Chapter 4 Technological progress, diffusion, and opportunities for developing countries: lessons from China

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Technological progress, diffusion, and opportunities for developing countries: lessons from China*

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ABSTRACT

The nature of technology used in products plays a major role in determining the governance structure of value chains and the benefits of participation for developing countries. Standardization through breaking production into modules with a high degree of functional autonomy (limited mutual interference between modules) can dramatically reduce the amount of research and development (R&D), learning by doing, and the number of complementary skills needed to produce a good. This greatly increases opportunities for developing country firms to participate in formerly capital-intensive industries through reducing entry costs into global value chains. However, widespread access to standardized products with little ability to modify technical features can lead to an excessive supply of homogeneous products in a local market, resulting in intense price competition and limited technology transfer. By contrast, technology that facilitates scope for product modification and greater interaction with technology owners can help boost technology transfer and product upgrading by developing country firms. The chapter illustrates this interaction between changes in technology and opportunities for developing countries through developments in the automotive and mobile phone handset industries, with a particular reference to China's growth experience. It also finds that automation is likely to have only a limited impact on developing countries' opportunities to participate in value chains through the offshoring of production by high-income countries, at least in the short term.

- Policies for helping domestically owned firms become technologically standalone – what some might refer to as "techno-nationalism" – do not necessarily help countries move into higher value-added production within GVCs. Instead, policymakers should encourage firms to be full partners in global technology ecosystems and to pursue open source innovation solutions.
- Automation might become a threat to developing country employment in the long term if consumption does not increase fast enough to generate sufficient additional labor demand to offset the labor-saving impact of technological change. In the short term, however, automation will not dramatically reduce the attractiveness of low-wage destinations, especially for labor-intensive tasks that require human dexterity, such as in the apparel industry.
- While automation does not pose immediate risks, governments need to develop a comprehensive digital strategy to maximize the gains from GVCs.

* This chapter draws from background studies and ongoing research collaboration with the following researchers: Chiara Criscuolo, Yoshihiro Hashiguchi, Keiko Ito, Jonathan Timmis, Ke Ding, Shiro Hioki, Mai Fujita, Tim Sturgeon, Eric Thun, Yuqing Xing, Satoshi Nakano, Kazuhiko Nishimura and Jiyoung Kim.

1. Introduction

An increasing number of developing countries is recognizing that participation in global value chains (GVCs) is an important prerequisite for economic development. At the same time, however, they fear that the prospects for value chain upgrading is limited, because once they join a value chain their production activities become "locked in" to the lower value-added segments of global production systems. Added to these concerns, they fear that new labor-saving technologies, such as robotization and automation in manufacturing, could erode the previous attractiveness of a cheap labor force as a source of comparative advantage. The analysis presented in this chapter shows that joining and upgrading in GVCs is still possible, provided that firms' strategies and policy interventions adapt themselves to the new and evolving technology environment.

Standardization, modularity and digitalization have made even complex technologies progressively more "diffusable" over the years, and this represents a new opportunity for firms from developing countries to join and move up the value chain. Standardization and modularity tend to increase as a technologies and products mature, managers try to reduce uncertainty and lower costs, and best practices get codified in the supply base. Today digital technologies enable standardization and modularity in increasingly complex features, products, and transactions. The greater spillover resulting from standardization and modularity allows faster diffusion of technology. The digitalization of many complex industrial productions enables even more firms and countries to leapfrog to more advanced technology. We use case study evidence from the automotive and mobile phone industries to support this thesis. We show that more standardization, or less complexity, of both products and production processes in value chains that are typically technology-intensive, such as the automotive and mobile phone ones lowered the entry costs into complex, technology intensive, products. Standardization has dramatically reduced the amount of R&D, learning by doing, and the number of complementary skills needed to produce a car or a phone handset.

Modularization and standardization lower the entry costs to product upgrading, but this does not translate automatically into technological advancement for the manufacturers. To move up to high value-added segments of technologically advanced value chains requires learning additional and complementary skills, even though they may be unrelated to some parts of manufacturing activities (e.g. marketing, sales, etc.). Our discussion on the success and upgrading of the Chinese smartphone industry offers an example of the strategies that have allowed some firms to leverage technological progress to upgrade, get closer to the global technology frontier, and become global brands.

In this chapter we also conclude that the need to graduate from labor-intensive production is not urgent. We show that automation reduces some of the incentives for GVCs to relocate to lower wage countries: the rising stock of industrial robots in high-income countries over the period 2003-2015 appears to be mildly associated with lower foreign direct investment (FDI) flows from richer to poorer countries. Yet, automation is not going to dramatically reduce the attractiveness of low-wage destinations in the near term, especially for labor-intensive tasks that require human dexterity. In the apparel industry, for example, soft materials like fabrics are difficult to handle through automation compared to solid materials such as metal or wooden objects, and sewing/stitching can still be out of the reach of robots' hands (see the evidence in Section 4.) And even in highly automatized industries such as electronics, human fingers are still needed for the assembly of devices made of thousands of tiny components. This is, for example, the case for smartphones, as discussed in interviews with manufacturers. A bigger challenge for GVC newcomers is rather to be competitive vis-à-vis existing production clusters and countries with high density of supply chains. These induce to lower costs for various support functions and services, beyond automation, and the density of supply chains supports responsiveness.

The rest of the chapter is organized as follows. In Section 2, we discuss the role of the GVC power relations in determining the way that technological progress creates opportunities for new entrants. In Section 3, we illustrate how two specific technological and business innovations, i.e. production modularization and platforms (a digital evolution of modularization), have played a fundamental role in opening up opportunities for new entrants in technology-intensive industries such as automotive and mobile phones. Section 4 discusses what strategies have allowed new manufacturers to leverage the opportunities from production modularization and platforms to upgrade because entry per se does not translate into immediate technological progress for these entrants. Then, Section 5 discusses one area of great public concern recently: robots and automation. Section 6 presents some policy implications from the discussion.

2. Technological progress and value chain dynamics

The extent to which technological progress will disrupt the present configuration of supply chains and open them to new players depends, in part, on the form of GVC power relations. Inomata (2017) employs the analytical framework developed by Gereffi, Humphrey, and Sturgeon (2005) to show how power relations between buyers and suppliers, as determined by the nature of transactions and the capabilities in the supply base, affect opportunities for new participants in GVCs. Gereffi *et al.* (ibid.) define five forms of GVC power relations: market-type, modular-type, relational-type, captive-type, and hierarchy-type (see Annex), and among them the modular-type GVCs are particularly interesting for our discussion. A "module" generally refers to a composite of subcomponents grouped by the type of function assumed in the final product. Each module has a high degree of functional autonomy (namely, the mutual interference between modules is small), while the standardized architecture of a module's interface makes it easy to combine multiple modules. Modularization can be employed in manufacturing of complex products, where production processes are simplified and partitioned. In modular types of production, knowledge-intensive segments (such as the harmonization of core components) are limited to only a few stages of the production process.

Accordingly, modularization reduces technological barriers to entry. It lowers the amount of R&D and learning-by-doing necessary to integrate into skill- and capital-intensive value chains (Sturgeon and Thun, 2019, and Xing, 2018). Chesebrough and Kusunoki (2001) further note that modularization also tends to reduce product uniqueness – a feature associated with high value added – which they refer to as "the modularity trap". Firms adopting the same modules basically produce very similar products. This undermines firms' profitability, mainly due to the high levels of competition. Section 2 will discuss this in more detail.

Therefore, adoption of advanced modules alone does not generate technological progress in manufacturers. Modularization helps to move into more complex value chains. But, in order to capture more value and increase profit margins, firms also need to learn to manage more complex processes (i.e. a process where a higher number of complementary skills is needed), and to master more complex tasks (i.e. tasks with some features that makes them unique). The smile curve shows there competences need to be developed to escape the modularity trap: the right-hand side (downstream) edge of the curve, where local firms capture value through branding and product ownership. This requires developing expertise in business functions such as design and marketing. These are capabilities very different from production skills, as are the features of the ecosystem and institutions that support them. These topics will be the subject of Section 3.

