more open to trade today than in the 1990s. The risk now is that, as countries seek to expand manufacturing employment, a surge in protectionism and the undoing of trade agreements will create an institutional environment less supportive to openness. New trade restrictions reached a postcrisis high in 2016.[14] And the current high uncertainty regarding trade policy due to Brexit, the United States' pullout from the Trans-Pacific Partnership trade agreement, and questions as to whether

**Figure 3.6 The "Smile" Curve for Chinese Exports of Electrical and Optical Equipment Deepened between 1995 and 2009**

*Changes in hourly compensation, by production stage, in manufacture of electrical and optical equipment exports, China and selected high-income economies, 1995 and 2009*




*Source:* Meng, Ye, and Wei 2017.
*Note:* The "smile curve" depicts variation in compensation per hour across different stages of bringing a manufactured product to market (adapting the smile curve concept first proposed circa 1992 by Acer Inc. founder Stan Shih, and further discused in chapter 1). Bubble size indicates a country's relative value added gain in terms of U.S. dollars, millions. The numbers appended to the country abbreviations refer to sectors: 14 is ICT, 12 is basic metals, 28 is financial services, 20 is wholesale trade, 9 is chemicals, 30 is renting of machinery and equipment and other business activities, 2 is mining, and 10 is rubber and plastics.

additional trade agreements may be renegotiated is already estimated to have a negative impact on world trade growth (Constantinescu, Mattoo, and Ruta 2017). At the same time, the Comprehensive Economic and Trade Agreement (CETA) between Canada and the European Union has been ratified, and a similar trade deal between Japan and the European Union is currently being negotiated. However, if a broadly less open trade environment does emerge, it would undermine opportunities for export-led manufacturing in LMICs.

### Capital Flows: Changes in FDI Composition across Sectors and Countries

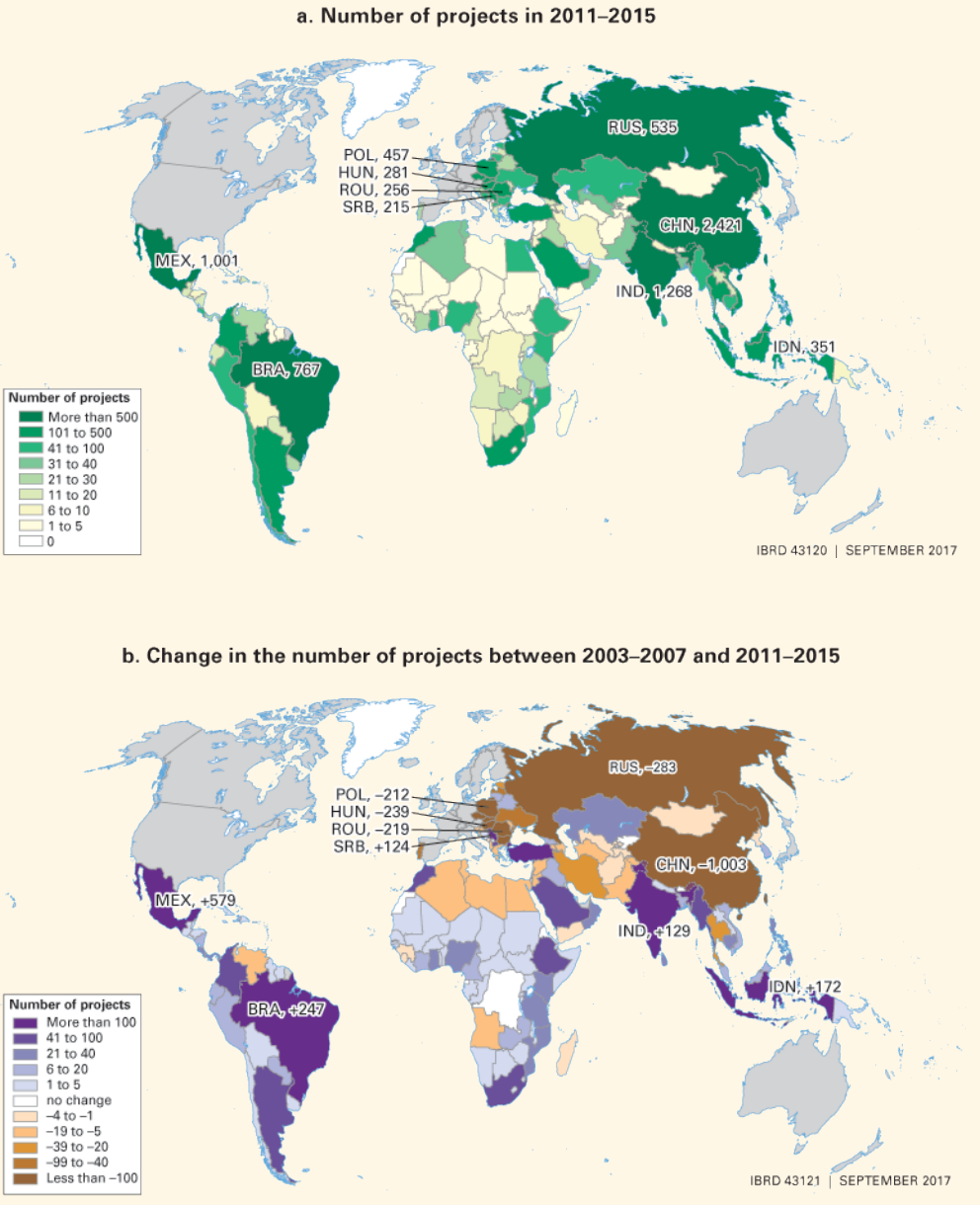
The literature distinguishes four types of FDI: (a) natural resource–seeking investment (focused on exploiting natural resources); (b) market-seeking investment (serving large domestic or regional markets); (c) strategic asset-seeking investment (driven by investor interest in acquiring strategic assets through mergers and acquisitions); and (d) efficiency-seeking investment. This latter type of investment is typically export-oriented; leverages local factors of production to reduce costs; and involves the transfer of production and managerial know-how, access to distribution networks, and sources of finance. In the past, it has been particularly conducive to the development of export-led manufacturing opportunities in low- and middle-income countries (Tadesse and Shukralla 2013). For example, FDI played a role in jump-starting Honduras's light manufacturing sectors. Similarly, owing to FDI and its linkages with domestic firms, Mexico developed its aerospace industry in less than two decades.

Global inflows of "greenfield"[15] FDI in manufacturing increased moderately in 2011–15 relative to 2003–07. However, evidence indicates a changing composition of destination countries, at least partly reflecting the "flying geese" pattern explained in chapter 2 (map 3.1). For example, the number of greenfield FDI projects in manufacturing declined between these two periods in China and Eastern European countries such as Bulgaria, Hungary, and Romania, but they increased in India, Brazil, India, Indonesia, Malaysia, Mexico, and Vietnam.

At the same time, the share of manufacturing in greenfield FDI inflows has declined over the past decade, from 42 percent in 2003 to 28 percent in 2015 (figure 3.7). Much of this decline was picked up by the services sector, which suggests that FDI is increasingly shifting to services over manufacturing. This is not so surprising because the services sector is a growing source of value added in the value chain of most manufactured goods, with some large emerging markets also benefiting as destination countries. Brazil, India, Malaysia, and Mexico, for example, experienced an increase in the number of "greenfield" FDI projects in the services sector between 2011 and 2015 relative to 2003–07 (map 3.2). Services are often less sophisticated in LMICs, and therefore larger FDI inflows could help both the receiving sector and have spillover benefits for the manufacturing sector too.

**Map 3.1 The "Flying Geese" Paradigm Is Reflected, Albeit Weakly, in the Changing Composition of Manufacturing Greenfield FDI Inflows between 2003–07 and 2011–15**

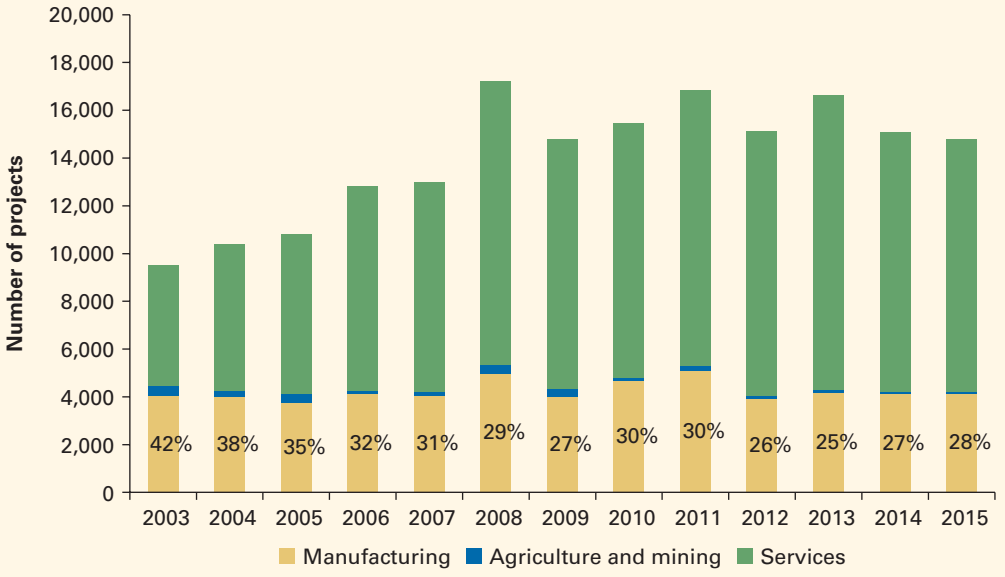
*Number of new greenfield manufacturing projects in selected countries, 2003–07 relative to 2011–15*




*Sources:* World Bank calculations based on fDi Markets (www.fDimarkets.com).
*Note:* For panel a, high-income countries (as defined in 1994) are not covered. Labels indicate the number of projects during 2011–15 for the 10 countries with the largest change relative to the period 2003–07. For panel b, high-income countries (as defined in 1994) are not covered. Labels identify the 10 countries with the largest change in the number of projects between 2003–2007 and 2011–2015. FDI = foreign direct investment.

**Figure 3.7 The Share of Manufacturing in the Number of Greenfield FDI Projects Declined between 2003 and 2015**

*Number of greenfield projects globally, by sector, 2003–15*



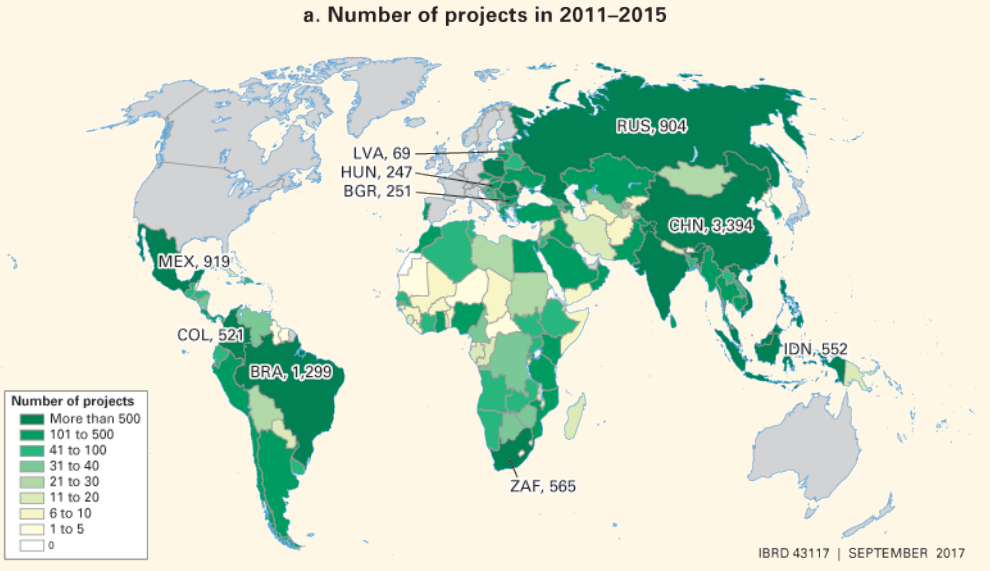

*Source:* World Bank calculations based on fDi Markets (www.fDimarkets.com) data.
*Note:* FDI = foreign direct investment.

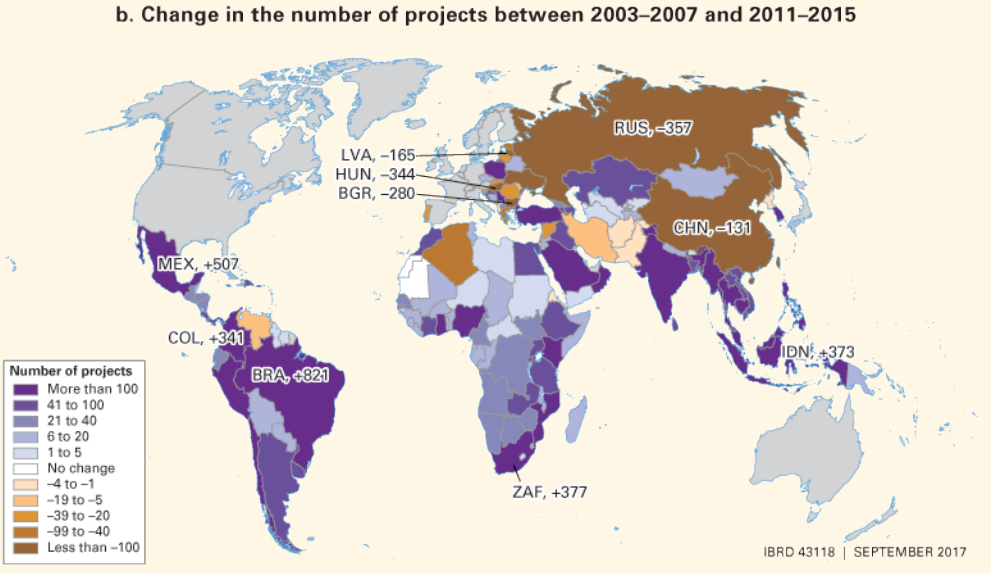
Given China's prominent role in the manufacturing sector, the increase in its outward FDI signals shifting opportunities for both China and other LMICs. Whereas much of China's outbound FDI had been focused on commodities, the country has shifted toward using outbound mergers and acquisitions (M&A) FDI to acquire higher technology. For example, Chinese outward M&A FDI in the electronics, computing, and optical equipment sector increased from 20 projects in 2003–07 to more than 100 projects in 2011–15, with the destination being, almost exclusively, high-income countries, including the United States. The same magnitude of increase characterized the machinery and equipment sector, albeit from a lower base in 2003–07, with Germany emerging as the major destination country (figure 3.8). This likely reflects the acquisition of German robotics companies by Chinese firms as a way to access new technology without indigenously having to innovate. This shift is consistent with a broader aim to move up into higher-quality, more advanced manufactured goods in China. Another shift, although still at a low level, involves outbound FDI from China into labor-intensive tradables in Africa and Asia.[16]

These trends in the emerging international trade and investment landscape are also relevant for the transfer of technology embedded in the flow of goods and capital, especially in a world where technology will increasingly

**Map 3.2 Most Countries Experienced an Increase in the Number of "Greenfield" FDI Projects in the Services Sector in 2011–15 Compared to 2003–07**

*Number of services sector greenfield projects in selected countries, 2003–07 relative to 2011–15*

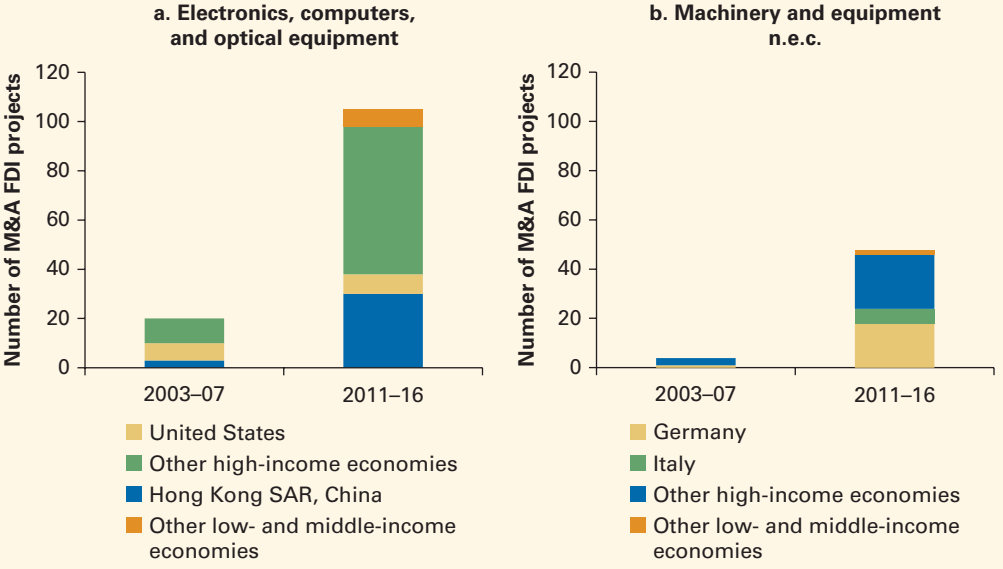



*Source:* World Bank Calculations based on fDi Markets (www.fDimarkets.com) data.
*Note:* For panel a, high-income countries (1994 classification) are not covered. Labels indicate the number of projects during 2011–15 for the 10 countries with the largest change relative to the period 2003–07. For panel b, high-income countries (1994 classification) are not covered. Labels identify the 10 countries with the largest change in the number of projects between 2003–07 and 2011–15. FDI = foreign direct investment.

**Figure 3.8 Outward M&A FDI from China in the Electronics and Machinery Sectors, almost Entirely to High-Income Economies, Increased Fivefold between 2003–07 and 2011–15**

*Number of M&A FDI projects in the electronics and machinery sectors from China to the rest of the world, 2003–07 relative to 2011–15*




*Source:* Calculations based on Thomson ONE database.
*Note:* The first two high-income destination economies in terms of the number of deals are presented in each graph separately from the group of high-income economies. M&A = mergers and acquisitions; FDI= foreign direct investment.

matter for manufacturing competitiveness. Perhaps one of the most valuable external sources of technology transfer is participation in GVCs where trade and FDI are complements. Firms embedded in multinational production earn higher returns on innovation, face lower research and development (R&D) costs, and exploit scale better than firms selling to domestic markets (Guadalupe et al. 2012). As GVC participation becomes more stable, opportunities expand for supplier firms to become acquainted with newer, more advanced technologies, skills, and processes (Kugler and Verhoogen 2012), thereby boosting process innovation and even product innovation. But, as discussed earlier, the technology itself is changing—and is a megatrend all on its own.

## Labor Flows: Brain Drain and Brain Gain

Migration flows in the past have overwhelmingly comprised low-skilled labor moving from low- and middle-income economies to high-income economies (Docquier, Lowell, and Marfouk 2009; UN 2013), but with little impact on manufacturing-led development. From 1990 to 2010, the migrant

stock residing in the "North" (Europe and North America plus Australia, Japan, and New Zealand) but born in the "South" (all other countries and regions) increased by 85 percent, more than twice as fast as the global migrant stock (38 percent) (UN 2012). And in 2015, the largest receiving countries were the United States (46.1 million) and Germany (11.1 million), while the largest source countries were India (13.9 million) and Mexico (13.2 million) (World Bank 2016).[17] However, the overall impact of this migration on population structures and therefore the relative abundance of low-skilled labor in both low- and middle-income economies and high-income economies is limited (UN 2012). Further, in high-income economies, migrant workers tend to be concentrated in agriculture, mining, construction, and some personal services, but not manufacturing (Widmaier and Dumont 2011).[18] Rather than low-skilled workers going to where the capital or technology are, manufacturing has been marked by the reverse pattern: flows of capital going to where labor is abundant.

More recently, an increase in the movement of highly skilled workers has implications for possible "brain gain" and resulting opportunities for manufacturing-led development. The number of migrants with tertiary education in OECD countries grew by 70 percent between 2001 and 2011. And this growth was driven to some extent by migrants originating from Asia, whose number grew by 79 percent over the same period (ILO, OECD, World Bank 2015). In the United States, the number of immigrants with college degrees increased from 3.1 million in 1990 to 11.1 million in 2015 (Batalova and Fix 2017). Immigrants are playing a significant role in the most dynamic sectors of the economy, most notably health care and science, technology, engineering, and mathematics (STEM) occupations (OECD, ILO, World Bank 2015). For the United States, Hunt (2013) argues that immigrants working in engineering occupations are performing better and obtaining higher wages than native engineers. Traditionally, this type of migration has been viewed as detrimental to the country of origin because of the resulting "brain drain." However, there has been a shift in the literature underscoring the potential benefits of skilled migration arising from remittances, diaspora links, the return migration of talented entrepreneurs and technical workers, and the creation of trade and business networks to help more firms move into higher value added goods (OECD, ILO, World Bank, 2015). In addition, the possible incentive effects of migration prospects on human capital formation in LMICs have been highlighted (Stark and Wang 2002).

This "brain gain" is best reflected in the experience of Asian economies such as Japan, the Republic of Korea, and Taiwan, China, that have relied on their diasporas as sources of knowledge (Plaza 2013). More industrialized labor-sending economies with large, skilled emigrant populations such as India and China have also been able to tap their expatriates and develop mentor-sponsor models in certain sectors or industries. For instance, Agrawal et al. (2011) provide empirical evidence in support of the contribution of the diaspora to some of the most important innovations in India.

Diasporas may also provide origin-country firms access to technology and skills through professional associations, temporary assignments of skilled expatriates in origin countries, distance teaching, and return (mainly for a short period) of emigrants with enhanced skills (Plaza and Ratha 2011). Kerr (2008) finds evidence of transfer of knowledge between ethnic emigrant groups in the United States and their home countries, and this diffusion of knowledge is found to affect productivity in high-tech manufacturing sectors.

With new technology's greater reliance on skilled workers, the prospects of highly skilled workers either returning to their home countries or not being able to migrate to high-income economies due to shifting visa restrictions, for example, has implications for manufacturing-led development. The impact is not just on production workers, but also on service workers (for example, researchers, designers, managers, marketers) that are providing an increasing share of value added in the manufacturing process. Among the different modes of services trade, the movement of individual services suppliers stands out as the most restrictive mode of supply (World Bank 2015b). Quantitative restrictions, nationality and residency requirements, technical standards and licensing, labor market tests, and visas and employment permits make up a range of measures that limit the movement of individual services providers, whether temporary or permanent (Chaudhuri, Mattoo, and Self 2004; Goswami and Sáez 2013). These restrictions will have some effect on knowledge flows and spillovers, but they may also keep more skilled labor to pair with unskilled labor in lower-income countries. A more skilled workforce, in turn, might increase countries' capabilities to compete in global manufacturing.

## Trends in Industry 4.0: Smart Automation and the Internet of Things, Advanced Robotics, and 3-D Printing

*Key message: The prospects of manufacturing export-led development are further affected by emerging technologies in ways that could vary substantially by type of technology and across countries with different levels of manufacturing sector development.*

The prospects of manufacturing export-led development are further influenced by emerging technologies, which are creating new product lines. "New technologies" encompasses a wide range of advanced goods; for example, nanotechnology, new materials, and biotechnologies may affect what materials are used and introduce a range of new products. However, the production of these advanced manufactured goods (such as wearable tech, autonomous vehicles, biochips and biosensors, and new materials) are most likely to colocate with R&D facilities in high-income economies as they are being developed. This mirrors the manufacture of certain capital goods and advanced inputs (such as semiconductors, doped wafers for semiconductors, and fiber-optic cables), which stayed in high-income economies during Industry 3.0.

At the same time, the assembly of high-tech goods such as laptops and mobile phones did move to low- and middle-income economies with Industry 3.0. The same is unlikely to happen with the advanced manufacturing product lines associated with Industry 4.0 because of the likely skill and infrastructure requirements throughout the product's value chain.

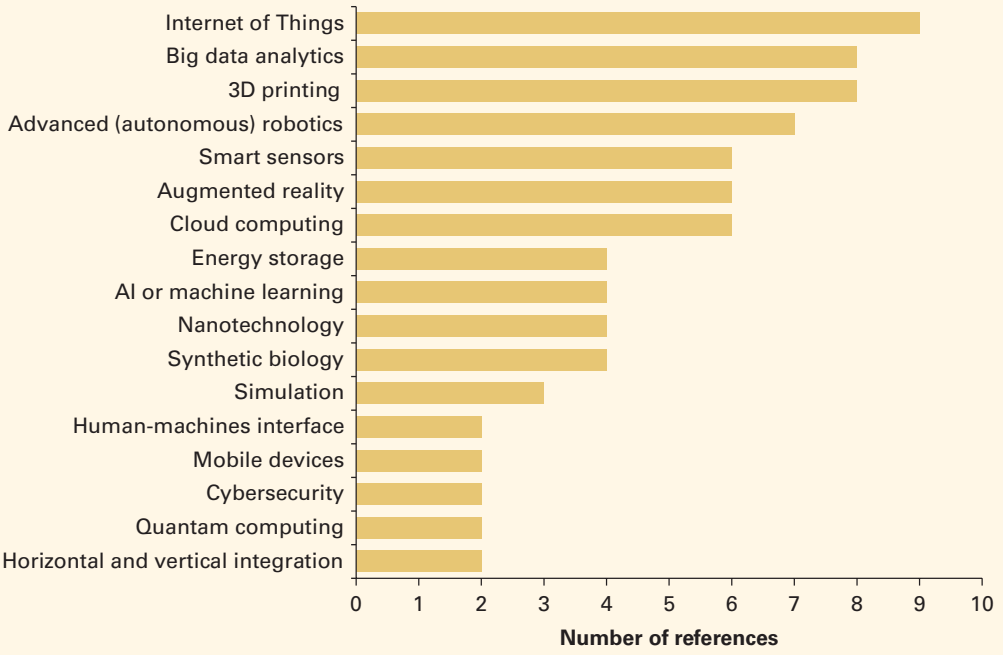
More than through these new advanced goods, however, the biggest impact on low- and middle-income countries (LMICs) will likely be through new manufacturing *process* technologies that affect the production of traditional manufactured goods. These new process technologies, by making countries relatively more efficient in producing traditional goods, can have implications for comparative advantage and therefore patterns of globalization. The focus here is on robotics (particularly artificial intelligence [AI]-enabled); digitalization and Internet-based systems integration (IoT), including sensor-using "smart factories" (that may also be AI-enabled); and 3-D printing. These are among the most emphasized technologies in the Industry 4.0 literature (figure 3.9). Moreover, while not all these technologies are new (robots and 3-D printing have been around for decades, and IoT builds on ICT legacy technologies), cost innovation, software advances, and evolving business formats and consumer preferences are fueling their adoption (Comin and Ferrer 2013).

### ICT, the Internet of Things, and Smart Factories

The greater diffusion of existing ICT technologies can reduce trade and coordination costs and strengthen globally fragmented production. There is evidence that more widespread use of scale-neutral digital technologies, such as ICT, have allowed firms in some low- and middle-income economies to access wider markets through reducing the costs of matching buyers and sellers all over the world. These technologies include smartphones, video and virtual-reality conferencing, and computer translation. For example, Lendle and Olarreaga (2017) find that the impact of distance on cross-border trade flows—across 61 countries and 40 product categories—is about 65 percent smaller for eBay transactions relative to total international trade. More generally, Osnago and Tan (2016) and World Bank (2016a) find that a 10 percent increase in an exporter's rate of Internet adoption led to a 1.9 percent increase in bilateral exports. Newer ICT technologies in the Internet of Things (IoT) space, such as big data and cloud computing, some of which are already in use, can similarly strengthen GVCs. In particular, they can further reduce the costs of coordinating globally fragmented production by making it easier to track and monitor components as they move through the supply chain. Cloud computing, for example, can change the landscape of information storage and exchange and enable better, more cost-effective coordination of globally fragmented production. Of late, the analysis of large, fast-moving, and varied streams of "big data" has received much attention since it can enable firms in GVCs to optimize complex distribution, logistics, and

**Figure 3.9 Technologies Associated with Industry 4.0 are Emphasized to Different Degrees in the Literature**

*Industry 4.0 technologies, by relative emphasis in recent studies*




*Source:* Cirera et al. (2017).
*Note:* Figure shows the number of references to various technologies from a review of 10 studies/reports on Industry 4.0 published in 2015 or after. These reports are from the OECD, World Economic Forum, UNIDO, McKinsey and Company, Boston Consulting Group, Deloitte, PWC, Accenture, EY, and Germany Trade and Investment. The review enables a categorization of Industry 4.0 technologies by level of current emphasis (most, moderate, and least). AI = artificial intelligence.

production networks. A 2011 Microsoft survey of 152 decision makers within automotive, aerospace, electronics, and industrial equipment manufacturing companies in France, Germany, and the United States found that customer transactions data can enable firms to better forecast demand and experience a 20–30 percent reduction in inventory costs (Microsoft Corporation 2011).

At the same time, greater digitalization through the IoT may shorten value chains in the future, shifting production if it becomes more efficient to rebundle activities in "smart" factories. The IoT is defined as "the use of sensors, actuators, and data communication technology built into physical objects"—from roadways to pacemakers—that enable those objects to be tracked, coordinated, or controlled across a data network or the internet (Manyika et al. 2013; UNIDO 2016). "Smart" factories use the IoT not just to automate production but also to communicate and share information to

optimize the whole value chain. These factories have two salient features: The first is the physical-to-digital technologies embodied in machines and equipment that enable sensing, monitoring, and control. The second is the communication between the disparate parts of the value chain. Capgemini (a Paris-based multinational information technology consulting corporation) surveyed 1,000 senior executives of large companies across key sectors and countries in 2017, finding that 76 percent of manufacturers either have an ongoing smart-factory initiative or are working on formulating one. Only 6 percent of manufacturers are what Capgemini calls "Digital Masters": factories at an advanced stage in digitalization production processes. The survey finds that smart factories will enable the efficiency of manufacturing firms to grow at seven times the annual average rate of growth since 1990 (CapGemini 2017).

The greater diffusion of existing ICT technologies and a new wave of digitalization through the IoT emphasizes the growing importance of services in the broader manufacturing process. The generation of data and its subsequent use in "smart" factories will be central to this servicification of manufacturing. For instance, interconnected manufacturing where machinery and equipment are connected to the Internet requires the transmission of data across the entire production chain. And ICT-related services are the predominant producer and user of these data. For example, data processing services, such as cloud computing, produce data for "smart" factories while advanced data analytics use this real-time information to optimize production processes (see chapter 5).

### Advanced Robotics (and Artificial Intelligence)

Increased automation in high-income countries due to greater robotics use[19] and other Industry 4.0 initiatives like smart factories have already enabled some leading firms, albeit in small measure, to reshore historically labor-intensive manufacturing activities back to high-income economies and closer to the final consumers. Two well-known recent examples of this are Philips shavers in the Netherlands and Adidas shoes in Germany (*Assembly* 2012; Bloomberg 2012; *Economist* 2017a, 2017b; *Financial Times* 2016). In each of these cases, the unit labor cost of production was rendered lower in the newer factories than in an offshore plant. A report by Citigroup and the University of Oxford's Oxford Martin School finds that 70 percent of Citi institutional clients surveyed believe automation will encourage companies to move their manufacturing closer to home, with North America seen as having the most to gain from this trend, while China, Association of Southeast Asian Nations (ASEAN) member countries, and Latin America are seen as having the most to lose (Citigroup 2016).

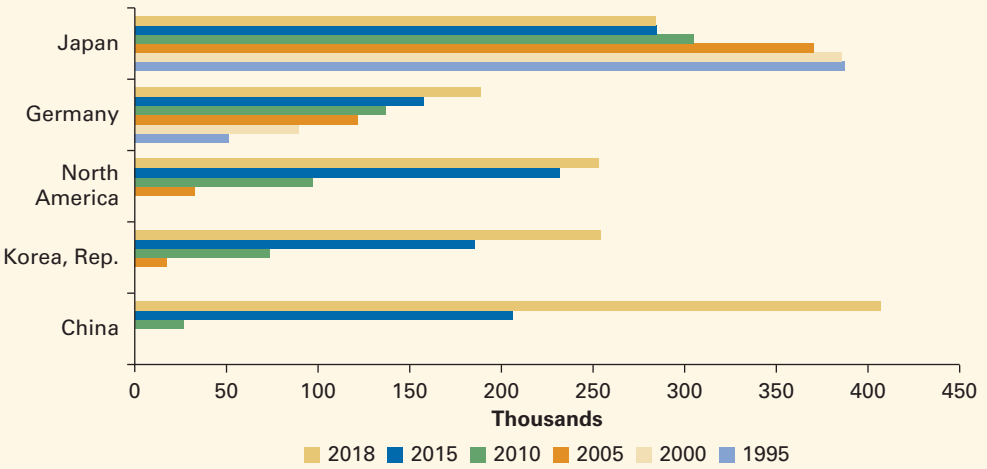
Yet the available evidence suggests that reports about the advent of reshoring, and resulting changes in globally fragmented production, are greatly exaggerated. Longitudinal data for firms from the German Manufacturing Survey (1,450–1,650 observations in the individual survey

waves in 1997, 1999, 2001, 2003, 2006, 2009, and 2012) show that about 2 percent of all German manufacturing companies were active in reshoring between 2010 and mid-2012—a percentage that seems, surprisingly, to be decreasing. Similarly, survey data for Austria, Denmark, France, Germany, Hungary, Portugal, Netherlands, Slovenia, Spain, Sweden, and Switzerland show that only around 4 percent of firms have moved production activities back home—much lower than the 17 percent of firms that offshored activities in the decade before. For every backshoring company, there are more than three offshoring companies (De Backer et al. 2016).[20]

China stands out as a middle-income country that is rapidly automating production through robotization to address declining wage competitiveness. Standard Chartered Global Research (2016) found that 48 percent of 290 manufacturers surveyed in the Pearl River Delta would consider automation or streamlining processes as a response to labor shortages; Less than a third would consider moving capacity either inland or out of China. Nationally, the country is projected to have more than 400,000 industrial robots in operational stock in the manufacturing by 2018, more than doubling the number in 2015 (figure 3.10).[21] This would give China the distinction of having the highest number of installed industrial robots in the world, accounting for more than a third of total robots projected to be installed globally. Some high-profile firms are already substituting a

**Figure 3.10 High-Income Countries Were the Largest Users of Industrial Robots in the Manufacturing Sector between 1995 and 2015, but China Is Expected to Have the Largest Operational Stock by 2018**

*Operational stock of industrial robots in the manufacturing sector, selected countries and regions, 1995–2018*




*Source:* Calculations based on Industrial Robots Statistics, International Federation of Robotics.
*Note:* Industrial robots are also used in agriculture, mining, utilities and construction. The stock of industrial robots in China, for example, is projected at around 600,000 in 2018 when these sectors are included.

substantial number of workers with industrial robots. For example, Foxconn—the firm known for producing Apple and Samsung products in China's Jiangsu province—recently replaced 60,000 factory workers with industrial robots (*South China Morning Post* 2016).

The more widespread use of labor-saving technologies in established global centers of manufacturing can challenge established patterns of comparative advantage. By reducing the relative importance of wage competitiveness, robotics and smart factories can change what it takes for locations to be competitive in the global market for manufactures. If high-income economies are reshoring production, this could affect current manufacturing exporters and stifle the potential entry of newcomers. The case of China is potentially even more important given recent expectations of an en masse migration of light manufacturing activities to poorer economies with lower labor costs, such as those in Sub-Saharan Africa. Kee and Tang (2015) note that China has been increasing the domestic content of its exports by substituting domestic for imported materials. And if China moves into more sophisticated exports while automating and retaining market share of the less sophisticated exports, then the expected en masse migration of manufacturing jobs may not occur.[22] In other words, China could be seen to be shortening the length of its value chain.

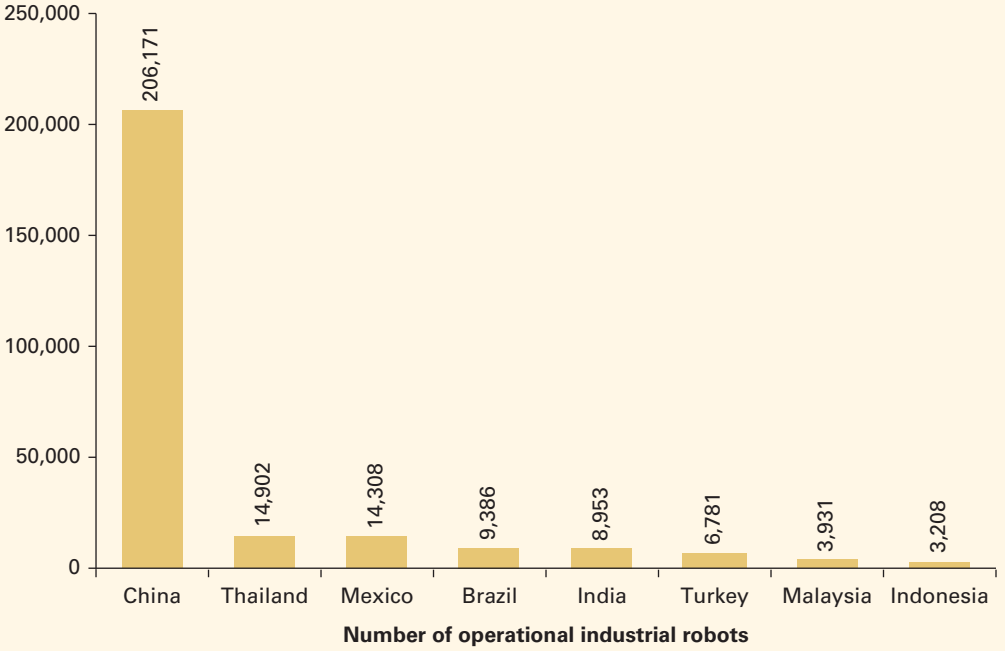
Despite a presumption that only high-income countries and China will be adopting advanced processed technologies such as robotics and smart factories, it is worth noting that several large emerging markets (including Brazil, India, Indonesia, Malaysia, Mexico, Thailand, and Turkey) also had nontrivial stocks of industrial robots in 2015 (figure 3.11). There is also evidence of "smart" production processes in these countries—for example, in the 3-D printing of auto parts in India (box 3.1). Many multinational corporations are increasingly locating high-skilled, ICT-heavy, and technical skill-based work in emerging markets, owing to the availability of technical and engineering talent at competitive wages. This is clearly an area where certain countries such as India have demonstrated competitive advantage in terms of skilled and technical professional workers. Outward FDI from emerging markets for the acquisition of technology or other know-how from firms based in Europe and the United States might also accelerate the incorporation of Industry 4.0 technologies in these economies.

### 3-D Printing

3-D printing, still too costly to be widely used, can be either scale-reducing or scale-enhancing, with mixed implications for the geography of global production. Scale is expected to matter less with 3-D printers than with other new manufacturing process technologies, and the demand for customized, quickly delivered goods could lead to geographically dispersed manufacturing activity—that is, a "micromanufacturing" model, whereby even small businesses in a wide range of LMICs can access international designs and print them locally. However, this scenario might be constrained by the

**Figure 3.11 Several Large Emerging Economies Had Nontrivial Stocks of Operational Industrial Robots in 2015**

*Operational stock of industrial robots, selected countries and regions, 2015*




*Source:* Calculations based on Industrial Robots Statistics, International Federation of Robotics (accessed October 11, 2016), https://ifr.org/industrial-robots/statistics/.

**Box 3.1 3-D Printing: Myth or Reality?**

The extent of 3-D printing's commercial viability is under debate, but three examples highlight the potential across a range of sectors. The decision to transform production to 3-D printed manufacturing is affected not only by the cost-cutting potential but also by shifts in consumer demand and the ability to customize outputs and significantly shorten time to market. The examples below also illustrate how adoption disrupts supply chains and shifts jobs.

**Starkey: 3-D Printing of Hearing Aids in Mexico**

Almost the entire in-the-ear hearing aid market has shifted to 3-D printing in just six years. The global hearing aid market is a US$8 billion market, where customization is a key feature of quality and where the product is both small and of high value, making it a good candidate for 3-D printing. U.S. hearing aid industry leader Starkey, along with its rivals, shifted nearly all its production to 3-D printing and reduced the order-to-delivery time to three to four days. However, there was no need to shift production sites because Starkey could transform production in its existing Mexico maquila plant while using express delivery services to ensure its three- to four-day delivery requirement (95 percent of production is delivered this way).