3. Opportunities from modularization and platforms: examples from the car and mobile phone industries

3.1 Automotive industry: the modularization of cars

Manufacturers in the automotive industry tend to show hierarchical power relations. A car is an extremely complex system containing over 15,000 different components, including key components that are often design-specific and difficult to substitute. During the assembly stage, the parts must be carefully aligned with one another in harmony, and the risk of interference between parts is not uncommon. For example, the "computerization" of modern cars has increased the risk that the air-conditioning system will interfere with electronic-intensive modules, which need to be located nearby within a narrow space between the engine and the instrument panel. Because of the high degree of manufacturing complexity, the automotive industry is highly prone to vertical integration and therefore to adopting a GVC power relation of the hierarchical type. This ensures a holistic and systematic coordination of every aspect of production from start to finish.[1]

However, developments in design schemes have spurred changes that have increased modularity in the auto industry. Large scale modularization in the automotive sector is already two decades old (Takeishi and Fujimoto, 2001).[2] Here however, we focus on a few recent examples. In 2013, Nissan introduced a design scheme called the "common module family" into the production lines of several key models. The scheme's objective was to reconfigure the production system so as to reduce costs yet also maintain the variety of product line-ups. This was pursued through the modularization of products, which increased the proportion of standardized common components that can be shared among different models, while also reducing costs through bulk purchases of common inputs. Even before the introduction of Nissan's scheme, Volkswagen devised the "modular transverse matrix platform" to develop a wide range of different products, including its standard models, such as the Golf, as well as luxury cars, such as Audi. Toyota later adopted the "Toyota new global architecture" for Prius in 2015, while Hyundai Motors, aided by its fully-automated assembly system, engaged in the large-scale outsourcing of its main car components, including the cockpit and chassis (Nikkei Business, 2013).

The implementation of modularization schemes has opened up new opportunities for firms from developing countries. As discussed earlier, modularization simplifies the production of a complex product by reducing knowledge-intensive segments of production (such as the harmonization of car components), with the effect of substantially lowering technological barriers to market entry. For example, Shenyang Aerospace Mitsubishi Motors China ran a joint business with a US auto-parts supplier, Delphi, to sell engines, transmissions, and other core system components to local car manufacturers in China (Oshika *et al.*, 2009). Engines and transmission systems were generally produced in-house. However, digital technology now makes it possible to pre-adjust the components to the specifications of a customer's individual car models with the help of electronic control units (ECUs).[3] Local manufacturers were thus able to enter the low-end Chinese car market without the need to develop sophisticated in-house technology. Firms such as Chery, BYD, and Geely were able to produce inexpensive, small cars that meet the needs of first-time car buyers. Between 1995 and 2010, domestic firms increased their share of the Chinese car market by 31.9 percent (Brandt and Thun, 2016). Obviously, the lower barriers to entry generated by opening up access to platform technology were only partly responsible for this spectacular rise in market share. Market structure and competition, ownership, and the mode of foreign entry are also crucially important in determining the scope for innovation and upgrading.

The gradual transformation of the automotive industry's value chains from the *hierarchical-type* to the *modular-type* was associated with an increased ability to codify transactions.[4] Codification has enabled firms to unbundle tasks (design, fabrication, assembly, and marketing), and for competition to take place in specific segments of production, rather than at the level of the whole industry, as traditionally envisaged in classical theories. As a result, the automotive industry changed from a vertically-integrated production system to one where value chains operate in a more open environment, thus increasing opportunities for emerging companies in developing countries.[5]

3.2 Electronic equipment industry: from modularization to the emergence of platforms and platform leaders

The electronic equipment industry covers a wide range of products, from personal computers (PCs) to mobile communication devices. Typically, the industry's supply chains are characterized by long supply lines that connect global buyers with electronic hardware manufacturers and assemblers. Global buyers are manufacturers of final consumer products, such as Apple, Hewlett-Packard, Toshiba, NEC, Samsung, and LG, that organize and preside over their own global production networks and tend to be located in traditional knowledge clusters. Suppliers tend to be dispersed nationally, regionally, and globally.[6] The long supply lines are the result of the delinking of innovation, design, heavy engineering, and standard-setting from production and assembly (a GVC pattern common in technologically-intensive industries).[7] This, together with the standardization of many information-communication technology (ICT) processes, including important ones,[8] led to a modular type of power relations for electronic equipment GVCs.

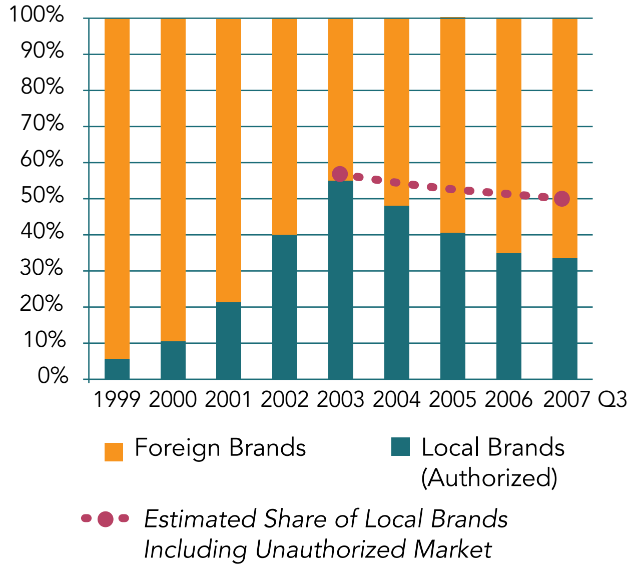
At the turn of the new millennium, platforms and platform leaders emerged as dominant new players in the electronics equipment GVCs.[9] A "platform" is defined as "a set of common components, modules, or parts from which a stream of derivative products can be efficiently created and launched" by "constraining the linkages among the other components" (Baldwin and Woodard, 2009). Platforms are built on core technology modules which define the fundamental technical parameters of the products manufactured through the platform. A large-scale integrated circuit, which often determines the performance level of the final product in which it is embedded, provides a good example of a core technology module. A platform leader is a firm that controls core technology modules, and therefore governs the final product's functions and performance. Such companies are still predominantly from rich countries. Yet, over the years, platform leaders from developing countries have also emerged. Particularly notable is the emergence of MediaTek as one of five dominant global players in mobile phone processors applications, and the associated dominance in China's mobile-phone market. We will discuss their role in what follows.

The advent of platforms has significantly destabilized the traditional set-up of electronic equipment GVCs. The mobile phone industry in China illustrates well the potential for disruption by platforms. By integrating most of the mobile phone's functionalities, platform solutions (sometimes referred to as "reference designs") have lowered the cost and time required by manufacturers to design low-end mobile phones. This has allowed Chinese brands, especially producers of imitative products, known as Shanzhai, to capture significant market shares despite having low expertise in core aspects of mobile phones technology. These brands grew from a share of less than 5 percent of the domestic mobile-phone market in 1999 to more than 50 percent by 2003 (see Figure 4.1). Their business model consisted in catering the domestic markets with low-priced handsets, which they were able to produce at low cost by leveraging the platforms' digital technology.

The modularization of the final products' architecture is what makes platforms effective in allowing newcomers to the GVCs. A platform is a complete module on its own that does not require surrounding components to have any product-specific attributes, except those regarding connection. Accordingly, any parts suppliers that have adopted the platform's interface can enter the market. Correspondingly, this tends to invite a massive entry of producers into the industry. In the case of China's mobile-phone industry, the marketing strategy of MediaTek, the chip vendor from Chinese Taipei mentioned earlier that came into the integrated circuit chip market in China. Shiu and Imai (2009) argue that the company boosted their influence in the industry by devising a unique marketing strategy. Alongside the production and sales of chipsets, they also offered an assembly blueprint for mobile phone terminals as a package bundle. The blueprint provided a thorough how-to guideline for producing mobile phones that embody its chipsets, such as the layout of parts configuration and electrical wiring, and even included a list of recommended parts suppliers.[10]

The turnkey solution of MediaTek's platform, however, turned out to be a double-edged sword.[11] While it enabled local manufacturers with limited knowledge and experience to enter the mobile handset market, it also became difficult for them to differentiate their final products, and little technology and know-how was transferred to the manufactures of the low-cost handsets. There are two reasons for this. First, as part of its marketing strategy, MediaTek decided to disclose only about 20 percent of its software source code, leaving the remaining 80% "black-boxed". This meant that users of their platform ecosystem were bound to produce products whose designs were highly subordinate to the platform's interface specification. The second factor was that the platform invited massive entry of producers into the market, as discussed earlier. This resulted in excessive supply of homogeneous goods for those manufacturers using the platform, as well as market fragmentation, severe price competition and low profit margins. Under these conditions, producers had very limited room for expenses in R&D or innovation that could have encouraged upgrading.[12] The GVC power relations of the industry was also affected. As China experienced an excess supply of undifferentiated mobile-phone terminals, the industry's value chains went from the *modular type* to the *market type*.[13]

FIGURE 4.1 The mobile-phone market in China prior to the smartphone



2007 China market share

Foreign brands		Top 5 local brands	
Nokia	28.9	Lenovo	6.5
Motorola	18.8	Nigbo-Bird	4.3
Samsung	11.1	Amoi	3.2
Sony-Ericsson	5.5	ZTE	2.3
LG	3.1	Konka	1.8
Top 5 foreign Share	67.4	Top 5 local Share	18.1

Note: Because of the lack of coverage of unauthorized makers' shipment, the share of local brands is biased downward. The broken line represents a rough estimate of the share of local brands including unauthorized makers.
Source: Imai and Shiu (2011), compiled from estimates by MII, CCID, and Pday Research Center.

4. Upgrading options

4.1 Surviving the price wars: options for firms in developing countries

What are the options for firms in developing countries to avoid excessive price competition at the low end and upgrade their value chains? The previous section illustrates two examples showing that the introduction of new technologies can disrupt the existing form of supply chains and stimulate market entry of emerging firms in GVCs, but can also lead to an excessive supply of undifferentiated products. This significantly reduces the profitability of the industry, leading to a high level of market fragmentation, falling prices, and little scope for innovation and upgrading. Given this background, what are the options for firms in developing countries? Can excess capacity and falling prices be avoided? What are good approaches to upgrading the position of emerging market firms in high technology areas?

Some local manufacturers have upgraded their own value chains through a commitment to active learning, enabled by open platforms and a shift in consumer demand. Ding and Hioki (2017) illustrate how technological transfer and value-chain upgrading happened in the Chinese mobile phone industry over the course of the last 15 years. As described earlier, in the early 2000s, the mobile-phone industry in China left little room for upgrading, dominated as it was by the "shanzhai sector". In recent years, however, Chinese companies in the industry have achieved remarkable growth (Table 4.1) and some of them have rapidly achieved international brand status in the global smartphone market. Furthermore, the domestic market positions of Chinese firms have also changed significantly (Table 4.2). From 2010 onward, Chinese products gained market share in products with mid-range prices, while still keeping their absolute advantages in the low price market. Some Chinese firms even began to enter the high-end segment of the smartphone market.

These trends were triggered, in part, by changes in consumer preferences regarding technology features. MediaTek maintained its advantage during the 3G era, yet it was not able to keep its dominant position when 4G was introduced.[15] Qualcomm, as the world's largest owner of 3G and 4G technology patents, increased its share of China's smartphone-baseband IC market. Its shipment share in China's 4G market accounted for more than 50% in 2015. Four Chinese companies in the top ten list in Table 4.1. primarily adopted Qualcomm's platforms: Xiaomi (70% of all models, as of 2015), OPPO (70%), VIVO (60%), and ZTE (50%). The high demand for Qualcomm's 4G technology was primarily driven by the dramatic increase in consumer demand for products of greater quality, functionality, and better data transmission. The increase in internet users interested in accessing communication platforms (WeChat, Taobao, and Didi) along with the upgrading of preferences that is consistent with a wealthier society, led to a surge in the demand for mid-range and high-end products. In particular, consumers demanded handsets with 4G technology, for their ability to provide faster and more stable transmission. Qualcomm's strategy was to focus on these middle-range and high-end segments of the market by

TABLE 4.1 Shipments of major smartphone makers in the global market, million units

	Vendors	2011	2012	2013	2014	2015	2016	2017
1	Samsung	95	198	299	308	320	310	316
2	Apple	93	136	153	193	232	216	216
3	Huawei	17	31	52	75	108	139	153
4	OPPO	N/A	5	18	31	45	95	118
5	VIVO	N/A	3	12	30	44	82	95
6	Xiaomi	N/A	7	19	65	73	58	92
7	LG	19	26	48	59	60	N/A	56
8	ZTE	17	31	42	45	51	57	46
9	Lenovo	4	23	45	N/A	45	50	39
10	Gionee	N/A	N/A	N/A	N/A	N/A	N/A	24

Note: N/A means the relevant information is not available.

Source: Ding and Hioki (2018), compiled from data by IHS iSuppli, a market research firm.

serving a few emerging local firms with production capabilities that can accommodate the technological profiles of Qualcomm's platform. This is in a sharp contrast with MediaTek's strategy of providing turnkey solutions to numerous undifferentiated manufacturers with minimum production capabilities.

Qualcomm also adopted an open platform approach and became highly proactive in developing new products and resolving problems jointly with its customers. This is because deepening technological complexities now entails much closer collaboration between platform vendors and mobile phone makers as well as the suppliers of other relevant components (amplifier and antenna, etc.). Furthermore, the life cycle of a mobile phone became much shorter (from 2 years in the 2/3G era to 6 months in the 4G era) while the expected time span for investing in research and development of IC chipsets became considerably longer. Platform vendors must therefore predict the future market trend two or three years in advance of the release of a new model, and keep continuous communication with their customers to learn about end-consumers' demand and preferences.

Reducing product modularity by opening the platform source codes to its users, allowed Qualcomm to offer them the possibility to undertake significant product differentiation on their own. It is reported that Qualcomm has opened approximately 80% of its hardware driver source code, compared to only 20% by MediaTek, as pointed out earlier. Under certain circumstances, the company even allows its customers to adjust the platform's design parameters (such as radio frequency specifications). Qualcomm offers regular support to its platform users and assists them in conducting co-marketing, often jointly holding product release conferences or introducing them to overseas carriers. In this way, the company constantly exchanges technological and marketing information with its customers. Such interactions are highly relevant for developing the competitive advantages of local manufacturers.[16]

TABLE 4.2 Market share of local smartphone brands in China

	2014 Q4			2015 Q3		
	Share of total	Share of local brands in each segment	Share of local top 3	Share of total	Share of local brands in each segment	Share of local top 3
High-end (>500$)	16%	Information unavailable	4.2%	13.5%	Information unavailable	9.4%
Mid-range (250-500$)	20.4%	76.5%	44.6%	24.8%	81.9%	58.8%
Low-end (<250$)	63.6%	100%	45.4%	61.7%	100%	48%

Source: Ding and Hioki (2018), compiled from data by GFK market research.

Qualcomm also provided its customers with various opportunities to cooperate with global suppliers, which further helped to accelerate the upgrading of the Chinese mobile phone industry. For example, Xiaomi collaborated with Biel Crystal (for cover glass), OPPO with Texas Instruments (for power chips), VIVO with Sony (for a front dual camera) and ArcSoft (for the camera software).

In summary, over time technological innovation and the strategies of major firms have driven dramatic changes in the participation of domestic firms in the Chinese mobile phone industry. MediaTek from Chinese Taipei enabled local firms to enter the market by providing a highly standardized platform that gave a turnkey solution for those without sufficient knowledge and experience to manufacture high-tech mobile phone terminals. However, the lower technological barrier to entry caused an excessive supply of undifferentiated products in the low-end market, leading to intense price competition. Referring back to the GVC typology, MediaTek's platform transformed the industry's value chains from the *modular type* to the *market type*. Subsequently, Qualcomm's higher level of commitment and collaboration with customers (through opening up most of the platform's software source code, technical assistance, and joint product development or product promotion) enabled local firms that had accumulated the minimum expertise to accommodate Qualcomm's technological profiles to upgrade their final products. Thus, Qualcomm's platform further changed power relations of this value chain into the relational type, in line with the increasing complexity of final product characteristics.[17] These developments required continuous efforts by local emerging companies to learn through active interactions with more advanced firms.