*(Box continues on next page)*

**Box 3.1 3-D Printing: Myth or Reality?** *(continued)*

**Stratasys: 3-D Printing of Auto Parts in India**

In India, the 3-D printing of auto parts has become cost-effective because specifications can vary across models and there is a need for some flexibility in production. The participation of local firms in developing 3-D printers themselves has also helped reinforce the trend and to encourage Stratasys, a United States–Israeli owned global 3-D printer leader, to invest in India. 3-D printing trends by multiple organizations in the manufacture of auto parts such as headlights, taillights, and turbochargers show that, for products where neither customization nor time to market is critical, there is still potential for reducing both fixed and variable costs of manufacturing in the plant.

**Adidas: Footwear "Speedfactories" in Germany and the United States**

Additive manufacturing of unskilled-labor-intensive goods such as footwear is not widespread, but it could lead to substantial workforce reductions in LMICs if the costs and time needed to print these goods continue to decline. Adidas has grabbed considerable attention with its investments in the 3-D printing of athletic footwear, a sector that has long played an important role in employing workers in LMICs. 3-D printing shortens the design-to-production cycle of new models from up to 18 months to one week. Adidas, the leading adopter of 3-D printing, established two "Speedfactories" in Ansbach, Germany, and Atlanta to each produce 500,000 pairs of shoes annually. The transfer eliminates 1,000 jobs in Vietnam's workforce and creates 160 technician jobs each in Ansbach and Atlanta. 3-D printing in the athletic footwear market segment is driven by reducing transport and labor costs; improving reliability; and reducing time to market for new models while bringing manufacturing closer to markets, with premium products likely to be displaced first.

**Technological Advances and Siting Considerations**

Technological breakthroughs will also affect the range of goods for which 3-D printing could be viable. Whereas plastic resins were initially the medium available, metal printing and mixed-materials printing are now available. And the printing of biological material is under development. Speed has also been a 3-D constraint, but here too advances are being made. For example, new techniques in bound-metal deposition can build objects at a rate of 500 cubic inches an hour, compared with 1–2 cubic inches an hour using a typical laser-based metal printer (*Economist* 2017a).

As 3-D printing expands, there is still a question of the choice of location. While there is always the possibility of greater dispersion of production sites, many expect the development of 3-D printing manufacturing hubs, particularly if the cost of 3-D printers remains high and there are advantages of centralizing logistical support in transportation hubs. The expectation is that many firms may choose to locate in large consumer markets—or in lower-cost locations with easy access to these markets and where intellectual property rights and data flow issues can be reliably addressed.

*Source:* Arvis et al. 2017.

scarcity of trained technicians and engineers or by reliable electricity supply. The weak protection of intellectual property rights is another factor: firms will be unlikely to send designs to places where they can easily be printed without limit for customers not paying license fees or royalties. Further, countries that are not open to trade in services risk being left behind because the 3-D printing model effectively substitutes trade in services (through the payment of license fees and royalties for designs) for goods trade.

Either given these limitations on the widespread capabilities to use 3-D printing or if scale economies in 3-D printing itself turn out to be strong, printing activity will likely cluster in hub locations. There could therefore be reshoring and concentration of 3-D printing activity, likely close to major markets in Europe, North America, and Asia as well as potentially the largest of the emerging markets. Although 3-D printing has mainly been used for prototyping so far, it already has a considerable presence or significant potential in certain industries—although largely in higher-income countries (as further discussed in box 3.1 and chapter 4).

It is worth noting that much like IoT and smart factories, 3-D printing emphasizes the increasing servicification of manufacturing. The technology eliminates the need to move manufactured goods over long distances from production centers and instead puts the premium on trade in services—primarily data flows—as part of the manufacturing process. For example, designs, data, and other information from a product designer/producer in an exporting country will be delivered digitally for printing in a target market (Arvis et al. 2017).

## Conclusion

This chapter has explored how new technologies and evolving globalization patterns are changing what it takes to be competitive and therefore the feasibility of manufacturing-led development in the future. The end of the commodities super-cycle, together with China's production upgrading, provides new opportunities for export-led manufacturing in countries hitherto less involved in GVCs. At the same time, weak import demand resulting from the trade slowdown following the 2008 global financial crisis, the declining trade in parts and components, and China's continued expansion at even the lower end of GVCs present new challenges.

The potential for low- and middle-income economies to boost their manufacturing exports in the future, and leverage them for growth, is also affected by how emerging technologies change globalization patterns, and this could vary substantially across countries with different levels of development of the manufacturing sector. The faster diffusion of ICT and related developments in the IoT could strengthen the current structure of GVCs. But greater digitalization in smart factories and advanced robotics might reduce the importance of low labor costs in determining comparative advantage, laying greater emphasis on skills, complementary services, and other aspects of firm ecosystems. Furthermore, 3-D printing may make it feasible to produce in smaller batches with neither an emphasis on scale nor a larger ecosystem of suppliers—which may be particularly useful for countries that currently have limited manufacturing bases. Last, but not least, these technologies associated with Industry 4.0 emphasize the increasing servicification of manufacturing driven, in large part, by the growing importance of data in production processes.

The impacts of shifting technologies and globalization patterns will not necessarily be uniform across different manufacturing subsectors. The feasibility of continued opportunities for export-led manufacturing will depend on a subsector's magnitude of automation, the extent of trade in international markets, the degree of export concentration, and importance of complementary services.

New process technologies and shifting globalization patterns may also affect the desirability of manufacturing subsectors in terms of their potential for spillovers or dynamic growth gains. Whereas manufacturing held out the promise of both more productivity and job creation in the past, there may be more trade-offs going forward. For example, the adoption of robotics in the manufacture of motor vehicles will reduce the labor intensity of production, while 3-D printing of medical equipment, if it reduces international trade, may diminish the scope for productivity growth through increasing specialization and technology diffusion. Chapter 4 examines these dimensions of manufacturing-led development in the future.

## Notes

1. The literature on structural change during the 1960s documented canonical shifts of output and labor, first from agriculture to industry and later from industry to services, in the structural transformation of today's high-income economies (Chenery 1960; Clark 1940; Kuznets 1971). This was, at least in part, attributable to changing demand patterns: owing to higher income elasticities for manufactures and services, the share of expenditures in agricultural goods tends to decline, and beyond a sufficiently high level of income, consumers tend to shift their demand toward services, which have an even higher income elasticity of demand than manufactured goods. Fisher (1935) referred to this transformation in demand patterns as a "hierarchy of needs."
2. The sharing of large durable items, such as cars, is one trend that is already starting. If capital goods and production spaces become more versatile and programmable, there may lower needs for machinery, equipment, and construction materials.
3. However, urbanization is also raising a challenge, particularly in Africa and South Asia, where it is occurring at lower levels of income and without the same availability of low-skilled manufacturing jobs to absorb the growing labor force.
4. SDG 9 is "Build resilient infrastructure, promote sustainable industrialization, and foster innovation" (UN SDG website: http://www.un.org/sustainabledevelopment/sustainable-development-goals/).
5. The commodities super-cycle refers to the rise, and fall, of many physical commodity prices (such as those of food products, oil, metals, chemicals, fuels, and the like) during the first two decades of the 2000s (2000–14).

6. The increased trade elasticity of services and commodities is possibly because of the increasing tradability of services and the growing demand for commodities in emerging markets.
7. The weakness in investment growth, in particular, can help to explain lower trade growth in the postcrisis period because investment is the most trade-intensive component of aggregate demand.
8. On the production side, the slowdown in China's GDP is concentrated in the industrial sector, which depends more than other sectors of the economy on imported inputs. Similarly, on the demand side, the decline in China's share of investment in GDP reduces trade because investment draws in more imports than other components of aggregate demand.
9. Frederick (2017) suggests that the slowdown in trade between 2005 and 2015 appears to have been driven by oil, fuels and other basic commodities and raw materials rather than trade in intermediates and final products of more complex GVCs such as electronics, automobiles, and apparel. The value of trade and growth rate of trade in these sectors have continued to increase since the rebound from the economic crisis (2010–15).
10. There is a positive association between growth in real labor productivity per employee in manufacturing by country and year, and growth in global production fragmentation as measured by the import context of exports.
11. The relative unit labor cost (RULC) concept compares the unit labor cost of production across countries after accounting for changes in the nominal exchange rate, and allows for a fairer comparison of wage competitiveness across countries than just wages. Ahmed and Chen (2017) provide details of how these RULC values are estimated, following the approach of Ceglowski et al. (2015).
12. It may also eventually boost upstream intermediate and capital goods sectors that are now adversely affected.
13. USA 14 and CHN 14 refer to the ICT sector in these countries.
14. In 2016, Group of Twenty (G-20) countries took more trade-restrictive measures than trade-facilitating ones, with a gradual shift away from subsidies and safeguard measures and toward more opaque, distortive measures such as localization requirements, export incentives, and other trade finance measures. The share of G-20 imports affected by trade-restrictive measures put in place since the 2008 global financial crisis continues to rise gradually. Of the 2,978 trade-restrictive measures recorded among WTO members since 2008, only 740 had been removed by mid-October 2016. Although tariffs have declined considerably since the late 1980s, there has been little further progress since the financial crisis, and nontariff measures remain pervasive in goods trade.
15. This refers to an investment project where a company builds the entirety of its operations in a foreign market starting from scratch.

16. Calculations based on fDi Markets database.
17. Despite the focus on migration to high-income OECD countries, South-South migration is often larger than South-North migration in certain regions—India, Jordan, Kazakhstan, South Africa, Thailand, and Ukraine are among the destination countries among LMICs, mostly for migrants from neighboring countries (Ratha and Shaw 2007).
18. According to census data circa 2000, 15 percent of the overall stock of migrants across OECD countries were employed in manufacturing, compared with almost 70 percent in the services sector (calculations based on OECD Stat data).
19. The apparent retrenchment in Japan's use of industrial robots since 1995, while everyone else has been expanding rapidly, is noteworthy. Japan had government finance programs to promote the use of robots as early as the 1960s, and therefore may have adopted the technology before it was fully mature. This perhaps reflects a cautionary tale about mistimed incentives.
20. Some companies were offshoring and reshoring activities during the same time period.
21. In addition to rising wage pressures, the introduction of robots in China may also reflect the perception that the production of robots will be a growth manufacturing industry. This implies that robots might substitute labor earlier than evolving labor costs would traditionally dictate.
22. Collier (2008) argues that Africa's ability to compete with Asian manufacturers may be constrained given the head start and competitive advantages of the latter. Ceglowski et al. (2015) find that the lack of competitiveness is even true for basic labor-intensive sectors like textiles. Based on the apparel market, there is no indication that African countries (except for Ethiopia) are becoming successful exporters of labor-intensive manufactures in the face of China's falling competitiveness.

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CHAPTER 4

# Likely Impacts of Trends on the Feasibility and Desirability of Manufacturing-Led Development

## Introduction

The nature of international competition and sources of comparative advantage, as described in chapter 3, are changing—with implications for the feasibility and desirability of manufacturing. New process technologies hold open the potential to produce higher-quality manufactured goods at lower prices. And in established centers of manufacturing, dense ecosystems of suppliers are increasingly competing on reduced time to market, faster innovation, and scale economies as opposed to lower wages. This is particularly true in China for some of the high- and medium-skill global innovator industries.[1] Between these two trends—changing patterns of globalization and changing technology—technology is likely to have the bigger effects, but both are raising the bar in terms of what it will take to be an attractive location for production.

As a result, manufacturing-led development strategies could become less feasible, i.e., what it would take to provide an enabling environment for firms to enter and compete in world markets could rise. First, if processes that are based on new labor-saving technologies in high-income economies reduce the importance of low wages in determining costs, current production processes in less industrialized countries may not be as viable in the future. In particular, if higher-quality goods can be produced at lower prices with new technology, those using older technologies may not be able to stay in business. Therefore, under the status quo processes, there will likely be fewer entry points in global value chains (GVCs), and even maintaining production could become increasingly challenging. If low wages are no

longer sufficient to stay competitive, these producers might need to meet more demanding ecosystem requirements in terms of infrastructure, logistics and other backbone services, regulatory requirements, supplier base, and so on.

The second way manufacturing-led development in less industrialized countries may become less feasible concerns the rising requirements to support the adoption of new technologies at home. If producing using old processes renders firms in low- and middle-income countries uncompetitive, they may need to adopt the new technologies, too. And the capacity needed to use the new technologies raises the bar for the characteristics the enabling environment must have in terms of information and communication technology (ICT) infrastructure, connectivity, skills, regulatory framework for the data ecosystem, and intellectual property rights.

The desirability of manufacturing, in turn, will depend on the extent to which manufacturing itself is feasible, and on whether low- and middle-income countries must adopt new labor-saving technologies to be competitive. If manufacturing is less feasible in a location, the extent of the accompanying pro-development characteristics will fall. What may be at risk if countries adopt new labor-saving technologies is that the combination of pro-development characteristics will change: while still a source of productivity gains, manufacturing's job creation features, particularly for unskilled workers, will not be as pronounced. On the flip side, if countries can maintain the use of traditional production processes, the job potential would remain the same, but the impact on productivity and innovation would be more ambiguous. On the one hand, the productivity potential of using traditional technologies could fall as more of the effort to innovate would switch to the new technologies that are being used in high-income countries. On the other hand, if industrialization under older technologies is needed as a stepping stone to develop the capabilities needed to move into newer technologies, this traditional strategy could still have dynamic gains.

As in the earlier discussions in chapters 1 and 2, the extent to which the feasibility and desirability are changing varies across manufacturing subsectors. This chapter examines in more detail how the bar is rising given changing technologies and patterns of globalization before looking at how patterns vary across subsectors and how they modify our sector typology from the one given in chapter 2 based on associated combinations of pro-development characteristics.

## Implications for Feasibility: The Bar Is Rising

*Key message: The bar for establishing or maintaining competitiveness in global manufacturing will likely be higher in the future—even for countries that are not adopting new technologies. The extent of the impact of emerging technologies and changing patterns of globalization will differ by manufacturing industry.*

Low- and middle-income countries (LMICs) have traditionally competed based on lower-cost labor, but new labor-saving technologies are making labor a smaller share of overall costs. Therefore, low wages in themselves are not sufficient when they are more than offset by other costs in the business environment. Even new types of ICT associated with the Internet of Things (IoT)—such as cloud computing and big-data analysis—that can reduce costs of globally fragmented production will place a premium on skills and supporting ICT infrastructure. Further, given shifting consumer preferences for speed and customization, the traditional manufacturing model of mass production is giving way to production lines that favor shorter, tailored production runs—not only requiring enhanced flexibility afforded by advanced design for manufacturing and assembly but also supported by superior logistics.

Being far from the technological frontier is no insulation from potential disruption because technologies associated with Industry 4.0 are also relevant to the production of traditional manufactured goods. For example, smart factories or 3-D printing[2] can improve the production of auto parts, fabricated metals, footwear, or plastics—that is, not just advanced manufacturing products such as new medical devices, advanced robots, or new electronics. Therefore, *not* adopting new process technologies may drive firms that use lower-quality production processes out of the market, particularly if the new processes combine higher volumes with higher quality and lower prices.

Given new technologies and shifting globalization patterns, cheap labor as a source of competitive advantage is increasingly giving way to more demanding ecosystem requirements for countries to compete while still using technologies associated with Industry 2.0. The quality of infrastructure and logistics and other backbone services, regulatory requirements, the density of the supply base, and information flow about markets are becoming increasingly important for better connectivity, which will be key in reducing time to market and raising responsiveness to changing customer needs. The ease of doing business will warrant greater attention to support a production model reliant on highly differentiated tasks. Technological change will raise the requirements for high-quality education to meet changing demands for skills (shifting from operators to engineers). Moreover, the increasing "servicification" of manufacturing will also raise the bar on what is feasible, thereby placing a premium on increasing the productivity of services embodied and embedded in manufacturing (as further discussed in chapter 5). Despite all of these changes, there is still scope for countries using Industry 2.0 technologies to compete if the costs of doing business are substantially reduced. For example, if countries in Sub-Saharan Africa add massively to their labor pools while also substantially improve their business environments, this might slow down the adoption of labor-saving technologies in the high-income countries.

The alternative—using Industry 4.0 technologies to produce traditional manufactured goods—has a higher bar, too. New technologies place higher

demands on the availability and reliability of ICT services, the data ecosystem, skills, and logistical services. To the extent that they involve more embodied and embedded services, links to these services will be important. And if the time to market matters that much more and links with suppliers need to be that much more seamless, then the feasibility of using these new production processes depends on the ecosystem as well as the technical requirements. It may be particularly challenging for firms in countries with a less established manufacturing base to leapfrog into using new technologies, not having already established certain processes, skills, and networks using more accessible technologies. Inability to participate in the use of new technologies may therefore become a source of increased polarization across countries.

### The Bar May Be Rising More in Some Subsectors

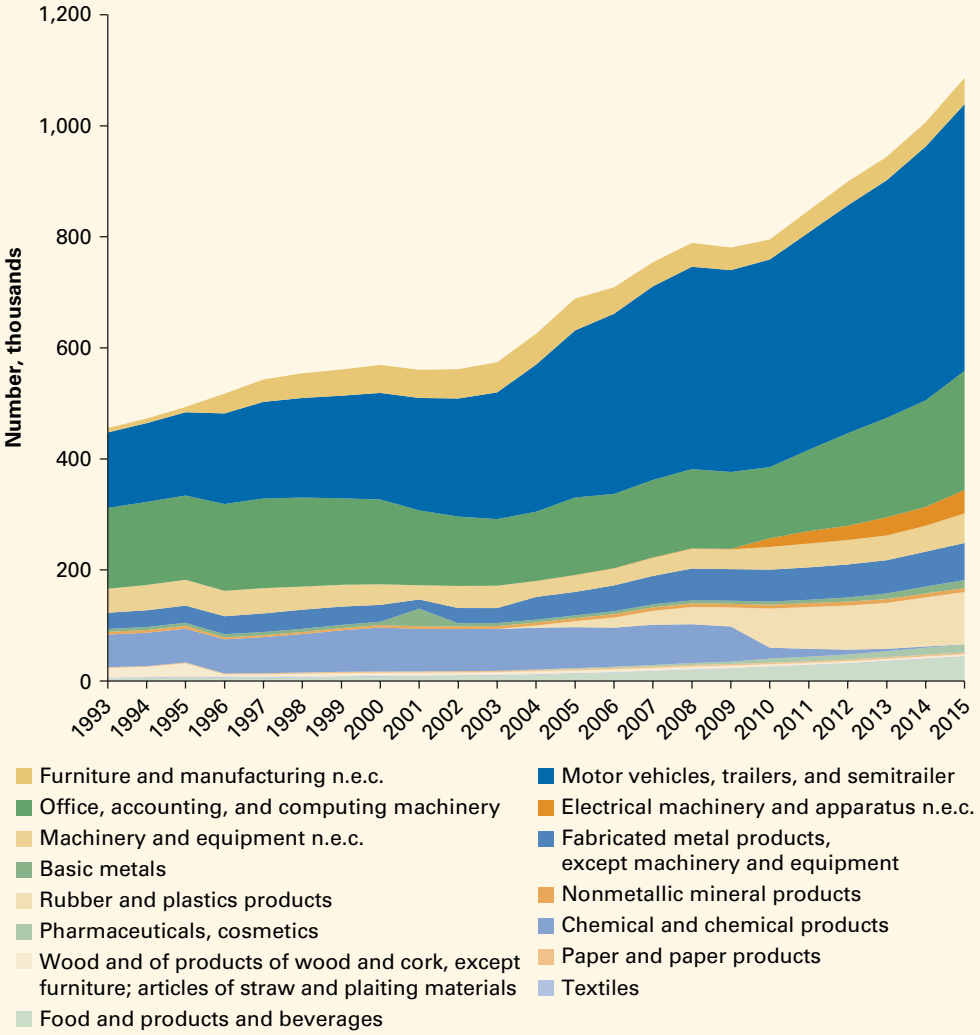
The changing feasibility of manufacturing subsectors can be assessed on the relative magnitude of automation, export concentration, and services intensity, conditional on the extent to which they are internationally traded. These dimensions represent key ways in which new technologies and changing globalization patterns are affecting production, as discussed in chapter 3, with implications for how high the bar is rising for countries to be competitive locations for manufacturing. The adoption of labor-saving technologies (such as robots, 3-D printing, or "smart" factories) makes low wages a less important determinant of competitiveness. This brings into question the feasibility of the labor-intensive production processes typically used in less industrialized countries, although the adoption of robots, for example, varies across manufacturing subsectors (figure 4.1).

Similarly, manufacturing subsectors whose exports are concentrated among a few countries illustrate where it may be harder for less industrialized countries to maintain their competitiveness, let alone enter or expand production, owing to large scale and agglomeration economies. The rise of services as a necessary complement to the success of manufacturing also deserves emphasis—the focus here being on professional, scientific, and technical services, which are more likely than other services to be associated with a rising bar. The impact of these trends on the feasibility of production will be influenced by the extent to which subsectors are traded. The more they are traded, the more the demands on competitiveness will rise, whether a country tries to adopt new technologies or simply to remain viable using traditional technologies.

The combinations of potential changes in the three dimensions described above—automation, export concentration, and services intensity—provide a new categorization of subsectors based on their changing feasibility (figure 4.2). Six manufacturing subsectors combine a relatively high Herfindahl-Hirschman index of export concentration with a relatively high number of robots per 1,000 workers currently in use:[3] electronics, computers, and optical instruments; pharmaceutical products; transportation equipment; other machinery and equipment; electrical machinery and apparatus;

**Figure 4.1 While the Stock of Operational Industrial Robots in High-Income Countries Varies by Manufacturing Subsector, the Transportation Equipment and Electronics Subsectors Experienced the Largest Increases between 1993 and 2015**

*Global operational stock of industrial robots, by manufacturing subsector, 1993–2005*

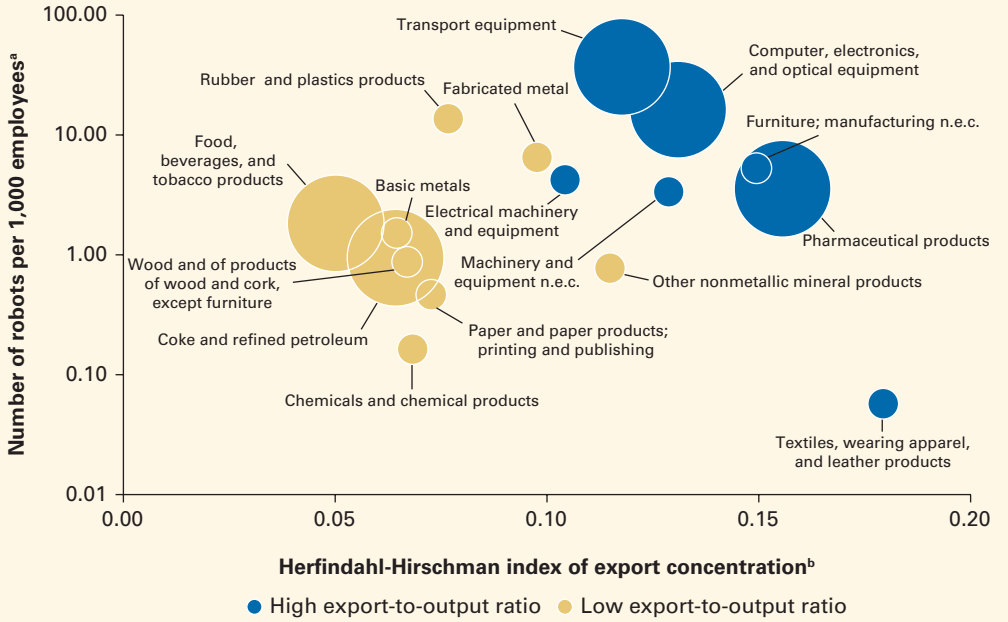



*Source:* Calculations based on World Robotics database, International Federation of Robotics.
*Note:* n.e.c. = not elsewhere classified.

and manufacturing not elsewhere classified (n.e.c.). These are also the most internationally traded manufacturing sectors. Given the combination of high export concentration and high automation, they are likely to be the most competitive sectors to break into or maintain. In addition, electronics, computers, and optical instruments; pharmaceutical products; and transportation equipment also have relatively high shares of professional services input in total value added.

**Figure 4.2 The Bar Is Rising for Some Manufacturing Subsectors More than Others, Owing to the Relative Magnitude of Automation, Export Concentration, and Services Intensity, Conditional on the Extent to Which They Are Internationally Traded**

*Export concentration and automation of global manufacturing subsectors, grouped by trade and services intensity, circa 2011–15*




*Sources:* Calculations based on United Nations Industrial Development Organization (UNIDO) Industrial Statistics INDSTAT database; International Federation of Robotics (IFR) World Robotics database; and UN Comtrade database.
*Note:* Bubble colors indicate the subsectors' export-to-output ratios as reflected in two categories: above and below 40 percent, using combined 2011 UN INDSTAT and Comtrade data. Bubble size reflects the share of professional, scientific, and technical service inputs in value added and is defined by two categories: those above and below 10 percent, using 2014 World Input-Output Database (WIOD) data.
a. The number of robots per 1,000 employees uses the 2015 stock of operational robots from IFR data and the number of 2013 employees from 2015 UN INDSTAT observation.
b. The Herfindahl-Hirschman index is a commonly accepted measure of market concentration based on market share of each firm competing in a market. Here it is adapted to the share of countries in the total exports of a particular sector or good, using 2013 UN Comtrade data.

Textiles, apparel, and footwear are the least automated subsector, but these goods are characterized by a high degree of export concentration, primarily because of China's dominance in recent years. Other nonmetallic products are also relatively more concentrated in terms of exporting countries, but this means little given that they are the most nontraded manufacturing subsector. Fabricated metal products and rubber and plastic products stand out in that they are quite automated, but with less export concentration and a lower overall trade intensity. A range of commodity-based and capital-intensive manufactures are both less automated and have the lowest trade concentration ratios—and global competition will likely be the least in these sectors. Among them, however, food processing and coke and refined

petroleum are among the manufacturing subsectors that are relatively more intensive in the use of professional services.

Table 4.1 simplifies the presentation in figure 4.2 by using binary categories to group how the different subsectors are expected to be differentially affected by automation, export concentration, and professional services intensity. Although this treatment helps bring out important sources of variation within manufacturing, the actual mapping of characteristics and exposure to change is expected to vary, potentially widely, across products within these subsectors. Table 4.1 also illustrates how expected changes in feasibility map onto the groupings based on the potential for spillovers and job creation, as described in chapter 1.

The appropriate groupings may change in the future, depending on what insights are expected. In this section, the groupings are based on expected changes in feasibility. But clearly the sources of change affect not only the subsectors' potential feasibility but also their potential for spillovers and growth gains as indicated by their tradedness and job creating potential. The next section examines the implications for the subsectors' evolving desirability.

## Manufacturing Subsectors Where the Bar May Be Rising More

Among the six manufacturing subsectors facing greater automation and high trade concentration, all are traditional GVC-intensive subsectors where the research and development (R&D) and design-intensive segments are typically carried out in high-income economies while the labor-intensive assembly occurs in low- and middle-income economies. Robotization threatens the relocation of this labor-intensive assembly, given that autos, electronics, and heavy machinery are ecosystem-intensive industries, requiring closely clustered suppliers that can provide inputs on a just-in-time basis. The reshoring of these activities may also be influenced by complementarities between tasks (Grossman and Rossi-Hansberg 2008; Healey and Ilbery 1990), which relates to the concern that separating production from R&D is harming a firm's long-term ability to innovate.[4]

Of these six subsectors, the bar may be rising the most for electronics, computers, and optical instruments; pharmaceutical products; and transportation equipment because they also embody a relatively high share of professional services input. Manufacturing n.e.c. (which includes the production of furniture, toys, jewelry, sports equipment, and musical instruments) is the subsector least associated with innovation and therefore technology diffusion. Of greater concern here is that the subsector is characterized by high labor intensity, as shown in chapter 1.

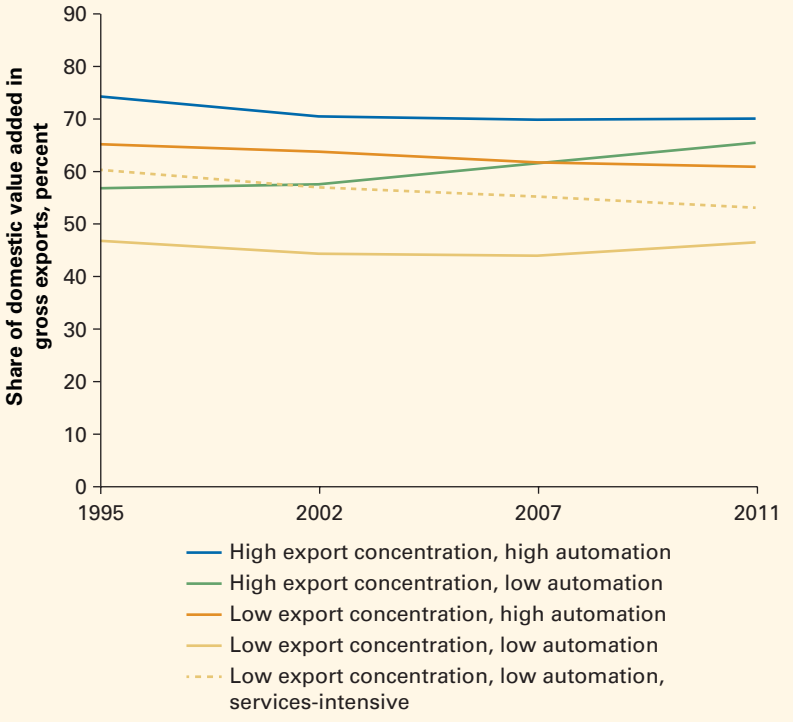
The manufacturing subsectors with the highest export concentration and automation were also more concentrated in terms of export locations to begin with: the top 10 exporting countries accounted for 77 percent of total exports in 1995. And this share declined only marginally, to 73 percent, by 2011, which suggests that scale and agglomeration remain important (figure 4.3). Except for manufacturing n.e.c., this group of

**Table 4.1 Map of Manufacturing Subsectors, within Typology Groups, against Impacts of Projected Changes to Feasibility from Automation, Export Concentration, and Professional Services Intensity**

| Tradedness | | Low | | | | High | | |
|---|---|---|---|---|---|---|---|---|
| Current absorption of unskilled labor | High | **Commodity-based regional processing** | | | | **Low-skill labor-intensive tradables** | | |
| | | Wood products<br>Paper<br>Basic metals | Nonmetalic minerals | Plastics and rubber<br>Fabricated metals | Food processing | Textiles, apparel | Manufacturing n.e.c. | |
| | Medium | | | | | **Medium-skill global innovators** | | |
| | | | | | | | Electrical machinery | Transportation equipment |
| | Low | **Capital-intensive regional processing** | | | | **High-skill global innovators** | | |
| | | Chemicals | | | Coke and refined petroleum | | | Computers, electronics, and optical equipment |
| | | | | | | | | Pharmaceuticals |
| Sources of changing feasibility | Export concentration | n.a. | x | n.a. | n.a. | x | x | x |
| | Automation | n.a. | n.a. | x | n.a. | n.a. | x | x |
| | Servicification | n.a. | n.a. | n.a. | x | n.a. | n.a. | x |
| Primary change scenarios | | Limited change currently expected | Limited change despite high export concentration because trade in international markets is negligible | Automation | Servicification | High export concentration | High export concentration and automation | High export concentration automation, and servicification |

*Note:* The table maps the manufacturing subsector group typology laid out in chapter 1 (and depicted in figure 1.3)—which is based on the desirable pro-development characteristics of tradedness and unskilled labor absorption—against the three potential sources of change to the feasibility of manufacturing: automation, export concentration, and "servicification" (services intensity). These patterns hold on average for the two-digit sectors. The actual extent of labor intensity, tradedness, and exposure to changes will clearly vary at more disaggregated levels. n.e.c. = not elsewhere classified. n.a. = not applicable.

**Figure 4.3 Change in Top 10 Exporting Countries' Share of Total Exports across Manufacturing Subsectors, 1995–2011**




*Source:* Calculations based on OECD-WTO Trade in Value Added (TiVA) dataset.

subsectors make up what chapter 1 defined as "high-skill global innovators" and "medium-skill global innovators." The top 10 exporting countries for the high-skill and medium-skill global innovator industries through much of the 1995–2011 period were high-income economies, with the exceptions of China and Malaysia. The share of global exports accounted for by the top 10 LMICs other than China increased from about 5 percent to 9 percent of total exports in these industries between 1995 and 2011. In 2011, this list of countries, ranked from larger to smaller export share for the high-skill global innovator industries, included Malaysia, Mexico, the Philippines, Thailand, India, Indonesia, the Russian Federation, Costa Rica, Vietnam, and Brazil. For the medium-skill global innovator industries, they included Mexico, Brazil, India, Thailand, Turkey, Russia, South Africa, Romania, Indonesia, and Argentina.

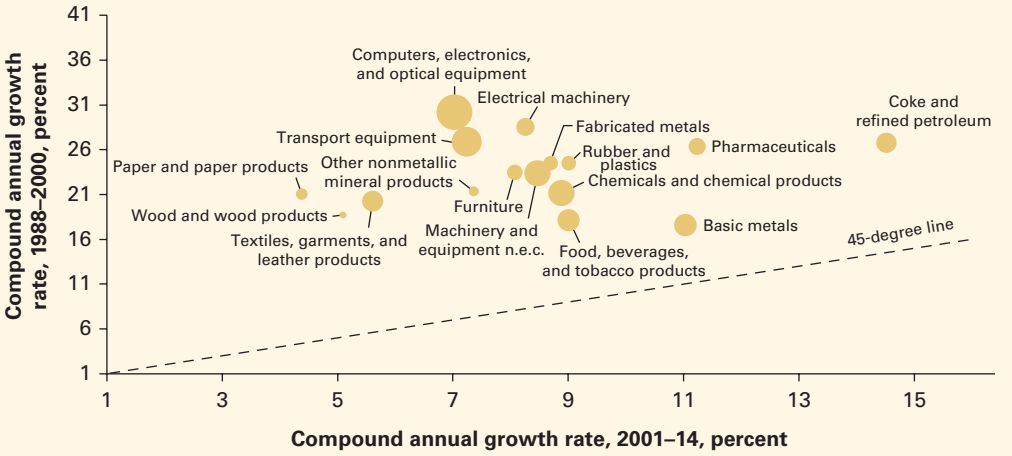
Some of these GVC-intensive sectors have also experienced the largest declines in trade growth since the 2000s and may reflect weakening import demand that is more structural than cyclical. Notably, the manufacture of coke and refined petroleum experienced the largest increase in trade growth between 1988 and 2000 and the largest decline between 2001 and 2014,

but this was largely driven by highly volatile commodity prices. Moving beyond this subsector, trade during the 1990s grew the most in electronics, computers, and optical instruments; electrical machinery and equipment; and transportation equipment—manufacturing subsectors where production has typically been organized in GVCs. Subsequently, between 2001 and 2014, while trade growth fell across the board, the largest declines were in precisely these manufacturing subsectors (figure 4.4).

Even within these two-digit, GVC-intensive subsectors, the industries with the largest declines in trade growth in the 2000s were those characterized by greater vertical specialization, measured by the share of parts and components in total trade of the subsector. For example, in electronics, computers, and optical instruments, the manufacture of radio, televisions, and communication equipment (–10 percent) and the manufacture of electrical industrial machinery (–6 percent) experienced the largest declines. Smaller drops in world trade growth were recorded in subsectors where GVCs are less developed, such as the manufacture of watches and clocks (–0.7 percent) (Constantinescu, Mattoo, and Ruta 2015).

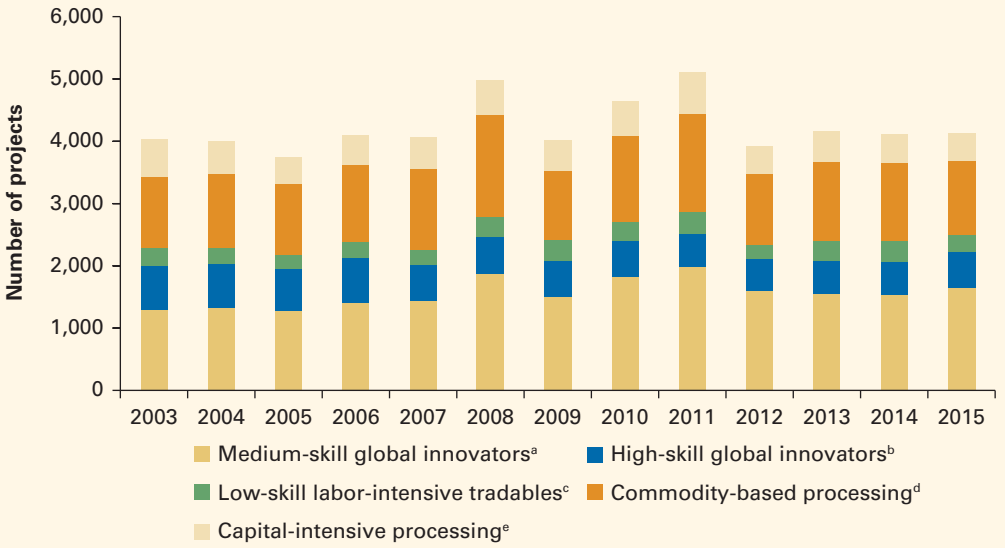
Of all "greenfield" (not previously developed) FDI inflows into the manufacturing sector, medium-skill and high-skill global innovator industries—defined in chapter in 1 to include electronics, computers, and optical instruments; pharmaceutical products; transportation equipment; other machinery and equipment; and electrical machinery and apparatus—attracted a relatively large number of projects consistently between 2003 and 2015 (figure 4.5). These are the very industries that are relatively automated and have a high export concentration. However, in the

**Figure 4.4 Manufacturing Trade Growth, by Subsector, 1988–2000 vs. 2001–14**




*Source:* Calculations based on World Integrated Trade Solution (WITS) data.
*Note:* Bubbles above the 45-degree line denote faster growth of trade in 1988–2000 relative to 2001–14. Bubble size reflects the share of the sector in total trade in 2001–14.

**Figure 4.5 Global Greenfield FDI in Manufacturing Projects, by Sector Type, 2003–15**




*Source:* World Bank calculations based on fDi markets database.
*Note:* FDI = foreign direct investment.
a. "Medium-skill global innovators" are R&D-intensive manufacturers of transportation equipment, electrical equipment, and other machinery and equipment n.e.c. (not elsewhere classified).
b. "High-skill global innovators" are R&D-intensive manufacturers of computing, electronics, and optical instruments, as well as pharmaceutical products.
c. "Low-skill labor-intensive tradables" employ a relatively high share of blue-collar workers with distinctly high employment-to-output ratios: textiles, apparel, and leather products as well as furniture and manufacturing n.e.c.
d. "Commodity-based processing" manufactures products closely linked to agricultural raw materials or mining products, including food processing, wood products, paper products, basic metals, fabricated metal products, nonmetallic mineral products, and rubber and plastic products.
e. "Capital-intensive processing" includes two regional processing sectors—chemical products and refined petroleum products—that employ lower shares of blue-collar workers than do the commodity-based regional processors.

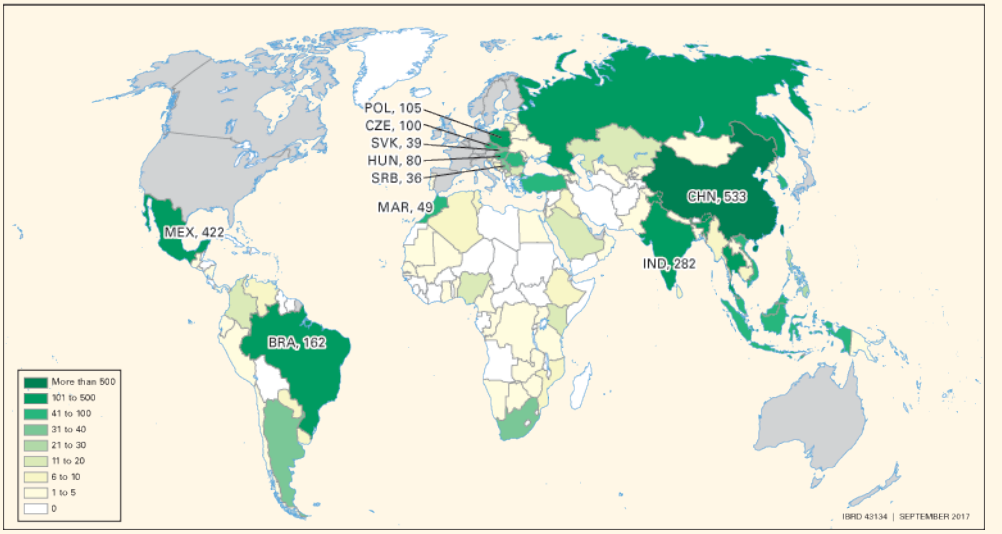
transportation equipment subsector, for example, some high-income economies, China, and countries in Europe and Central Asia experienced a decline in the number of greenfield FDI projects during 2011–15 relative to 2003–07, but certain large emerging economies such as Brazil, India, Mexico, and Thailand experienced an increase over the same period (map 4.1). This difference may reflect a predominance of efficiency-seeking FDI, whereby these countries provide the right combination of costs and capabilities, but it may also be linked to demand considerations, whereby countries with large domestic markets are attractive for FDI.