4.2 Implications of market shifts from feature phones to smartphones

So far, we have focused on the impact of disruptive technology embedded in key hardware components (such as IC chipsets). However, disruption of value chains also can be driven by software evolution. Sturgeon and Thun (2019) show how the smartphone market provides an opportunity to assess how companies can upgrade in manufacturing GVCs following disruptive technological change. The introduction of smartphones in 2007 opened up opportunities for upgrading by Chinese firms. With its iPhone handset, launched in 2007, Apple established a platform with a partly open architecture, the Apple iOS. Third-party developers can access the platform, and design tools and sell applications (apps) on Apple's online store, but governance of the resulting ecosystem is closed (Parker *et al.*, 2016). Partly in response to the iPhone, Google launched the Android OS for mobile handsets one year later. In contrast to iOS, Android has an open technology architecture and largely open governance. The Android OS was licensed for free and its "source code" published through the Android Open Source Project for all to use or modify as needed. As the leading internet search company, with revenues coming mainly from online ad placement fees, Google wanted more people to access the internet (and thus the Google search engine). The expectation was that continued growth in the use of Google's search engine would create more revenue than would fees from Android licenses.

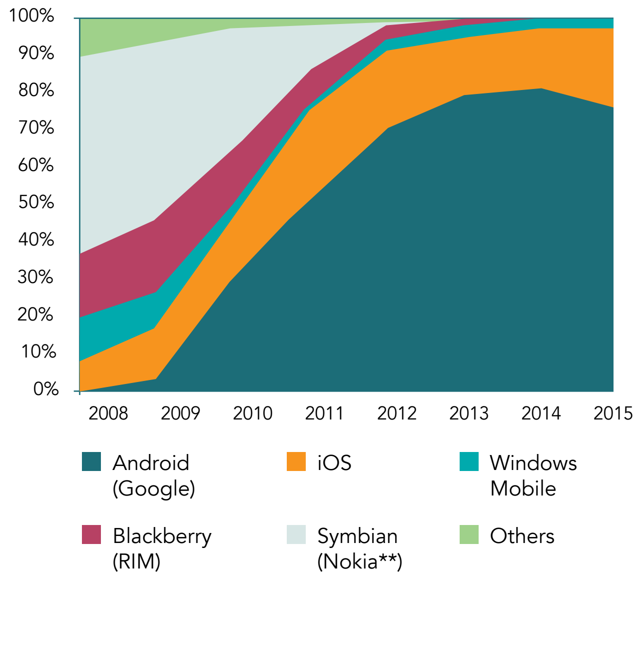
The impact of Android on the mobile telecom value chain was profound, as it caused the composition of the handset industry to shift dramatically. By 2016, all operating systems that predated the Apple iOS were reduced to single-digit market shares (see Figure 4.2, left-hand panel). A parallel shift also occurred in the market of phone manufacturers. The profits for handset sales were almost entirely taken by two firms: Apple, with 75 percent, and Samsung, with 25 percent (Reisinger, 2016). Incumbents (producers of pre-smartphone-era feature phones) collapsed from a 60 percent market share to less than 10 percent. In fact, of all the incumbent firms, only Samsung was able to make the transition to Android (and to the smartphone market) successfully (see Figure 4.2, right-hand panel). At the same time, a plethora of new firms, mostly Chinese, emerged.

The same pattern seen in previous waves of technological progress was observed for smartphones. With the availability of highly-integrated chip sets linked to an open-source operating system, Google's Android lowered the barriers to entry for new firms with lower capabilities, and also reduced product distinctiveness and the value-added from manufacturing handsets. The two leading brands, Samsung and Apple, which covered 35 percent of the market in 2016, had relatively stable market shares. The remainder of the market was very fragmented and unstable. In particular, firms outside of the top five, which account for nearly half of the world market, were subject to high volatility and short spells (Table 4.3). This is typical of the so-called "modularity trap" (Chesbrough and Kusunoki, 2001). Only handset makers with significant software development capabilities were able to differentiate themselves and achieve stable market share. This evolution was unlike the pre-smartphone era, described in Sturgeon and Linden, 2011. At the time, the top five firms, including industry pioneers Nokia and Motorola, dominated for many years with relatively stable market shares.

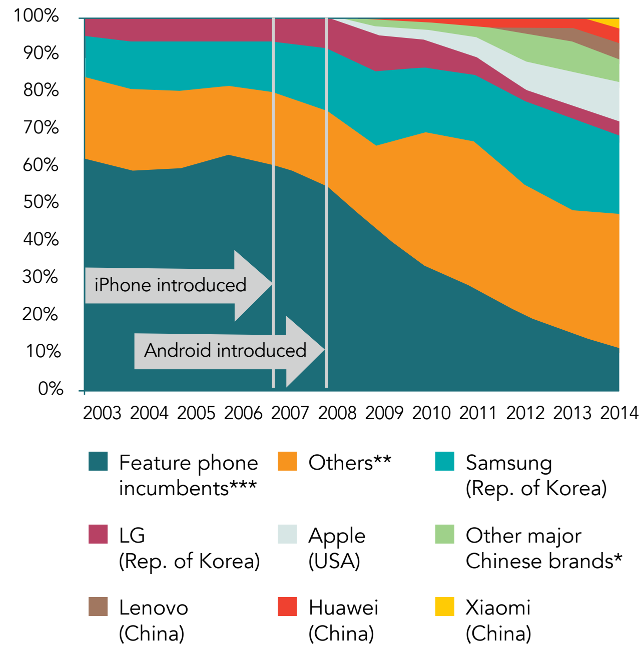
Global manufacturing of mobile handsets moved mostly to China, driven by both supply and demand factors. In 2016, China accounted for more than three-quarters of global production (HIS Markit Data). China remains the main assembly location for all top firms, with the exception of the two brands from the Republic of Korea, namely Samsung and LG.[18] A key attractiveness of China as assembly location is the fact that it accounts for about one-third of total global demand, representing the largest mobile phone market worldwide. Moreover, a number of Chinese brands, including Huawei, Xiaomi and Oppo, have emerged as increasingly popular, first among Chinese consumers, and increasingly in foreign markets (HIS Markit Data; Xing, 2018).

Chinese smartphone producers are upgrading through building their own brands and being strategic on what components to build. This is different from the traditional view that firms upgrade along a predetermined sequence of manufacturing tasks. They are no longer participating only as suppliers of global brands or producers of low-cost undifferentiated devices. Rather, they succeeded in unseating the market leaders, Samsung and Apple, from the Chinese domestic market by focusing on customer

FIGURE 4.2 Shift from feature phones to smartphones



Notes: Based on unit sales to end users. *Others include Linex (open source) WebOs (Hewlett Packard and others), and Bada (Samsung). ** Symbian, originally developed by a UK-based software company and compatible only with (UK-based) ARM processors, pushed the hardest by Nokia but also used in keyboard-based "smartphones" made by Motorola and Sony Ericsson.
Source : Gartner Newsroom Press Releases (Various Years).



Notes: Based on unit sales to end users. Data are indicative only since not all firms were identified in all years. From 2003-2008 only the top five firms were identified. In subsequent years the top ten were identified. *Unspecified Chinese brands identified in the data in various years include ZTE, TCL, and Yulong. **Brands identified in the data in various years include HTC (Chinese Taipei), BenQ (Chinese Taipei), and RIM (Canada) are included the remainder "Others" category. ***Feature phone incumbents include Nokia (Finland), Motorola (USA), Sony-Ericsson (Japan-Sweden), and Siemens (Germany).
Source : Gartner Newsroom Press Releases (Various Years).

Source: Sturgeon and Thun (2019), and HIS Markit Data.

orientation, and by growing their design and marketing capabilities (Brandt and Thun, 2010, 2011, 2016; Thun, 2018; Xing, 2018). By building their brands, these firms moved from their original focus on cost-conscious customers, and increasingly toward mid-range consumers demanding value for money (Brandt and Thun, 2010 and 2016, refer to this progression as the "fight for the middle"). In so doing, they managed to upgrade their position in the mobile phone value chain, serving the Chinese market first, and then becoming increasingly successful in other markets (see Figure 4.3). As a result, by 2017, Chinese brands had captured 87 percent of the domestic market.

Successful Chinese firms also rely on knowledge-intensive intermediates and globally available technology. None of the top Chinese brands (Huawei, Oppo, Vivo and Xiaomi) has core technological capacity in-house. These firms rely on GVCs for technology and develop products that depend on interoperability and compatibility with global markets. Successful Chinese brands have not indigenized production in China. They have a truly global R&D footprint, where countries globally attract tasks in which there is local expertise. Moreover, all major handset producers mostly source their inputs from the same technology suppliers. Key technology suppliers include mostly firms from developed countries such as Google, Samsung, Qualcomm, Broadcom, and leading semiconductor companies ARM and NXP.

As shown above, the smartphone market makes the case that, following disruptive technological change, one key reason for Chinese firms' upgrading was the strong connectivity to global technology ecosystems. Growing own design and marketing capabilities allowed Chinese firms to respond rapidly to changes in market demand and consumer taste. Their reliance on GVCs allowed them to develop products that are interoperable and compatible with global markets. Incidentally, the local presence of foreign firms enhanced the mutually beneficial relationship between foreign core technology providers and local manufacturers. Domestically-owned firms had better and faster

TABLE 4.3 Top five mobile handset brand market share in five-year intervals
(millions of units)

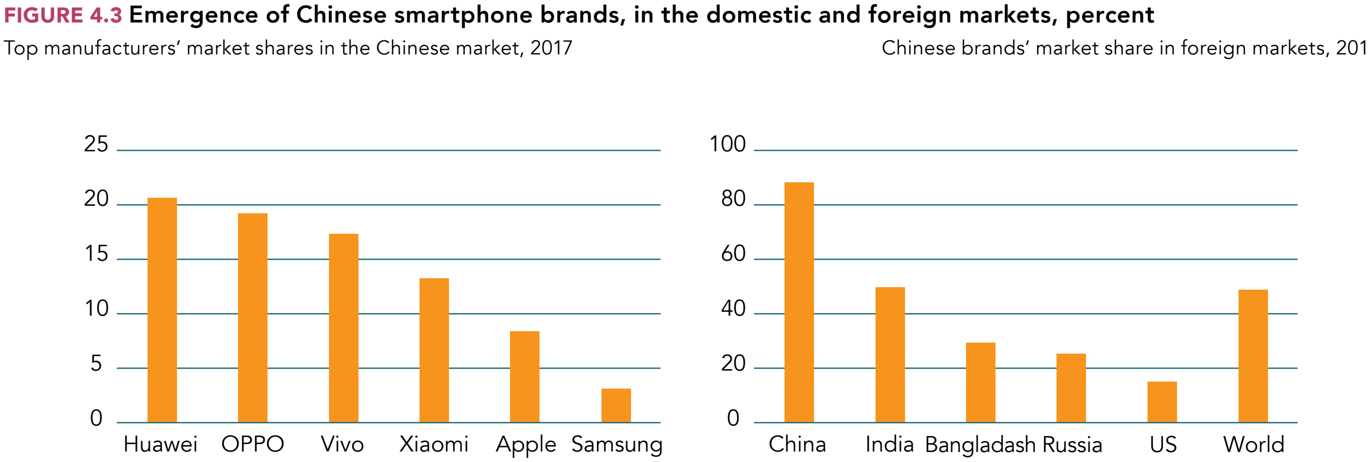
Feature phone era (through 2007)							
2003				2007			
Company	Home country	Sales	Market share	Company	Home country	Sales	Market share
Nokia	Finland	180,672	35	Nokia	Finland	435,453	38
Motorola	United States	75,177	15	Motorola	United States	164,307	14
Samsung	Republic of Korea	54,475	11	Samsung	Republic of Korea	154,541	13
Siemens	Germany	43,754	8	Sony Ericsson	Japan/Germany	101,358	9
LG	Republic of Korea	26,214	5	LG	Republic of Korea	78,576	7
Others		139,696	27	Others		218,604	19
TOTAL		519,989	100	TOTAL		1,152,840	100
Smart phone era (after 2007)							
2011				2016			
Company	Home country	Sales	Market share	Company	Home country	Sales	Market share
Nokia	Finland	422,478	24	Samsung	Republic of Korea	306,447	21
Samsung	Republic of Korea	313,904	18	Apple	United States	216,064	14
Apple	United States	89,263	5	Huawei	China	132,825	9
LG	Republic of Korea	86,371	5	Oppo	China	85,300	6
ZTE	China	56,882	3	Vivo	China	72,409	5
Others		805,666	45	Others		682,314	46
TOTAL		1,774,564	100	TOTAL		1,495,358	100

Source: Sturgeon and Thun (unpublished), using HIS Markit Data.

access to technology inputs that boosted the competitiveness of their products, and owners of core technology benefited from expanding their sales in a large and growing Chinese market.

The importance of connectivity to key players is also demonstrated through network analysis. Criscuolo *et al.* (2017) apply network theory to an examination of foreign peer effects on firm-level total factor productivity (TFP). Based on Chinese

FIGURE 4.3 Emergence of Chinese smartphone brands, in the domestic and foreign markets, percent

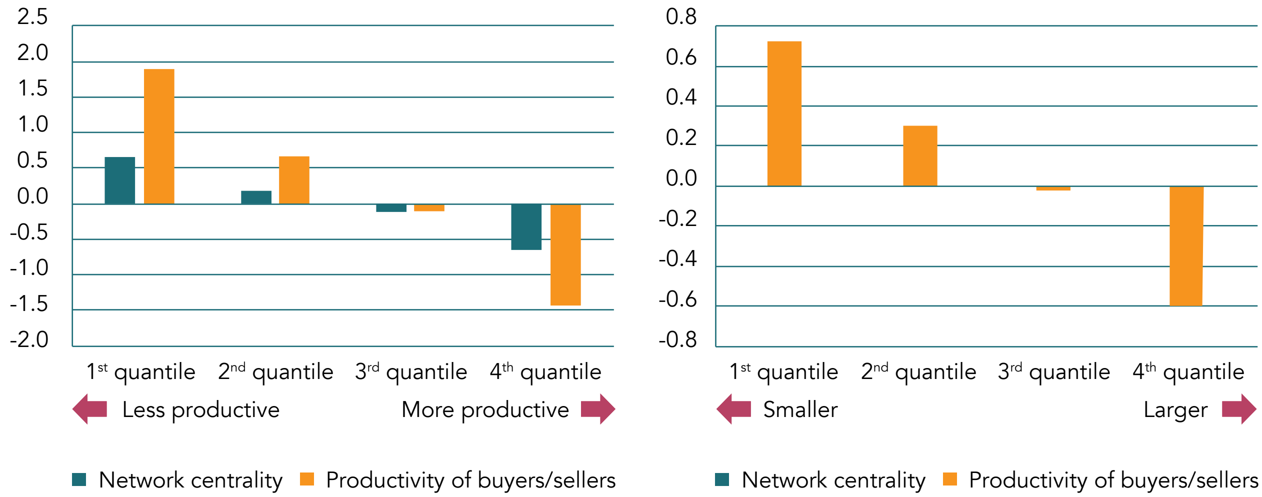


Source: Xing (2018).

FIGURE 4.4 TFP elasticities of Chinese firms with respect to centrality index and average productivity of their buyers/sellers

(a) Comparison among firms with different levels of initial productivity
(Percentage)

(b) Comparison among firms with different sizes
(Percentage)



Source: Criscuolo *et al.* (2018).