Further, these sectors that are already relatively more robotized are also the most susceptible to 3-D printing, which raises the possibility of greater dispersion in the geography of production. Products where competition from 3-D printing is likely to be particularly intense can be identified by looking at instances where printing is already technologically feasible[5] and where a substantial portion of trade travels by air. The use of air

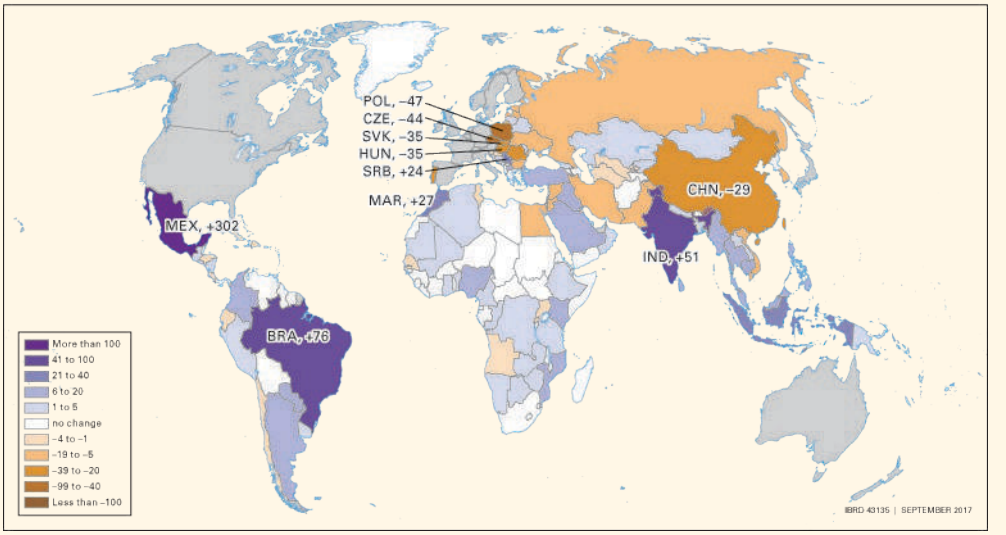
**Map 4.1 The Number of Greenfield FDI Projects in the Transportation Equipment Sector Increased in Some Emerging Economies such as Brazil, India, Mexico, and Thailand During 2011–15 Compared with 2003–07**

*FDI in Greenfield transportation equipment projects in low- and middle-income countries, 2003–07 and 2011–15*

**a. Number of projects, 2011–15[a]**




**b. Change in number of projects, 2003–07 to 2011–15[b]**




*Source:* World Bank based on fDi Markets database.
*Note:* FDI = foreign direct investment. High-income countries (as defined in 1994) are not included.
a. Legend indicates number of projects in 2011–15. For each color, the first number indicates the lower bound for the category and the second number the upper bound for the category.
b. Legend indicates the change in the number of projects between 2003–07 and 2011–15, corresponding to the periods before and after the global financial crisis. Those in purple indicate increases, with greater increases in darker purple colors, while those in orange indicate declines in the number of projects, with darker orange colors indicating larger declines.

transport suggests that time is of the essence for trade transactions—but it is also associated with high value-to-weight ratios, and so would likely be the first type of trade to be disrupted by 3-D printing.

Table 4.2 lists the top 20 products in terms of trade value that fit these two criteria. They are largely medium- or high-technology manufactured goods in one of four subsectors: electronics, computers, and optical instruments; transportation equipment; other machinery and equipment; or electrical machinery and apparatus. Based on the extent to which these "printable" products form a substantial proportion of total exports, preliminary estimates suggest that the largest impacts are in industrialized countries.[6] Whether the production of these goods moves to less industrialized countries would depend on the evolving consumer base and capabilities to use additive manufacturing technology. There might well be a geographical concentration of 3-D printing-based production, with the printed goods then being shipped to multiple countries rather than being printed in many locations.

Some other subsectors are relatively more automated, too, but the scope for reshoring production may be limited because they are less traded and less concentrated in terms of export locations. Rubber and plastic products and fabricated metal products are sectors with high current use of robots per 1,000 workers, even higher than in many of the GVC- intensive sectors

**Table 4.2 Top 20 Products Susceptible to 3-D Printing**

| Rank | SITC | Product |
|---|---|---|
| **1** | 5429 | Medicaments, n.e.s. |
| **2** | 7599 | Parts and accessories (other than covers, carrying cases, and the like) suitable for use solely or principally with the machines of subgroups 751.1, 751.2, 751.9, and group 752 |
| **3** | 7149 | Parts of the engines and motors of heading 714.41 and subgroup 714.8 |
| **4** | 7929 | Parts, n.e.s. (not including tires, engines, and electrical parts) of the goods of group 792 |
| **5** | 8722 | Instruments and appliances used in medical, surgical, or veterinary sciences (including sight-testing instruments but excluding electrodiagnostic and radiological instruments and apparatus) |
| **6** | 8996 | Orthopedic appliances (including crutches, surgical belts, and trusses); splints and other fracture appliances; artificial parts of the body; hearing aids and other appliances worn or carried or implanted in the body, to compensate for a defect |
| **7** | 7843 | Other parts and accessories of the motor vehicles of groups 722, 781, 782, and 783 |
| **8** | 7726 | Boards, panels (including numerical control panels), consoles, desks, cabinets, and other bases, equipped with two or more apparatus of subgroup 772.4 or 772.5, for electrical control or the distribution of electricity |
| **9** | 6956 | Knives and cutting blades, for machines or for mechanical appliances; interchangeable tools for hand tools or for machine tools; plates, sticks, tips, and the like for tools |

*(Table continues on next page)*

**Table 4.2 Top 20 Products Susceptible to 3-D Printing** *(continued)*

| Rank | SITC | Product |
|---|---|---|
| **10** | 7139 | Parts, n.e.s., for the internal combustion piston engines of subgroups 713.2, 713.3, and 713.8 |
| **11** | 7285 | Parts, n.e.s., of the machines and mechanical appliances of headings 723.48, 727.21, and 728.41 through 728.49 |
| **12** | 7478 | Taps, cocks, valves and similar appliances, n.e.s. |
| **13** | 8842 | Spectacles and spectacle frames |
| **14** | 8928 | Printed matter, n.e.s. |
| **15** | 6942 | Screws, bolts, nuts, coach screws, screw hooks, rivets, cotters, cotter pins, washers (including spring washers) and similar articles, of iron or steel |
| **16** | 5421 | Medicaments containing antibiotics or derivatives thereof |
| **17** | 7284 | Machinery and mechanical appliances specialized for particular industries, n.e.s. |
| **18** | 7239 | Parts, n.e.s., of the machinery of group 723 (excluding heading 723.48) and of subgroup 744.3 |
| **19** | 8131 | Lamps and lighting fittings (including searchlights and spotlights), n.e.s. |
| **20** | 8211 | Seats (other than those of heading 872.4), whether or not convertible into beds and parts thereof |

*Source:* Arvis et al. 2017.
*Note:* SITC = Standard International Trade Classification; n.e.s. = not elsewhere specified.

described above. Yet because they are less concentrated in terms of export locations—the share of the top 10 exporters (in terms of domestic value added of gross exports) declined from 68 percent in 1995 to 63 percent in 2011—the LMICs that have a revealed comparative advantage in these sectors are less likely to be adversely affected. To the extent that these two subsectors are regionally traded through regional value chains (and their trade-to-output ratio over the past two decades has substantially increased), the potential impact of automation on reshoring may be higher. The current use of robots is extremely low in most LMICs that produce these exports, and therefore the direct impact of automation on jobs in these sectors will likely be low. That these sectors are already capital-intensive may further dull the threat of job disruption.

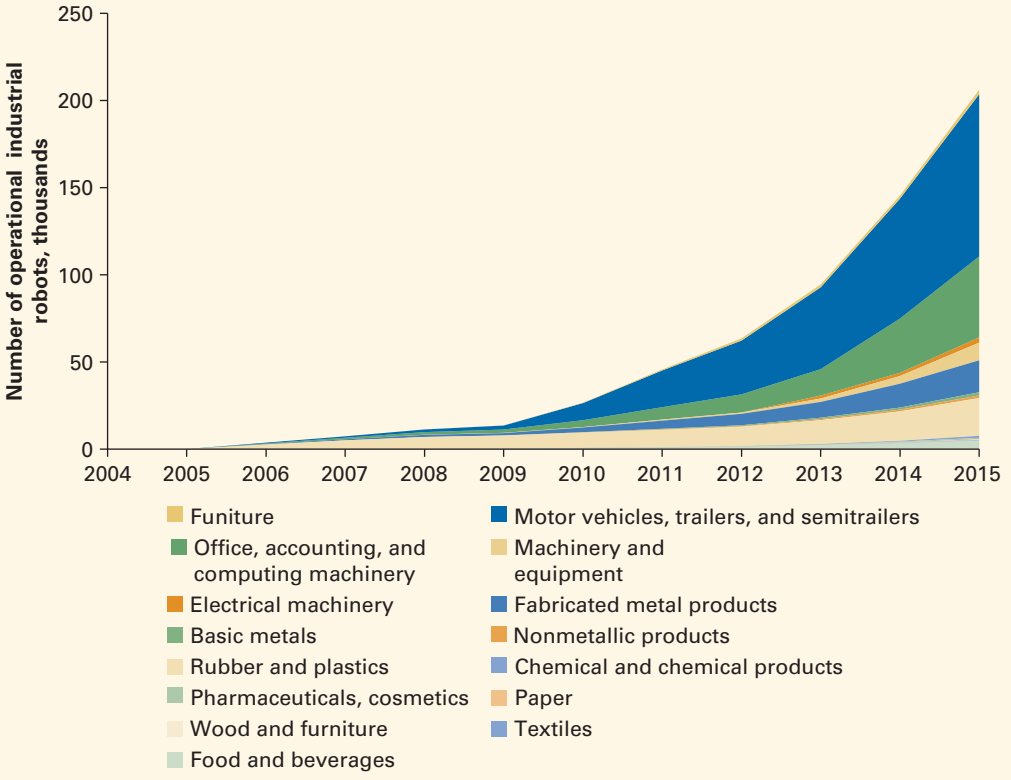
### Manufacturing Subsectors Where the Bar May Be Rising Less

Among low-skill labor-intensive goods that are highly traded internationally (as defined in chapter 2), manufacturing n.e.c.—comprising furniture, jewelry, toys, sports equipment, and musical instruments—has a robot-to-labor ratio that is even higher than transportation equipment and other machinery and equipment. Some of these products, such as furniture (including consoles, desks, cabinets, and seats) and light manufactures (such as spectacles), are also susceptible to 3-D printing (table 4.2).[7] This 3-D printing could therefore affect a set of low-skill labor-intensive industries (as shown in chapter 1), in which many labor-intensive economies have a comparative advantage.

In contrast, the textiles, apparel, and footwear subsector has been slow to automate—including in China, where wages continue to rise (figure 4.6)—and might still migrate to less industrialized economies.

Further, despite early signs of the use of 3-D printing in the textiles, apparel, and leather products subsector, large-scale relocation from the world's current largest producers appears unlikely. While manufacturers of garments, apparel, and leather goods have traditionally sourced production in countries with low labor costs, greater demands for customization open up the possibility of 3-D printed goods, which are design-intensive, typically produced in small batches on short cycles, and require proximity to consumer markets. Take the example of footwear manufacturing, where 3-D printing can dramatically shorten the design-to-production cycle from 18 months to less than a week (*Economist* 2017). Adidas, the German sporting goods company, has established "Speedfactories" in Ansbach, Germany, and Atlanta, which will use computerized knitting, robotic cutting, and 3-D printing almost exclusively to produce athletic footwear. The two Speedfactories are expected to initially produce around 500,000 pairs of shoes per year in the near term. This will still account for only a small percentage of Adidas' athletic footwear

**Figure 4.6 Use of Industrial Robots in China, by Manufacturing Subsector, 2004–15**




*Source:* Calculations based on International Federation of Robotics (IFR) World Robotics database.

manufacturing of over 300 million pairs of shoes annually. Therefore, large-scale import substitution effects, especially among the world's current largest producers in China and Vietnam, appear unlikely.

Finally, although the export of these labor-intensive tradables has been concentrated in China, recent FDI patterns in apparel and leather products are indicative of the "flying geese" paradigm.[8] The combined share of the top three countries exporting textiles, apparel, and leather products (in terms of domestic value added) increased from 29 percent to 49 percent between 1995 and 2011. Much of this increased concentration was related to China's share in the export of apparel and leather products, which more than doubled from 1995 (14 percent) to 2011 (31 percent). Yet, recent greenfield FDI inflows in the apparel and leather products sector show a change in the composition of destination countries in 2011–15 compared with 2003–07, which is indicative of the "flying geese" pattern (map 4.2).[9] China and Eastern European countries such as Bulgaria, Hungary, and Romania experienced a decline in the number of greenfield FDI projects over this period, while Ethiopia, Indonesia, Serbia, and Vietnam experienced an increase. FDI may have migrated from China to LMICs in Asia and Africa and from higher- to lower-income countries in the Europe and Central Asia region.

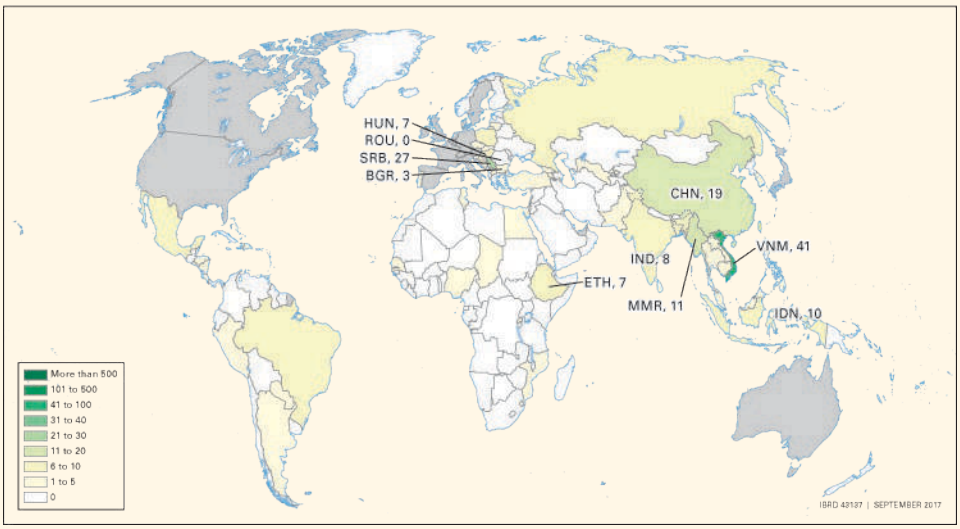
For most less industrialized countries, opportunities will be least affected in sectors that are less automated, and where export locations are geographically less concentrated together with robust FDI inflows. These manufacturing industries typically produce goods that are bulky to transport, such as construction materials within nonmetallic mineral products or those that require proximity to raw materials: basic metals, coke and refined petroleum, wood products, paper products, and food processing. As a word of caution, the manufacture of food, beverages, and tobacco and coke and refined petroleum stand out as relatively intensive in the use of professional services, and so the bar might be rising somewhat more in those subsectors. From a jobs perspective, being competitive in the food processing industry might be particularly relevant, given that it accounted for 13 percent of the world's total manufacturing employment in 2011 (chapter 1, table 1.2).

Exports of food processing and coke and refined petroleum are the least concentrated, with the combined share of the top 10 exporting countries at 48 percent in 2011, unchanged since 1995. The exports of other commodity-based processing manufactures were somewhat more concentrated, but a combined share of the top 10 exporting countries declined from 63 percent in 1995 to 55 percent in 2011.[10] Recent patterns show that of all greenfield FDI inflows into the manufacturing sector, commodity-based processing manufactures consistently attracted a relatively large of projects between 2003 and 2015. And while China and a several upper-middle-income and high-income countries in Eastern Europe and Central Asia experienced a decline in the number of projects during 2011–15 compared with 2003–07, large emerging economies such as Brazil, India, Indonesia, Mexico, Thailand, and Vietnam saw an increase (map 4.3). This is perhaps indicative of market-seeking FDI in sectors that are less traded internationally.

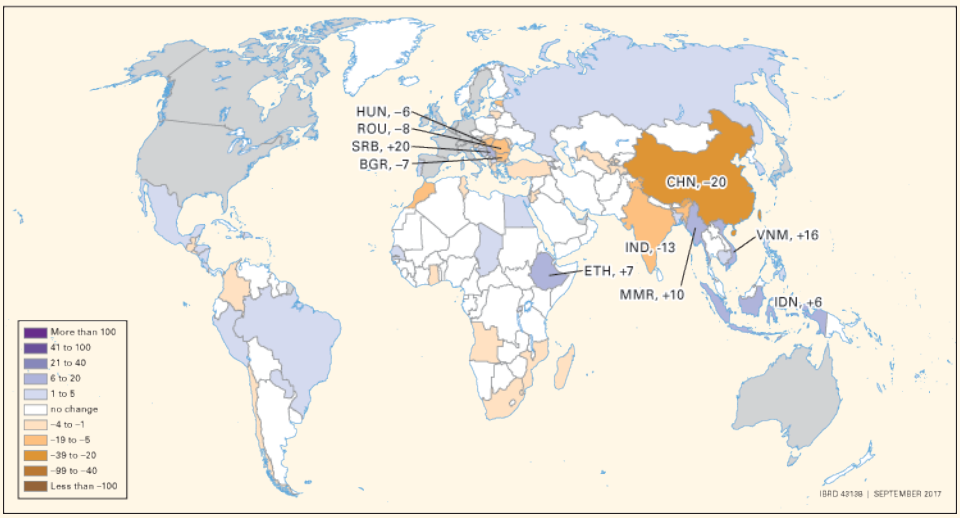
**Map 4.2 Greenfield FDI Inflows in the Apparel and Leather Products Subsector Are Indicative, at Least in Part, of the "Flying Geese" Paradigm—with Vietnam Standing Out as a Particular Beneficiary, Followed by Serbia and Myanmar**

*Greenfield FDI for projects in the apparel and leather products subsector, low- and middle-income countries, 2003–07 and 2011–15*

**a. Number of Projects, 2011–15[a]**




**b. Change in Number of Projects, 2003–07 to 2011–15[b]**

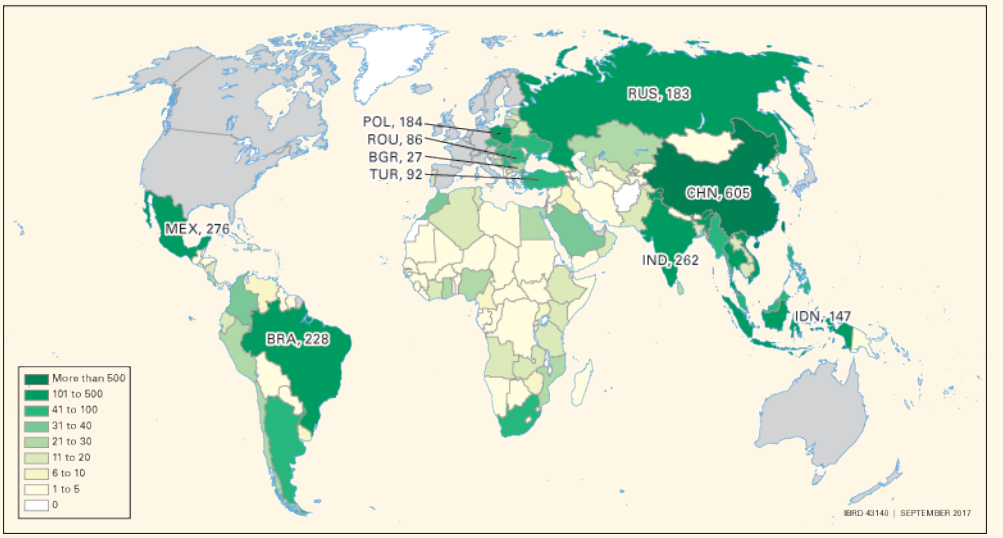



*Source:* World Bank based on fDi Markets database.
*Note:* FDI = foreign direct investment. High-income countries (1994 classification) are not included.
a. Legend indicates number of projects in 2011–15. For each color, the first number indicates the lower bound for the category and the second number the upper bound for the category.
b. Legend indicates the change in the number of projects between 2003–07 and 2011–15, corresponding to the periods before and after the global financial crisis. Those in purple indicate increases, with greater increases in darker purple, while those in orange indicate declines in the number of projects, with darker orange indicating larger declines.

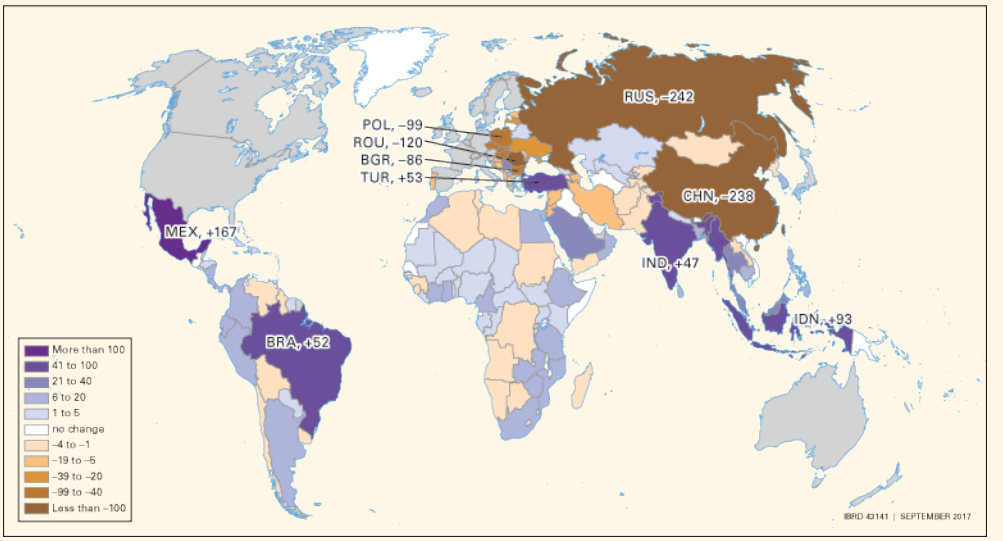
**Map 4.3 Large Emerging Economies Such as Brazil, India, Indonesia, Mexico, Thailand, and Vietnam Saw an Increase in the Number of "Greenfield" FDI Projects in Commodity-Based Manufactures between 2003–07 and 2011–15**

*Greenfield FDI for commodity-based processing in low- and middle-income countries, 2003–07 and 2011–15*

**a. Number of projects, 2011–15[a]**




**b. Change in number of projects, 2003–07 to 2011–15[b]**




*Source:* World Bank based on fDi Markets database.
*Note:* FDI = foreign direct investment. High-income countries (1994 classification) are not included.
a. Legend indicates number of projects in 2011–15. For each color, the first number indicates the lower bound for the category and the second number the upper bound for the category.
b. Legend indicates the change in the number of projects between 2003–07 and 2011–15, corresponding to the periods before and after the global financial crisis. Those in purple indicate increases, with greater increases in darker purple colors, while those in orange indicate declines in the number of projects, with darker orange colors indicating larger declines.

## Other Opportunities in the Manufacturing Sector

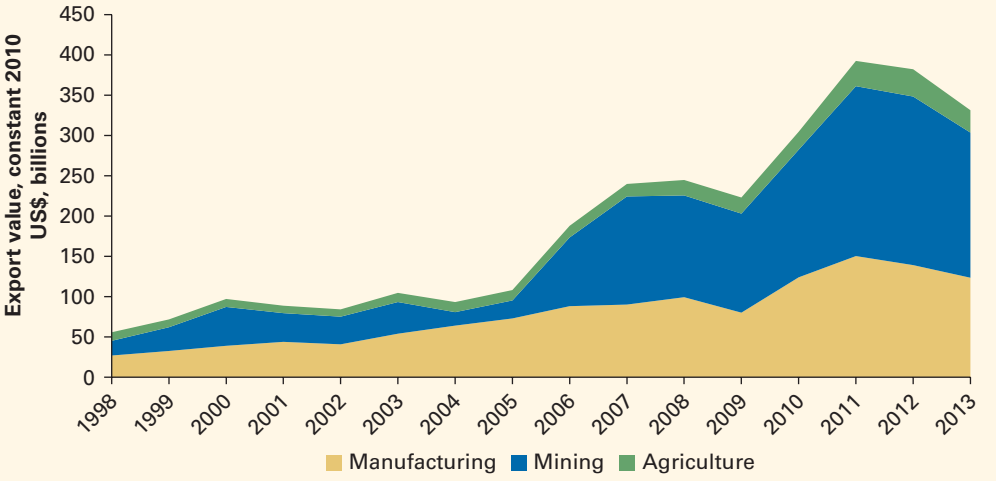
For less industrialized countries, there will likely still be room for lower-quality, lower-price goods produced and consumed domestically. In the past, highly traded manufacturing sectors were characterized by market segmentation in low- and middle-income economies. There has, for example, been a simple structure to China's markets: a small premium segment served by foreign companies realizing high margins at the top and a large low-end segment served by local firms offering low-quality, lower-price products at the bottom[11] (Gadiesh, Leung, and Vestring 2007). For example, Shanghai Jahwa, China's oldest cosmetics company, thrived by developing low-cost products catering to the distinct tastes of Chinese consumers. Or take the example of the garments sector in India, where Arvind Mills took a seemingly global product—blue jeans—and refashioned it to fit the budgets of millions of rural villagers. And India's Bajaj Auto has withstood international competition in the motor vehicles sector by producing low-cost, durable scooters, with a ubiquitous distribution and service network (Dawar and Frost 1999). Yet if robots and smart factories enable relatively higher-quality goods to be produced at lower costs, the option of lower-quality, lower-price local manufacturing may become less feasible, particularly in sectors that are easily traded.

The scope for productivity gains might be greater for lower-quality, lower-price goods that are regionally traded, where countries can exploit opportunities beyond the domestic market. India's pharmaceutical exports is a case in point: some of these products can also be sold more broadly in the region or in countries at similar development levels (Hafner and Popp 2011). For African countries, many of which are marginal players in GVCs, a regional market for such goods holds considerable promise. In 2014, commodities were relatively less dominant, and the share of all manufactured products in intra-Africa trade, at 43 percent, was roughly double the share of Africa's exports to all trading partners (figures 4.7 and 4.8).

Further, most manufacturing industries have seen large increases in their intra-Africa trade shares between 2000 and 2014 (figure 4.9). This evidence suggests that boosting trade between African countries should be expected to increase the importance of manufactured goods in total merchandise exports. For example, fueled by strong domestic demand for wood construction materials and furniture, Ethiopia's wood products industry currently employs more than 40,000 workers, mostly in small, low-productivity informal firms producing low-quality products for the domestic market (Dinh et al. 2012).

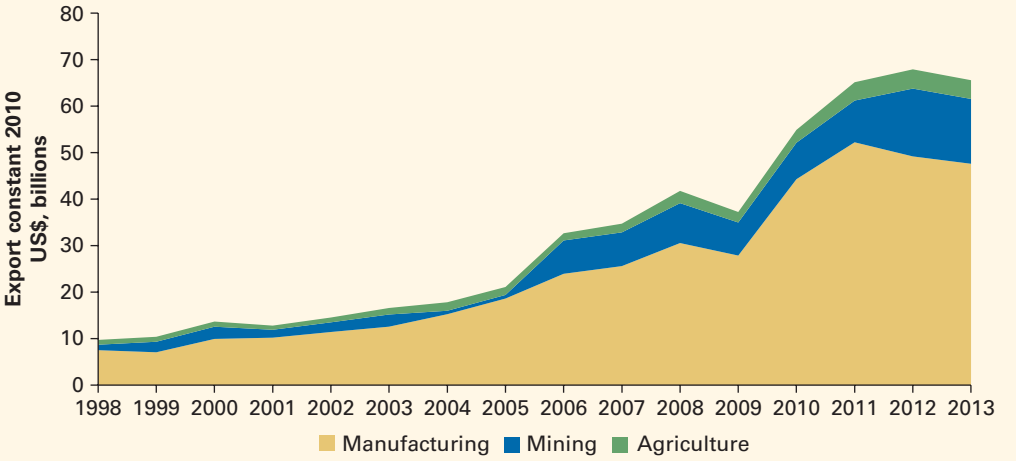
Less industrialized economies could also use new technologies in the production of traditional manufactured goods to preserve the competitiveness of their current export baskets. Many LMICs have a comparative advantage in commodity-based processing, where plentiful natural resources or labor give them the low-cost advantage. From Indonesia, Indah Kiat Pulp and Paper (IKPP), for example, moved into export markets for paper products by drawing on a ready supply of logs—the product of favorable

**Figure 4.7 Value of Total Exports in Sub-Saharan African Countries, by Sector, 1998–2013**




*Source:* Nayyar and Nee 2016.

**Figure 4.8 Value of Intra-Africa Exports Among Sub-Saharan African Countries, by Sector, 1998–2013**

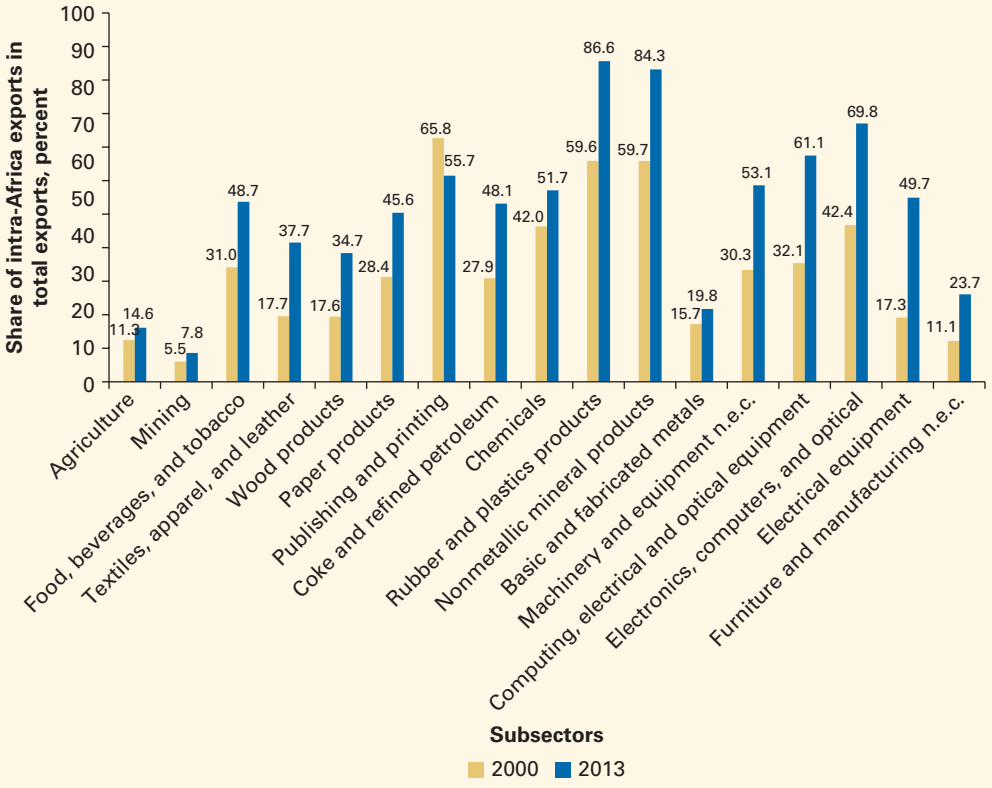



*Source:* Nayyar and Nee 2016.

tropical growing conditions and low harvesting costs. Yet IKPP complemented this cost advantage with investment in advanced machinery to improve product quality, providing a sustainable basis for long-term competitive success. Similarly, Mexico's Cemex became one of the world's lowest-cost producers in the logistics-intensive cement industry by complementing low

**Figure 4.9 Most Manufacturing Industries in Sub-Saharan Africa Experienced Large Increases in Intra-Africa Exports as a Share of Total Exports between 2000 and 2013**

*Share of intra-Africa exports in total manufacturing exports, by subsector, 2000–13*




*Source:* Nayyar and Nee 2016.
*Note:* n.e.c. = not elsewhere classified.

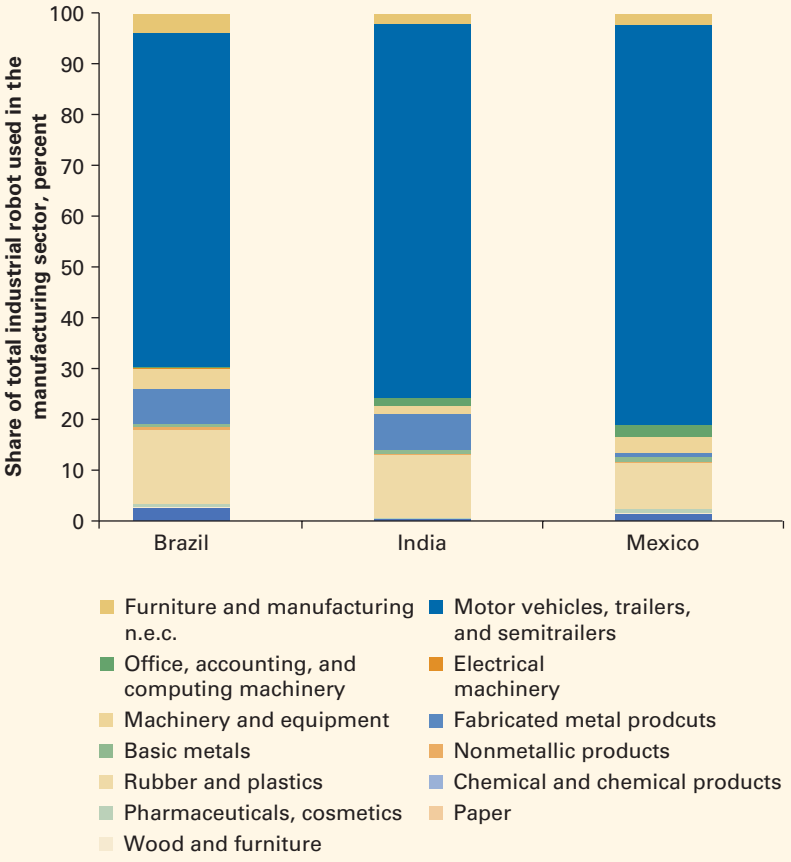
production costs with ICT. Its managers have worked closely on systems development with IBM, and the company has invested extensively in employee development programs designed to support its emphasis on logistics, quality, and service (Dawar and Frost 1999).

It will likely be easier to use the new technology in the production of the same goods than to leapfrog into using it with no track record of making those goods. This is evident in the fact that, in middle-income countries with an international presence in the manufacture of transportation equipment (such as Brazil, India, and Mexico), the operational stock of industrial robots is used almost entirely in the sector (figure 4.10).

In sum, the manufacturing sector's job creation capacity is of increasing concern, especially for lower-skilled workers, in less industrialized countries. But manufacturing industries that are less traded and currently less automated (commodity-based processing, for example) will remain

**Figure 4.10 Much of the Operational Stock of Industrial Robots in Brazil, India, and Mexico in 2015 Resided in the Manufacture of Transportation Equipment**

*Use of industrial robots in selected middle-income countries, by manufacturing sector, 2015*




*Source:* Calculations based on International Federation of Robotics (IFR) World Robotics database.

entry points for hitherto less industrialized countries and drivers of low-skill employment. These industries span a range of sectors, including food processing, wood products, paper products, basic metals, nonmetallic mineral products, coke and refined petroleum, and chemical products.

Countries that combine low wage costs with a sound business environment could maintain the cost-effectiveness of labor-intensive production over greater robotization in highly traded sectors such as textiles, garments, and footwear. Domestic or regional markets for lower-quality, lower-price manufactures will also likely remain in sectors that are highly traded and already quite automated: electronics, machinery, and light consumer goods.

Therefore, manufacturing will likely remain in most countries' futures—just not necessarily as the same source of dramatic growth that the East Asian manufacturing powerhouses experienced in the past.

## Implications for Desirability: Pro-Development Characteristics Are Shifting

*Key message: New technologies and shifting patterns of globalization may also affect the desirability of manufacturing-led development in terms of its potential for dynamic growth gains and job creation.*

### Potential Threat to Jobs and the Shortening of Global Value Chains

The combinations of desirable characteristics in the manufacturing sector are likely to shift, particularly with new Industry 4.0 process technologies which are already in place, largely in high-income countries (HICs). Although tasks across the manufacturing sectors are potentially automatable, there is still a window when countries may be able to compete using older technologies. So the desirability of manufacturing in terms of its scope for potential spillovers will vary, depending on whether countries compete using older technologies or new ones. At least for now, robotics and 3-D printing are used in relatively few countries. If lower-income countries can continue to use traditional technologies and remain competitive, much of the feared potential job disruption will not come to pass. However, even if such a strategy is viable in the short run, the longer-run dynamics are still uncertain. If innovation efforts shift to more advanced goods and new technologies, and if the benefits slow from technology diffusion using older technologies, the potential for spillovers and dynamic gains associated with these older technologies might diminish.

Just how many current jobs, in manufacturing and beyond, are put at risk by technological improvements is at the heart of concerns about the future, but recent evidence reveals that many of these concerns are exaggerated, especially in low- and middle-income countries (LMICs). Some studies estimate that half or more of current occupations across all sectors could be automated away by new technologies (Bowles 2014; Frey and Osborne 2013; Manyika 2016; World Bank 2016).[12] A major criticism of these estimates is the assumption that a whole occupation can be automated away based on the automatability of its constituent tasks. Breaking down occupations into tasks with varying levels of automatability, Arnzt, Gregory, and Zierahn (2016) find that the share of jobs that could be automated away in a set of Organisation for Economic Co-operation and Development (OECD) economies is much lower than other estimates, with 6–12 percent of current jobs at high risk of automation When this approach is extended to cover a broader set of economies, the threat of automation to jobs is

found to be relatively modest, at 2–8 percent for LMICs (Ahmed and Chen 2017), as shown in figure 4.11.

Although the direct impact of automation on current jobs in LMICs is still limited, these are estimates of current jobs that could be lost—and do not include the additional "potential jobs" that could be lost by never being created. For example, because HICs are adopting new technologies and keeping production in their countries, the product cycle stops and production does not migrate to lower-income countries. Further, if the only way LMICs can compete in manufacturing GVCs is by adopting labor-saving processes (automation), this, too, will eliminate a set of potential additional jobs. Taken together, these effects could be much bigger than the direct substitution of machines or software for current jobs.