BOX 4.1

"Value chain migration" — Can it be another scenario for surviving price wars?

In the face of increasing competition and attrition in home markets, some small-scale Chinese firms established new value chains with other developing countries by tapping into the uncultivated low-end markets at destination. Fujita (2017) presents the case of motorcycle industry in Viet Nam.

Prior to the entry of Chinese firms, the motorcycle industry in Viet Nam had been dominated by a handful of Japanese- and Chinese Taipei-invested manufacturers producing sophisticated yet expensive models that were far beyond the reach of the majority of the population. In this context, Chinese firms, faced with saturated consumer demand in the home market, saw Viet Nam, a low-income country with only expensive models available, to be a promising outlet for their low-priced Chinese products.

The penetration of Chinese firms into the motorcycle industry in Viet Nam started with the massive export of finished vehicles. However, in 2002, the Vietnamese government enforced a measure against the imports of assembled vehicles and implemented high local content rules. As a result, firms' market entry mode in Viet Nam shifted from vehicle exports to component exports, and then to FDI, giving rise to a new form of China's GVCs serving the low-end market in Viet Nam.

Particularly notable was the performance of Chinese-invested parts suppliers who teamed up with Vietnamese assemblers. They capitalized on the competitive advantages attributed to their local partners; namely, the knowledge of the local demand profiles and the capacity to handle individual dealers scattered around the country. The latter property was especially important because low-priced motorcycles mainly catered to consumers in rural provinces. Business statistics reveal that these teams of Chinese parts suppliers and Vietnamese assemblers collectively outperformed Lifan, a big Chinese-invested motorcycle manufacturer which entered the Vietnamese market with its own brand name.

While this "value chain migration" strategy provided a quick route for small-scale Chinese firms to escape from intense competition at home, there is a problem of sustainability in the targeted low-end market at destination. Indeed, with rapidly rising incomes in Viet Nam, the market for low-priced motorcycles in the country nearly disappeared by the early 2010s, only a decade after its emergence. The teams of Chinese suppliers and local assemblers failed to keep up product development in order to meet changes in consumer demand, primarily due to the lack of the technology required to upgrade their products. In the end, the entire market is dominated by five foreign-invested manufacturers from Japan, Chinese Taipei and Italy, collectively accounting for a 98% share, including Honda's 63% (Nguyen Thi Thu Ha and Ho 2013).

Source: Fujita (2017)

and Japanese firm-level microdata as well as multi-country input-output tables, the study investigates the relationship between firm performance and the position of firm operation within the GVCs. The GVC position of firm operation is determined by two factors: network centrality, which represents particular firm's interconnectedness with other players in the network, and (weighted) average productivity of its buyers/sellers, which indicates the relative importance of the firm's peers. TFP elasticities with respect to these two factors define overall peer effects on the firm in question. Their estimation results for China, presented in Figure 4.4, reveal that firms that are initially (i.e. at the beginning point of observation) less productive or smaller are likely to improve their productivity faster than others when they are connected to the key players in the production networks.[19] This implies that, for small emerging companies in developing countries, "to whom to be connected" in the international production networks is highly relevant, at least in the long run, when we consider the impact of technological progress on economic development (see Box 4.1).[20]

The question that remains unanswered is whether firms from other countries can replicate the positive experience of these Chinese firms. Are firms from smaller countries precluded this opportunity? And does automation of production even prevent initial entry based on low wages? The next section will discuss the impact of automation on offshore potential of low cost-locations.

5. Is automation reducing the offshoring potential of low-cost locations?

Historically, new technologies and changing trade patterns have tended to widen the circle of countries benefiting from expanding production. As countries' costs rise, production tends to move into more capital-intensive goods, with the more labor-intensive tasks moving to lower-cost locations offshore. This "flying geese" model[21] of industrialization and trade has been observed for several decades, as the more labor-intensive tasks have shifted from developed economies to the newly industrialized economies of East Asia and China. The question now is whether automation in established manufacturing centers may reverse this process by reducing offshoring.

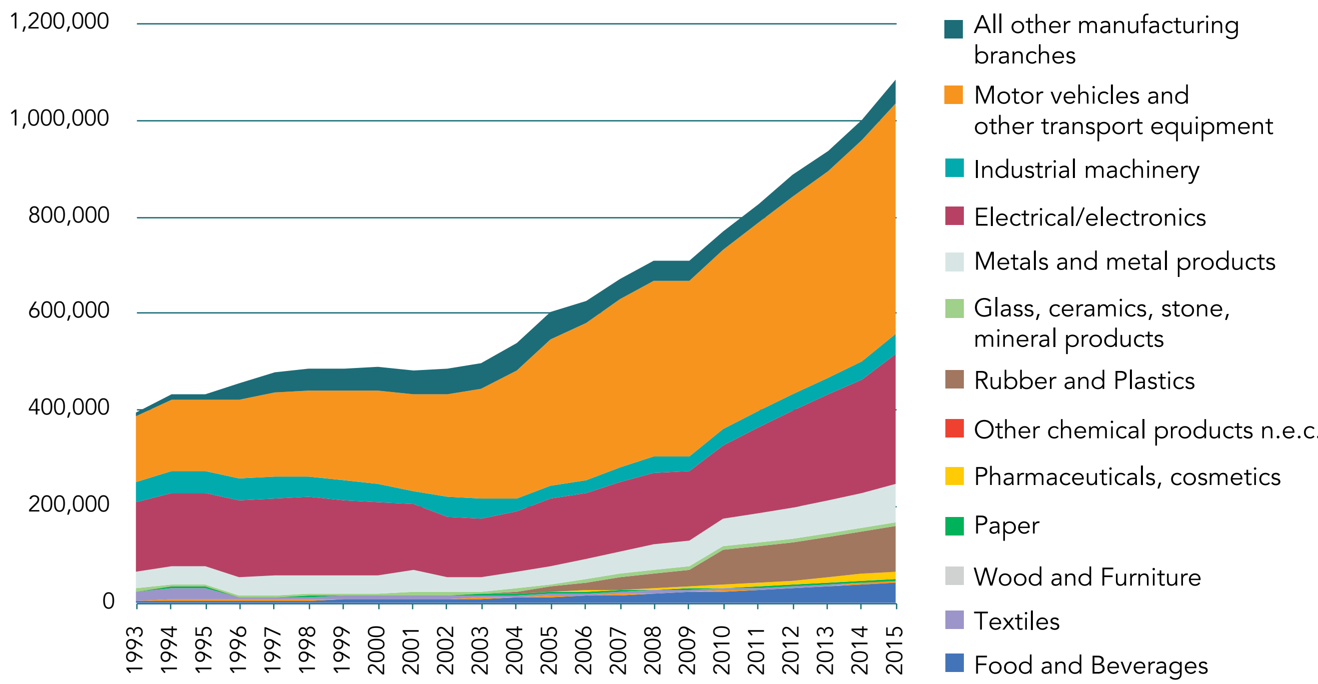
There is an increasing amount of anecdotal evidence on how increased automation has already enabled some leading firms to reshore labor-intensive manufacturing activities back to high-income economies. Foxconn, the world's largest contract electronics manufacturer best known for manufacturing Apple's iPhone, has recently announced it will spend $40 million at a new factory in Pennsylvania, using advanced robots and creating 500 jobs (Lewis 2014). 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 (Assembly 2012; Bloomberg 2012; Economist 2017a, 2017b; Financial Times 2016).

China too 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. Some high-profile firms are already substituting a substantial number of workers with industrial robots. For example, Foxconn, producing Apple and Samsung products in China's Jiangsu province, recently replaced 60,000 factory workers with industrial robots (South China Morning Post 2016). 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.

More systematic evidence on robots and reduced offshoring, as manifested in FDI flows from high-income countries to low- and middle-income countries, has emerged recently. Based on firm-level data for 3,313 manufacturing companies across seven European countries, Kinkel, Jager and Zanker (2015) find that firms using industrial robots in their manufacturing processes are less likely to offshore production activities outside Europe. Hallward-Driemeier and Nayyar (2018) find a non-linear relationship between the intensity of robot use[22] in high-income countries (HICs) and FDI from HICs to low/medium-income countries (LMICs) between 2003 and 2015. For some time, the increasing intensity of industrial robots moved together with flows of FDI from HICs to LMICs. This is consistent with the literature which argues that many of the tasks that are suitable for automation are also suitable for offshoring (Autor, Dorn and Hanson 2015). For instance, routine tasks that follow explicit codifiable procedures are well suited to automation because they can be computerized, and well suited to offshoring because they can be performed at a distance without substantial loss of quality (Autor, Levy and Murnane, 2003). The non-linearity – whereby beyond a threshold level of robot intensity there is a negative association between robot use in HICs and FDI flows from HICs to LMICs – reflects the fact that the scale of use may be a significant factor in making robots economically attractive.

The relationship between robots and offshoring, however, varies across sectors. Hallward-Driemeier and Nayyar (2018) show that the use of robots in high-income countries has increased steadily over the past two decades, with the steepest increases in motor vehicles and other transport equipment, and electrical machinery and electronics[23] (see Figure 4.5). As automation increases, penetration rates are starting to increase even in other manufacturing and services industries, such as logistics and food production. However, the textiles and apparel sector still remains amongst the least automated, especially apparel. A lower rate of robot intensity in this sector is associated with rates of new FDI from high income to low- and middle-income countries that are greater than those of highly automated industries such as automotive and electronics (see Figure 4.6). Data on FDI (not reported here)

FIGURE 4.5 Operational stock of robots in high-income countries, 1993-2015



Source: Hallward-Driemeier and Nayyar (2018), using International Federation of Robotics Database.

also suggests that some 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 (Hallward-Driemeier and Nayyar 2017).

6. Policy implications

This chapter draws several lessons on how to achieve upgrading to move closer to the global technological frontier, largely based on the experience of China's automotive and electrical equipment industries.[24] The successful firms depend on access to constantly evolving global technology and knowledge-intensive intermediates. A number of Chinese smartphone manufacturers, for example, have succeeded in entering and upgrading in GVCs by leveraging global technology ecosystems and by responding rapidly to changes in market demands and consumer tastes.

Technological progress triggered these changes. Modularization of product architecture offered a new entry point to GVCs for small-scale firms in developing countries. The important message of our study, however, is that entry into GVCs alone does not translate automatically into technological upgrading. To move up to high value-added tasks in technologically advanced value chains requires additional and complementary efforts by local actors.

Here, the development of mutually beneficial relationships between foreign core technology providers and local manufacturers is the key. Local firms have better (and faster) access to technology inputs that boost the competitiveness of their products, and the owners of core technology benefit from expanding their sales in large and growing markets. The ability of governments in developing countries to nurture such relationships depends on their ability to reform the domestic investment environment in a manner to stimulate and rationalize technological transfer/sharing by advanced firms within a sequence of local supply chains.

One important aspect of the reform is building capabilities of local manufacturers. Manufacturing can no longer thrive with unskilled workers alone, and many tradable services are skill intensive. Recourse to industrial polices to stimulate GVCs, however, can have unintended consequences. Some incentives may take the form of implicit or explicit subsidies, and lead to trade tensions. Weaker bargaining power of governments, compared to large lead firms in GVCs, also means that there is the risk that incentives result in sizeable transfers of rents to the firms, reducing the social dividend of being in GVCs.

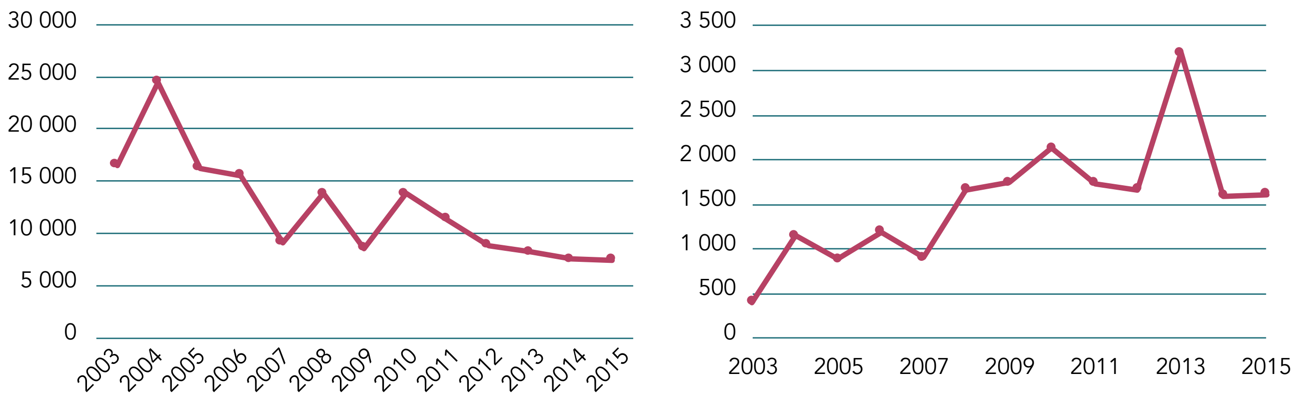
Another important dimension of domestic reform is the development of legal/institutional bases. Creating an attractive investment environment is a multi-faceted task. Policy-planners have to consider various domestic factors that might affect firms' investment decisions: physical infrastructure, trade policies,

FIGURE 4.6 Robot stock in electronics and automotive relative to apparel in high-income countries (ratio) vs FDI flows from high-income to middle- and lower-income countries in electronics and automotive relative to apparel (ratio), 2003-15

(a) Number of FDI Projects

Electronics and automotive products

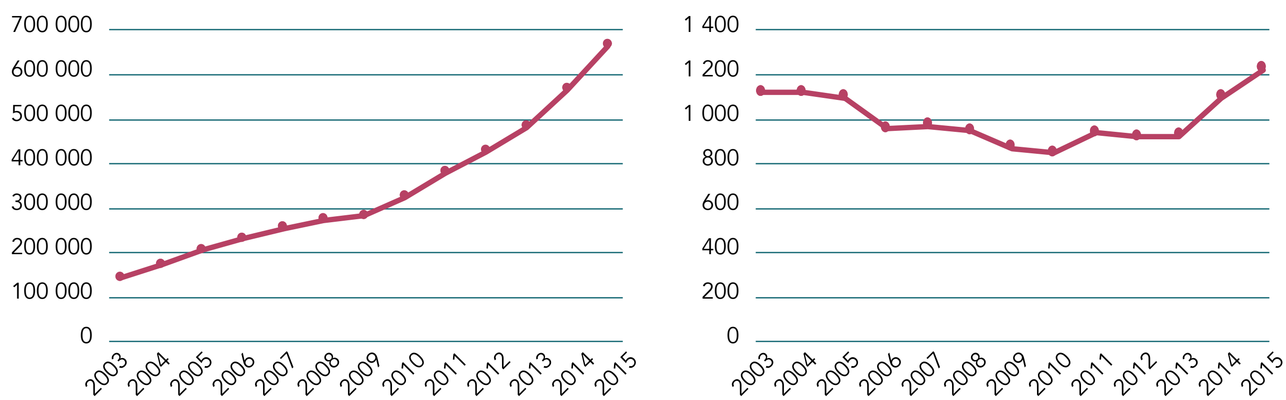
Textiles, apparel and leather products



(b) Stock of Industrial Robots

Electronics and automotive products

Textiles, apparel and leather products



Source: Hallward-Driemeier and Nayyar (2018), using International Federation of Robotics Database.

competition policies, wage levels, workers' educational attainment, and so on. Among them, increasing attention is being paid to the role of the legal system in facilitating capital inflows, especially into developing economies. Even though the issue is not touched in the preceding argument, it is worth shedding a light on this important aspect of globalization.