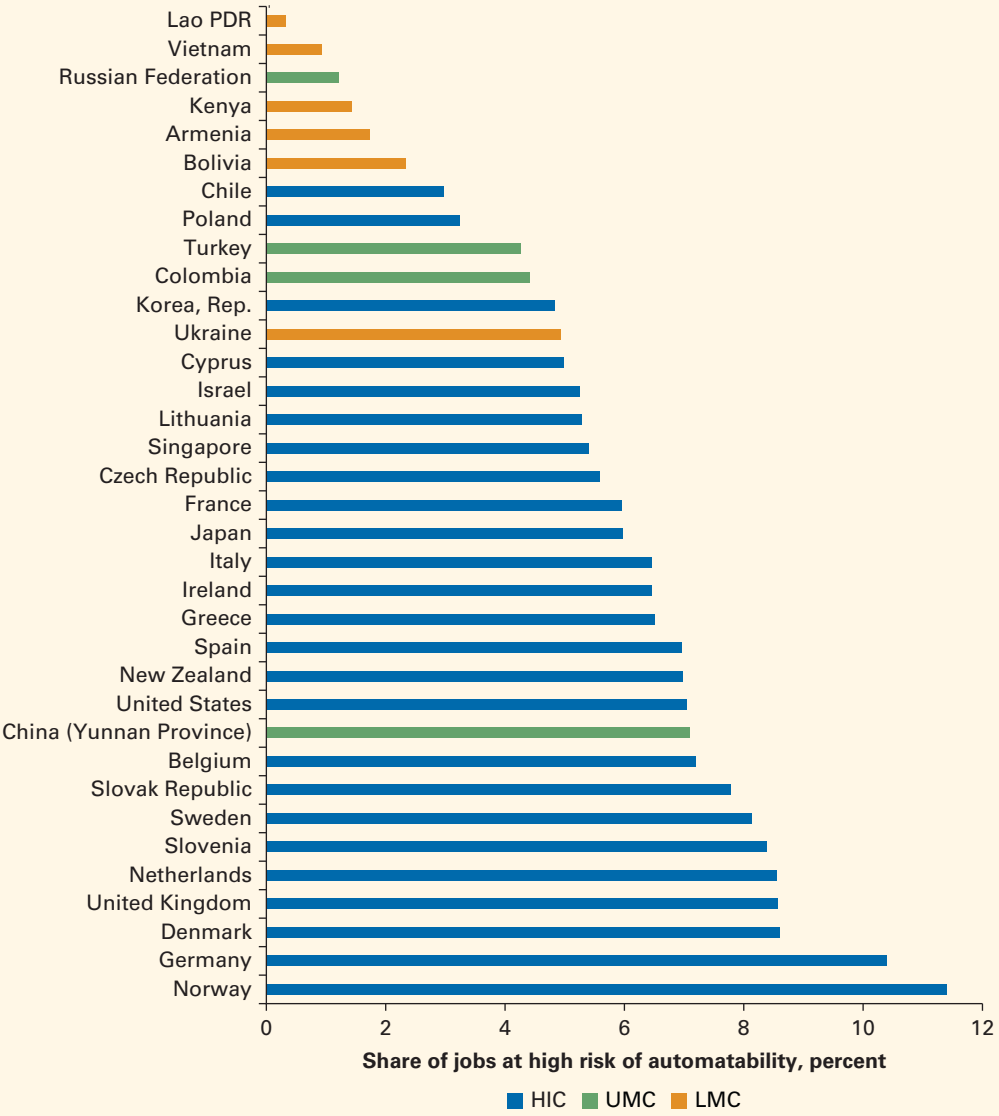
As a result, new trends in technology and changing patterns of globalization may erode the unique desirability of the manufacturing sector, which earlier combined productivity increase with large-scale unskilled labor absorption. Much will depend on how the costs of new technologies evolve and at what pace. Although emerging technologies in areas such as artificial intelligence, robotics, and 3-D printing have been around for a while, they tend to diffuse and be adopted more rapidly than technologies had been in the past (Brynjolfsson and McAfee 2011, 2014; Comin and Hobijn 2010). Yet, it is not yet economically viable to robotize all jobs.

Beyond the effects on the number of jobs, the experience of high-income economies suggests that that these technological advances are leading to labor market polarization in the middle of the skills spectrum. The tasks considered the most susceptible to automation, even under current technologies, are those that are done mostly by workers in the middle of the skill distribution (Acemoglu and Autor 2011). Because machines increasingly perform the tasks of medium-skilled workers, Acemoglu and Autor (2011) argue that those workers will increasingly perform the tasks previously assigned to lower-skilled workers, leading to growth of jobs requiring tasks at the top and bottom of the skill distribution. This has been observed in the United States and several other high-income economies (Autor, Katz, and Kearney 2006; Goos and Manning 2007; Goos, Manning, and Salomons 2014). These studies show that for the European Union (EU) and the United States over the 1992–2009 period, occupations requiring either high or low education (such as managers in the former and sales staff in the latter) grew, while occupations with medium education (such as clerks) declined in number.

The automation of medium-skill tasks could be seen as skill-biased technical change, although technologies associated with Industry 4.0 may also increasingly substitute cognitive or nonroutine tasks. It is increasingly the highly skilled workers who will be doing the nonroutine tasks that require more effective judgment and creative thinking. These emerging technologies could require workers with high levels of skill to monitor, maintain, and direct the capital (such as robots). Even in the face of lower net aggregate demand for workers, demand may increase for more educated

**Figure 4.11 Share of Current Jobs at High Risk of Automation Based on Task Automatability, Selected Countries by Income Level, 2009 Onwards**

*Share of workers at high risk of automatability (percent of current jobs)*




*Source:* Ahmed and Chen 2017.
*Note:* "High risk of automatability" means a probability that more than 70 percent of current jobs could be automated based on task automatability. Estimates follow the methodology of Arnzt, Gregory, and Zierahn (2016) using data from the Programme for the International Assessment of Adult Competencies (PIAAC) and the World Bank's Skills Towards Employability and Productivity (STEP) Skills Measurement Program. For countries covered in the PIAAC, data span the period between 2009 and 2016. For countries included in STEP, data correspond to the period 2012–14. LMC = lower-middle-income country. UMC = upper-middle-income country. HIC = high-income country. Income levels follow the World Bank Group's fiscal year 2017 income classifications.

workers. In the classic case of the Tinbergen race between technology and education,[13] as characterized in Acemoglu and Autor (2011), changes in the skill premia, (that is, the wage differential between a skilled and unskilled worker) depend on the differences in the paces of skill-biased technical change and the growth of the supply of skilled labor. If the pace of skill-biased technical change exceeds the pace of skilled labor supply growth, then the skill premia will rise (Ahmed and Chen 2017). What may be new is that new technologies will increasingly be able to also replace cognitive, nonroutine tasks that only people previously could have done (Autor, Levy, and Murnane 2003).[14]

As with the evidence on the number of jobs, automation technologies and shifting globalization patterns show limited polarization of LMIC labor markets so far. Labor force surveys show that middle-skilled occupations that are intensive in routine and manual skills have decreased across many LMICs (World Bank 2016). However, using census data across a range of LMICs, Maloney and Molina (2016) do not find strong evidence for labor market polarization, at least not yet. This may be attributable to a range of factors: In many poorer countries, constraints on technological absorptive capacity, the skill of the workforce, the ability to mobilize resources for large capital investments, and capacity for maintenance may make it less easy to substitute away from labor. Furthermore, the sector of middle-income workers engaged in codified tasks is small, with large shares of the labor force employed in agriculture as well as low-skill services and artisanal production (Falco et al. 2015). Yet, in addition to China robotizing rapidly, there are some early signs (such as the relative decline in the machine operators category in Brazil, Indonesia, and Mexico) of potential polarizing forces (Maloney and Molina 2016). Furthermore, there might be continued downward pressure on unskilled wages in less industrialized countries to remain competitive on Industry 2.0 in the face of technological advances.

Most the of the discussion on the desirability of manufacturing has been on the employment impacts. But if GVCs shorten because of Industry 4.0 technologies, the spillovers and benefits associated with international trade in manufactured goods will likely be affected too. For example, if the use of labor-saving advanced robotics results in reshoring of previously unskilled labor-intensive tasks to high-income economies or enables China to retain low-value-added manufacturing segments, prospects for countries hitherto less involved in GVCs to enter or expand will diminish. This matters because the international fragmentation of production in manufacturing sectors has been associated with faster productivity growth in the past (Constantinescu et al. 2017).

Similarly, 3-D printing may eliminate the need to trade manufactured goods over long distances and thereby shorten supply chains. For example, a Brazilian factory that currently exports printable goods to EU member states could reduce transport costs and potentially avoid liability for tariffs

at the border by using a printing hub within the EU, which would receive the goods previously shipped physically as disembodied data, with printed goods then shipped by road (or drone) to all EU member states. In terms of quantitative magnitude, the overall potential for 3-D printing to disrupt trade flows is substantial, estimated at between 4.6 percent and 14.9 percent of global trade flows (Arvis et al. 2017).

## The Changing Mix of Pro-Development Characteristics across Manufacturing Subsectors

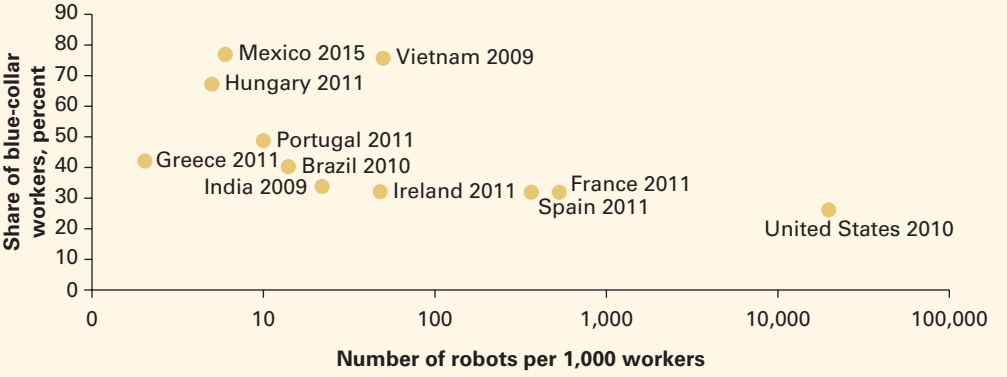
Figure 4.2 illustrated likely shocks that helped identify how feasibility demands across manufacturing subsectors are rising—that is, where international competition is intensifying, where services intensity is high, and where automation may make traditional methods less viable in the future. Table 4.1 linked figure 4.2 to the manufacturing sector typology developed in chapter 1 to show how the combination of pro-development characteristics may regroup subsectors in light of these changing trends.

In particular, the desirability of a manufacturing subsector will be reduced to the extent that automation puts employment, particularly of unskilled workers, at risk and shortens GVCs, thereby diminishing the spillovers associated with trade. Automation and tradedness are highest among the medium- and high-skill innovators, along with manufacturing n.e.c. from the low-skill labor-intensive tradables group. Therefore, these are the manufacturing subsectors where the desired combination of pro-development characteristics might change the most. Textiles and apparel is, then, the only highly traded subsector not expected to have disruption from automation in the near future. Among the less traded processing subgroups, petrochemicals join the other labor-intensive processing industries as facing only some disruption from automation, while rubber, plastics, and fabricated metals are more likely to face disruption.

There are variations across countries in the extent to which manufacturing sectors are automated, but workers employed in routine/manual labor-intensive tasks in lower-income countries are at risk of losing jobs to automation, even if their jobs are currently less automated than in other countries. The manufacture of transportation equipment, which is already relatively the most automated in terms of robot-to-labor ratio in high-income economies such as France and the United States, is less automated in LMICs. As this process of robotization intensifies further, countries such as Hungary, Mexico, and Vietnam risk losing jobs in the manufacture of electronics, computers, and optical equipment, where a high share of blue-collar workers perform routine or manual assembly jobs (figure 4.12). Even in labor-intensive tradable industries such as garments and apparel, which are characterized by negligible robot use at present, there is the potential risk of automation in the future, given that they have the highest shares of blue-collar workers among all manufacturing sectors performing repetitive manual tasks (figure 4.13).

**Figure 4.12 The Manufacture of Electronics, Computers, and Optical Equipment Is Highly Automated in High-Income Countries, but Continues to Employ a High Share of Blue-Collar Workers in Low- and Middle-Income Countries**

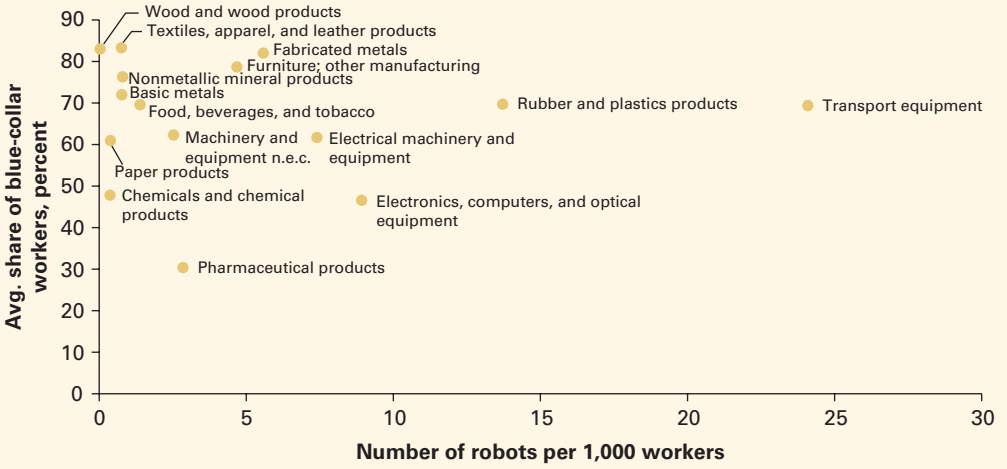
*Shares of blue-collar workers and number of robots used in electronics, computers, and optical equipment manufacturing, selected countries, 2011*




*Source:* Calculations based on International Federation of Robotics (IFR) World Robotics database and University of Minnesota's Integrated Public Use Microdata Series (IPUMS) International database.

**Figure 4.13 Even in Industries Characterized by Negligible Robot Use at Present, There Is the Potential Risk of Automation in the Future, Given Their Shares of Blue-Collar Workers Doing Repetitive Manual Tasks**

*Average shares of blue-collar workers and robots per 1,000 workers, by manufacturing subsector, selected countries, 2011*




*Sources:* Calculations based on International Federation of Robotics (IFR) World Robotics database; and University of Minnesota's Integrated Public Use Microdata Series (IPUMS) International database; and United Nations Industrial Development Organization (UNIDO) Industrial Statistics (INDSTAT) database.
*Note:* Average blue-collar shares per subsector are calculated as follows: (1) Country sector blue-collar share is calculated using census data harmonized by IPUMS International. (2) Take simple average of blue-collar shares across 19 countries for which data are available. The sector aggregation is based on International Standard Industrial Classification (ISIC) rev. 3 two-digit classification. n.e.c. = not elsewhere classified.

## Conclusion

First, despite emerging technologies and changing globalization patterns, some manufacturing industries will remain feasible entry points for less industrialized countries, including some industries that are labor-intensive. They include a range of commodity-based processing manufactures that are less automated, less concentrated in terms of export locations, and less intensive in the use of services than other types of manufactures. Despite a rising bar to be globally competitive, countries with low unit labor costs could also remain cost-effective in the production of labor-intensive tradables such as textiles, garments, and footwear, given the limited automation in that subsector thus far. Further, domestic or regional markets for lower-quality, lower-price manufactures across industries will also likely remain viable.

Second, for manufacturing sectors that are more automated and where trade is more concentrated, although technology may be disruptive, the inability to use it may be even more disruptive. If the new technologies deliver significant efficiency gains and goods are traded, it will be difficult to maintain domestic production using processes that do not take advantage of new technologies. That a country has low ICT use today does not mean its jobs will not be affected; it may mean that even more jobs are not created or even lost. Therefore, firms in less industrialized countries may need to adopt labor-saving technologies that raise efficiency to remain globally competitive.

Third, doomsday scenarios about technological unemployment are overblown because, as in the past, new technologies could also lead to greater job creation. Concerns about the wide-scale displacement of workers by new technologies—an expression referred to as technological unemployment (Acemoglu and Restrepo 2016; Bessen 2016; Mokyr, Vickers, and Ziebarth 2015)—date back as far as the Industrial Revolution. Yet, two centuries of automation and technological progress have not made human labor obsolete. Several explanations offer themselves. The faster growth and job-creating effect of technological change has proven to be greater than any labor displacement effect. Automation of some tasks for some occupations has improved productivity, thereby lowering output prices and boosting product and labor demand (Bessen 2015, 2016). Technological change in the past has also led to the creation of new occupations. These general equilibrium effects, whereby new technologies lead to greater job creation or the creation of new occupations, are not captured by studies that estimate their potential labor displacement effect.

In sum, manufacturing will likely continue to deliver on productivity, scale, trade, and innovation, but just not with the same number of jobs. So its unique desirability in terms of the twin wins of productivity and jobs is eroding. Even as manufacturing may become less labor-intensive, some services are coming to share many of the pro-development characteristics traditionally associated with manufacturing: they are becoming tradable in

addition to being sources of innovation and technology diffusion. These services, too, however, may require more demanding supporting environments and may be skill-intensive. But the services sector will still have desirable qualities across a growing range of activities. Chapter 5 explores this increasingly important role of the service sector in the production process and beyond.

## Notes

1. See chapter 1 for a discussion of the sector typology. The five categories are commodity-based regional processing, capital-intensive regional processing, low-skill labor-intensive tradables, medium-skill global innovators, and high-skill global innovators.
2. The book uses "3-D printing," but the discussion applies to broader forms of additive manufacturing, too.
3. The Herfindahl-Hirschman index is a commonly accepted measure of market concentration based on market share of each firm competing in a market. Here, it is adapted to the share of countries in the total exports of a particular sector or good.
4. Research- and skill-intensive manufactures (such as pharmaceuticals, semiconductors, and microprocessors) with little labor-intensive assembly will likely continue to be located in high-income economies.
5. Present-day feasibility being based on a review of the business and technology literature, as well as consultation with industry groups.
6. Among LMICs, Costa Rica stands out with a large potential impact of 3-D printing, perhaps owing to a well-developed medical equipment sector. The estimated impact is similarly high in the Dominican Republic, which has exports concentrated in products that satisfy the same conditions. In dollar terms, impacts are large in other middle-income exporting countries of manufactured goods, like China, India, and Malaysia.
7. Also in this category, toys are already produced by 3-D printers, given the advantage of size and single raw material requirement.
8. The "flying geese" paradigm is a model for the international division of labor based on dynamic comparative advantage (Akamatsu 1962). As the comparative advantages (on a global scale) of the "lead goose" cause it to shift further and further away from labor-intensive production to more capital-intensive activities, it sheds its low-productivity production to countries further down in the hierarchy in a pattern that then reproduces itself among the countries in the lower tiers.
9. Of all greenfield FDI inflows into the manufacturing sector, labor-intensive tradables attracted a relatively smaller number of projects between 2003 and 2015.
10. These industries (wood products, paper products, basic metals, nonmetallic mineral products, and chemical products) will likely remain everywhere—although some will be able to use newer technologies in smart factories too.

11. The low-end products are typically 40–90 percent cheaper than the premium ones.
12. Frey and Osborne (2013) found that up to 47 percent of current U.S. jobs were at high risk of automation due to emerging technologies, while Bowles (2014) found that the susceptibility to automation in European economies ranged from 45 percent to more than 60 percent in some cases. World Bank (2016) found that two-thirds of current jobs in a sample of low- to middle-income economies could be at high risk of automation.
13. Whereby episodes of inequality increase and subsequent falls repeat themselves with each new wave of technological innovation.
14. In contrast, earlier technologies could only replace workers doing tasks that were routine and could be codified. "Nonroutine cognitive" refers to tasks demanding flexibility, creativity, generalized problem-solving, and complex communications; it includes two-digit Standard Occupational Classification (SOC) occupations 11–29. "Routine manual" refers to tasks that follow precise and well-understood procedures, such as repetitive production and monitoring jobs performed on an assembly line; it includes two-digit SOC occupations 45–49 and 51–53. "Routine cognitive" refers to tasks such as those done by secretaries, bookkeepers, filing clerks, or bank tellers; it includes two-digit SOC occupations 41–43. "Nonroutine manual" refers to tasks that require innate abilities like dexterity, sightedness, and language recognition, and perhaps a modest amount of training; it includes two-digit SOC occupations 31–39.

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CHAPTER 5

# Beyond Production: The Role of Services

## Introduction

The boundaries between the manufacturing and services sectors in the broader production process are becoming increasingly blurred. For example, a consumer in the United States who buys an iPhone shipped from China is purchasing a complex bundle of goods and services, both embodied and embedded. The former includes services like research and design, which are inputs into the production process. The latter includes apps installed on the phone, which the consumer subsequently uses. Hence, manufacturers increasingly use services either for their own production needs (services *embodied* in goods) or for their customers (*embedded* services, such as sales and after-sales services bundled with goods). As a result, services are growing in importance to develop a competitive manufacturing sector—a process expected to intensify given the role that the generation and use of data will play in increasingly interconnected "smart" factories.

Further, the features of manufacturing that were once thought of as uniquely special for productivity growth might be increasingly shared by the services sector. Technologies associated with the information and communication technology (ICT) revolution have meant that several professional services can be internationally traded. At the same time, the deregulation of services markets has coincided with a marked increase in foreign direct investment (FDI) inflows for some services activities. This increased trade and investment integration means that services increasingly yield the benefits of scale, greater competition, and technology diffusion. Innovation has grown rapidly in certain segments of the services sector recently, too. These productivity-enhancing characteristics associated with different service sectors are reflected in those sectors' productivity levels

and contribution to economic growth. This is the good news. However, although the potential for widespread job creation also exists in the services sector, it tends not to be in those services with the greater potential for tradability and innovation.

## The "Servicification" of Manufacturing

*Key message: As services are increasingly embodied and embedded in manufactured goods and constitute a larger source of value in the broader production process, this "servicification" of manufacturing emphasizes growing complementarities and more ways in which the bar for success is rising.*

"Servicification" describes the development whereby manufacturing firms not only buy and produce more services than before but also sell and export more services as integrated activities (National Board of Trade of Sweden 2016). And these services increasingly account for much of the value added in a product's supply chain. The "smile curve"—coined by Stan Shih, Acer's CEO in the early 1990s—alludes to a U-shaped relationship between the stage of production in a supply chain and its contribution to total value added. It suggests that upstream activities such as research and development (R&D) and product design, together with downstream activities such as branding and advertising services, constitute a large share of value added, but the intermediate production stages such as component manufacturing and final assembly do not.

Ali-Yrkkö et al. (2011) produced a detailed breakdown of the value-added contributions of services and manufacturing components for the Nokia N95 phone. The parts (including processors, memories, integrated circuits, displays, and cameras) accounted for 33 percent of the product's value. Assembly accounted for only 2 percent. The remaining two-thirds of the product's value came from Nokia's internal support services (30 percent), licenses (4 percent), distribution (4 percent), retailing (11 percent), and operating profit (16 percent). Low and Pasadilla (2016) take a similar firm-level case study approach to analyze a range of manufacturing value chains around the East Asia and Pacific region. They find that in the Chinese bread value chain, for example, approximately 30 different services categories are involved in production, contributing around 72 percent of the value of the product.

The productivity of services, especially those "embodied" in goods, will be increasingly important for the feasibility of manufacturing-led development. Services are embodied in manufacturing production, either as inputs (such as design, marketing, or distribution costs included in the value of a good) or as enablers for trade to take place (such as logistics services or e-commerce platforms). Globally, more than one-third of the value of gross manufactures' exports come from the value added of embodied services, which increased marginally from 33.9 percent in 1995 to 34.8 percent in

2011, with distribution and business services making the largest contributions. Further, there has been a clear internationalization of services embodied in manufactured exports: the division between sources of services' value added changed from 23.1 percent domestic and 10.8 percent foreign in 1995 to 20.3 percent domestic and 14.5 percent foreign in 2011 (Bamber et al. 2017).

The servicification of manufacturing has gone furthest in the European Union, where embodied services accounted for 40 percent of gross manufactures' exports in 2011. Other regions are around the 30 percent mark, which is still substantial (Bamber et al. 2017).[1] Evidence from the Czech Republic, India, and Sub-Saharan Africa shows that this servicification of manufacturing has improved manufacturing productivity (Arnold et al. 2010; Arnold, Javorcik, and Mattoo 2011; Arnold, Mattoo, and Narciso 2008).[2]

The expansion of "embedded" services in the manufacturing process has further underscored the complementary nature of services in adding value to goods postproduction. These are services that are increasingly bundled with (or added to) manufactured goods. For example, a cell phone is a good, but it is tied to the use of telecommunications services, which allows the user to install apps with purchased content that can give rise to additional service transactions such as audiovisual services (streaming movies or music), publishing (e-books), or computer services (video games).[3] Even traditional consumer durables are increasingly coming with an assortment of after-sales services. Xerox, for example, has restructured itself into a "document solutions" company, offering not only technologically advanced printer systems but also services like document managing and consulting, which represent around 40 percent of Xerox's turnover (Benedettini et al. 2010). Manufacturing firms increasingly bundle advertising, warranties, and after-sales care with physical goods to foster brand loyalty, derive strategic benefits (since a product-service bundle is harder to imitate), and exploit additional sources of revenue (Gebauer et al. 2005).

The servicification of manufacturing is further enabled by using data that will play an increasingly important role in "smart" manufacturing. The Internet of Things, where networks, machines, and computers are connected to the Internet, requires the sending and receiving of data across the entire production chain. ICT services—such as custom computer programming services, software publisher services, telecommunications services, Internet publishing, and data processing services such as cloud computing—produce data for technology-intensive smart factories. At the same time, telecommunications, information services, and publishing services are also the most data-intensive sectors in terms of the use of data. Other services that are strong users of data include office support and business services, computer programming services, engineering services, advanced data analytics, advertising and market research, and R&D services. These services use real-time information through equipment logs, smart meters, or manufacturing sensors to optimize production processes

(Van der Marel 2016; Dijcks 2013; Opresnik and Taisch 2015). ICT service sectors, as the predominant producers and users of data, can therefore play a crucial role in boosting manufacturing competitiveness through the Internet of Things.

Although services are important for a competitive manufacturing sector—given their growing potential to add greater value in the manufacturing process—the ability to use some of the technology and provide this value added is also subject to a rising bar. If smart factories that use sensors and data feedback loops to improve their efficiency are sufficiently able to lower costs or expand output, it is crucial that they also be able to rely on the physical and regulatory infrastructure for ICT systems and dataflow. The potential to capture the value in these services is there, but the reform agenda to meet the needed requirements is demanding, too. To be competitive in sectors or products that will rely on these types of production systems, countries may have to meet this higher bar on services too.

## Prospects for Services-Led Development

*Key message: The pro-development characteristics of being internationally traded and being a source of innovation and technology diffusion are increasingly features of more services, but these services are unlikely to create jobs for unskilled labor, and the absence of a manufacturing base may constrain their development.*

### Services as an Alternative Source of Productivity and Jobs

The features of manufacturing that were once thought of as uniquely special for productivity growth might be increasingly shared by some service sectors, owing to changes in trade and technology, in several ways:

- *International tradability through ICT advances.* Dramatic changes in ICT have given rise to a category of "modern" services—financial, telecommunication, and business services—that can be digitally stored, codified, and more easily traded (Ghani and Kharas 2010). Regulatory barriers continue to inhibit actual trade in these services, although deregulation has coincided with a marked increase in FDI inflows.
- *Increasing benefits of scale.* ICT development also means that scale economies have become important in ICT-enabled service sectors as the marginal cost of providing an additional unit approaches zero. Take the example of data centers and search engines, all of which require high levels of fixed assets[4] and for which costs rapidly decrease with scale (Fontagné, Mohnen, and Wolff 2014).
- *Contribution to technology development.* R&D expenditure in services increased from an annual average of 6.7 percent of total business R&D during 1990–1995 to nearly 17 percent during 2005–10 (WTO 2013).[5]

When innovation is defined to take forms other than R&D,[6] the share of innovating firms is relatively similar across manufacturing and services in most countries (Pires, Sarkar, and Carvalho 2008).

The increasing prevalence of productivity-enhancing characteristics in services, including in low- and middle-income countries, expands the range of activities that will likely have positive spillovers for development. For example, based on World Bank Enterprise Survey data across manufacturing and service industries from a sample of six low- and middle-income countries (LMICs), information technology (IT) services are not very different from the manufacture of electronics, in that both are classified as "high" or "medium" across a range of learning-by-doing and innovation characteristics (box 5.1).

That the expanding opportunities for productivity gains have been realized is reflected in evidence suggesting that knowledge, ICT, and trade-intensive services such as telecommunication, finance, and distribution have recorded higher rates of productivity growth than manufacturing (Jorgenson and Timmer 2011). The services sector has also contributed increasingly to

**Box 5.1 Manufacturing and Services Subsectors across a Range of Pro-Development Characteristics**

A recent study explored the heterogeneity across different manufacturing and service industries with reference to a set of pro-development characteristics:

- *Two characteristics indicative of participation in international trade:* the direct exports-to-sales ratio and the indirect exports-to-sales ratio
- *Three characteristics that proxy for different types of innovation:* the share of firms that introduce new products, use new methods of production, and contribute to R&D spending
- *Three characteristics indicative of learning-by-doing:* the share of large firms (indicating potential for scale economies), the share of firms using a licensed technology from a foreign-owned firm, and the share of firms with formal training programs (indicating on-the-job learning)
- *Three characteristics indicative of the nature of factor use:* capital expenditure per employee (measuring capital intensity), years of schooling (measuring skill intensity), and the (full-time) employment elasticity of output

The statistical analysis is based on latest available World Bank Enterprise Survey for Brazil, China, the Arab Republic of Egypt, India, Nigeria, and the Russian Federation. This sample covers low- and middle-income countries from different regions of the world and provides representative firm-level information at the two-digit ISIC sector level.

For each chosen pro-development characteristic, an industry is classified as "high," "medium," or "low"' based on the aggregation of firm-level data within and across countries. For example, consider the average share of large firms across different industries—"large" firms being defined as those with more than 100 employees. This "average" represents a simple average for the six countries in the sample where the number for each country, in turn, is a simple average of the sampled firms.

*(Box continues on next page)*

**Box 5.1 Manufacturing and Services Subsectors across a Range of Pro-Development Characteristics** *(continued)*

The corresponding Z-scores for the numbers indicate the number of standard deviations away from the mean of a particular value. Hence, a Z-score of –0.72 for construction services implies that the share of large firms is 0.72 standard deviation below the mean. In contrast, a Z-score of 1.20 for textiles and garments implies that the share of large firms is 1.20 standard deviations above the mean. Assuming that the data are normally distributed, around 50 percent of all observations fall within 0.67 standard deviation above or below the mean. This establishes unique threshold points: industries that are more (or less) than 0.67 standard deviation above the mean are classified as "high" (or "low"). The remaining are classified as "medium." The methodology broadly follows Nayyar (2013).

Across the manufacturing and services sectors, industries with greater potential for productivity increases are less likely to create jobs for unskilled labor, and vice versa. Manufacturing industries that are categorized as "medium" or "high" along the dimensions of scale, on-the-job learning, and use of foreign technologies include electronics and communication equipment, machinery and equipment, and motor vehicles. Of these industries, electronics and communication equipment and machinery and equipment are classified as "medium" or "high" not only across the three innovation characteristics but also on skill intensity. IT services are similarly classified as "high" or "medium" on the potential for scale economies and formal worker training programs as well as on all three innovation characteristics, and are "high" with respect to skill intensity. At the same time, resource-based industries such as fabricated metal products, nonmetallic products, and wood products are classified as "low" or "medium" with respect to these innovation measures and skill intensity. Among the service sectors, construction and hotels and restaurants are characterized by "low" skill intensity and "low" scope for learning-by-doing and innovation.

Yet some unskilled-labor-intensive sectors share certain productivity-enhancing characteristics. For instance, basic metals and metal products have a relatively "high" share of large firms, highlighting the scope for scale economies. The sector is also classified as "high" regarding product and process innovation. Food, a major agribusiness industry, and light manufacturing such as garments are also both classified in the "medium" category across a range of pro-development characteristics, including the shares of firms that are large, have formal worker training programs, use foreign technology, and contribute to product and process innovation. Garments and leather products are also "high" in terms of trade in international markets. Among the service industries, wholesale and retail trade is not skill-intensive but is also classified as "medium" with respect to tradability, linkage effects, the use of foreign technology, and on-the-job learning programs.

*Source:* Cruz and Nayyar 2017.

economic growth in the past three decades (Fagerberg and Verspagen 2002), especially during periods of growth acceleration (Timmer and de Vries 2009). Further, there is evidence of unconditional convergence: countries starting from lower labor productivity in the services sector grew faster than those with higher initial labor productivity in that sector (Enache, Ghani, and O'Connell 2016; Kinfemichael and Morshed 2016). This relates to the fact that new ICT technologies, international tradability, and increased competition, especially since the 1990s, were no longer within the exclusive domain of manufacturing.

The reallocation of resources to service industries has thus far been productivity- and growth-enhancing in many LMICs. In Africa, for example, when growth-enhancing structural change kicked in during the 2000s, the bulk of this contribution was accounted for by the movement from agriculture into services (Enache, Ghani, and O'Connell 2016; McMillan, Rodrik, and Sepulveda 2017). And in India, the positive contribution of structural change to economic growth after the 1990s was largely attributable to the expansion of high-productivity service activities: finance, IT, business process outsourcing (BPO), and other business services (McMillan, Rodrik, and Sepulveda 2017). However, large productivity gaps between certain service sectors and agriculture may reflect differences in the stock of physical or human capital that workers were equipped with. And this means little for labor absorption because a farmer cannot be employed as a bank accountant without substantial investment of time and resources. In other words, without sufficient human capital, there are limits to how much labor can be absorbed in highly skill-intensive service sectors.

In fact, most service sectors that exhibit "productivity-enhancing" characteristics are less likely to be associated with large-scale employment creation for unskilled labor. For example, based on World Bank Enterprise Survey data across the manufacturing and service sectors from a sample of six LMICs (see box 5.1), IT services are classified as "high" or "medium" across a range of learning-by-doing characteristics such as potential for scale economies and formal worker training programs; exports;[7] and innovation as measured by new products, new processes, and R&D spending. At the same time, they also belong to the group that is "high" in skill intensity. Similarly, communication services are classified as "medium" or "high" regarding not only (indirect) international trade, the use of foreign technology, and on-the-job learning programs, but also skill intensity (table 5.1).

At the same time, services that will create jobs for unskilled labor are less likely to provide much by way of productivity gains. Services such as construction and hotels and restaurants are characterized by "low" skill intensity but also by "low" or "medium" productivity-enhancing traits: formal worker training programs, use of foreign technology, exports (direct and indirect), introduction of new products and new processes, and R&D spending (table 5.1).

There is also the issue of the *quality* of employment among lower-end service activities, which are the large employment creators for unskilled labor. Using data from India, Nayyar (2011) finds that similar workers earn less in wholesale and retail trade, hotels and restaurants, transport services, and community and personal services than in manufacturing. Similarly, in the United States, a Brookings report shows that lower-wage workers in manufacturing earn about 11 percent more than their peers in other sectors, while high-wage workers earn just 4 percent more (Helper, Krueger, and

**Table 5.1 There Is a Trade-Off between Productivity-Enhancing Characteristics and Jobs for Unskilled Labor in the Services Sector**
*Pro-development characteristics across manufacturing and services sectors, selected low- and middle-income countries, circa 2014*

| | Learning-by-doing | | | Trade | | Innovation | | | Factor use | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector | Share of large firms (more than 100 employees) | Share of firms with formal training programs | Share of firms that used a licensed technology from a foreign-owned firm | Exports-to-sales ratio | Indirect exports-to-sales ratio | Share of firms that introduced new products | Share of firms that introduced new methods | Share of firms that incurred R&D spending | Capital expenditure per employee | Years of schooling | (Full-time) employment elasticity of output |
| Electronics and communications equipment | Medium to high | | | Medium | | Medium to high | | | Medium | | |
| Machinery and equipment | | | | | | | | | | | |
| Motor vehicles | | | | | | | | | | | |
| ***IT and IT services*** | ***Medium*** | | | ***Medium to high*** | | ***Medium to high*** | | | ***High*** | | |
| Transport, *Storage, and Communications*[a] | | | | | | | | | | | |
| Leather products | Low to medium | | | Medium to high | | Medium | | | Low to medium | | |
| Garments and textiles | | | | | | | | | | | |
| Basic metals and metal products | Medium | | | Medium | | Medium to high | | | Medium to high | | |
| Plastics and rubber | | | | | | | | | | | |

*(Table continues on next page)*

**Table 5.1 There Is a Trade-Off between Productivity-Enhancing Characteristics and Jobs for Unskilled Labor in the Services Sector** *(continued)*

| | Learning-by-doing | | | Trade | | Innovation | | | Factor use | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sector | Share of large firms (more than 100 employees) | Share of firms with formal training programs | Share of firms that used a licensed technology from a foreign-owned firm | Exports-to-sales ratio | Indirect exports-to-sales ratio | Share of firms that introduced new products | Share of firms that introduced new methods | Share of firms that incurred R&D spending | Capital expenditure per employee | Years of schooling | (Full-time) employment elasticity of output |
| Chemical products | | | | | | | | | | | |
| Fabricated metal products | Low to medium | | | Medium | | Low to medium | | | Low to Medium | | |
| Nonmetallic mineral products | | | | | | | | | | | |
| Wood products | | | | | | | | | | | |
| Food | | | | | | | | | | | |
| ***Construction*** | ***Low to medium*** | | | ***Low*** | | ***Low to medium*** | | | ***Low*** | | |
| ***Hotels and restaurants*** | | | | | | | | | | | |
| ***Wholesale and retail*** | ***Medium*** | | | ***Medium*** | | ***Medium*** | | | ***Medium*** | | |

*Source:* Cruz and Nayyar 2017.
*Note:* The analysis is based on latest available World Bank Enterprise Survey for six low- to middle- income countries from different regions: Brazil, China, the Arab Republic of Egypt, India, Nigeria, and the Russian Federation. For each group of pro-development characteristics, each industry is classified as "high," "medium," or "low"' based on the aggregation of firm-level data within and across countries. Assuming normal data distribution (around 50 percent of all observations falling within 0.67 standard deviations above or below the mean), observations that are more than 0.67 standard deviations above the mean are classified as "high"; less than 0.67 SD as "low"; and the remaining as "medium." Manufacturing sector rows are set in roman type, services sector rows in italics and boldface. IT = information technology. R&D = research and development.
a. "Transport, storage, and communications" comprises highly heterogeneous economic activities and therefore the classifications for this aggregate grouping might conceal more than they reveal.

Wial 2012). Much of this likely relates to the distinction between formal manufacturing activity and informal services where firms in the former offer a wage premium owing to efficiency wages or institutional factors such as such minimum wages, labor codes, and union bargaining (Söderbom and Teal 2004; Verhoogen 2008). However, recent experimental evidence from Ethiopia indicates that not all manufacturing jobs are better than self-employment in services or agriculture: in the studied factories, there is no evidence of an industrial wage premium, and there are significant concerns about worker health and the safety of working conditions (Blattman and Dercon 2016).

Among service sectors, tourism and retail trade are perhaps exceptions in that they are both traded and create jobs for unskilled labor. The exercise, based on Enterprise Survey data across the manufacturing and service sectors from a sample of six LMICs (box 5.1), shows that wholesale and retail trade is not skill-intensive but is also classified as "medium" in tradability, linkage effects, use of foreign technology, and on-the-job learning programs. Similarly, many low-income countries have used tourism services to help diversify their exports away from volatile primary sectors. In Uganda, for instance, services account for just over half of total exports, with 45 percent of that figure made up of tourism.[8] Furthermore, technology has the potential to transform some low-productivity services such as construction and tourism services (for example, through e-commerce platforms) as it allows services to be produced and traded just like goods and hence generate greater employment opportunities.

Although the use of automation technologies in the services sector is currently negligible, especially relative to manufacturing,[9] the creation of jobs for both unskilled and skilled workers in the services sector might also be disrupted by new technologies, particularly augmented reality (AR). AR refers to a live direct or indirect view of a physical real-world environment whose elements are augmented by computer-generated sensory input that make sound, video, and graphics look more like reality. Combined augmented reality and intelligence (A-RI) systems can significantly reduce the costs of moving ideas and people across the world (box 5.2). These technologies could reshape the how and where services are "produced." This has important policy implications because as new technologies reduce labor demand in agriculture and manufacturing, services activities may become the last resort of labor demand. Yet, despite the rapid progress in the past decade, the expansion of these systems will require large investments in infrastructure to become widely adopted.

### Service-Led Development without a Manufacturing Base

Whether services "need" a manufacturing core to develop depends on the extent to which they are either embodied or embedded in goods. Several services—such as design, marketing, and distribution—are vital inputs into the production of manufactured goods. Others, such as logistics services

### Box 5.2 Will Augmented Reality and Intelligence Systems Increase Automation in the Services Sector?

Augmented reality and intelligence (A-RI) systems can dramatically reduce the costs of "moving people" and make services more tradable and scalable. Although merchandise transportation costs and communication costs have substantially declined with the Industry 3.0 revolution, the costs of face-to-face interactions remain high. Meeting in person is costly not only because of transportation costs but also because it can require substantial commuting time, which translates into high opportunity cost. When thinking about communication across countries, language barriers are also relevant. Both transportation and opportunity costs can be dramatically reduced by the emerging technologies of augmented reality (AR) and artificial intelligence (AI). The expansion of these technologies would facilitate the possibility of trading and reaching larger scale of services related to business consultancy, education, health, and entertainment, among others.

A-RI systems are already present. Several software programs are already available from leading IT firms (such as Google, Cisco, and Apple) that enable high-quality simultaneous translation, combined with high-quality images and sounds. AR has been already applied in several areas, including education, games, industrial design, the health industry, military activities, and transportation. Capabilities currently classified as AI include successful understanding of human speech (for example, Apple and Google apps that interact with users); high-level competition in strategic game systems (including chess and Go); autonomous cars (for example, in Uber driverless cars); intelligent routing in content delivery networks; military simulations; and interpretation of complex data. An example of the remarkable advances of AI happened in 2016 when a computer program beat a top-notch professional Go player without handicaps, in what is considered one of the most complex strategic games.

Yet, A-RI systems have a long way to go before they become a globally adopted technology that revolutionizes manufacturing and services. Several limitations must be overcome:

- The advances in A-RI will require an immense and robust interconnection of networks and the interdependence of new systems and technologies.
- The best architecture is a local "cloud" that is less than 100 kilometers from an access node (Weldon 2016)—a limitation imposed by the physics of propagation and the speed of light.
- Despite some of these technologies being already available, access to A-RI systems is unevenly distributed and still incipient (*Economist* 2017).
- Although the diffusion of new technologies is happening much faster than older ones, their adoption across firms and individuals within LMICs (the penetration rate) remains low (Comin and Mestieri 2013).

Therefore, there are still some limits on how much A-RI systems can disrupt manufacturing and services by 2030, but governments should start preparing for how these systems may lead to what Baldwin (2016) calls "globalization's third unbundling."

*Sources:* Baldwin 2016; Comin and Mestieri 2013; *Economist* 2017; Weldon 2017.

and e-commerce platforms, enable trade to take place. Hence, to the extent that services are embodied in manufacturing, there will likely be a symbiotic relationship between the two sectors.

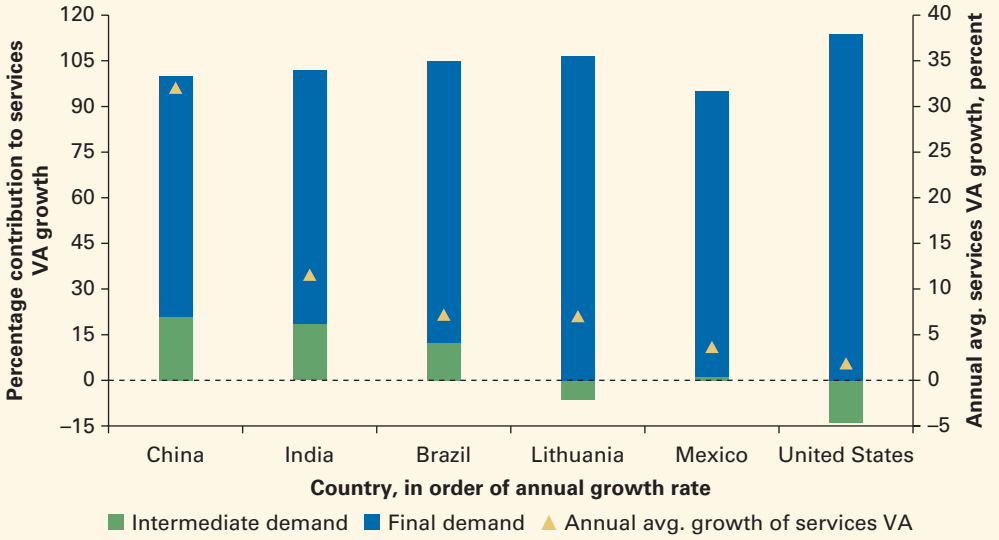
The same may hold true for how embedded services are added to another good and often bundled together in a single product—including apps

for personal electronic devices, after-sales maintenance services for consumer durables, or "smart" solutions for "smart" factories. There is the possibility for certain embedded services to develop without firms being involved in the complementary manufacturing process. A range of "stand-alone" services also are directly consumed by final consumers or may be embodied in other services—professional, scientific, and technical services, for example. Some service industries—such as health, education, and tourism—are entirely stand-alone. Others—such as transportation, retail trade, professional services, financial services, and telecommunication services—serve consumers directly but are also linked to manufacturing activity.

The increasing servicification of manufacturing underscores the growing interdependence of the two sectors and therefore may limit the extent to which services can grow independent of a manufacturing core. For example, in China and India, which experienced high rates of growth in services value added between 2000 and 2014, net intermediate demand from other sectors accounted for only about 20 percent of this growth in both countries (figure 5.1). Of this, net demand from manufacturing accounted for about 8 percent and 14 percent in China and India, respectively. But this is *net* intermediate demand, which captures both use of services input in manufacturing

**Figure 5.1 Net Intermediate Demand from Other Sectors Accounted for a Fraction of Annual Growth in Services Value Added between 2000 and 2014**

*Contribution of net intermediate and final demand to growth in services value added, selected countries, 2000–14*



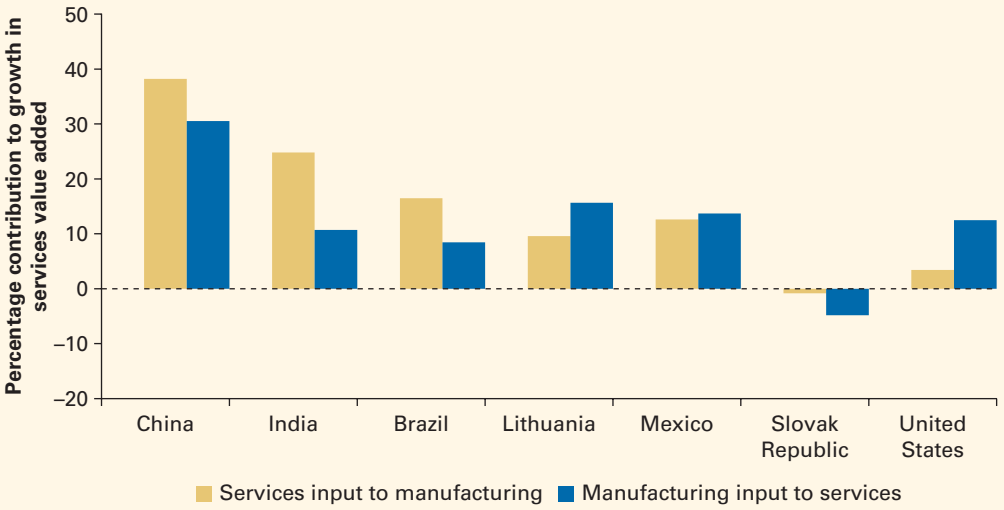

*Source:* Cruz and Nayyar 2017.
*Note:* VA = value added. Net "intermediate demand" refers to the purchases and sales of inputs from other sectors. "Final demand" refers to the purchases of services by the final users.

and input from manufacturing into services. In China, for example, services input into manufacturing accounted for 38 percent of the annual average growth in services value added between 2000 and 2014, while manufacturing input into services accounted for 30 percent (figure 5.2). This reflects the symbiotic relationship between the two sectors, as manifested by a range of services that are either embodied or embedded in manufactured goods.

Yet, some services cater to final demand and can therefore create development opportunities independent of a country's manufacturing base. Several "stand-alone" services (in which the transaction takes place directly between a service provider and the final consumer) include tourism, health care, BPO, and other professional services. Numerous LMICs have sought to diversify their export baskets through offshore professional services. Many countries began with BPO services, such as contact and call centers, which laid the foundation for higher-value services such as finance and accounting. India was at the forefront of diversifying into these operations Nayyar (2012), where exports account for about two-thirds of the value-added growth in professional services (figure 5.3). Other countries that have successfully entered the market are Costa Rica and the Philippines (boxes 5.3 and 5.4). Medical tourism is also on the rise, including in Sub-Saharan African countries, where many hospitals are treating foreign

**Figure 5.2 Net Intermediate Demand from the Manufacturing Sector Accounted for a Fraction of Annual Growth in Services Value Added between 2000 and 2014, but This Hides the Fact That These Sectors Buy and Sell from Each Other**

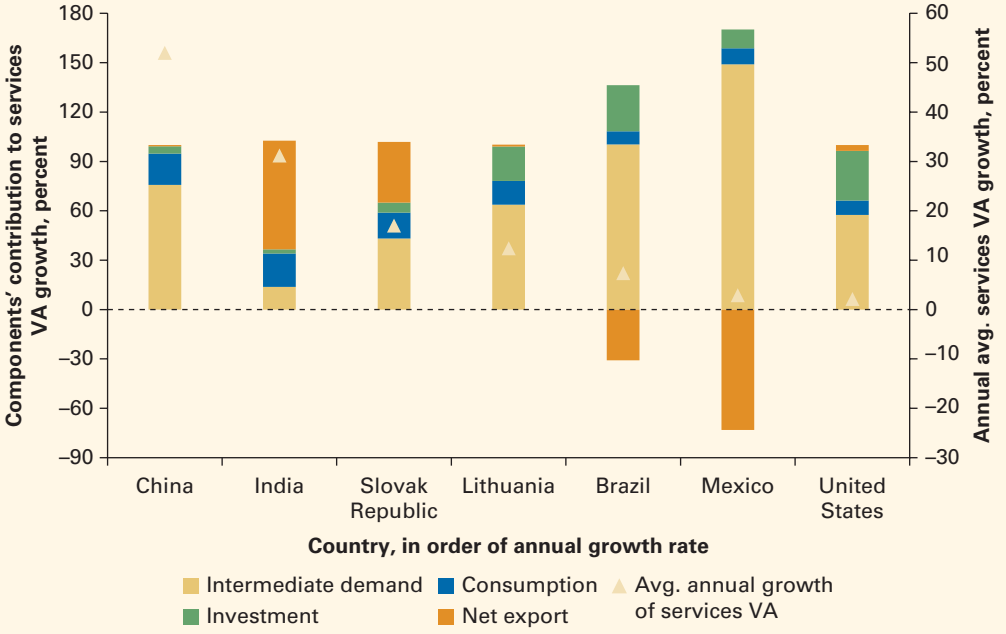
*Contribution of intermediate demand from manufacturing to services and vice versa to growth in services value added, selected countries, 2000–14*




*Source:* Cruz and Nayyar 2017.
*Note:* "Net intermediate demand" captures both services input into manufacturing and manufacturing input into services.

**Figure 5.3 The (Real) Value Added Growth in Professional Services between 2000 and 2014 Was Driven by Final Demand in Some Countries, but Was More Closely Associated with Intersectoral Links in Other Countries**

*Decomposition of value added growth in professional and technical services, selected countries, 2000–14*




*Source:* Cruz and Nayyar 2017.
*Note:* Growth rates for China and India are enormous and reflect that the size of the professional services sector in 2000 was small, whereas the reverse was true for the United States. "Intermediate demand" refers to the purchase and sale of inputs from other sectors, as opposed to "final demand," which refers to the purchases of services by the final users. VA = value added.

patients (Dihel and Goswami 2016). These experiences speak to the potential for services to contribute to growth and job creation independent of a country's manufacturing base (boxes 5.3 and 5.4).

A range of services embedded in goods also deserve emphasis because they may provide growth opportunities in LMICs independent of a manufacturing base. In fact, the development of content that tailors global business and technology solutions to local needs is essential to penetrate a market in these services, which provides an advantage to domestic firms. Take the example of mobile phone applications where local language and cultural considerations have to be taken into account in the design and marketing of the apps. Adequate technological solutions also need to be adapted. In areas with low communication coverage, for example, lower-technology solutions need to be designed—for example, by using narrowband instead of broadband, mobile money instead of bank transfers, and so on.

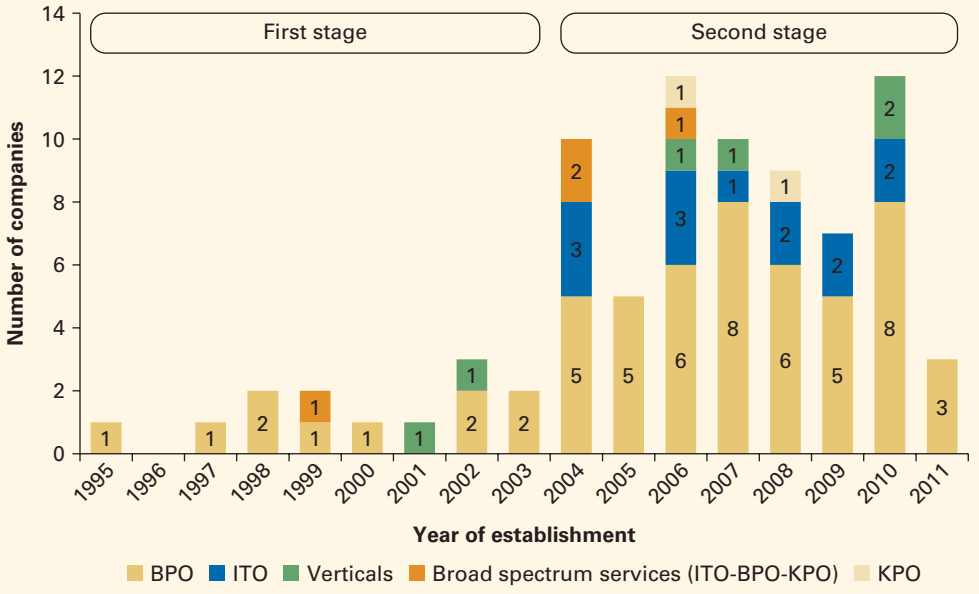
### Box 5.3 Costa Rica in the Offshore Services Global Value Chain: Opportunities for Upgrading

Costa Rica is a pioneer in attracting offshore services to Latin America. Since the mid-1990s the country has been a preferred location for multinational corporations (MNCs) looking to reduce costs and take advantage of the country's unique combination of benefits, including its proximity to the U.S. central time zone, its largely bilingual population, and its relatively safe and stable security environment. These MNCs have set up both captive centers and third-party service providers in Costa Rica, with the latter allowing companies to use the country as a platform to export competitively priced services.

This "first mover" strategy produced excellent results. In 2005, 33 MNCs in Costa Rica employed 10,802 people and exported around US$387 million in services. These figures had tripled by 2011, when close to 100 offshore-services MNCs operating in the country, employing 33,170 workers and exporting US$1,390 million (CINDE 2012). Most of the offshore services operations that exist today in the country were established between 2004 and 2011, and more than 50 percent of these operations were concentrated in the BPO segment (figure B5.3.1).

Competition, however, has grown considerably over the past decade as a plethora of new countries have begun vying for the opportunity to participate in the global services sector. In Latin America alone, most governments are actively recruiting offshore services providers to set up operations in their countries. These governments hope to attract offshore-services MNCs by offering inexpensive

**Figure B5.3.1 Number of Offshore Services Companies in Costa Rica, by Year of Establishment and Segment of Value Chain, 1995–2011**




*Source:* Fernandez-Stark, Bamber, and Gereffi 2013.
*Note:* "First stage" refers to 1995 to 2003. "Second stage" refers to 2004 to 2011. BPO = business process outsourcing. ITO = information technology outsourcing. KPO = knowledge process outsourcing.

*(Box continues on next page)*

### Box 5.3 Costa Rica in the Offshore Services Global Value Chain: Opportunities for Upgrading *(continued)*

educated labor, and good telecommunications infrastructure. As more countries enter the industry, it is more difficult to compete based on costs, especially for small nations with limited labor pools such as Costa Rica.

Costa Rica has attracted some of the top companies in the offshore services industry to establish operations within the country, and the MNC representatives reported satisfaction with the quality of labor provided by Costa Rican employees. The country has a positive track record for cultivating quality. Although certain segments of the Costa Rican offshore services value chain are coming under pressure, the evolution of the global offshore services industry since its inception has created important new opportunities that Costa Rica can leverage.

*Source:* Fernandez-Stark, Bamber, and Gereffi 2013.

### Box 5.4 The Philippines in the Offshore Services Industry

The services sector in the Philippines has been dominated by the emergence of a strong call-center base. Among the first firms to set up operations in the country were U.S.-owned AOL and Sykes, both in 1997. The country's cultural affinity with the United States rapidly gave it a competitive edge over India's call centers. The resulting growth was explosive. In 2004, the sector employed approximately 100,000 people, generating US$1.4 billion in exports (Kleibert 2015). By 2014, the offshore services sector had more than 1 million employees, with an estimated US$18 billion in exports, which is 20 percent of the Philippines' total exports. This also made the BPO sector the second largest contributor to the Philippines' foreign-exchange earnings (after remittances) (Santos 2014).

Early on, the country's participation was predominantly in voice-based call center operations. These cover a wide range of tasks such as negotiating credit card repayments, troubleshooting, and booking flights and hotel room services, among others. At the turn of the century, the country began upgrading into nonvoice procedures including email, chat, and even social-media branding as well as captive operations for finance and accounting and human resources. J. P. Morgan, Citibank, Deutsche Bank, HSBC, Wells Fargo, and Bank of America are among the firms with fully owned back offices in the Philippines (Kleibert 2015). In the late 2000s and early 2010s, service exports also began in the medical transcription sector and in gaming and animation. These higher-value services require more trained personnel, but they yield higher revenue per employee (Fernandez-Stark, Bamber, and Gereffi 2011). Nonetheless, call centers and back-office services still accounted for 66 percent of BPO exports in 2012 (Kleibert 2015).

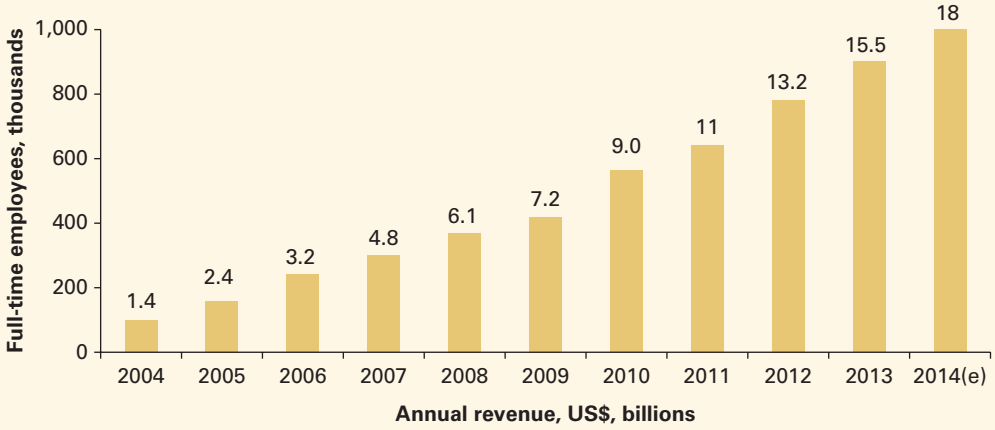
The success of the Philippines as a strong competitor in the BPO industry is mostly attributed to its large English-speaking youth population.[a] Call centers draw on previously marginalized labor markets (youth and female labor pools), hiring many young workers with high school diplomas and in some cases basic tertiary education. Firms are typically very large; for example, Accenture's operations employ 45,000 people, making it one of the largest employers in the country. Even the back-office finance and accounting services operations can have up to 12,000 full-time employees each.

*(Box continues on next page)*

**Box 5.4 The Philippines in the Offshore Services Industry** *(continued)*

The large labor force of the Philippines allows it to host big operations and to easily reduce costs for more transactional activities by developing cities beyond metropolitan areas to host offshore services operations. Furthermore, call center agents earn a good salary by average standards in the Philippines.

**Figure B5.4.1 Employment and Revenue in the Offshore Services, Philippines, 2004–14**




*Source:* Kleibert 2015.
*Note:* e = Estimated.

*Sources:* Bamber et al. 2016; Fernandez-Stark, Bamber, and Gereffi 2011.
a. A liberalized telecommunications sector, which drastically reduced costs in the 1990s, combined with effective export processing zones with strong incentives, also helped to drive competitiveness in the sector (Kleibert 2015).

This market for apps development and start-ups is booming everywhere, including in Africa, which has seen several incubators and accelerators emerge and support the development of local technological solutions and start-ups. FinTechs, AgTechs, e-health, and distance learning are just some of the areas where the digital revolution is taking place and is showing the potential of embedded services for economic growth and development (Bamber et al. 2017).

## Conclusion

The features of manufacturing once thought to be uniquely special for productivity growth are increasingly shared by some service sectors that are internationally tradable through ICT advances, yield the benefits of scale, and contribute to technology development. Yet, without sufficient human

capital, there are limits to how much labor can be absorbed in these productivity-enhancing service sectors—finance, information technology, accounting, and legal services—which are also highly skill-intensive.

On the flip side, low-end services that will create jobs for unskilled labor are less likely to provide much by way of productivity gains. Therefore, a given service subsector is unlikely to provide opportunities for productivity growth and job creation for unskilled people simultaneously. However, there is the possibility for technology to enable low-productivity services such as construction and tourism services to be internationally traded while continuing to generate greater employment opportunities for unskilled labor.

Further, while a range of "stand-alone" services and some embedded services can provide growth opportunities without a manufacturing core, the increasing servicification of manufacturing underscores the growing interdependence between the two sectors. Given this deepening interdependence, policies that improve productivity across different parts of the value chain will result in the whole being greater than the sum of its parts. The agenda therefore should be to prepare countries to use synergies across sectors to participate in the entire value chain of a product while also exploiting stand-alone opportunities beyond manufacturing.

## Notes

1. These estimates of embodied services value added in the export of manufactured goods are based on input-output tables and therefore only capture services provision related to an economic transaction outside the boundaries of the firm. In practice, many firms provide some services in-house too.
2. There is similarly scope for the greater use of services, such as engineering and marketing, to improve the efficiency of agricultural production. In Australia, for example, agricultural exports are nearly one-third embodied services. By contrast, in Thailand, the services value added is only around 17 percent of gross exports of agricultural products (Bamber et al. 2017).
3. The streaming of audiovisual content on a television or mobile device illustrates the growing value in embedded services. The digital market for music, either downloaded and listened to offline or streamed, has also been undergoing strong growth, with revenue close to US$6 billion in 2016 (Bamber et al. 2017).
4. The fixed assets include server farms, cooling systems, secure sites, and so on.
5. This increased expenditure may reflect growing R&D investments in certain services sectors, the outsourcing of R&D to specialized laboratories that are classified as being in the services sector, and better measurement of R&D in services (Lopez-Bassols and Millot 2013).

6. Innovation apart from R&D might include marketing and organizational innovation, for example.
7. When looking at linkage effects in terms of indirect exports (that is, those embodied in manufactured goods' exports), IT services are classified in the "high" category.
8. A key issue is the development of domestic value chains based around these activities (hotel chains in tourism can develop strong backward linkages with other suppling sectors in goods as well as services), such as the supply of cleaning products and towels, as well as food and beverages.
9. Calculations based on 2015 Industrial Robots Statistics, International Federation of Robotics (IFR).

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PART III

# PREPARING FOR CHANGE: REFOCUSING THE MANUFACTURING-LED DEVELOPMENT AGENDA TO ENABLE NEW OPPORTUNITIES

*Part III calls for a shift in development strategy on two dimensions. The first is to balance the need to address the potential disruptions with preparing conditions to enable workers and firms to pursue new opportunities. The disruptive impact of shifting technologies and patterns of globalization will be greatly ameliorated by the extent to which new businesses, jobs, and markets can be developed. The second dimension is to shift the focus from "production" to the broader "manufacturing process," which expands the sources of productivity and job opportunities. The policy agenda to support this overall shift in strategy in turn has three dimensions—competition, capabilities, and connectedness (3Cs)—that need to be reformulated to incorporate appropriate responses to the coming changes.*

*Many items of this policy agenda are not new, but several are taking on new urgency in light of heightened global competition. And some of the changing competitive conditions provide new considerations about how to evaluate the potential benefits and risks of targeted approaches as well as the ways horizontal and targeted approaches can complement each other to support the development of the 3Cs. A typology of countries along the 3Cs—including the match between current production patterns and the types of shocks different manufacturing subsectors are expected to face—can help policy makers to prioritize the needed reforms.*

CHAPTER 6

# Policy Recommendations for Manufacturing-Led Development in the Future

## Introduction

Change is coming, bringing with it uncertainty and likely disruptions in manufacturing-led development strategies. Much of the media attention is on the downside risks associated with new technologies and changing globalization patterns. Countries do need to address the costs of change. However, they also need to better position themselves to take advantage of opportunities. Therefore, the overall impact of change depends critically on what countries can do to enable their firms (including new ones) to add value and create jobs in the new and evolving environment. Building on the issues raised in part II, this chapter identifies policy priorities and discusses the broader implications of changing technology and globalization patterns for development strategies in the future.

As heightened global competition raises the bar for what it takes to succeed in export-led manufacturing, the feasibility agenda is at the heart of expanding the set of available opportunities. The broad challenges in this feasibility agenda can be represented by competitiveness, capabilities, and connectedness (3Cs)—each with a twist to address new dimensions. *Competitiveness* addresses the shift from low wages to broader considerations of the business environment in determining low unit labor costs. *Capabilities* address the need for workers and firms to strengthen their ability to adopt and use new technologies—and the additional regulations and policies needed to support this. *Connectedness* highlights not only shifts in the trade agenda, but also the growing synergies across sectors to achieve success in manufacturing. The twist is that these traditional dimensions of reform need to be reconceptualized, both to highlight those traditional dimensions where reforms have become more urgent and to capture new dimensions of the reforms in line with the coming demands of heightened international competition.

The 3Cs create a country typology to help tailor recommendations to different contexts—but the typology also needs to be matched with the types of changes countries are likely to face. As chapter 4 discussed, new technologies will have differential impacts across manufacturing subsectors. Some may become more demanding of capabilities (for example, transportation equipment, electrical machinery, and medical equipment) while others may not, at least not in the near future (for example, garments). Some may show increased needs for connectivity (such as manufacturing not elsewhere classified [n.e.c.]) while others may not (such as food processing, wood products, or nonmetallic mineral processing). If countries are producing products, or aiming to enter new sectors, where the demands are increasing in a "C" that they are not strong in, that should be a signal of where reform priorities lie. So, in describing the more detailed recommendations within each "C," distinctions are made by country, indicating likely priorities.

Beyond the specifics of *what* to do, there are still strategic questions on *how* to strengthen competitiveness, capabilities, and connectedness, including through targeted policies. The focus is on what is new in the debate over horizontal and targeted approaches, including whether it will be possible to leapfrog and use new technologies with a limited manufacturing base. On the one hand, it may be more feasible to meet the more challenging requirements on the 3Cs through targeting locations and sectors rather than providing needed reforms, programs, and infrastructure to a country as a whole. On the other hand, placing bets on a specific sector is fraught with risk, given the uncertain nature of technological change. Similarly, when choosing specific locations for developing production activity, establishing linkages will be more important than in the past, given the premium on technology diffusion.

As countries tackle the feasibility agenda, the merit of sector-specific approaches must also be assessed on the shifting relative desirability of sectors. The increasing interdependence between sectors also means that attempts to support production activities in isolation from complementary services are unlikely to be successful. While any strategy faces uncertainty, when raising productivity across sectors, the whole might be greater than the sum of its parts.

## A Country Typology: Competitiveness, Capabilities, and Connectedness (3Cs)—with a Twist

*Key message: Countries need to position themselves to maximize emerging opportunities in the manufacturing sector with a reform agenda that strengthens competitiveness, capabilities, and connectedness.*

As part II laid out, the feasibility and desirability of manufacturing are shifting in the face of a changing external environment and new technologies that shift the basis of comparative advantage. The framework developed

here focuses on three dimensions of how to tackle the new challenges of being an attractive location for production.

First, the importance of low wages in determining low unit labor costs is increasingly giving way to more demanding ecosystem requirements. Established manufacturing centers can advance faster, given the advent of labor-saving technologies and strong firm ecosystems comprising high-quality infrastructure and other backbone services, skilled labor pools, regulatory frameworks and contract enforcement mechanisms, and high-density supplier bases. "Catch-up" for countries hitherto less involved in global manufacturing on this agenda, while not new, will therefore acquire greater urgency than before to counter possible agglomeration effects that may make production more concentrated. This urgency places a premium on the first pillar of the policy agenda: the *competitiveness* of the business environment.

Second, if low- and middle-income countries need to adopt new technologies to remain or become competitive, it is critical to expand their absorptive capacity. Knowing that a new technology exists, or even buying a license to use it, is not sufficient to be able to use it in practice or to apply it to a product that is successfully taken to market. These capabilities require the right sets of skills for managers and workers in firms. They also require the necessary infrastructure and regulatory frameworks to be in place to support the use of new technologies. For example, if a country does not certify certain standards or support data flows in ways that will be recognized by trading partners or others in the value chain, either the technology cannot be used or its benefits cannot be realized. These needs underlie a second pillar of the policy agenda: building the *capabilities* of workers, firms, and countries to adopt new technologies.

Third, new connections between firms, growing demands for customization and to get goods to market quickly, and the increasing role of embodied and embedded services ("servicification") in manufactured goods put more emphasis on access to markets. To maintain or expand such access requires continuing to support trade in goods through tariff reductions, low nontariff barriers (NTBs), and efficient logistics. The servicification of manufacturing also calls for greater emphasis on reducing restrictions in services, particularly trade restrictions, which tend to be much higher in services than goods. Further, as more machines become connected to the Internet, both during the production process and postproduction, new rules on international data flows become an important complement to the traditional rules for flows in goods. In sum, these trade and related behind-the-border regulatory reforms support the third pillar of the policy agenda: *connectedness* to input and output markets.

Taking the three pillars of the policy agenda together, it is possible to map out how countries currently compare—with each other and against the standards that are likely to be needed to attract production in the future. The resulting typology, based on the 3Cs, highlights how relative reform priorities may vary across countries.

## Where Countries Stand in the 3Cs Space

To illustrate how countries perform across the 3Cs typology, each of the 3Cs is described by a summary measure that aggregates relevant indicators. These indicators were selected to highlight a mix of policy areas that are either expected to have greater urgency going forward or represent a new set of issues that need to be addressed.[1]

**Competitiveness.** A country's competitiveness combines the dimensions of the ease of doing business, the rule of law, and the use of mobile technologies to complete financial transactions. The World Bank's *Doing Business* "distance to frontier" score measures the adaptability and strength of the business environment.[2] The rule of law highlights the growing importance of contracting and intellectual property rights in the diffusion of new technologies.[3] Finally, the availability of mobile finance is indicative of the country's ability to support embedded services in goods as well as to include some of the embodied services that are increasingly going to be traded through information and communication technology (ICT).[4]

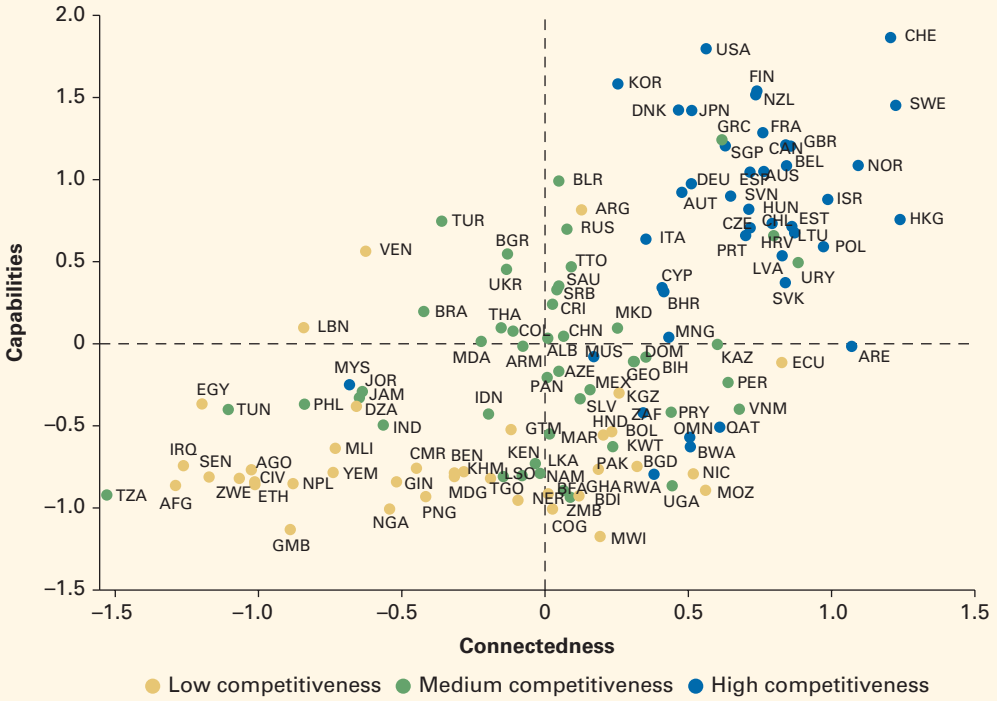
**Capabilities.** A country's capabilities to support technology diffusion and innovation combine the dimensions of ICT use, tertiary school enrollment rates, and the share of royalty payments and receipts in trade. First, because ICT is the basis for many of the new technologies (from advanced robotics and Internet of Things [IoT] to 3-D printing), the extent of ICT use is critical.[5] Second, tertiary school enrollment rates capture the skill potential of the workforce. It is not that all skills will need tertiary education, but this variable better differentiates across countries than secondary enrollment rates, and there will be an increased need for some skilled workers to support less skilled production jobs. Finally, the use of royalty payments captures the extent to which the firms in a country are accessing technology. For many of the high-income countries, the relevant measure is royalty receipts, because they are key sources for generating technology. This measure indicates the arm's-length use of technology, but does not capture the intrafirm transfer of technology among multinational corporations (MNCs) and their affiliates.

**Connectedness.** A country's connectedness to markets combines the dimensions of logistics performance, restrictions on trade in manufactured goods, and restrictions on trade in professional services. The logistics performance captures how well a country can move goods around. Already an important component of goods trade, logistics performance will be all the more important in complex connected supply chains or if demand rises for customization and quick delivery times. The extent of import restrictions on manufactured goods trade is also a natural measure of connectedness. The added inclusion of trade restrictions on professional services underscores the importance of access to quality professional and technical services to the success of manufacturing production itself.

This variation in the 3Cs across countries today is striking and brings out patterns across the three dimensions, including several complementarities.

In figure 6.1, the axes represent the summary measures of countries' capabilities and connectedness, while the colors of country markers indicate competitiveness. For each summary measure, the relevant indicators are converted to z-scores to normalize their scales and are then averaged. On the capabilities and connectedness indexes, countries are categorized as "high" or "low" based on the median z-score value. On the competitiveness index, countries as categorized as "high," "medium," or "low" (shown by the color shading of the markers) based on partitioning the data into terciles.

**Figure 6.1 Country Distribution in Space of Competitiveness, Capabilities, and Connectedness, Circa 2012–14**




*Sources:* Calculations based on Kee, Nicita, and Olarreaga 2009; International Telecommunications Union's ICT Indicators Database; and the following World Bank databases: World Development Indicators, Worldwide Governance Indicators, Global Findex, Logistics Performance Index, and Services Trade Restrictiveness Index.
*Note:* Country data are for the 2012–14 period or the latest available year. Each of the 3Cs is described by a summary measure that aggregates relevant indicators. "Competitiveness" consists of the ease of doing business, the rule of law, and the use of mobile technologies to complete financial transactions. "Capabilities" comprises information and communication technology (ICT) use, tertiary school enrollment rates, and the share of royalty payments and receipts in trade. "Connectedness" combines the dimensions of logistics performance, restrictions on trade in manufactured goods, and the restrictions on trade in professional services. Countries are categorized on the "capabilities" and "connectedness" indexes based on their median z-score value. They are categorized as high, medium, or low in competitiveness based on partitioning the z-scores into terciles. Note that Ireland and the Netherlands, because of tax treatments, have extreme values on the royalty payments (further boosting the "capabilities" measure) and thus are not shown as outliers in the upper right quadrant.

Those countries in the upper-right quadrant have greater capabilities to support technology diffusion and innovation as well as better connectedness to trade and complementary services, while those in the upper left are neither as technology- nor trade-ready. The competitiveness index (supporting business environment) also has clear patterns in moving from lower left to upper right: there is only one "light blue" country (lowest tercile in competitiveness) in the upper-right (high capabilities and high connectedness) quadrant. The countries ranking highly on each of the 3Cs are largely high-income countries, which are likely to be better placed to address the higher requirements that changes in technology, trade, and increased servicification may bring. On the flip side, only one country in the lower-left (low capabilities and low connectedness) quadrant is also marked in dark blue (top tercile in competitiveness). Therefore, for most of those in the bottom-left quadrant, which comprises low- and middle-income countries, the rising bar will be particularly challenging.

Relatively few countries occupy the upper-left quadrant: those high in capabilities but low in connectedness. These largely include upper-middle-income countries in Latin America and Eastern Europe and Central Asia. Many more countries occupy the lower-right quadrant—those low in capabilities, but high in connectedness—and they span many regions of the world, including Sub-Saharan Africa and South Asia. Further, competitiveness is more closely associated with capabilities than with connectedness. Only three countries in the bottom tercile of competitiveness are also above average on capabilities. At the same time, countries across the competitiveness spectrum are above average on connectedness. This suggests that many countries are well connected to international markets despite lacking the complementary policies that establish a competitive business environment.

## How Subsector Variation in the Impact of Technology and Globalization Affects Countries' Priorities for the 3Cs

The relevance of countries' performance on the 3Cs also needs to be matched with how demands for them are changing based on countries' production patterns and the differential impact of technology across sectors. Chapter 4 described three sets of trends that affect the feasibility of being competitive in different manufacturing subsectors:

- *Magnitude of automation:* changes in the use of labor-saving technologies, with the emphasis on sectors where the introduction of robots, 3-D printers, or smart factories would raise the need for capabilities to adopt new technologies[6]
- *Export concentration:* the level of concentration in global trade, whereby some subsectors may be harder to enter or expand in because of large-scale economies or ecosystems operating in those subsectors
- *Services intensity:* the rise of professional or technical services as a needed complement to the success of manufacturing

Yet a fourth dimension that serves as a filter on some of these other trends is *tradedness*: the extent to which subsectors are internationally traded. If they are traded, the demands on competitiveness are rising, whether a country tries to adopt new technologies or simply to remain viable using traditional technologies. On the other hand, if a sector trades very little, that international trade is concentrated may have less impact on competitiveness (for example, in nonmetallic minerals). Depending on the combination of trends a sector is expected to face, the demands across the 3Cs will vary. Thus, countries, depending on *what* they make, will then also face pressures to reform across different policy areas to maintain their current comparative advantages.

Table 6.1 links these sets of trends to what they are likely to imply for priorities in the 3Cs agenda. The trends do not map one-for-one to each of the 3Cs, but there are some associations. The closest association is between the adoption of new technologies and "capabilities." However, if countries can compete using traditional technologies, they may not need to have the same "capabilities," but they would need to be that much stronger in "competitiveness" to be viable (at least in the short to medium terms). International concentration in trade is associated with rising demands on both "connectedness" and "competitiveness," if the sector is one characterized by international trade. Thus, in the case of nonmetallic minerals, although its trade is concentrated among few countries, it is the least traded of all the sectors, and thus is not exposed to significant globalization trends. The last trend is services intensity, which is most closely tied with "competitiveness"—the ability to have the complementary elements of professional services in the ecosystem for manufacturing to take place successfully. To the extent that these services can be traded, services intensity could also be linked to "connectedness," particularly if services are embodied in a widely traded good.

Categorizing the impacts of the trends as "high" or "low," table 6.1 illustrates various combinations of the trends to develop scenarios, with the last column providing examples of sectors expected to be facing one of five scenarios (each of which is further described below).

Countries' current position in the 3Cs space may or may not be compatible with the magnitude of automation technologies, trade concentration, and services intensity that already characterize manufactured goods in their current export basket. Figure 6.2 repeats figure 6.1, but now only includes countries which have a revealed comparative advantage (RCA) in the group of subsectors relevant to each one of five scenarios (panels a–e). Further, the country markers are coded by shape to indicate either (a) countries whose 3Cs are already well suited to the expected levels needed by the subsectors in which they have an RCA (shown as circles); or (b) countries at some risk of displacement (shown as crosses, or "Xs"). In the latter group, subsectors where countries have an RCA are expected to require higher competitiveness, capabilities, or connectedness—or any combination thereof—than these countries currently demonstrate.

**Table 6.1 Impact of Automation, Trade Concentration, and Services intensity on Feasibility of Manufacturing Subsectors and on 3C Agenda Priorities**

| | Extent of impacts of new technology and globalization | | | | Priorities within 3Cs agenda | | | |
|---|---|---|---|---|---|---|---|---|
| Scenario[a] | Increasing concentration of international production | Traded | Use of robots or 3-D printers | Use of Services | Competitiveness | Capabilities | Connectedness | Subsectors likely to be in this scenario[b] |
| 1 | High | High | High | High | Yes | Yes[c] | Yes | Transportation; electronics; pharmaceuticals; electrical machinery |
| | High | High | High | Low[e] | | | | Machinery and equipment; manufacturing n.e.c. |
| 2 | High | High | Low | Low | Yes | .. | Yes | Textiles, garments, and leather products |
| 3 | Low | Rising | High | Low | .. | Yes[d] | .. | Rubber and plastics; fabricated metals |
| 4 | Low | Low | Low | High | Yes | .. | .. | Food processing; chemicals; coke and refined petroleum |
| 5 | Low | Low | Low | Low | .. | .. | .. | Wood products; paper products; basic metals |
| | High | Low[f] | Low | Low | .. | .. | .. | Nonmetallic minerals |

*Note:* 3Cs = competitiveness, capabilities, and connectedness. Shading of rows (from dark to light) designates the breadth of agenda items that would likely need to be addressed. n.e.c. = not elsewhere classified. "Competitiveness" consists of the ease of doing business, the rule of law, and the use of mobile technologies to complete financial transactions. "Capabilities" comprises information and communication technology (ICT) use, tertiary school enrollment rates, and the share of royalty payments and receipts in trade. "Connectedness" combines the dimensions of logistics performance, restrictions on trade in manufactured goods, and the restrictions on trade in professional services.

a. "Scenario 1" refers to high trade concentration—highly automated. "Scenario 2" refers to high trade concentration—not very automated. "Scenario 3" refers to low trade concentration—highly automated. "Scenario 4" refers to low trade concentration-not very automated—services intensive. "Scenario 5" refers to low trade concentration—not very automated.

c. If adopting new technology, capabilities must be high; if instead competing using older technologies, capabilities need not be as high, but competitiveness must be that much higher.

d. If competing using traditional technologies, high competitiveness will be needed.

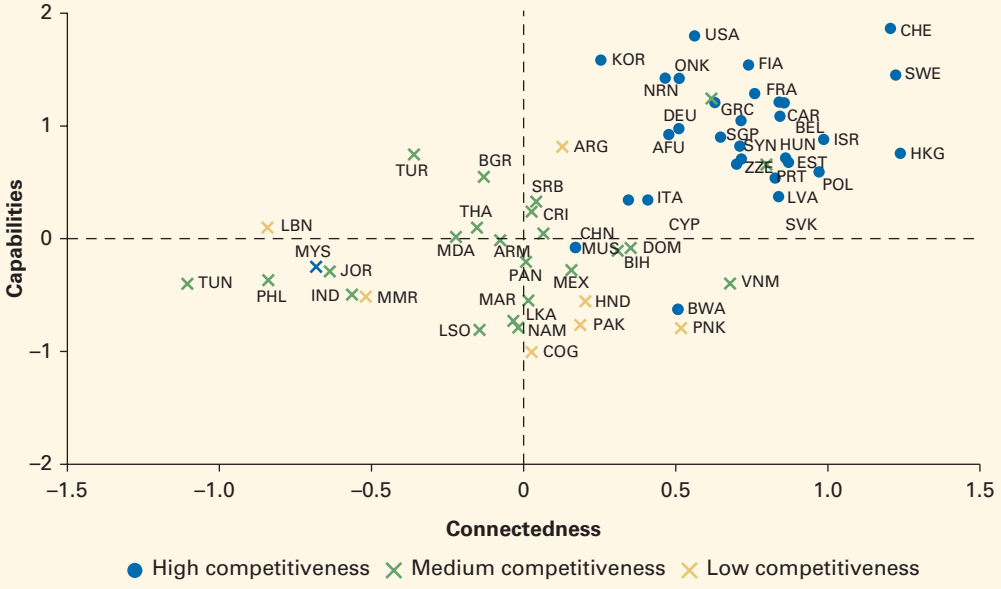
e. Although the need for services is lower, these subsectors' openness to trade and concentration in trade makes competitiveness important.

f. Although the trade concentration is higher, nonmetallic mineral products is the least traded subsector. At most, competition issues are raised.

**Figure 6.2 How Well Do the Technology, Trade and Servicification Requirements of the Manufacturing Subsectors in Which Countries Have RCAs Match These Countries' Readiness in Capabilities, Connectedness and Competitiveness?**

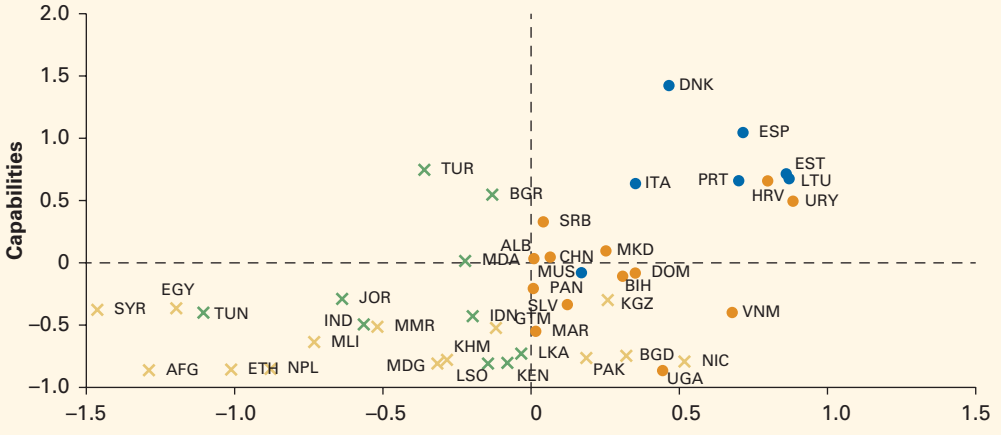
*Country distribution in competitiveness, capabilities, and connectedness, by manufacturing subsector scenario, circa 2012–14*

**a. Scenario 1: All 3Cs needed (transport equipment, electronics, pharmaceutical, electrical machinery, machinery and equipment n.e.c., and manufacturing n.e.c.)**




● High competitiveness ✕ Medium competitiveness ✕ Low competitiveness

**b. Scenario 2: Higher competitiveness and high connectedness needed (textiles, apparel, and leather products)**

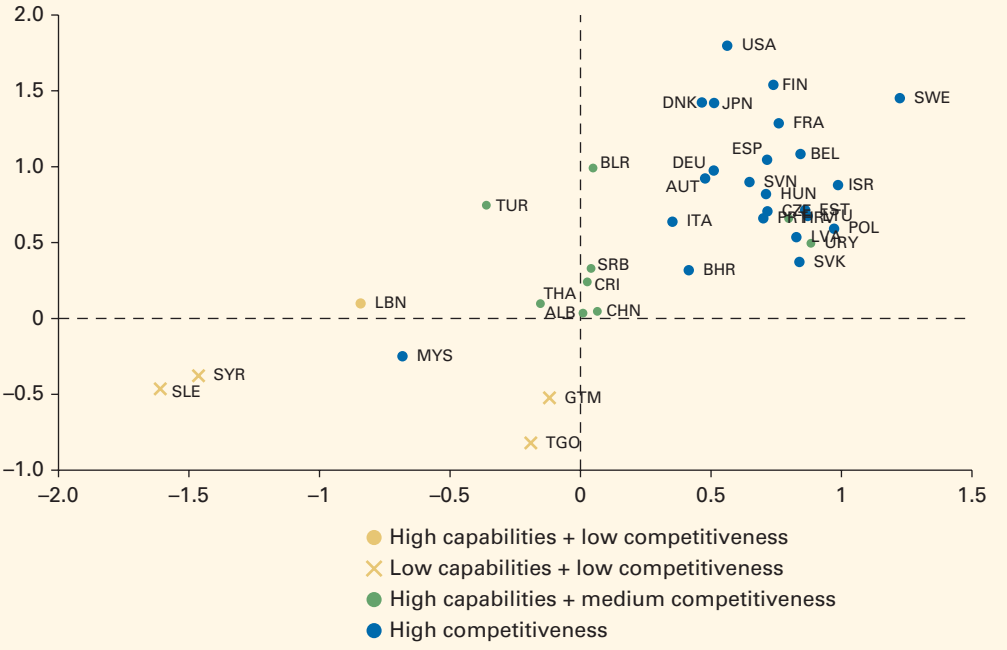



● High competitiveness + High connectedness
● Medium competitiveness + High connectedness
✕ Medium competitiveness + Low connectedness
✕ Low competitiveness

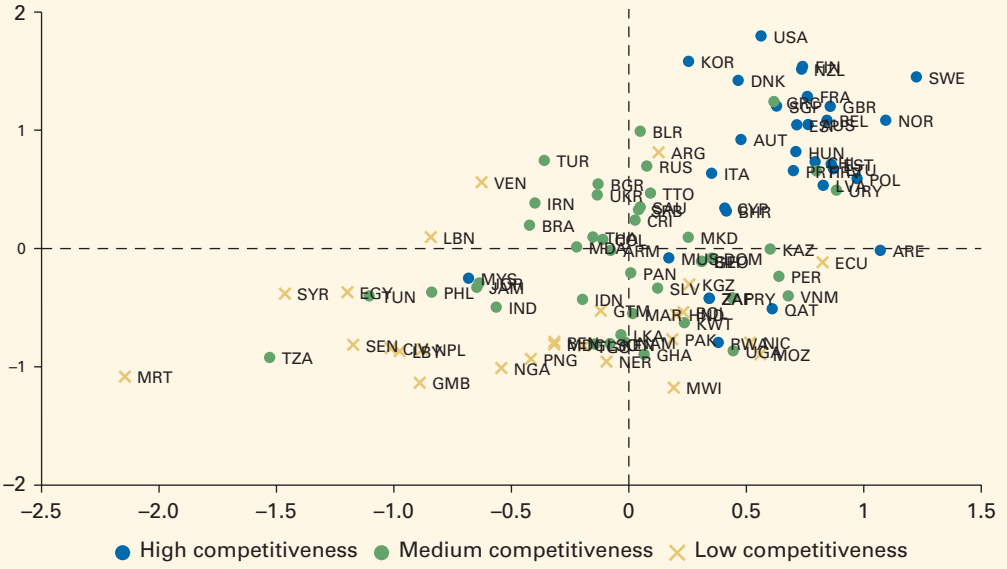
*(Figure continues on next page)*

**Figure 6.2 How Well Do the Technology, Trade and Servicification Requirements of the Manufacturing Subsectors in Which Countries Have RCAs Match These Countries' Readiness in Capabilities, Connectedness and Competitiveness?** *(continued)*

**c. Scenario 3: High capabilities needed (rubber and plastics, fabricated metals)**



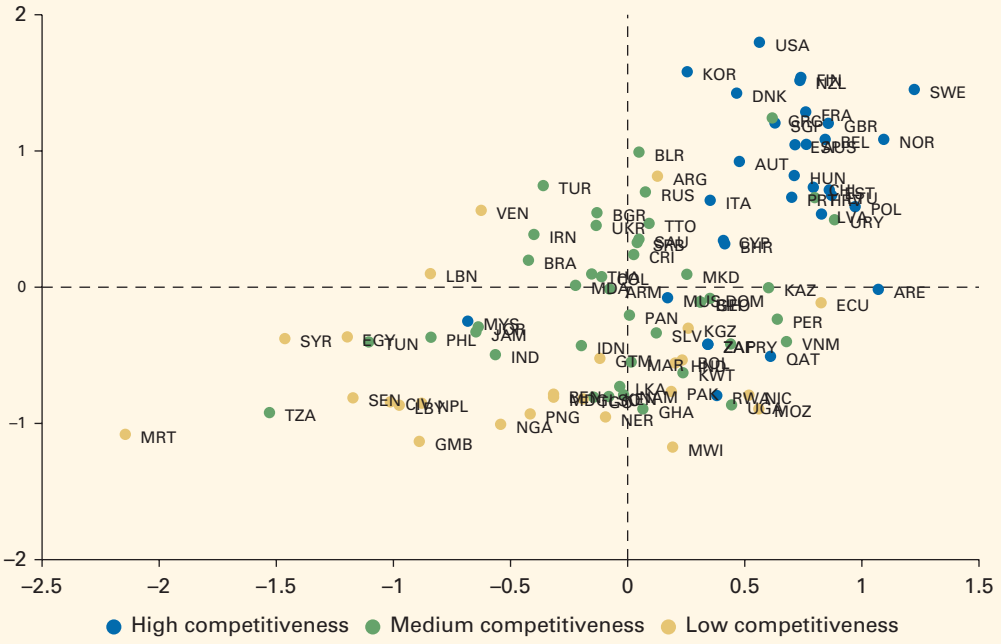

**d. Scenario 4: Higher competitiveness needed (food and beverages, coke and refined petroleum)**




*(Figure continues on next page)*

**Figure 6.2 How Well Do the Technology, Trade and Servicification Requirements of the Manufacturing Subsectors in Which Countries Have RCAs Match These Countries' Readiness in Capabilities, Connectedness and Competitiveness?** *(continued)*

**e. Scenario 5: No significant change anticipated (wood, paper, basic metals, nonmetallic mineral products)**




*Sources:* Calculations based on Kee, Nicita, and Olarreaga 2009; International Telecommunications Union's ICT Indicators Database; and the following World Bank databases: World Development Indicators, Worldwide Governance Indicators, Global Findex, Logistics Performance Index, and Services Trade Restrictiveness Index.
*Note:* Figure displays the countries that have an revealed comparative advantage (RCA) in at least one of the manufacturing subsectors indicated in the respective panel subtitle. Countries designated by circles are those whose 3Cs already meet the expected needs of the subsectors in which they have an RCA. Countries designated by crosses (Xs) are those at risk of displacement in the subsectors in which they have an RCA. Panel legends further indicate distinctions of circles and crosses by color, based on their categorization as high, medium, or low across a combination of the 3Cs. "Competitiveness" consists of the ease of doing business, the rule of law, and the use of mobile technologies to complete financial transactions. "Capabilities" comprises information and communication technology (ICT) use, tertiary school enrollment rates, and the share of royalty payments and receipts in trade. "Connectedness" combines the dimensions of logistics performance, restrictions on trade in manufactured goods, and the restrictions on trade in professional services. Countries are categorized on the "capabilities" and "connectedness" indexes based on their median z-score value. They are categorized as high, medium, or low in competitiveness based on partitioning the z-scores into terciles. Note that Ireland and the Netherlands, because of tax treatments, have extreme values on the royalty payments (further boosting the "capabilities" measure) and thus are not shown as outliers in the upper right quadrant.

In the panels of figure 6.2, the crosses highlight the country-subsector pairs that could be at risk in the future.

**Scenario 1: All 3Cs needed.** Given high trade concentration, exposure to new technology, and services intensity, a strong performance on each of the 3Cs is needed (for example, in transport equipment, electronics, and pharmaceuticals). Some subsectors (such as electrical machinery, machinery and equipment n.e.c., and other manufacturing n.e.c.) do not have the same

high association with services, but because they are traded and export concentration is high, the need for competitiveness in the business environment is likely to be high over time as well. Thus, all countries with an RCA in any of the six sectors where the reform agenda comprises each of the 3Cs will be charted in the 3Cs space—and given an "X" if they are not strong on all three 3Cs (figure 6.2, panel a). By construction, those not in the upper-right quadrant will be shown as an "X," as will those in the upper-right quadrant that are not blue (high in competitiveness). Mostly high-income countries are thus well placed to produce in these sectors and to have the ability to do so using the new process technologies.

However, some countries not in this quadrant that currently have an RCA in one or more of these subsectors—Mexico and Vietnam, for example—are marked with "Xs," reflecting the need for these countries to address the capabilities gaps (although the gap is not too large) if they want to use more of the new processes or combine high connectedness with high competitiveness (in the top tercile, as indicated by blue) to make competing while using traditional technologies viable (at least in the short to medium runs). For India, which is in the lower-left quadrant with a green cross (indicating low connectedness and capabilities and medium competitiveness), reforms would be needed on two of three dimensions to maintain its RCAs in these high trade concentration—highly automated manufacturing subsectors.

**Scenario 2: Higher competitiveness and high connectedness needed.** Given high trade concentration but no exposure to new technology (for example, in textiles and garments), these are subsectors where connectedness is needed and at least some competitiveness. Those countries on the left side of the x-axis have low connectedness in this subsector, and so all are shown as "Xs" (figure 6.2, panel b). In addition, among those on the right side of the x-axis *and* with low competitiveness (in the lowest tercile, as indicated by a yellow "X"), such as Bangladesh and Pakistan, the competition from trade means that low wages are not sufficient and more needs to be done to improve the competitive environment. Although this is a low-skill and labor-intensive subsector, it is still demanding to enter, given the demands on connectedness and competitiveness.

**Scenario 3: High capabilities needed.** These are subsectors exposed to new technologies but not highly concentrated in terms of international trade (for example, rubber and plastics, and fabricated metals). Countries with an RCA in these subsectors are shown as "Xs" if they are neither strong in capabilities nor highly competitive (which could make competing while using traditional technologies viable) (figure 6.2, panel c). However, under this scenario, there are relatively few "Xs" because few countries with low capabilities have an RCA in these subsectors. Malaysia is the one exception: despite being low on capabilities, it is not an "X" because it has high competitiveness.

**Scenario 4: Higher competitiveness needed.** These are subsectors not exposed to high trade concentration or new technology, but are relatively

services-intensive (food, chemicals, and coke and petroleum products). Therefore, under this scenario, only the dimensions of competitiveness need to be medium or high. Regardless of the quadrant in terms of capabilities and connectedness, only those countries with low competitiveness (yellow) are marked as "Xs." Given the number of countries in food processing, there are many that do register as an "X."

**Scenario 5: No significant change anticipated.** These are subsectors with no exposure to trade concentration or technology and that are low in use of services—or do have international concentration but are very low in trade (for example, wood products, paper products, basic metals, and nonmetallic minerals). Hereunder this scenario, what it takes for production to be feasible is not likely to change in the short run. In figure 6.2, panel e, all countries are marked as circles; given how many countries have RCAs in these sectors, this is a more encouraging result.

It is worth noting that these five scenarios are developed for countries that have an RCA in these subsector groups. The exercise will be just as meaningful for countries that currently do not have such RCAs and will follow the thought experiment described in table 6.1, depending on where they are situated in the 3Cs space.

However, there are three caveats to keep in mind in interpreting how much countries are at risk if current export baskets are incompatible with their performance on the 3Cs:

- First, the mapping of expected changes to these 3Cs is not exact. For example, that a sector is expected to use more advanced processes does not necessarily mean countries must be in the top half of the capabilities distribution to be successful in the sector (the threshold could be lower—or higher).
- Second, the chart uses quadrant boundaries as cutoffs; many countries are close to the middle and so not far from being above the threshold. Looking where they lie on the continuum is what is important in the end. For example, Mexico is close to being in the upper-right quadrant, which would then match its RCAs in the electronics and transport equipment subsectors.
- Third, that the country has RCAs in certain subsectors that do not match their performance on the 3Cs perhaps reflects the country's ability to develop solutions in particular subsectors and locations, even if not on average across the country. This may be particularly true in large countries where aggregate numbers conceal pockets of particular skills, international connectedness through foreign direct investment (FDI), or subnational locations with stronger regulatory frameworks. There can even be private solutions to areas in which the country as a whole is not strong, for example, firms in locations where skills are weak can provide in-house training programs.

Therefore, the aim of figure 6.2 is to indicate where reform priorities are likely to lie under each of the five scenarios. And, in general, matching countries'

RCAs with their levels of competitiveness, capabilities, and connectedness will be important to ensure that spillovers are captured and development is inclusive.

## How to Strengthen the 3Cs: Policy Recommendations

*Key message: Business environment reforms will acquire greater urgency in the competitiveness agenda to reduce unit labor costs, while regulations will need to adjust to new business forms. Policies to enable technology adoption in manufacturing production processes, through strengthening skills, management capabilities, and innovation infrastructure, will need emphasis. New technologies do not make basic principles of trade cooperation old, yet certain aspects of the trade reform agenda will become even more pressing, and new rules will need to underpin new forms of trade enabled by technological advance.*

Where countries lie in the 3Cs space highlights relative priorities for reforms—and can guide some of the sequencing of priorities within the dimension(s) that a country currently needs to strengthen. The policy priorities will vary by combination of the 3Cs, and if countries want to move into a new quadrant of figure 6.2, an expanded set of policies will be needed to make that transition (table 6.2).

Countries in the low-connectedness, low-capabilities quadrant likely still have key fundamentals to improve, with the urgency rising to address them. For those in, or aiming to be in, the high-connectedness, high-capabilities quadrant, the agenda is that much more demanding. Countries that need to improve more on one dimension can emphasize the agenda for that "C." And countries whose current exports are in sectors likely to demand greater connectivity or capabilities (as shown by the "Xs" in the panels of figure 6.2) can also identify the agenda items most relevant for them. On many of the agenda items, countries can undertake reforms on their own. On others, including standards, dataflow, and trade issues, collective engagement is needed.

The distribution of countries across different indicators within the summary measure for each of the 3Cs provides more nuance on possible reform priorities. Each of the 3Cs is represented by a summary measure (described earlier), but an analysis of how countries perform across the different constituent indicators can illuminate specific policy challenges in a country. For example, India is a country where significant restrictions on services trade lower its connectedness measure (see appendix A.

This section turns to each of the 3Cs in more detail, differentiating the appropriate sequencing across the 3Cs country typology. The focus is on what is new in the agenda or what needs to be given priority in the face of expected changes rather than exhaustively covering all the issues in supporting private sector development more broadly.

**Table 6.2 New Technologies Shift the Policy Areas to Prioritize—With Sequencing Appropriate to a Country's Current Position**

*Policy priorities to strengthen manufacturing-led development, by country's level of competitiveness, capabilities, and connectedness*

| Dimension | Priorities for countries currently "lower" on this dimension | Priorities for countries currently, or aiming soon to be, "higher" on this dimension |
|---|---|---|
| Competitiveness | Strengthen the business environment<br>Promote flexible labor markets<br>Liberalize backbone services critical to supporting manufacturing | Facilitate firm entry and exit, and the reallocation of capital and workers; improve bankruptcy procedures and universal coverage of social protection to facilitate worker mobility and to lower costs of disruption |
| | *Develop mobile finance to facilitate use of embodied and embedded services* | *Set competition policy framework for network platforms; adjust regulations for new business forms*<br>*Facilitate contracting, to enable greater use of sharing economy on production side* |
| Capabilities | Prioritize literacy, numeracy, basic ICT, and socioeconomic skills, but also invest in the development of advanced skills for people with access to higher education | *Develop programs to strengthen more-advanced skills, creativity* |
| | Improve basic management skills and processes | *Emphasize the use of data and data processes within production* |
| | Develop certification of quality standards | *Support the development of a data ecosystem (access to ICT, policies on localization, network security, IPR)* |
| Connectedness | Reduce restrictions on trade in goods, particularly inputs (lower tariffs and NTBs, support trade facilitation) | Further facilitate trade in services, including removing restrictions on FDI |
| | Strengthen basic logistics | *Support IoT logistics systems*<br>*Develop regulatory frameworks to support cross-border data flow* |

*Note:* Traditional agenda items of rising urgency are set in roman. Items that relate more specifically to new technologies are set in italics within blue shading. ICT = information and communication technology. IoT = Internet of Things. IPR = intellectual property rights. FDI = foreign direct investment. NTB = nontariff barriers.

## Reform Priorities for Competitiveness

### Business Environment Reforms

As China's wages rise, manufacturers will increasingly look to other offshore locations for low-cost manufacturing tasks; for example, wage costs in Vietnam are typically less than half of China's, while those in Ethiopia are only a quarter of China's and half of Vietnam's (Dinh et al. 2012; Standard Chartered Global Research 2016). However, given that new technologies are making labor a smaller share of overall costs, this places a greater premium on the business environment agenda, including regulations, access to

finance, basic infrastructure, quality control mechanisms, and tax regimes. Many low-income economies fare poorly on these different metrics, and the resulting lack of scale and time-to-market advantages required for offshore production activity erode their competitiveness. Therefore, there is a greater urgency for priorities within the business environment agenda that remain foundational for countries hitherto less involved in export-led manufacturing.

For countries that are already more connected to global value chains (GVCs) or have significant manufacturing activity, the agenda broadens to put more emphasis on resource reallocation and firm adaptability as competition from abroad intensifies. The time and cost of opening a business can affect entrepreneurship and the ability of firms to respond to emerging opportunities in new industries. Similarly, effective bankruptcy regimes that facilitate exit affect how quickly resources trapped in unviable firms can be reallocated to more efficient uses. The extent to which tax, credit market, labor market, and other regulations that affect day-to-day business operations are evenly applied also matters for allocative efficiency (Hseih and Klenow 2009; Bartelsman, Haltiwanger, and Scarpetta 2013 ).[7] A predictable and transparent business environment also reduces the costs associated with discovery (Andrews and Cingano 2014; Baker, Bloom, and Davis 2015; Bartelsman, Haltiwanger, and Scarpetta 2010), although the appropriateness of this agenda is likely narrow, as emphasized in the "capabilities" discussion.

An important corollary to facilitating the adjustment of firms and resources is supporting workers during employment transitions. As discussed in chapters 3 and 4, most new technologies are expected to be labor-saving. Workers will be displaced and may need assistance in moving to new opportunities, such as through training (discussed in more detail under "Reform Priorities for Capabilities" below) as well as the reform of social protection systems to better reflect changes in the nature of work. In many countries, social protection is tied to employment status. But as the gig economy expands and more work becomes governed by short-term contracts, this shift can reduce not only the number of people covered but also the mobility of workers with coverage who fear losing access to their benefits (World Bank 2016).

### Competition Policy Reforms

Many service sectors and utilities needed to support manufacturing—telecommunication and ICT, transportation, power, and water—are monopolies or oligopolies, either public or private. In many countries, regulations in the trucking industry, for example, are notorious for stifling competition and raising costs, often while raising the rents paid to politically connected owners. Deregulation in key services markets has had tangible impacts on manufacturing activity in the past. Take the example of India, where the productivity of downstream manufacturing firms increased following the liberalization of telecommunication and transport services in the

1990s (Arnold and others 2016). Regulatory reforms in many of these services, such as telecommunications, will also be needed to enable greater participation in the digital economy. Therefore, improving the efficiency of services embodied in manufacturing will be central in countries with weaker competitiveness frameworks. Again, the agenda is not a new one, but the urgency in addressing it is rising.

Competition in other important input markets also assumes greater urgency because it supports backward and forward linkages in the value chain of manufactures. Reforms that boost competition in input markets have spillovers on downstream manufacturing firms. In many low- and middle-income countries (LMICs), markets for key inputs such as fertilizer and cement are often saddled with entry barriers and anticompetitive behavior. In Honduras, for example, competition policy reform (which eliminated discretionary procedures and reduced the registration time from three years to 90 days) promoted the entry of new firms and products in commodity-based manufactures such as fertilizers and pesticides (World Bank 2014).

Among countries with stronger competitiveness frameworks, new technologies raise new issues around competition policy. The rapid pace of technological change means that firms, rather than governments, are often taking the lead in driving the standards agenda. For example, private industry groups were responsible for developing the information and communications standards for Wi-Fi that eventually became de facto international standards. Today, drones and automobiles equipped with sensor technology are being tested and marketed before the development of international standards and national regulations. Where rival companies are developing differing standards and technical norms, the stakes are high in terms of opportunities for export-led manufacturing. And where large MNCs are involved, much of the oversight will likely remain in high-income countries (box 6.1). There are also concerns that some larger emerging markets might seek to set their own standards as the required ones—using access to their markets to leverage compliance from would-be exporters.

### Reforms to Support New Business Models

New technologies can improve access to financial services in ways that expand opportunities for manufacturing, including in countries with a relatively weak business environment. Mobile payment systems are an increasingly intricate part of ensuring services can be embedded in goods—and that trade in digital services can be embodied in the making of goods. Beyond the inclusive and governance benefits of mobile money, it will be an important complement to the manufacturing agenda. The growing number of countries following early examples such as Kenya's M-Pesa (a mobile-phone–based money transfer application) shows the wide applicability of this approach.

New technologies are also being used to develop new business forms, with implications for competition, contracting, and financial services to support new manufacturing arrangements. Several new business forms with

### Box 6.1 New Challenges for Competition Policy in the Digital Economy Era

Applying competition frameworks to digital markets for goods and services requires a deeper understanding of the microeconomic features of these markets. In traditional markets, having price reflect production costs and consumer demand was an indication of competition; in digital markets, competitive pricing and product quality also reflect other factors such as network externalities. For example, if there are significant network effects, consumers benefit the more people use the platform or service. Similarly, there are multi-sided platforms such that demand for one product on the platform (such as search engines) creates positive externalities for the other group on the platform (advertisers).

Three characteristics of digital markets have implications for competition policy. First, because the pace of innovation is rapid, old technologies can become obsolete quickly, and the boundaries of markets change rapidly, reducing the relevance of market concentration at a point in time. Second, some markets display winner-takes-all dynamics; that is, the first company to launch the innovative product may be able to dominate the entire new segment and later have access to key information to continue innovating to win other segments. Related to that, some markets or platforms have network effects and economies of scale and scope on the demand and supply sides whereby networks, products, or services become more valuable as more consumers use them. Along with the issue of the pace of change, this raises the question of whether policies need to be applied ex ante or ex post to prevent abuse of dominance. Third, the ownership of data is a factor of competitiveness and market power, and therefore companies tend to compete intensively for data, including data that come from the Internet of Things (IoT) and services embedded in goods. One question for regulators is whether concentration of the ownership of data is restricting competition or improving the quality of a service—and what the implications are for future innovation in digital markets.

Taken together, the nature of new competition policy challenges are as follows:

- *Antitrust enforcement needs to safeguard against the abuse of dominant position.* The concentration of data ownership—a key input that provides competitive advantage—could strengthen market power. "Big data" accumulation and the reliance on algorithms can lead to abuse of dominant position. Recently, the European Commission fined Google €2.42 billion for abusing its market dominance by giving advantage to its own comparison shopping service in its search results. A similar investigation was opened in Brazil, while in Russia, Google committed to remove restrictions on phone manufacturers and let third-party applications appear on all devices. This concern is particularly pertinent in upper-middle-income countries, where the rate of digitalization and Internet access allows many consumers to access digital markets. In many LMICs, vertical integration between providers in digital markets and data transmission providers (telecom operators) raises additional issues of potential exclusionary behavior that can foreclose or restrain start-ups and developers of digital products.
- *Collusion and price agreements can increase the prices of goods sold.* New ways of coordinating prices among competitors have appeared as well: companies can use algorithms (a step toward artificial intelligence) and prices available on digital platforms to automatically fix collusive prices. Another concern involves "price parity," "most-favored-nation," or "best price" clauses that online platforms have included in contracts with sellers. Under these types of clauses, retailers or producers cannot sell their products at a more competitive rate on other digital platforms or distribution channels, eliminating price competition. In response to antitrust investigations in various countries in Europe and the Asia-Pacific region, Booking.com and Expedia have modified these clauses to allow their competitors to offer lower room rates

*(Box continues on next page)*

**Box 6.1 New Challenges for Competition Policy in the Digital Economy Era** *(continued)*

and Amazon has eliminated these clauses for book sales. As the penetration of digital markets expands in LMICs, competition authorities have to monitor market dynamics more closely to screen for potentially collusive behavior and take into account practices that have been detected in other jurisdictions.

- *Rules might be needed to promote healthy competition in digital markets.* Restrictions on transferring data and content from one platform or company to another is a way to constrain competition in digital markets that consumers need to be protected against. Countries have started to discuss regulations to allow for data portability and weaken possible lock-in effects. Ensuring interoperability between platforms is also desirable to allow consumers to choose between platforms and innovations to enter the market.

Competition authorities need to exercise some flexibility and case-by-case study as new issues arise. Given the global nature of the digital economy, collaboration across countries is important. Regulations and guidelines for the implementation of competition frameworks should be holistic, encompassing the broader digital economy, to avoid becoming obsolete because of rapid technological change. And the approach to competition also needs to be complemented with regulations on the side of privacy and data security.

*Source:* World Bank Group (2017c).

the potential to be disruptive have been in service sectors that are highly regulated (for example, Uber and taxis; Airbnb and the hotel industry). For manufacturing, the prospect for expanding the sharing economy to warehousing, production facilities, and vehicles could significantly reduce the costs needed to set up a business. Such arrangements, however, will rely on contract enforcement, more sophisticated payment systems, and competition policies overseeing platform production systems. As such, they will likely be more relevant in countries with stronger competitiveness capabilities.

## Reform Priorities for Capabilities

### Skills-Focused Education and Training Policies

Education and training policies will need to be redesigned to deliver more of the new skills needed for countries to take advantage of emerging opportunities. As countries become increasingly connected and engaged in more complex production processes, meeting the changing need for skills will be important to ensure that more people can access jobs, which are likely to become increasingly nonroutine and cognitive. This might involve greater investment in the development of advanced ICT-related skills, such as software programming and coding or complementary skills in engineering—offered in ways that are inclusive to ensure that women and men can benefit from these opportunities.[8]

Another important dimension to keep in mind is that skills programs will need to be more responsive to changing industry demands. The use of

private providers and incentive contracts (whereby participant placement is a [partial] condition for payment) help align incentives in improving the effectiveness of training programs. Having private sector actors involved in setting curricula can also help reflect the types of skills future employees will need. In addition, given rapid and unexpected changes in the global economic landscape, countries would benefit from placing a premium on developing "soft" skills that foster adaptability, creativity, problem solving, and initiative (World Bank, forthcoming).

The rapid changes in technologies and related production processes mean that countries with "low" capabilities will need to establish basic numeracy, literacy, and ICT-related skills with greater urgency as a prerequisite for the workforce to develop more advanced skills. This effort can be complemented with a focus on advanced skills for a subset of the population that has access to higher-quality education. There are examples of low-income countries where skills are low, on average, but with pockets of a highly skilled labor force that have completed tertiary education. The development of India's software and information technology (IT) sector illustrates this role of institutes of higher learning in engineering and management sciences. Education systems should therefore be adaptable to harness this potential.

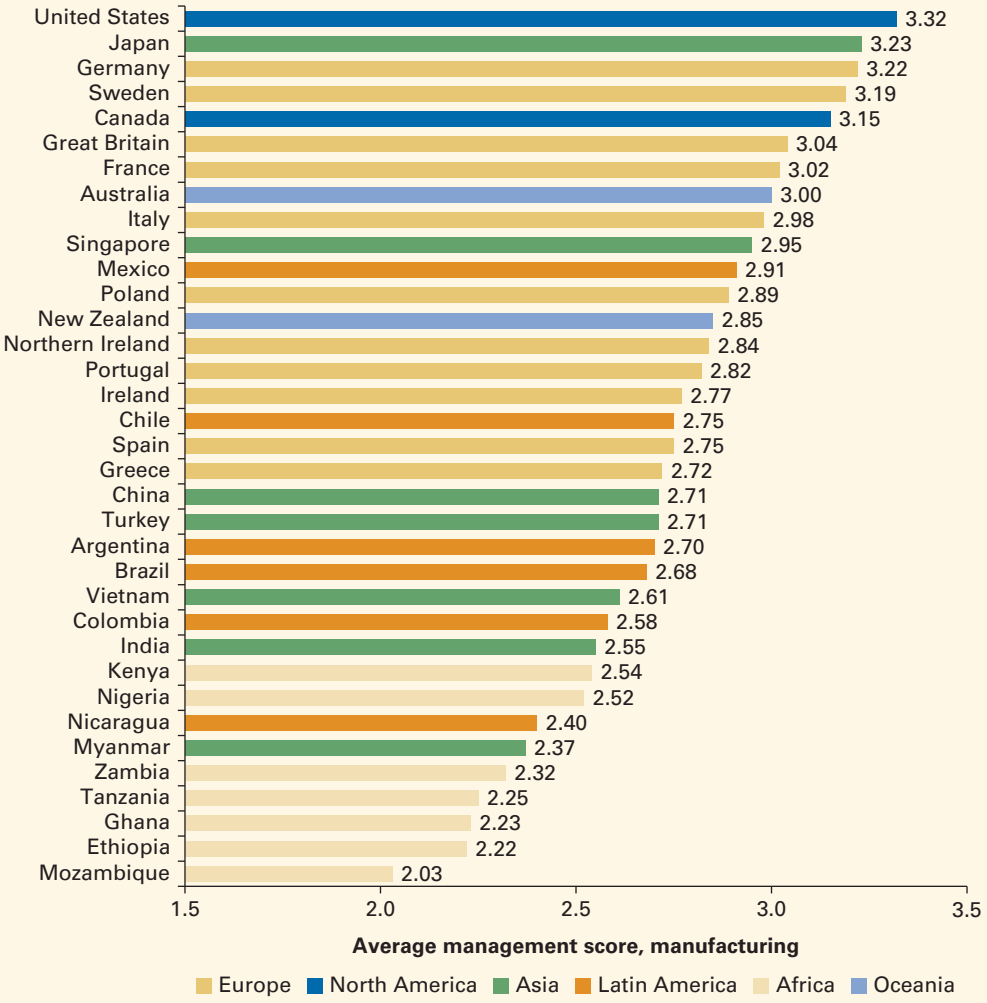
### Strengthening Firm Capabilities

The adoption of more flexible manufacturing production processes, including technologies associated with Industry 4.0, will require not only new skills and training for employees but also more autonomy for production and decision making. Therefore, managerial and organizational practices that strengthen firm capabilities will be needed to facilitate the adoption of new technologies in production processes. These complementary capabilities have been the focus of the innovation literature for decades, at times described as absorptive capacity (Cohen and Levinthal 1990) or as technological and innovation capabilities (Lall 1992). More recent evidence emphasizes the importance of managerial and organizational practices for innovation—both independently and in support of technological capabilities (research and development [R&D])—across countries and firms with different capabilities (Cirera and Maloney, forthcoming).

Firms in LMICs tend to have weaker management practices overall, in particular regarding human resources (figure 6.3). However, the nature of some of the new technologies should reinforce good managerial practices—if the capabilities are there. For example, the IoT dramatically increases the availability of real-time information, thereby proving an incentive for stronger organizational and managerial practices to use systems integration across multiple locations to improve efficiency.[9]

In ensuring access to new technologies for manufacturing, the priority for LMICs should be the diffusion of improved production processes, differentiating across firms and countries including over time as capabilities expand. While innovations on the frontier grab headlines and the imagination of policy makers, far more impact in improving firm productivity and

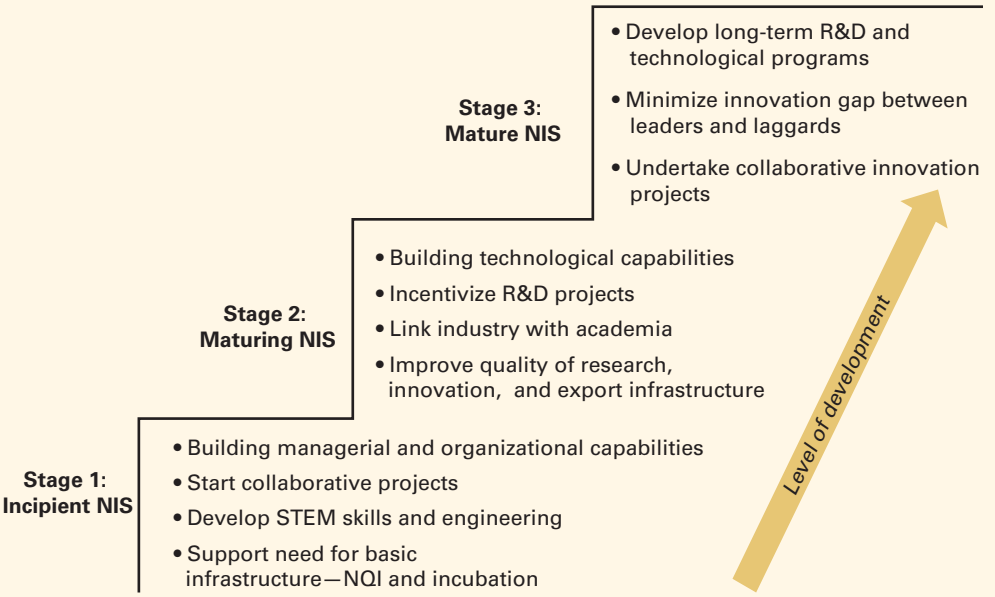
**Figure 6.3 Average Management Scores, Selected Countries, 2014**




*Source:* World Management Survey dataset, 2013–14 survey wave 4, http://worldmanagementsurvey.org/.
*Note:* The survey covered firms ranging in size from 50 to 5,000 employees. The survey methodology measures management scores using an interview-based evaluation tool that ranges from 1 ("worst practice") to 5 ("best practice") across 18 key management practices (Bloom and Van Reenen 2007).

employment outcomes can be achieved by helping firms catch up and move closer to the frontier.[10] There is a need to start with improvement of more basic managerial and organizational practices (which will allow firms to use and adapt the new processes) and to proceed to more sophisticated technological knowledge associated with Industry 4.0 further along (Cirera and Maloney, forthcoming). Therefore, rather than trying to jump straight to R&D subsidies to develop new Industry 4.0 technologies (or home-grown alternatives to existing ones), the mix of policy instruments should reflect this capabilities escalator (figure 6.4).

**Figure 6.4 Capabilities Escalator of Innovation Policy Needs**




*Source:* Cirera and Maloney, forthcoming.
*Note:* NIS = national innovation systems. NQI = national quality infrastructure. R&D = research and development. STEM = science, technology, engineering, and mathematics.

Cirera and Maloney (forthcoming) provide a review of existing technology transfer mechanisms in Organisation for Economic Co-operation and Development (OECD) countries that can be mapped to different stages of capabilities. In Stage 1, dedicated field services are designed to support broader managerial and organization capabilities that can help in the adoption of more basic technologies. In Stage 2, other mechanisms, such as technology-oriented services and technology centers, are targeted to the adoption of more complex technologies. In Stage 3, these and targeted R&D centers can also be used to support the generation of new technologies.[11] In the face of new technologies, there will be an increased need for flexibility of these tools and institutions, both in adapting them to specific circumstances and combining them in new ways to reflect the increasing complexity of manufacturing.

### Technology Infrastructure Reforms

To realize the promise of Industry 4.0, the standardization of key components and systems will become even more important than before for processes to connect across locations. This interaction transcends operational and organizational boundaries as firms in different sectors—such as suppliers, logistics companies, and manufacturers—are linked to each other in a value chain. Therefore, addressing coordination needs is likely to be

increasingly important in countries' approaches to national innovation systems. Further, interfaces will need to be harmonized according to internationally agreed norms and standards (for example, as in Universal Serial Bus [USB] cables and Bluetooth protocols, among other industry standards). For the manufacturing industry, it is more urgent than ever to meet this standardization challenge—one that will define the mechanisms for cooperation in advance.

Lower-income countries that score lower on capabilities have typically not been involved in the process of setting international standards, but the ability to meet these standards has affected their opportunities to access export markets.[12] With more complex products and processes, improving quality infrastructure (QI) systems to certify quality standards will become arguably more important than before to facilitate export opportunities. For example, QI is increasingly embedded in the physical and software components of deeply interconnected manufacturing processes: sensor-based applications, control systems, and continuous monitoring devices. If QI requirements are set too high, they function as nontariff barriers (NTBs) to trade and development.

Although new technologies may change the content of some standards and the growing pressures to meet them, the overall agenda to strengthen QI retains many of its old pillars (World Bank 2017a):

- Designing the legal and regulatory framework in line with international good practices
- Working toward the elimination of excessive technical regulations
- Ensuring that QI institutions are streamlined, competent, impartial, and credible
- Building the capabilities of quality assurance service providers
- Stimulating demand from the private sector to adhere to quality standards by upgrading firm capabilities to produce higher-quality products
- Supporting peer-to-peer learning events
- Leveraging global knowledge with regional and international counterparts

To address the difficulty LMICs face in conforming to international standards, the International Organization for Standardization (ISO) developed the *ISO Action Plan for Developing Countries 2016–2020* (ISO 2016).[13] However, given the scale of physical, human, and financial resources needed, many LMICs would still need to receive assistance to take part.[14]

For countries and firms with higher capabilities, the data ecosystem will be increasingly important in the use of Industry 4.0 technologies, raising new regulatory issues regarding intellectual property rights, data security, and privacy. The protection of corporate data will play a key role as the IoT continuously generates information that is transmitted and evaluated in factories, production areas, and also across company boundaries. Data protection is equally relevant for consumers. For example, if embedded services

collect more data from consumers, concerns about data privacy and security will also rise. These issues are compounded when data flows cross international borders (as is further addressed in the next subsection in the discussion on new rules for cross-border data flows). Legal provisions can ensure security, create acceptance, and encourage innovation, but they need to keep up with the development of new business models.

## Reform Priorities for Connectedness

### Basic Trade Cooperation Principles and New Technologies

For countries that are less "connected" to the global economy, the reciprocal opening of markets and trade facilitation need to be tackled with greater urgency, and new technologies do not dilute the importance of this old trade agenda. Although significant progress has been made in addressing trade restrictions on manufactures, lower-income economies seeking new opportunities for export-led manufacturing will still benefit from reducing restrictions on importing intermediate inputs and from secure market access in their destination markets.

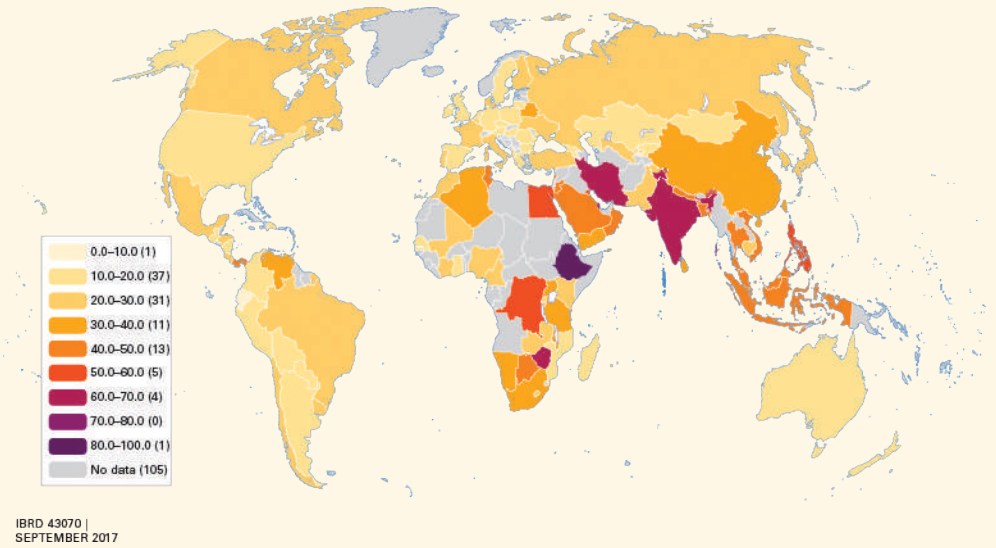
Tariffs remain high in some sectors or are not subject to stringent commitments, and several nontariff measures (NTMs) also affect trade flows. Similarly, trade facilitation that aims at better logistics and easing border clearance[15] merits even greater emphasis given heightened global competition and the increasing importance of delivery time, especially in higher-income markets. The World Trade Organization (WTO) 2013 Trade Facilitation Agreement (which entered into force in February 2017) represents an important step forward in facilitating the movement of goods across borders, especially for lower-income countries. Importantly, market access restrictions, the connectivity agenda, and regulatory cooperation remain indispensable for new forms of trade enabled by technological advance, such as e-commerce.

At the same time, given the servicification of manufacturing, the services trade reform agenda will become even more pressing, particularly for the more "connected" countries. Services reforms are relevant per se, but their importance is magnified by changing technologies, whereby services are increasingly embodied in the production and sale of goods—through banking, transport, and telecommunications, for example.[16] In this context, higher barriers to services trade will become even more costly for countries that preserve them, increasing the need for reform in this area.[17] But services trade remains hampered by substantial policy barriers,[18] with restrictions more common in LMICs than in high-income countries (map 6.1). For example, major barriers to FDI and some barriers to cross-border electronic trade of ICT-enabled services have impeded Indonesia's participation in GVCs for electrical goods and motor vehicles (Bamber et al. 2017).

### New Rules for Cross-Border Data Flows

As new technologies create new forms of international trade, new rules will also need to emerge to respond to changing regulatory needs. Take, for example, "smart" production processes that require systems and machines to

**Map 6.1 Restrictiveness of Services Trade Policy, 2008–10, Global by Country**




*Source:* Borchert, Gootiiz, and Mattoo 2012.
*Note:* The map compares the restrictiveness of services trade policy across countries based on the World Bank Services Trade Restrictions Index, which ranges from 0 to 100. The database covers 103 countries (79 low- and middle-income countries) and includes financial, basic telecommunications, transport, distribution, and selected professional services. The information for the database was collected between 2008 and 2010.

communicate with other machines or give access to data that could be hosted abroad. Restrictions on cross-border data flows therefore affect the ability to use many of these new technologies in the manufacturing sector. Restrictions on trade in data flows could also be an obstacle in the trade of services embedded in goods. 3-D printing, for example, raises particular regulatory challenges (box 6.2). At the same time, cross-border data flows expose firms and consumers to novel threats to their intellectual property or privacy.

Therefore, the agenda on intellectual property rights and privacy concerns in trade agreements will likely be emphasized with these cross-border data flows. While securing intellectual property rights (IPRs) has long been a trade concern, what is new is the extent of digital trade and the role that data are playing in both manufacturing and new embedded services in goods. Content providers could restrict the provision of some services to countries where IPRs are inadequately protected. Countries with weak IPR protection therefore will have difficulties generating exportable content as well as difficulties getting access to imported content. There are similar concerns that without adequate IPR, 3-D printing may not even be a viable technology for some countries (box 6.2). As for privacy concerns, the European Union (EU) 1995 Data Privacy Directive, for example, makes it illegal to transfer personal data outside of the EU unless the European Commission has found that the third country receiving the personal data provides adequate protection.

### Box 6.2 New Policy Issues from 3-D Printing as Trade Shifts from Goods to Digital Files

Although WTO rules are arguably flexible and technologically neutral—thereby reducing the need for major legal changes due to the emergence of 3-D printing (National Board of Trade Sweden 2016)—the shift in emphasis from goods to services trade raises three policy issues with added implications for government revenues:

- What constitutes a "good" or a "service"—and hence which trade rules apply?
- How can intellectual property rights be safeguarded when counterfeiting operations could be diffused?
- What new rules are needed to safeguard digital trade?

**"Goods" or "Services"?**

Classification issues determine which trade rules apply, but cases are not always clear-cut. In principle, charges for electronically delivered products—as for designs delivered digitally for printing—are captured as trade in services, as opposed to goods ordered electronically, which are still treated as trade in goods.

Assuming, for instance, that a printer in an importing market acquires a license to reproduce from the original designer, license fees that would reflect a charge for the use of intellectual property, which is included under trade in services. By contrast, if an individual consumer acquired the right to a single, nonreproducible version of the design for private printing, that transaction would be captured under the relevant services category (such as information or publishing services) rather than as a use of intellectual property.

In the short term, many countries and firms will struggle to implement these definitions accurately in practice.

**Intellectual Property Safeguards**

As 3-D printing becomes viable and mainstream, one of the most significant concerns involves intellectual property right (IPR) protection. Since IPR protection for 3-D printing will largely be focused on computer-aided design (CAD) files, the issues are in part similar to the challenges previously faced in the context of digitization of books, movies, and music, which were shared largely on peer-to-peer networks among end users or hosted on website platforms.

From the end user's standpoint, 3-D printing could allow the user to obtain counterfeit goods without the intervention and assistance of commercial counterfeiters. Thus, IPR holders cannot go after large-scale counterfeiting manufacturers, because piracy is more decentralized. Pursuing individual end users that make or order 3-D printed objects is cumbersome and costly. Protection offered for private and noncommercial use under the international intellectual property law regime would further reduce the incentive for right holders to go after end users.

Furthermore, to protect one's IPR, the right holders must analyze not only the traditional patent law, but also trade secret, copyright, and other intellectual property laws.

**Digital Trade Safeguards**

For 3-D printing to be a viable technology, data flows between countries need to be relatively free. This is necessary not only because what flows across borders is a digital file, but also because, in the printing process, there can be data transfers from sensors back to the original firm to ensure quality and

*(Box continues on next page)*

**Box 6.2 New Policy Issues from 3-D Printing as Trade Shifts from Goods to Digital Files** *(continued)*

adherence to how the files are used. Data localization measures in a range of countries have led to some fragmentation of the Internet, which could slow down the rollout of 3-D printing technologies.

Establishing a conducive environment for data flows at the national level is also critical to enable LMICs to participate in 3-D printing activity. They will need to have secure, reliable, and reasonably priced Internet access and the ability for the files and supporting data flows to move across borders.

Finally, the shift to 3-D printing could have significant impacts on government revenues. WTO members' practice since the 1990s has been to not impose customs duties on electronic transmissions. Although the movement of the good across borders could be subject to a tariff, the trade of a CAD file does not trigger any customs payment. For those countries that still rely on tariff revenues, if 3-D printing takes off, this could shift the nature of where governments can receive revenue.

## Capturing the Wider Agenda: Regional Trade Agreements

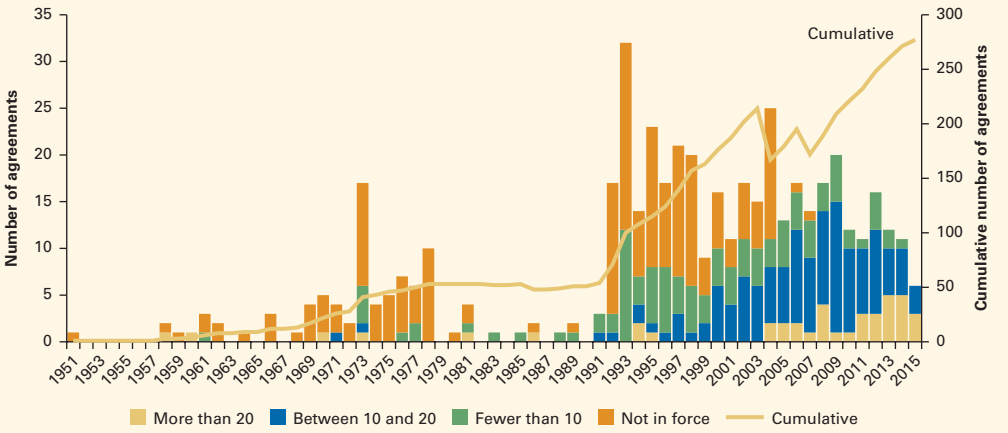
Regional and bilateral trade agreements have expanded dramatically in number and in scope, with provisions covering trade in services, data flows, and e-commerce. The number of preferential trade agreements (PTAs) notified to the WTO rose from about 50 in 1990 to around 280 in 2015, increasingly covering a range of nontariff measures (figure 6.5). Specifically, more than half of the PTAs include "deep" provisions in new policy areas (data protection and e-commerce, for example) that are often beyond the current mandate of the WTO (Hofmann, Osnago, and Ruta 2017).

Provisions related to IPR and consumer and data protection are on the rise in trade agreements (figure 6.6). Further, while not ratified, the proposed Trans-Pacific Partnership has the deepest and broadest rules to date on e-commerce (box 6.3). Therefore, regional and bilateral trade agreements will remain central in driving connectedness to markets through both old and new reform agendas, but their effectiveness will be influenced by related policy uncertainty, as described in chapter 3.

"Deep" trade agreements can provide the institutional framework that governments in developing countries need to coordinate and commit their policies to exploit new trade opportunities in a changing environment. Specifically, by increasing the potential connectivity of different economies, new technologies may make it harder for countries with weak institutional and regulatory systems to enjoy the benefits of globalization. The reason is that weak institutions in the exporting country can impose negative externalities on importers. Hence, deep agreements, where this type of regulatory cooperation often takes place, are likely to be even more important going forward than they have been in recent years.

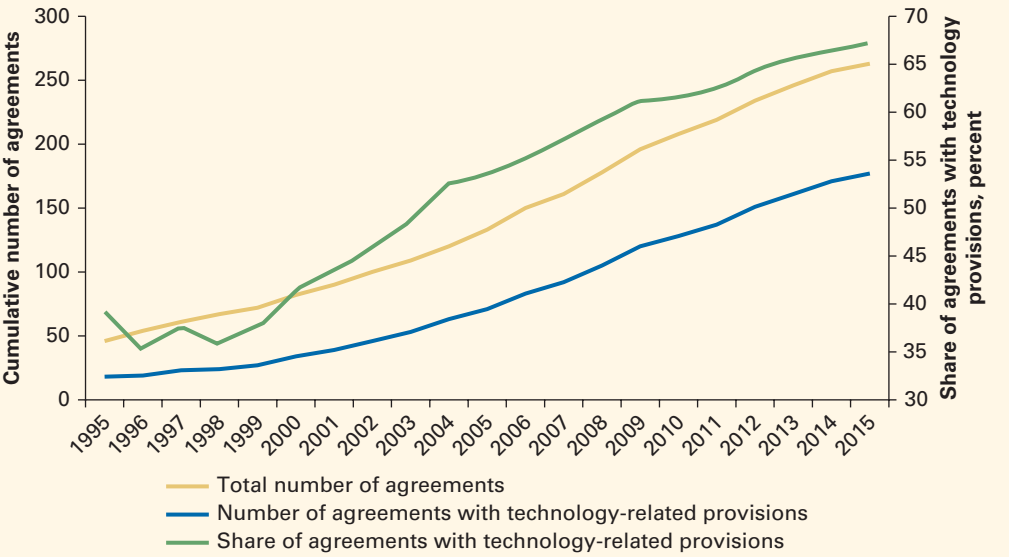
Last but not least, as the trend of customization intensifies, larger markets or countries located close to larger markets will become more attractive centers of production. But "deep" trade agreements could make geography matter less by enabling firms in smaller economies to experience scale economies through access to these larger markets.

**Figure 6.5 Number and Depth of Preferential Trade Agreements, 1951–2014**




*Source:* Hofmann, Osnago, and Ruta 2017.
*Note:* PTAs (preferential trade agreements) provide preferential access, such as through reduction of tariffs or nontariff measures, for specified products within a bloc of participating countries. Within the total number of agreements in a given year, the different-colored bars indicate the number of provisions covered by the relevant number of agreements. For example, in 2008, 4 agreements covered more than 20 provisions, 10 agreements covered between 10 and 20 provisions, and 3 agreements covered fewer than 10 provisions.

**Figure 6.6 Number and Share of Trade Agreements Containing Data Flow–Related Provisions, 1995–2015**




*Source:* Hofmann, Osnago, and Ruta 2017.

### Box 6.3 Proposed Trans-Pacific Partnership: Deepest, Broadest Rules Yet on Data Flows and E-Trade

Many LMICs lack the appropriate framework to deal with data disputes or provide the legal certainty for companies concerned about data protection. Recent trade deals that do include provisions on data flow provide some insights into possible larger templates. The Trans-Pacific Partnership (TPP)[a] is one that rules out data localization requirements (under its e-commerce chapter) and insists that countries have the right legal framework and institutions in place to address data disputes. But overall, even though the TPP goes further than any other trade deal by also including provisions on source codes and trade secrets, some experts remain concerned that it is not very deep and does not offer concrete guidance on how to put this legal framework in place or how to increase privacy protection.

**More specifically, the TPP**

- Prohibits the imposition of customs duties on digital transmissions, including products distributed electronically, such that software, music, video, e-books, and games are not disadvantaged;
- Prevents TPP countries from favoring national producers or suppliers of such products through measures such as discriminatory taxation or outright blocking or other forms of content discrimination;
- Encourages TPP parties to provide for electronic authentication and signatures for commercial transactions;
- Requires TPP members to maintain a legal framework for electronic transactions consistent with the principles of the United Nations Commission on International Trade Law (UNCITRAL) Model Law on Electronic Commerce 1996 or the United Nations Convention on the Use of Electronic Communications in International Contracts;
- Requires TPP members to adopt and maintain consumer protection laws related to fraudulent and deceptive commercial activities online and to ensure that privacy and other consumer protections can be enforced in TPP markets;
- Requires parties to have measures to stop unsolicited commercial electronic messages (spam); and
- Recognizes that governments have different ways of implementing privacy protections and promotes interoperability between those diverse legal regimes.

*Source:* TPP Agreement text.
a. The TPP, signed in February 2016 by 12 countries, is currently being negotiated by the remaining 11 countries after the United States withdrew in January 2017.

## Revisiting the Feasibility and Desirability of Targeted Industrial Policies

*Key message: While there is a long-standing debate over the extent of market and government failures associated with targeted industrial policies, what is of interest here is to understand how new technologies and changing globalization patterns add new elements to understanding the risks and benefits of targeted approaches.*

In light of Industry 4.0 technologies, the merit in policies that target the expansion of a manufacturing sector will depend on the sector's shifting

desirability, as measured by spillovers and dynamic growth gains, or in meeting other public objectives, such as employment for specific groups. Identifying market failures or spillovers as justification for targeted government intervention remains a relevant disciplining device. However, governments will need to determine the acceptable level of evidence, especially considering that the results will also likely vary depending on how narrowly interventions are targeted. The narrower or more disaggregated the targeted sector, the harder it is likely to be to find hard evidence of such spillovers or to make the case that they will be widely shared. Chapter 1 made the case at a fairly broad level of aggregation, documenting the different prevalence of characteristics associated with potential spillovers, such as tradedness, rates of innovation, or labor intensity.[19] It also documented, however, that there is variation in these characteristics within disaggregated industries across countries and over time.

While making the case for the shifting *desirability* of targeted approaches, the case for meeting changing *feasibility* requirements also must be met. Countries still need to assess the constraints to entry and expansion and how these are likely to vary across sectors and over time. Increasingly, the case for meeting the feasibility requirements is itself a dynamic and more challenging commitment.

## New Considerations on the Desirability of Targeted Approaches

### Consideration 1: If industrialization is associated with dynamic gains and if countries face a limited window to industrialize, are targeted interventions to develop manufacturing necessary?

A new concern is that the adoption of labor-saving technologies in high-income countries might substantially affect the ability of lower-income countries to industrialize in the future. The central question is whether lower-income countries, particularly those with a more limited manufacturing base, should target manufacturing now because the opening for technologies and processes associated with Industry 2.0 to be viable is narrowing (Crespi, Fernandez-Arias, and Stein 2014; Lin and Chang 2009; Page 2012).

If countries can leapfrog into using new technologies, there is no cost for not developing a manufacturing sector at this point. However, if countries need to have developed a manufacturing sector using traditional (Industry 2.0) methods to build the capabilities needed to support more sophisticated processes in the future, the dynamic cost of not industrializing now could be that manufacturing opportunities are closed off in the future. Therefore, if it is still viable to produce using Industry 2.0 methods now, targeted approaches to develop a subsector now could still put the country on the path to raise capabilities and productivity over time. The potential dynamic gains could be substantial—and justify the use of government interventions to achieve this outcome.

However, even if leapfrogging technology may not be possible, it still does not necessarily follow that targeting manufacturing sectors is the right choice. Policy makers still need to understand why the sector has not

developed on its own: Are there market failures or government failures that need to be addressed to make the approach feasible—let alone to capture spillovers? Not only would this case need to be made, but to also achieve the dynamics gains over time would require a credible plan on how to continue improving the 3Cs such that the dynamic gains could be feasible. Intervening now to support the introduction of 2.0 processes in certain sectors or locations will not be sufficient.

### Consideration 2: The diffusion of labor-saving Industry 4.0 technologies might place greater emphasis on creating job opportunities

Whereas spillovers and dynamic productivity gains have traditionally been a major motivating factor for industrial policy, new labor-saving technologies are raising the stakes in the debate over targeting sectors based on their job creation potential. This is understandable if traditional sources of job creation, and therefore means of livelihood, are coming under threat. Job creation may also still have some productivity spillovers. For example, jobs provide opportunities for learning by doing, for enabling people to use time productively, and for strengthening their sense of ties to their community, thus deepening social cohesion. Being actively employed can also reduce the risks of scarring, whereby spells of unemployment lower workers' future employment trajectories.

However, trying to develop a sector using labor-intensive production processes when new technologies are more efficient is not likely to be sustainable or viable for very long. At the same time, as noted in chapter 4, there are some sectors where such labor-saving technology has not been introduced. Targeting such sectors could be a strategy for providing jobs in the short run and potentially building more capabilities to move into production of more sophisticated products as technological changes spread. For example, unskilled-labor-intensive commodity processing sectors still have easier entry points. They are less traded internationally but offer employment opportunities for the unskilled. Labor-intensive tradables may have even higher job creation potential, but the need to demonstrate low unit labor costs is rising.

### Consideration 3: An increasingly uncertain global economic landscape might make sector-specific approaches riskier than before

Sector-specific interventions may be riskier than in the past because of rapid changes and increasing uncertainty in the global economic landscape. The extent and pace of technological change is unknown, although technology diffusion has been accelerating. Technologies such as 3-D printing, robotics, and artificial intelligence (AI) are not new, but their applications have been expanding across sectors as they improve what they can do and as the costs associated with using them fall.

With change happening so quickly, there is a risk of betting on and investing in sectors where the technology in use becomes obsolete. This risk

is then further compounded by uncertainty in demand for goods going forward, too, because obsolescence occurs on both the supply and demand sides. In addition, recent political events are testing the commitment to international trade cooperation, with renewed calls for protectionism in some countries. In some high-income countries, trade has been cited as contributing to job losses in manufacturing, but *which* manufacturing sectors will be most adversely affected remains unclear.[20] So this uncertainty as to how trade and production will evolve makes sector-specific bets that much riskier.

### New Considerations about the Feasibility of Targeted Approaches

Successfully targeting manufacturing sectors will also increasingly depend on the shifting feasibility for a country to be competitive, given changing technologies and globalization patterns. Chapter 4 showed that a range of commodity-based processing manufactures are both currently less automated and less traded, which makes these sectors easier for countries scoring lower on the 3Cs to compete and expand in, even with fewer productivity benefits. These sectors include mining-based manufactures such as basic metals and nonmetallic mineral products as well as agriculture-based industries such as food processing, paper and paper products, and wood and wood products.[21] Garments and apparel is a more traded sector, especially within GVCs, and therefore harder to compete in. Yet minimal use of automation technologies means that the "flying geese" pattern—when a more eveloped "lead goose" country moves from labor-intensive to higher–skill manufactured goods, enabling less developed countries to enter (Akamatsu 1962)—remains a possibility in this sector. It might be more feasible, then, for countries to target these manufacturing sectors and achieve success in the global market.

It is in these very labor- or resource-intensive manufactures sectors where many lower-income countries currently have an RCA, as shown in chapter 2. Therefore, given the uncertainty, grounding assessments of feasibility in market signals on comparative advantage will help diversify the risks of targeting. The distortion of market signals and the resulting shift of resources to noncompetitive sectors can slow a country's accumulation of physical and human capital, which is necessary to develop a viable advanced industrial structure over the medium term (Lin 2012).[22] Importantly, comparative advantage must be looked at not only in terms of sectors, but in terms of tasks as well. For example, it would be easier to move from labor-intensive garments to electronics assembly than from electronics assembly to making electronic components.

Although policies that address competitiveness, capabilities, and connectedness are ex ante "horizontal," they disproportionately benefit some sectors more than others. For example, building a railway line between a steel town and a seaport, instead of a road between the horticultural export region and an airport, means that the government implicitly favors *connectedness* for the steel industry. Similarly, more government funding to

electronics engineering departments than to chemical engineering departments implicitly favors building *capabilities* in the electronics industry (Chang 2009). With this in mind, and given current or nascent production patterns, countries should look at the sector-specific impacts of their reforms in the 3C space.

In fact, if the bar is rising for locations to be attractive for production, it might be more feasible for countries to prioritize reforms in the 3Cs based on which sectors might be disproportionately affected. This sends two messages: First, even sector-specific reforms will still have benefits that could be shared across other subsectors. Second, taking a sector lens will still highlight agenda items in the 3C space—even as specific skills, regulations, or standards needed for a sector guide the content of choices within that space. When countries seek to build their 3Cs, they have to start somewhere; for example, they cannot teach all skills or certify all standards from the beginning. Making choices that complement each other (for example, improving skills and standards in the same broad sector) is more likely to help open that market for expansion. However, important questions remain as to how the sectors are selected and choices are made.

Similarly, policies that target improving competitiveness, capabilities, and connectedness in specific locations may also be less daunting than trying to improve all these conditions countrywide. The recent literature goes beyond the enabling business environment to focus on the "entrepreneurship ecosystem," where the interactions and interdependencies among factors such as regulations, markets, institutions, infrastructure, and human capital create a more favorable or less favorable environment for firms (Stangler and Bell-Masterson 2015). Given the multitude of factors that need to come together to make a country a viable production center, it might be more feasible to target the development of firm ecosystems in specific locations. These could be "competitive" cities or special economic zones (SEZs), such as export processing zones or industrial and technology parks, which offer a range of financial incentives (for example, tax breaks or subsidies); infrastructure facilities (for example, uninterrupted electricity supply); access to land; and a simplified regulatory framework (Hausman, Lee, and Subramanian 2005).

At the same time, if the gap between firms and their processes used in an SEZ and those of non-SEZ firms are that much larger, the risk is that the zones are simply enclaves, greatly reducing the scope for spillovers. This is particularly troublesome, given that the spillovers associated with adopting new technologies may be greater than before, further widening the gap between the social and private returns to technology adoption. The stakes may be particularly high if the adoption of new technologies is predicated on the diffusion of old technologies: if countries do not do some manufacturing using Industry 2.0 and 3.0 methods, it will not be possible to leapfrog to start at Industry 4.0. Therefore, enabling a larger cross-section of firms across sectors to access new technology as it diffuses assumes greater importance. This places a premium on the linkages agenda, which addresses

interdependence at all spatial scales (such as labor pools at the regional level, shared knowledge at the global level, and so on).

### Adaptation of Institutional Frameworks—Aided by New Technologies

An institutional framework that improves government-industry information flows in an inclusive and transparent way will become increasingly important to assess the changing desirability and feasibility dimensions of targeted approaches. Since the private sector is likely to better understand the location and nature of the market failures that inhibit industrial development, a fluid dialogue with the government is an important source of policy-relevant information. Rodrik (2004) refers to "public-private coordination councils," which could seek out and gather information on investment ideas, achieve coordination among different state agencies, push for regulatory changes to eliminate unnecessary transaction costs, and generate a package of relevant financial incentives for new activities when needed. Harrison and Rodríguez-Clare (2010) argue that governments should create a "social process" whereby different industry organizations compete with proposals for government support. An example of such public-private dialogue is when the lack of reliable air transport to major markets led the association of flower exporters in Ecuador during the 1980s to convince the government to set up the required number of cargo flights for this activity (Hernández et al. 2007).[23] Ensuring that a wide range of private sector actors are included is important for the process to lead to more inclusive outcomes.

In addition, the expansion of competitive pressures and establishment of iterative evaluation processes provide a disciplinary mechanism for targeted and horizontal policies alike. Successful targeted policies have typically combined inducements to firms for investment and risk taking with monitoring and evaluation, whereby governments allow nonproductive firms to fail and exit the market.[24] Despite long-standing concerns that vertical policies may enable chosen sectors to capture the political process to guarantee continued special treatment, horizontal interventions such as infrastructure provision are also often plagued by corruption (Maloney and Nayyar 2017). In fact, targeted sectoral policies may be associated with fewer "leakages," owing to the easier monitoring of beneficiaries (Chang 2009). Therefore, the case for horizontal and vertical policies cannot be based on the argument that governments will uniquely mismanage the latter. In principle, suitably designed targeted policies can also increase competitive pressures. For example, tax holidays or other tax-subsidy schemes that encourage firms to be active in the same sector will decrease concentration in that targeted sector and enhance incentives for firms to innovate (Aghion et al. 2015).

New technology itself could help reinforce the institutional framework for assessing the desirability and feasibility of targeted approaches—thus

minimizing the risks of government failure. From experience, three dimensions are important: (a) engagement with the private sector, which facilitates the collection of information; (b) transparency and accountability through an iterative evaluation process; and (c) better government capacity. While not a panacea, new ICT applications could help strengthen these arrangements. For example, using ICT and Web-based platforms can improve the inclusivity, transparency, and communication strategies with the private sector (World Bank 2016). Similarly, the IoT as a means of disseminating information, coordinating market players, and potentially collecting data during the production process can help provide needed feedback loops for monitoring and evaluation purposes.

### The Changing Feasibility and Desirability of Replicating Successful Past Approaches

In principle, countries can learn from the industrial upgrading trajectories of similar countries at earlier levels of development, much like the "flying geese" pattern of development (Akamatsu 1962). In the Republic of Korea, for example, the early success of electronics manufacturers was in household appliances, which then moved on to memory chips and subsequently semiconductors. This industrial upgrading followed the country's changing comparative advantage given the accumulation of physical and human capital (Lin 2009). However, the combination of countries already producing certain products, the changing mix of conditions needed (including the 3Cs) to support different manufacturing activities, and the potential for disruptive new technologies that shift the basis of comparative advantage mean that what was an effective strategy in the past may neither be feasible nor as desirable in the future.

Further, focusing on *which* goods others successfully made rather than on providing the right *conditions* for their production may miss what really mattered for development. Expanding a sector with potential externalities does not necessarily imply that they will automatically occur if the sector is not organized appropriately (Baldwin 1969; Lederman and Maloney 2010; Rodríguez-Clare 2007). For example, at the beginning of the 20th century, copper mining in the United States led to a knowledge network in chemistry and metallurgy that laid the foundations for subsequent diversification and industrialization, while in Chile the same industry nearly died (Maloney and Valencia 2016). Both the Republic of Korea and Mexico began assembling electronics in the early 1980s, yet only Korea has produced a truly indigenous electronic device, the Samsung Galaxy. These examples imply that *how* a good is produced is potentially more important than *what* is produced. Trying to follow trajectories in the product space is not likely to be viable unless the country can match the requisite levels of competitiveness, capabilities, and connectedness.

As countries tackle this agenda, they also need to keep an eye on the desirability and feasibility dimensions to expand the scope of action at the

sectoral level beyond manufacturing. Before thinking about how to boost manufacturing, policy makers should consider that new technologies and changes in globalization may have changed the sector's relative desirability. Manufacturing's dual promise of productivity growth and job creation is unlikely to hold going forward, given the increasing use of labor-saving technologies. At the same time, many professional services increasingly share productivity spillovers traditionally associated with manufacturing. For example, several business services are increasingly traded and are significant drivers of innovation too.

Moreover, the increasing blurring of lines between sectors and their growing interdependence mean that sectoral policies will be less likely to work in isolation. The crucial importance of embodied services for manufacturing competitiveness, for example, means that "picking" manufacturing sectors without the relevant complementary service sectors might have little meaning. Similarly, many services embedded in goods also are often bundled together, such as apps, mobile-phone apps, after-sales services for consumer durables, and "smart" solutions for "smart" factories. In sum, manufacturing and service activities are becoming increasingly interdependent in product value chains. And as a result, the productivity of one sector depends crucially on the productivity of the other.

## Conclusion

With reform priorities becoming more urgent, one key lesson is that new technologies and changing globalization patterns increase the complementarities between economywide and targeted approaches. On the one hand, it may be more feasible, at least in the immediate future, to meet the requirements to be competitive by targeting locations and sectors rather than attempting to reform and provide public investments throughout the whole economy. Targeted interventions may also be more desirable if there are dynamic gains associated with industrialization and if countries face a limited window to industrialize using technologies associated with Industry 2.0 (and where leapfrogging to Industry 4.0 is not possible). Also, in practical terms, horizontal policies still involve choices, because their rollout or focus will inevitably have differential effects across sectors.

On the other hand, for growth to be more inclusive over the long run, establishing the building blocks of competitiveness, capabilities, and connectedness across the economy would be necessary to exploit linkages across firms, sectors and regions. Similarly, given the growing uncertainty about the pace of technological change, horizontal policies that develop transferable skills would reduce risks in the future. Hence, the debate is not so much over targeted *or* horizontal policies than about the right mix between them, a mix that depends on what is feasible and what the underlying case for market failures and spillovers would be—not only in the immediate run but over time.

## Notes

1. The choice also reflects pragmatic concerns about data availability—for example, while indicators of data ecosystems and frameworks for data flow are of interest, they are not available for a large number of countries.
2. For more about the "distance to frontier" score and dataset, see "Distance to Frontier" on the World Bank's *Doing Business* website: http://www.doingbusiness.org/data/distance-to-frontier.
3. For more about the "rule of law" index and dataset, see the World Bank's *Worldwide Governance Indicators* website: http://info.worldbank.org/governance/wgi/#home.
4. For more about the "mobile finance" index and dataset, see the World Bank's Global Findex Database website: http://www.worldbank.org/en/programs/globalfindex.
5. The country's use of robots was considered as a potential indicator, too, but such data are only available for half of the countries. The two (ICT use and robot use) are closely correlated where the information on both is available, so choosing the variable with the larger country coverage is preferable.
6. Strictly, figure 4.1 in chapter 4 illustrates the intensity of robot use, but it highlights the same sectors that are most susceptible to 3-D printing. Smart factories could be used in any sector, but predominantly they are most promising when they are linked to very mechanized processes; hence "robot use" is a good first-order proxy for the three types of technologies.
7. It is possible that discriminatory regulations allow less productive firms to survive and expand at the expense of more productive ones.
8. Gender sorting across sectors and occupations is widespread and accounts for a significant part of gender differentials in earnings (Hallward-Driemeier 2013). New work shows promise in helping women move to traditionally male sectors where they too earn higher returns (Alibhai et al. 2017). Although new technology will continue to make physical strength less important in more sectors, programs to build capabilities need to be gender-informed to ensure that women have the same opportunities as men.
9. Similarly, as new technologies move to more flexible and customized production, new business models and relationships with customers are likely to develop. Again, management practices are going to be an important complement to benefit from new technologies.
10. In select countries and sectors, a subset of leading firms and research institutions will also push the global knowledge frontier forward.
11. Replicating this in developing countries, however, may not be straightforward, given the complex relationship between these mechanisms and existing private sector capabilities. For example, most of these mechanisms are implemented as public-private partnerships,

which face particular challenges in developing countries where limited numbers of firms are capable of participating. There can be greater market power and political connections for these firms, such that the programs, while addressing technology capabilities, could further distort other market failures.

12. This difficulty has been particularly evident in agriprocessing of products not grown in the European Union (EU) or the United States, or of goods with a cultural heritage associated with an LMIC. For example, Brazil's organic maté could not get certified in the EU because it was deemed outside the scope of the EU's organic legislation (WTO 2017).
13. *ISO Action Plan for Developing Countries 2016–2020* sets forth five objectives: (a) Standardization has a recognized, effective role in support of public policies; (b) national standards bodies' strategic capabilities strengthened; (c) national standards bodies' capacity strengthened at the operational and technical levels; (d) increased involvement of developing country members in international standardization; and (e) coordination and synergies with other organizations and among projects implemented.
14. The World Bank is working in countries like Ethiopia to offer two-pronged support: (a) strengthening the national quality infrastructure (NQI) institutions' capacity to deliver effective and efficient quality assurance services to enterprises, and (b) supporting more active private sector involvement for the development of NQI systems through the creation of demand for NQI services and increasing the number of private sector NQI service providers (World Bank 2017b).
15. It takes three times as many days, nearly twice as many documents, and six times as many signatures to import goods in poor countries as it does in rich ones. Africa, which is home to several low-income countries, has twice as many import procedures as the OECD countries (McLinden 2012). Similarly, the lack of competition in the market for logistics services, such as trucking, can result in high markups (Portugal-Perez and Wilson 2009; Raballand et al. 2010).
16. These embodied services are found to substantially boost the productivity of manufacturing firms (Arnold et al. 2016; Arnold, Javorcik, and Mattoo 2011; Fernandes and Paunov 2012).
17. Negotiations on services trade reforms have been slow and challenging. Many have focused on business-to-consumer transactions, where calls for consumer protection have been high. However, as more services are business-to-business (B2B)—and with larger, often repeat, contractual relationships in B2B—it might be possible to reinvigorate negotiations in that area.
18. The World Bank Services Trade Restrictions Database (and its accompanying Services Trade Restrictions Index [STRI], http://iresearch.worldbank.org/servicetrade/) reveals that restrictions on entry, ownership, and operations of foreign service providers remain common. Opaque and

discretionary licensing can make market access unpredictable in many countries, even when there is no explicit discrimination.

19. Chapter 1 documented how certain manufacturing sectors are more traded than others and therefore offer greater scope for productivity increases, and that they vary along various employment dimensions too. Thus, high-skill global innovator industries (electronics, transportation equipment, other machinery and equipment, pharmaceutical products, and electrical machinery) provide greater scope for technology diffusion and other spillovers, but are becoming increasingly automated. Meanwhile, low-skill labor-intensive tradables (textiles and apparel as well as other light manufacturing) continue to promise a large number of unskilled-labor-intensive jobs.
20. The literature points out that while trade, particularly with China, has contributed to losses in manufacturing jobs in Europe and the United States, technology has played a significant role too (Acemoglu and Autor 2011; Autor et al. 2014).
21. In general, it might be easier for countries hitherto less involved in global manufacturing to enter into less saturated markets where countries are not locked in ferocious competition over tight margins (Harrison and Rodríguez Clare 2010).
22. Arguing the existence of an externality does not obviate the importance of market signals. For example, Embraer is a successful aircraft company, which, as a state-owned enterprise, facilitated Brazil's entry into the aircraft industry in 1969, when the country's per capita income was only 8 percent that of the United States (Chang 2009). But with no measure of the subsidies received during the period when Embraer was a military project, it is impossible to know whether the ex post realized externalities were worth it (Maloney and Nayyar 2017). Similarly, the Ethiopian government is targeting the garment sector. With incentives provided to multinationals, and with considerable public investment in infrastructure (with assistance from China), new production facilities are being set up in Ethiopia. Again, the extent of the resources expended is not known, and it is still early to determine the catalytic role of these investments (Oqubay 2015).
23. The resulting surge in the value of flower exports—from less than US$0.5 million in 1984 to more than US$400 million in 2006—was attributable, at least in part, to this effort (Hernández et al. 2007).
24. For example, when Latin American countries pursued import substitution strategies in the 1960s and the 1970s, the governments provided support without market contestability or sufficient discipline, with the result that too many low-productivity firms operated alongside the high performers (Hausmann and Rodrik 2003). Firms in East Asian countries during those decades, in contrast, experienced a good balance between promotion and evaluation—for example, through budget subsidies with clear sunset clauses (Harrison and Rodríguez-Clare 2010).

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# Conclusion: Implications for Manufacturing-Led Development Strategies

New technologies and changing globalization patterns do not spell the end of manufacturing export-led development, but they do make it a less powerful strategy than before. Manufacturing will remain a part of development strategies, but it will likely contribute less to inclusive growth than it did in the past "miracles" of many current high-income industrialized economies, particularly those in East Asia. The feasibility of using Industry 2.0 technologies to attract production is becoming more challenging because cheap labor as a source of competitive advantage is increasingly giving way to more demanding firm ecosystem requirements. The alternative—enabling local firms to use Industry 4.0 technologies—has a higher bar, too.

At the same time, the sector's dual promise of productivity growth and job creation is unlikely to hold as widely in the future, affecting the desirability of manufacturing-led development. "Potential jobs" could be lost in low- and middle-income countries (LMICs) by never being created, as high-income countries adopt new technologies and keep more manufacturing within their own borders. Or, if the only way LMICs can compete in global manufacturing is by adopting labor-saving processes (automation), that, too, will eliminate potential jobs. New technologies could also shorten global value chains (GVCs)—3-D printing, for example, substitutes trade in services for trade in physical parts and components—and therefore reduce the productivity benefits associated with international trade in manufactured goods.

Some manufacturing industries will remain feasible entry points for hitherto less industrialized countries and drivers of low-skill employment. For example, a range of commodity-based processing manufactures are less automated and less concentrated in terms of export locations. Further, despite a rising bar to be globally competitive, countries with low unit labor

costs could remain cost-effective in the production of labor-intensive tradables such as textiles, garments, and footwear given the limited automation thus far. Domestic or regional markets for lower-quality, lower-price manufactures as a source of productivity gains and job creation will also likely remain unless new technologies can match the low price with goods of much higher quality. For manufacturers that serve low-quality, lower-price market segments in lower-income countries, regional trade agreements could enable scale economies and improve productivity by enlarging the size of "domestic" markets. This could occur even in manufacturing sectors that are both highly traded and already relatively automated: for example, sports equipment, musical instruments, jewelry, and toys (in the manufacturing not elsewhere classified [n.e.c.] sector) or motorcycles and small cars (in the transport equipment sector), where competing using traditional processes is likely to remain viable, at least for some time.

The increasing "servicification" of manufacturing is significantly raising the feasibility bar by placing a premium on increasing the productivity of services linked to manufacturing. Services that are either embodied or embedded in manufactured goods increasingly matter for manufacturing competitiveness and account for much of the value added in a product's supply chain. With "smart" production processes, for example, information and communication technology (ICT) service sectors—as the predominant producers and users of data—can play a particularly crucial role in boosting manufacturing competitiveness. Therefore, looking at the manufacturing process as a value chain of activities involved in designing, making, selling, and supporting the use of goods will deliver greater opportunities than the narrower focus on production per se. The increasing synergies between the manufacturing and services sectors mean that rather than focusing on sector-specific solutions, countries should pursue diverse sources of productivity growth throughout a product's value chain to best capture the potential spillovers.

The growth of the services sector within and beyond this broader manufacturing process will also present opportunities to benefit from further productivity growth and job creation, particularly as incomes rise and the demand for services grows disproportionately. The features of manufacturing once thought of as uniquely special for productivity growth might be increasingly shared by some services—particularly financial, telecommunication, and business services, which are now internationally tradable and yield the benefits of scale economies, competition, and technology diffusion.

However, most service sectors that exhibit these productivity-enhancing characteristics are less likely to be associated with large-scale employment creation for unskilled labor. The skill intensity of these professional services therefore limits the pro-development impact in LMICs, which have a large pool of unskilled workers. Services-led development, in turn, might be constrained by the paucity of high-skilled workers. And although some professional services do not need a manufacturing core to flourish, the growing interdependence between the two sectors cannot be emphasized enough.

Given shifting technologies and patterns of globalization, the attention to downside risks needs to be balanced with more attention to positioning firms and workers to take advantage of new opportunities. Competitiveness, capabilities, and connectedness (the 3Cs) will be central to manufacturing-led development strategies, but this agenda needs to be reconceptualized, both to highlight traditional reforms where there is greater urgency and to identify new reforms in line with the changing demands of new technology and heightened international competition. There may be opportunities to leapfrog current production processes and enter GVCs or new manufacturing sectors using the new technologies, but usually the improvement will be a continual process. Seeking to be on the frontier of new technologies may attract attention, but the development impact of catching up is considerable and likely to be much greater in LMICs.

Further, more demanding reform priorities increase the need to exploit the complementarities between economywide and targeted approaches. For instance, it may be more feasible to meet the competitiveness requirements by targeting production in certain locations rather than the whole economy. Similarly, countries could tailor strategies to strengthen the 3Cs based on what they do make (or aim to make) and the extent of changes they can expect to face in these sectors rather than across the board. Horizontal policies will inevitably have differential effects across sectors, which policy makers should take into account in setting priorities for reforms. Targeted interventions may also be more desirable if there are dynamic gains associated with industrialization and if countries cannot leapfrog to Industry 4.0 without having first developed traditional manufacturing processes. At the same time, for growth to be more inclusive over time, establishing the building blocks of competitiveness, capabilities, and connectedness across the economy would be necessary to exploit linkages and develop transferable skills. Given the increasing linkages across sectors, targeting narrow sectors is also unlikely to be feasible.

As countries adjust to the changing global economic environment, the policy agenda is challenging but urgent given the potential economic, social, and political costs. Change creates winners and losers. And much of the attention to date has been on the potential for new technologies to be disruptive, especially in the extent of worker displacement. Policy makers need to identify some concrete ways for LMICs to position themselves to address potential disruptions while expanding the scope to take advantage of the opportunities that technology and globalization will bring.

The manufacturing sector will remain a source of productivity gains and employment for unskilled workers, although not necessarily occurring in the same win-win combination as before. This means productivity and employment gains can be achieved, just not necessarily together. The risk of rising inequality is therefore real. Being unprepared for new opportunities will be costly—socially, economically, and politically—and complacency about this reform agenda is not an option.

## Future Research

Going forward, research priorities should include conducting more disaggregated analyses and expanding the availability of data about firms' use of technology. This would enable a deeper understanding of the drivers of technology adoption and its contributions to productivity and to the quality as well as the quantity of labor hired. Additional research should also explore the impact of other megatrends on production decisions, particularly the impacts of the climate change agenda, shifting demographics, and urbanization.

The next step is move the unit of analysis from the macro to the micro, from sectors and countries to firms and subnational units. The focus should be on analyzing firm-level data, where available, and on combining the data with relevant district- or province-level information, where possible. Even at the two-digit ISIC sector level, this book has made it clear that there are distinct patterns in the expected impacts of technology and in the shifting concentration of international production. But of course, there will be even greater heterogeneity in the scope for spillovers and contributions to productivity growth and job creation across firms within those sectors. More work is needed to learn how management practices and managerial capabilities, strategies for interacting with supplier networks, and decisions regarding technology adoption, quality upgrading, and pricing can affect the ability of firms and sectors to absorb technology and to help them compete in global markets.

Likewise, the analysis in the book has looked at the competitiveness, capabilities, and connectedness (3Cs) of countries in the aggregate. Assessing countries along the 3Cs provides a global overview of how relative reform priorities may vary; yet this assessment may conceal the variation in the 3Cs across different regions, provinces, or cities within countries. More granular variations in such measures can help identify which ones really do matter across firms and sectors and can help tailor relevant policy recommendations.

More generally, there is an urgent need to further the agenda on the collection and compilation of data related to the adoption of technologies associated with Industry 4.0, particularly in low- and middle-income countries. For example, this book has relied on country-level data about the use of robots from the International Federation of Robotics and has referred to imputations that estimated the susceptibility of sectors to 3-D printing. On the growing diffusion of the Internet of Things, the paucity of information, even aggregated by sector and country, is striking. Similarly, data about the evolving costs of those technologies are few and far between. Efforts to fill the gaps likely would involve a series of firm surveys, the collation and compilation of any existing data from industry associations, technology institutes, and market research studies, as well as a deep dive into highly disaggregated trade data (for example, at the six-digit level, to capture flows of 3-D printers and robots).

Improved data will better enable the identification of causal impacts when assessing the potential implications of the adoption of technologies associated with Industry 4.0. It could provide more nuanced evidence about the drivers of reshoring and about the extent to which the adoption of Industry 4.0 technologies in advanced countries has resulted in a decline in exports from low- and middle-income countries in the relevant sectors or products. Additional research could also be conducted on whether the adoption of new technologies in low- and middle-income countries has reduced job creation and the extent to which substitution effects of technology for labor are offset by expanding jobs if the sector is growing. Similarly, the potential for acquiring advanced technology through outward foreign direct investment from low- and middle-income countries to high-income countries as a means of production upgrading warrants further analysis.

Last, but not least, although this book has emphasized new technologies and changing globalization patterns as the bigger trends at the center of the evolving geography of production, other megatrends will matter too. For instance, trends in demography and urbanization will affect both the supply of and demand for manufactured goods. Similarly, changing consumer preferences—owing to climate change and the sharing economy—may impact both the demand for manufactures and where production takes place, to the extent that "green" becomes an important element in determining competitiveness. In-depth and careful analyses of those issues will be necessary to assess the future of manufacturing-led development strategies.

APPENDIX A

# Data Sources and Definitions

"Industry" is often used interchangeably with "manufacturing," but the latter is a subset of the former in the United Nations (UN) System of National Accounts. In this internationally agreed standard set of recommendations for compiling measures of economic activity, "industry" is defined to include mining, manufacturing, construction, and utilities. This book uses the term "manufacturing" rather than the full set of activities under "industry."

The period under consideration for much of the analysis is from the early 1990s to the latest year of available data. The early 1990s was chosen as the starting point because the information and communication technology (ICT) revolution enabled the global fragmentation of production during that time. The book also groups countries by World Bank income classification based on their per capita income levels in 1990 or 1994. The analysis presented in this book also applies a population filter whereby all countries below a population of 1 million are excluded.

The following explains the choice and use of data sources for specific variables used throughout the book.

**Manufacturing value added.** When looking at manufacturing in the aggregate, data on manufacturing value added (MVA) are taken from the World Bank's World Development Indicators (WDI) database. This source is preferred to the UN National Accounts because the WDI distinguishes between value added in purchaser prices and value added in basic prices (the difference being net indirect taxes), which varies by country. The period under consideration is 1994 to 2015. To compute country shares in global MVA, each country's MVA in constant 2010 U.S. dollars is divided by the MVA summed across all countries in the world. To compute the share of MVA in gross domestic product (GDP), the current local currency unit series is used. The MVA data on a small number of large economies are

missing in either 1994 or 2015. In these cases, the dataset is augmented by importing data from the UN Industrial Development Organization's (UNIDO) MVA database or by extrapolating the WDI data on MVA for later years using the trends in UNIDO's MVA database.

**Manufacturing employment.** The data on manufacturing employment are only available for a small subset of 67 countries. Even this sparse dataset is obtained from combining myriad data sources: the International Labour Organization's ILOSTAT database; the ILO's Key Indicators of the Labor Market (KILM) database; the Groningen Growth and Development Centre (GGDC) database, University of Groningen, Netherlands; and UN National Accounts. Further, given data limitations, the most recent year included is 2010.

**Manufacturing value added and employment, by subsector.** The data on value added and employment, by manufacturing subsector at the International Standard Industrial Classification (ISIC) two-digit level, are taken from the UNIDO Industrial Statistics (INDSTAT) database. The country coverage for these data is extremely limited, with a sparse time series. The sample therefore cannot be used to generalize about either regional groups or country groups by income level. Despite the limitations of the data, INDSTAT is the only source that enables subsectoral analysis.

**Trade patterns by manufacturing subsector.** Trade in value added, rather than gross exports, provides a more accurate description of a country's export basket by avoiding the double counting associated with the value of imported intermediates embodied in exports. Therefore, when calculating the top 10 exporting countries and their shares across different manufacturing groups, the report used the Trade in Value Added (TiVA) dataset of the Organisation for Economic Co-operation and Development (OECD) and World Trade Organization (WTO), which provides estimates of the domestic value added in gross exports. The last available year for these data in 2011. Further, TiVA's country coverage is limited and therefore may wrongly exclude a country from the list of top 10 exporters. However, the same exercise was repeated using UN Comtrade data, and there were no changes in the list of top 10 players.

To calculate the revealed comparative advantage (RCA) of countries' export baskets, however, the report used UN Comtrade for greater country coverage. With TiVA, it would not have been possible to analyze specialization patterns in Sub-Saharan African Africa as well as many countries in the South Asia, East Asia and Pacific, and Middle East and North Africa regions. RCAs are computed for two periods: 1992–94 and 2012–14.

**Share of blue-collar workers by manufacturing subsector.** The World Bank's International Income Distribution Data Set (I2D2), the largest global harmonized household survey database, could not be used to track the distribution of occupations by manufacturing subsector because data are only available for the manufacturing sector in the aggregate. Therefore, the book

instead used available data from the Integrated Public Use Microdata Series (IPUMS) International database, a project of the Minnesota Population Center at the University of Minnesota dedicated to collecting and distributing census data from around the world.

The country coverage, especially for more recent years and with the appropriate subsector concordances, was extremely limited. This resulted in the arbitrary selection of countries, the criteria for which were twofold: the availability of census data in or after 2008 and a sample that would include both high-income countries and low- and middle-income countries. The latter facilities an analysis of the variation in occupation intensities in the same subsector between countries at different levels of development.

The selected countries (and years of census data) were Armenia (2011), Belarus (2009), Brazil (2010), Costa Rica (2011), the Dominican Republic (2010), Ecuador (2010), France (2011), Greece (2011), Hungary (2011), India (2009), the Islamic Republic of Iran (2011), Ireland (2011), Mexico (2015), Panama (2010), Peru (2007), Portugal (2011), Spain (2011), the United States (2010), and Vietnam (2009).

**The 3Cs: competitiveness, capabilities, and connectedness.** Each of the 3Cs is described by a summary measure that aggregates three relevant dimensions. These nine component measures are reported in table A.1. "Competitiveness" consists of the ease of doing business (World Bank Doing Business), the rule of law (World Bank Worldwide Governance Indicators), and the use of mobile technologies to complete financial transactions (World Bank Global Findex). "Capabilities" consists of ICT use (International Telecommunications Union's ICT Indicators Database), tertiary school enrollment rates (World Bank's World Development Indicators), and the share of royalty payments and receipts in trade (World Bank's World Development Indicators). "Connectedness" combines the dimensions of logistics performance (World Bank's Logistics Performance Index), restrictions on trade in manufactured goods (Kee, Nicita, and Olarreaga 2009), and the restrictions on trade in professional services (World Bank's Services Trade Restrictiveness Index). Note for all but these last two measures, the scale is such that higher values represent stronger performance. The z-scores for the competitiveness, capabilities, and connectedness indexes are based on the simple average of the component measures. Each component measure, which is reported in table A.1, reflects data from 2012–14 or the latest available year.

## Reference

Kee, Hiau Looi, Alessandro Nicita and Marcelo Olarreaga. 2009. "Estimating Trade Restrictiveness Indices." *Economic Journal* 119: 172–99.

**Table A.1 Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy**

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| AFG | Afghanistan | SAR | LIC | 2.14 | .. | .. | 0.1 | 8.7 | 0.00 | 38.1 | –1.59 | –0.86 |
| AGO | Angola | SSA | LMIC | 2.24 | .. | .. | 0.4 | 9.9 | 0.27 | 38.4 | –1.07 | –0.76 |
| ALB | Albania | ECA | UMIC | 2.41 | 5.4 | 45 | 6.6 | 61.1 | 0.27 | 68.9 | –0.36 | –0.81 |
| ARE | United Arab Emirates | HIC | HIC | 3.94 | 3.0 | .. | 11.9 | .. | .. | 76.9 | 0.71 | 0.95 |
| ARG | Argentina | LAC | UMIC | 2.96 | 9.1 | 49 | 15.6 | 80.6 | 1.38 | 57.5 | –0.80 | –0.67 |
| ARM | Armenia | ECA | LMIC | 2.21 | .. | 32 | 9.0 | 44.0 | .. | 73.6 | –0.34 | –0.77 |
| AUS | Australia | HIC | HIC | 3.79 | 9.8 | 31 | 27.3 | 87.4 | 0.81 | 80.3 | 1.82 | 3.00 |
| AUT | Austria | HIC | HIC | 4.10 | .. | 58.5 | 27.5 | 80.6 | 0.63 | 78.9 | 1.85 | 1.57 |
| AZE | Azerbaijan | ECA | UMIC | 2.45 | 3.8 | .. | 19.3 | 23.4 | 0.04 | 68.0 | –0.60 | –0.89 |
| BDI | Burundi | SSA | LIC | 2.51 | 7.1 | 40 | 0.0 | 3.7 | 0.01 | 47.4 | –1.12 | –0.84 |
| BEL | Belgium | HIC | HIC | 4.11 | .. | 46 | 35.8 | 72.3 | 0.82 | 73.0 | 1.42 | 0.39 |
| BEN | Benin | SSA | LIC | 2.43 | 10.3 | .. | 0.5 | 13.7 | 0.02 | 48.5 | –0.58 | –0.72 |
| BFA | Burkina Faso | SSA | LIC | 2.73 | 9.5 | .. | 0.0 | 4.5 | 0.01 | 51.3 | –0.53 | –0.66 |
| BGD | Bangladesh | SAR | LMIC | 2.66 | .. | 35 | 2.0 | 13.4 | 0.03 | 40.8 | –0.70 | –0.69 |
| BGR | Bulgaria | ECA | UMIC | 2.81 | .. | 55 | 21.0 | 70.4 | 0.34 | 73.5 | –0.12 | –0.61 |
| BHR | Bahrain | HIC | HIC | 3.31 | 4.2 | 51 | 20.8 | 36.9 | .. | 68.4 | 0.46 | 1.17 |
| BIH | Bosnia and Herzegovina | ECA | UMIC | 2.60 | 1.7 | .. | 14.8 | .. | 0.15 | 63.9 | –0.29 | –0.77 |

*(Table continues on next page)*

**Table A.1 Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| BLR | Belarus | ECA | UMIC | 2.40 | 6.9 | 40 | 30.0 | 89.3 | 0.25 | 74.1 | –0.79 | 0.31 |
| BOL | Bolivia | LAC | LMIC | 2.25 | 8.7 | 21 | 1.6 | .. | 0.37 | 49.9 | –1.15 | –0.69 |
| BRA | Brazil | LAC | UMIC | 3.09 | 21.5 | 58 | 11.5 | 47.0 | 1.05 | 56.5 | –0.19 | –0.51 |
| BWA | Botswana | SSA | UMIC | 3.05 | 0.7 | 47 | 1.5 | 23.5 | 0.05 | 65.6 | 0.63 | 1.38 |
| CAN | Canada | HIC | HIC | 3.93 | 3.3 | 41 | 35.4 | .. | 1.41 | 78.6 | 1.84 | 2.30 |
| CHE | Switzerland | HIC | HIC | 3.99 | 0.8 | .. | 43.4 | 56.3 | 3.71 | 76.1 | 1.97 | 0.11 |
| CHL | Chile | LAC | HIC | 3.25 | 5.9 | 27 | 14.1 | 86.3 | 0.96 | 69.6 | 1.33 | –0.16 |
| CHN | China | EAP | UMIC | 3.66 | 9.3 | 66 | 15.9 | 37.6 | 0.50 | 64.3 | –0.34 | 0.78 |
| CIV | Cote d'Ivoire | SSA | LMIC | 2.60 | 25.4 | 68 | 0.5 | 8.8 | 0.04 | 52.3 | –0.62 | –0.28 |
| CMR | Cameroon | SSA | LMIC | 2.15 | 13.5 | 43 | 0.1 | 16.2 | 0.05 | 45.3 | –0.96 | –0.74 |
| COG | Congo, Rep. | SSA | LMIC | 2.38 | .. | 35.5 | 0.0 | 9.8 | .. | 40.6 | –1.04 | –0.71 |
| COL | Colombia | LAC | UMIC | 2.61 | 18.7 | 34 | 10.3 | 53.0 | 0.45 | 70.9 | –0.31 | –0.61 |
| CRI | Costa Rica | LAC | UMIC | 2.65 | 1.3 | 60 | 10.5 | 52.2 | 1.06 | 68.5 | 0.48 | –0.46 |
| CYP | Cyprus | HIC | HIC | 3.00 | .. | .. | 21.2 | 53.6 | 0.35 | 72.7 | 1.01 | –0.23 |
| CZE | Czech Republic | HIC | HIC | 3.67 | .. | 44 | 27.3 | 65.8 | 0.54 | 76.7 | 1.12 | 0.72 |
| DEU | Germany | HIC | HIC | 4.23 | .. | 59 | 35.9 | 64.9 | 0.75 | 79.9 | 1.78 | 0.60 |
| DNK | Denmark | HIC | HIC | 3.82 | .. | 55 | 41.5 | 80.7 | 1.13 | 84.9 | 2.04 | 2.91 |
| DOM | Dominican Republic | LAC | UMIC | 2.63 | .. | 33 | 5.7 | 47.1 | .. | 59.4 | –0.46 | –0.45 |

*(Table continues on next page)*

**Table A.1 Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| DZA | Algeria | MNA | UMIC | 2.77 | 29.7 | .. | 4.3 | 35.2 | 0.16 | 47.8 | –0.83 | –0.38 |
| ECU | Ecuador | LAC | UMIC | 2.78 | 2.6 | 20 | 8.2 | 40.2 | .. | 58.0 | –1.03 | –0.75 |
| EGY | Egypt, Arab Rep. | MNA | LMIC | 3.18 | 31.6 | 81.5 | 3.8 | 32.7 | 0.37 | 56.6 | –0.50 | –0.73 |
| ESP | Spain | HIC | HIC | 3.73 | .. | 45 | 27.5 | 88.6 | 0.72 | 75.7 | 0.90 | 1.68 |
| EST | Estonia | HIC | HIC | 3.36 | .. | .. | 29.0 | 71.3 | 0.15 | 81.1 | 1.33 | 0.70 |
| ETH | Ethiopia | SSA | LIC | 2.38 | 12.4 | 84 | 0.4 | 8.1 | 0.02 | 47.3 | –0.44 | –0.88 |
| FIN | Finland | HIC | HIC | 3.92 | .. | 47 | 31.9 | 89.0 | 2.10 | 80.8 | 2.07 | 1.67 |
| FRA | France | HIC | HIC | 3.90 | .. | 46 | 40.1 | 62.2 | 1.62 | 76.3 | 1.41 | 0.50 |
| GBR | United Kingdom | HIC | HIC | 4.07 | .. | 45 | 37.5 | 57.5 | 1.78 | 82.7 | 1.81 | 2.58 |
| GEO | Georgia | ECA | LMIC | 2.35 | 0.0 | 37 | 13.5 | 39.1 | 0.09 | 80.2 | 0.30 | –0.84 |
| GHA | Ghana | SSA | LMIC | 2.66 | 9.1 | 44 | 0.3 | 15.3 | .. | 58.8 | 0.12 | –0.16 |
| GIN | Guinea | SSA | LIC | 2.36 | 12.6 | .. | 0.0 | 10.4 | 0.02 | 46.2 | –1.17 | –0.80 |
| GMB | Gambia, The | SSA | LIC | 2.25 | 17.1 | .. | 0.1 | 2.9 | .. | 51.7 | –0.66 | .. |
| GRC | Greece | HIC | HIC | 3.24 | .. | 39.5 | 28.5 | 111.4 | 0.30 | 68.7 | 0.24 | –0.77 |
| GTM | Guatemala | LAC | LMIC | 2.48 | 8.8 | 48 | 2.6 | 18.3 | 0.57 | 62.9 | –0.99 | –0.67 |
| HKG | Hong Kong SAR, China | HIC | HIC | 4.07 | 0.8 | .. | 31.5 | 68.2 | 0.21 | 84.2 | 1.83 | 1.06 |
| HND | Honduras | LAC | LMIC | 2.46 | 7.0 | 34 | 1.7 | 21.0 | 0.42 | 59.1 | –0.95 | –0.54 |

*(Table continues on next page)*

**Table A.1 Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| HRV | Croatia | ECA | UMIC | 3.16 | 0.6 | .. | 22.8 | 69.5 | 0.62 | 73.0 | 0.20 | –0.23 |
| HUN | Hungary | HIC | HIC | 3.43 | .. | 40 | 26.5 | 53.7 | 1.60 | 73.1 | 0.40 | 0.26 |
| IDN | Indonesia | EAP | LMIC | 2.98 | 3.9 | 76 | 1.2 | 31.0 | 0.47 | 61.5 | –0.41 | –0.71 |
| IND | India | SAR | LMIC | 3.42 | 13.1 | 87.5 | 1.3 | 24.6 | 0.52 | 55.3 | –0.06 | –0.53 |
| IRL | Ireland | HIC | HIC | 3.79 | .. | 41 | 26.8 | 72.8 | 13.09 | 79.5 | 1.79 | 1.83 |
| IRQ | Iraq | MNA | UMIC | 2.15 | .. | .. | 0.0 | .. | 0.01 | 45.6 | –1.46 | –0.89 |
| ISR | Israel | HIC | HIC | 3.66 | 2.2 | .. | 26.9 | 66.8 | 1.18 | 71.7 | 1.17 | 1.07 |
| ITA | Italy | HIC | HIC | 3.76 | .. | 58 | 23.6 | 63.9 | 0.73 | 72.3 | 0.25 | –0.07 |
| JAM | Jamaica | LAC | UMIC | 2.40 | .. | .. | 6.2 | 27.9 | 0.50 | 67.5 | –0.23 | –0.53 |
| JOR | Jordan | MNA | LMIC | 2.96 | 22.6 | 64 | 4.5 | 44.3 | 0.05 | 57.3 | 0.46 | –0.82 |
| JPN | Japan | HIC | HIC | 3.97 | 4.7 | 56 | 29.8 | 62.4 | 3.10 | 75.5 | 1.51 | –0.23 |
| KAZ | Kazakhstan | ECA | UMIC | 2.75 | .. | 28 | 12.9 | 48.2 | 0.12 | 75.1 | –0.37 | –0.10 |
| KEN | Kenya | SSA | LMIC | 3.33 | 6.4 | 73 | 0.2 | 4.0 | 0.43 | 61.2 | –0.49 | 1.37 |
| KGZ | Kyrgyz Republic | ECA | LMIC | 2.16 | 2.0 | 28 | 3.1 | 45.7 | 0.09 | 65.2 | –1.00 | –0.72 |
| KHM | Cambodia | EAP | LMIC | 2.80 | .. | 60 | 0.4 | 13.1 | 0.08 | 54.8 | –0.92 | –0.60 |
| KOR | Korea, Rep. | HIC | HIC | 3.72 | 4.5 | 66 | 39.0 | 97.3 | 1.19 | 84.1 | 0.95 | 2.96 |
| KWT | Kuwait | HIC | HIC | 3.15 | 4.1 | 57 | 1.4 | 27.0 | .. | 59.6 | 0.03 | 0.86 |
| LBN | Lebanon | MNA | UMIC | 2.72 | .. | 77 | 19.4 | 42.4 | 0.14 | 55.9 | –0.79 | –0.68 |

*(Table continues on next page)*

**Table A.1** **Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| LKA | Sri Lanka | SAR | LMIC | 2.70 | 5.4 | 57 | 2.5 | 19.3 | .. | 58.8 | 0.07 | –0.81 |
| LSO | Lesotho | SSA | LMIC | 2.03 | 4.9 | 37 | 0.1 | 10.3 | 0.13 | 60.4 | –0.17 | .. |
| LTU | Lithuania | HIC | HIC | 3.63 | .. | 38 | 27.4 | 72.6 | 0.11 | 78.8 | 0.98 | 0.10 |
| LVA | Latvia | HIC | HIC | 3.33 | .. | .. | 24.6 | 66.5 | 0.14 | 80.6 | 0.79 | –0.08 |
| MAR | Morocco | MNA | LMIC | 2.67 | 9.8 | 45.5 | 3.0 | 25.2 | 0.12 | 67.5 | –0.08 | .. |
| MDA | Moldova | ECA | LMIC | 2.61 | .. | .. | 14.6 | 41.3 | 0.34 | 72.8 | –0.40 | –0.89 |
| MDG | Madagascar | SSA | LIC | 2.15 | .. | 37.5 | 0.1 | 4.4 | 0.40 | 45.1 | –0.69 | –0.80 |
| MEX | Mexico | LAC | UMIC | 3.11 | 13.8 | 42.5 | 10.6 | 29.2 | 0.20 | 72.3 | –0.47 | –0.36 |
| MKD | Macedonia, FYR | ECA | UMIC | 2.51 | 1.1 | .. | 16.7 | 39.9 | 0.50 | 81.7 | –0.17 | –0.37 |
| MLI | Mali | SSA | LIC | 2.50 | 10.7 | 77 | 0.0 | 26.2 | 0.04 | 53.0 | –0.76 | –0.66 |
| MNG | Mongolia | EAP | LMIC | 2.51 | 4.8 | 28 | 6.3 | 65.0 | 0.14 | 68.2 | –0.39 | 1.04 |
| MOZ | Mozambique | SSA | LIC | 2.68 | 3.1 | 30 | 0.1 | 5.4 | 0.05 | 53.8 | –0.87 | .. |
| MRT | Mauritania | SSA | LMIC | 1.87 | .. | .. | 0.2 | 5.4 | .. | 47.2 | –0.82 | –0.70 |
| MUS | Mauritius | SSA | UMIC | 2.51 | 4.5 | 42 | 14.5 | 38.4 | 0.15 | 72.3 | 0.85 | –0.63 |
| MWI | Malawi | SSA | LIC | 2.81 | 11.2 | 38 | 0.0 | 0.8 | .. | 54.4 | –0.33 | –0.53 |
| MYS | Malaysia | EAP | UMIC | 3.43 | 24.5 | 73 | 10.0 | 30.0 | 0.33 | 78.1 | 0.57 | 0.02 |
| NAM | Namibia | SSA | UMIC | 2.74 | 1.3 | 65 | 2.1 | 9.3 | 0.06 | 58.8 | 0.19 | 0.79 |
| NER | Niger | SSA | LIC | 2.56 | 8.6 | .. | 0.0 | 1.6 | 0.00 | 49.6 | –0.61 | –0.82 |

*(Table continues on next page)*

**Table A.1** **Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| NGA | Nigeria | SSA | LMIC | 2.63 | 30.1 | 36 | 0.0 | 9.8 | .. | 44.6 | –1.04 | –0.18 |
| NIC | Nicaragua | LAC | LMIC | 2.53 | 6.0 | 22 | 1.9 | .. | .. | 55.8 | –0.70 | –0.84 |
| NLD | Netherlands | HIC | HIC | 4.19 | .. | 39.5 | 41.0 | 73.8 | 6.27 | 76.4 | 1.93 | 2.51 |
| NOR | Norway | HIC | HIC | 3.73 | 0.8 | .. | 38.8 | 76.5 | 0.34 | 82.8 | 2.02 | 2.45 |
| NPL | Nepal | SAR | LIC | 2.38 | 13.0 | 76 | 1.0 | 15.9 | .. | 58.9 | –0.70 | –0.83 |
| NZL | New Zealand | HIC | HIC | 3.39 | 9.1 | 27 | 30.6 | 80.5 | .. | 87.0 | 2.02 | 2.08 |
| OMN | Oman | HIC | HIC | 3.23 | 3.2 | 46.5 | 4.8 | .. | .. | 67.7 | 0.46 | .. |
| PAK | Pakistan | SAR | LMIC | 2.92 | 7.5 | 48 | 1.0 | 10.2 | 0.21 | 51.8 | –0.79 | –0.82 |
| PAN | Panama | LAC | UMIC | 3.34 | 6.7 | 68 | 7.9 | 41.7 | 0.15 | 66.2 | –0.12 | –0.41 |
| PER | Peru | LAC | UMIC | 2.89 | 5.2 | 28 | 5.8 | 40.5 | 0.30 | 70.3 | –0.53 | –0.75 |
| PHL | Philippines | EAP | LMIC | 2.86 | 18.1 | 80 | 3.4 | 33.6 | 0.36 | 60.4 | –0.35 | –0.60 |
| POL | Poland | ECA | HIC | 3.43 | .. | 31 | 18.8 | 72.4 | 0.63 | 77.8 | 0.80 | –0.22 |
| PRT | Portugal | HIC | HIC | 3.41 | .. | 40 | 26.5 | 66.8 | 0.40 | 77.4 | 1.14 | 0.08 |
| PRY | Paraguay | LAC | UMIC | 2.56 | 7.1 | 25 | 2.7 | 35.6 | .. | 59.0 | –0.69 | .. |
| QAT | Qatar | HIC | HIC | 3.60 | 4.0 | 46.5 | 10.0 | 15.6 | .. | 63.7 | 0.88 | .. |
| RUS | Russian Federation | ECA | UMIC | 2.57 | 13.7 | 32 | 17.7 | 77.6 | 0.89 | 73.2 | –0.72 | 0.74 |
| RWA | Rwanda | SSA | LIC | 2.99 | 11.7 | 32 | 0.1 | 6.9 | 0.34 | 69.8 | 0.07 | 0.31 |
| SAU | Saudi Arabia | HIC | HIC | 3.16 | 1.4 | 72 | 10.8 | 59.7 | .. | 61.1 | 0.25 | 0.39 |

*(Table continues on next page)*

**Table A.1** **Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| SEN | Senegal | SSA | LIC | 2.33 | 41.8 | 36.5 | 0.7 | 10.2 | 0.06 | 50.7 | –0.15 | –0.72 |
| SGP | Singapore | HIC | HIC | 4.14 | 12.7 | .. | 26.9 | 68.2 | 2.31 | 85.1 | 1.88 | 0.97 |
| SLV | El Salvador | LAC | LMIC | 2.71 | 7.1 | .. | 5.0 | 28.9 | 0.55 | 61.0 | –0.59 | –0.57 |
| SRB | Serbia | ECA | UMIC | 2.76 | .. | .. | 16.1 | 57.6 | 0.61 | 72.3 | –0.09 | –0.33 |
| SVK | Slovak Republic | HIC | HIC | 3.34 | .. | .. | 21.8 | 54.5 | 0.35 | 75.6 | 0.48 | –0.07 |
| SVN | Slovenia | HIC | HIC | 3.18 | .. | .. | 26.6 | 84.8 | 0.44 | 76.1 | 0.95 | –0.02 |
| SWE | Sweden | HIC | HIC | 4.20 | .. | 34 | 34.3 | 65.1 | 2.65 | 82.1 | 2.04 | 3.08 |
| TGO | Togo | SSA | LIC | 2.62 | 11.4 | .. | 0.4 | 10.5 | 0.05 | 48.6 | –0.80 | –0.83 |
| THA | Thailand | EAP | UMIC | 3.26 | 7.1 | 74 | 8.4 | 50.9 | 0.80 | 72.5 | –0.11 | –0.45 |
| TTO | Trinidad and Tobago | LAC | HIC | 2.40 | .. | 34 | 18.1 | .. | .. | 61.0 | –0.14 | .. |
| TUN | Tunisia | MNA | LMIC | 2.50 | .. | 79 | 4.5 | 34.4 | 0.10 | 64.9 | –0.05 | –0.69 |
| TUR | Turkey | ECA | UMIC | 3.42 | 6.0 | 90 | 12.0 | 78.2 | .. | 67.2 | –0.06 | –0.42 |
| TZA | Tanzania | SSA | LIC | 2.99 | 55.0 | 51.5 | 0.2 | 3.8 | 0.01 | 54.5 | –0.43 | –0.17 |
| UGA | Uganda | SSA | LIC | 3.04 | 7.3 | 38 | 0.1 | 4.5 | 0.19 | 57.8 | –0.34 | 0.23 |
| UKR | Ukraine | ECA | LMIC | 2.74 | 20.9 | 35 | 10.0 | 81.5 | 0.55 | 63.9 | –0.80 | –0.29 |
| URY | Uruguay | LAC | HIC | 2.97 | 8.6 | 11 | 24.2 | 63.7 | 0.16 | 61.9 | 0.68 | –0.54 |
| USA | United States | HIC | HIC | 3.99 | 4.5 | 54 | 30.4 | 87.1 | 3.29 | 82.5 | 1.60 | 2.82 |
| VEN | Venezuela, RB | LAC | UMIC | 2.39 | 9.9 | 69 | 7.8 | 77.2 | .. | 33.4 | –1.99 | –0.15 |

*(Table continues on next page)*

**Table A.1 Summary Measures for Connectedness, Capabilities, and Competitiveness, by Economy** *(continued)*

| | | | | Connectedness | | | Capabilities | | | Competitiveness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WBC | Economy | Region | Income classification | Logistics Performance Index | Overall Trade Restrictiveness Index (%) | Services Trade Restriction Index (1–100) | Fixed broadband subscriptions (per 100 people) | School enrollment, tertiary (% gross) | IPR payments and reciepts (% of trade) | Doing Business Index | Rule of law | Transactions by mobile phone (%, age 15+) |
| VNM | Vietnam | EAP | LMIC | 2.98 | .. | 31.5 | 6.7 | 28.1 | .. | 63.8 | –0.27 | –0.57 |
| YEM | Yemen, Rep. | MNA | LMIC | 2.18 | 4.5 | 76 | 1.3 | 10.6 | 0.09 | 39.6 | –1.24 | –0.86 |
| ZAF | South Africa | SSA | UMIC | 3.78 | 4.7 | 62 | 3.0 | 19.3 | 0.87 | 65.2 | 0.06 | 1.17 |
| ZMB | Zambia | SSA | LMIC | 2.43 | 4.2 | 44 | 0.1 | .. | .. | 60.5 | –0.25 | –0.03 |
| ZWE | Zimbabwe | SSA | LIC | 2.08 | .. | 60 | 1.0 | 6.7 | 0.17 | 47.1 | –1.35 | –0.26 |

*Sources:* World Bank World Development Indicators, Global Findex, and Doing Business Index databases.
*Note:* "Income classification" groups of economies are defined by the World Bank income classification based on their per capita income levels in 2015. The term "country" in abbreviations is for ease of classification and do not indicate country status. HIC = high-income country. LIC = low-income country. LMC = lower-middle-income country. UMC = upper-middle-income country. Regional abbreviations are as follows: EAP = East Asia & Pacific; ECA = Europe & Central Asia; LAC = Latin America & Caribbean; MNA = North America; MNA = Middle East & North Africa; SAR = South Asia; SSA = Sub-Saharan Africa and HIC = All high-income countries regardless of region; .. = not available. In the "3Cs" typology, countries are scored for "connectedness," "capabilities," and "competitiveness" based on their median or tercile z-score values, each calculated as an aggregate of relevant summary measures. Economies with a population over a million and with coverage of the majority of variables are included in the table.
a. "Connectedness" combines the dimensions of logistics performance, overall trade restrictiveness on manufactured goods, and the restrictions on trade in professional services.
b. "Capabilities" combines use of information and communication technology (ICT) as measured by the number of fixed broadband subscriptions per 100 people; tertiary school enrollment rates; and the share of intellectual property right (IPR) royalty payments and receipts in trade.
c. "Competitiveness" combines indexes on the ease of doing business and the rule of law with the use of mobile technologies to complete financial transactions.

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