Nunn (2007), for example, introduces the concept "contract-intensive" products, which rely on production processes with complicated interactions between clients and suppliers at various stages of a production sequence. Such a product attribute is especially salient in industries with a high degree of market differentiation, for example airplanes or special industrial machinery. Accordingly, the countries with well-established legal systems and high-quality institutions are considered to have comparative advantages in producing this type of product, just in the same way that countries with an abundant cheap labor force are more competitive in producing labor-intensive products. And most importantly, the study also shows that "contract-intensive" products are often skill-intensive as well, and hence likely to be of high value-added.

Closely related to this issue is the evidence that patent laws in offshore destinations influence global firms' innovation decisions. Bilir and Sakamoto (2018), using detailed data on US patent grants/citations and US multinational firms' affiliate R&D investment, show that the presence of imitation risk from potential rivals at offshore destinations can drive leading multinational firms to innovate selectively. They do so by shifting development resources toward relatively short-lived products that are difficult to imitate before they become obsolete. Here, by reducing imitation risk, patent reforms at offshore destination facilitates innovation by multinational firms, but at the same time also increase the average economic lifespan of the products they seek to develop. This implies that a policy reform of intellectual property rights in less developed countries affects not only the level of innovation but also the type of innovation associated with offshoring activities, encouraging the development of technology with more sustainable economic values.

In conclusion, putting a foot in the door (of new industries) is not enough to thrive in GVCs. The examples of China and earlier developers show that developing through GVCs is a decades long journey that requires a reform effort sustained over time. While international connectivity is a key for entering GVCs, domestic governance matters for upgrading therein. Local governments need to offer well developed domestic legal systems, and guarantee the rule of law and high quality institutions. Good governance is crucial for attracting high value-added segments of global supply chains, where technological transfer/sharing between global firms and local suppliers is considered more solid and sustainable.

Industrial policy can have unintended consequences, and therefore should be carefully crafted. Policies for helping domestically-owned firms to become technologically standalone – what some might refer to as "techno-nationalism" – do not necessarily deliver the expected results. The world's most powerful technology companies, both from emerging and advanced countries, work with global suppliers and even with competitors in "open innovation" environments. Hence, the advice to policymakers seeking to upgrade toward the global technology frontier is to prioritize measures that encourage firms to be full partners in global technology ecosystems, rather than champions of domestic technology, or of so-called techno-nationalism.

Finally, while automation does not pose immediate risks to shut the door to labor intensive exports from developing countries, governments need to develop a comprehensive digital strategy. Our economies are increasingly sitting on a digital foundation, one that is generating high-speed growth and disruptive change. The employment and investment of tomorrow will be data intensive. Value in a knowledge economy is created by innovative ideas and data. As economies and firms from different countries grow similar in size, international trade will intensify. But trade may tilt away from physical goods and towards data. Importantly, the digitally-powered, knowledge-intensive GVCs that are emerging and are likely to dominate the future have a strong potential for inclusion. Moreover, they can contribute to expand markets for small businesses beyond traditional geographies. They can also expand financial inclusion, as data on e-commerce can be used as collateral, and smartphones link up the bottom half of world incomes to these opportunities.

ANNEX 4.1
Typology of global value chains[25]

Gereffi, Humphrey, and Sturgeon (2005) set out a typology of five global value chains (GVCs) on the basis of the structure of power relations between the contracting parties.

Market-type GVC
Producing a commodity of a generic nature does not require any specific investment in production facilities for a particular transaction, so both customers and suppliers have countless choices for alternative partners. They are connected mainly through open spot-market transactions in a shoulder-to-shoulder relationship. Also, the procurement of a generic commodity will not necessitate an exchange of detailed product specification between contractors because the key information is mostly reduced to the preset price of the product that can be found in a book of catalogs. The transaction cost for changing business partners is almost negligible, leaving the value chains in a constant state of flux because of their high price elasticity.

Modular-type GVC
In business management or industrial engineering the word "module" generally refers to a composite of subcomponents grouped by the types of functions that are assumed in making up the final product. The possibility of different combinations of differentiated modules enables producers to design multiple variants of a product. By the same token, if a complex transaction can be accommodated in the supply base by adjusting the combination of multipurpose equipment, the supplier will not have to incur transaction-specific investment (no hold-up problem) and is thus able to spread the equipment's use across a wide range of potential clients. Even though the information to be delivered between the contractors may be considerable (say, for producing a complex product), the relative easiness to codify transactions, as presumed in this type of GVC power relations, compresses the volume of interventions, and the supplier is able to take overall control of the production process. This implies that the transaction cost for changing business partners remains relatively low.

Relational-type GVC
When the manufacturing process involves specialized equipment (for example, the mold for a product of a particular shape), transactions become asset-specific, and the contracting parties become mutually dependent. The equipment for a specific purpose has limited scope for alternative uses, so its productivity will drop considerably when it is applied in other contexts. Accordingly, the service suppliers (the holders of the specialized equipment) are not motivated to look for other potential clients. But it is also difficult, or at least costly, for the client to expect the same level of performance from other third suppliers without these specialized facilities. As a result, both parties have little incentive to search for alternative business relations. Further, reinvestment in the specialized equipment for raising productivity deepens the asset-specificity of the transaction, thus trapping the parties in even more mutually dependent relationships.

Captive-type GVC
This type of transaction assumes an overwhelming disparity in power exercise among the parties, as seen in the business relations between a lead firm of global brands and its subcontracting local small companies. Service suppliers are expected to follow the client's instructions word for word and are subject to strict surveillance on product quality and delivery times. Unlike suppliers in the market-type GVC, the captive service suppliers have neither sufficient productive capacity to enjoy the scale of mass production, nor the specialized production facilities needed to claim its uniqueness, as attributed to the suppliers in the relational-type GVC. The availability of only mediocre production capability greatly narrows their opportunities to look for alternative business relations, imposing a captive position toward their clients.

Hierarchy-type GVC
This type of GVC generally refers to the relations within a vertically integrated firm, as with multinational corporations.

Notes

1. Sturgeon and Thun (2019) note that there are three reasons for the relatively short supply lines in the automotive industry. First, motor vehicles comprise several heavy, bulky and sometimes easily damaged components (engines, large metal parts, seats and painted items) that increase shipping costs. Second, the adoption of low-inventory, just-in-time assembly techniques and high product variety (vehicles can have dozens or hundreds of options) increase the motivation to locate module and sub-subsystem assembly close to or even adjacent to final assembly. Third, many countries, including the United States, China, Brazil, India, South Africa, and many others, have long-standing policies, both explicit and implied, that have encouraged FDI and high local content levels — and more recently, R&D and engineering investments—in return for market access. Because of their relatively recent importance in the industry, this has meant a wave of FDI by suppliers to provide local content.
2. "It is two German automakers, Volkswagen and Mercedes-Benz (presently DaimlerChrysler), that geared up the auto industry's modularization in the mid-1990s. Their new assembly plants, which started production in 1996 and 1997, introduced modularization on a large scale, specifically at Volkswagen's plants in Resende (Brazil), Boleslav (Czech Republic), and Mosel (former East Germany), and Mercedes-Benz's plants in Vance (U.S.) and Hambach (France)". Source: Takeishi and Fujimoto, 2001.
3. Shenyang Aerospace Mitsubishi Motors designed engines and transmissions, and then Delphi took charge of ECU adjustment to customize these system components according to the individual designs of customers' vehicles (Oshika *et al.*, 2009). The company codified the harmonization expertise and encapsulated it in a chip as a set of digital information, whereby potential conflicts among parts arising from variations in car bodies can be mediated through a mere parameter adjustment of ECUs.
4. This is consistent with the 3Cs model of Gereffi *et al.* (ibid.).
5. The modularization of car architecture has also invited new entrants from other industries. Panasonic's subsidiary Automotive & Industrial Systems develops system component packages in three areas: cockpit systems (displays, gauges, and car navigation devices); drive-assist systems (sensors, cameras, and LEDs); and power management systems (compressors and charge controls). Panasonic's technological know-how from manufacturing electrical equipment is fully applied to and embodied in the car production schemes (Nikkei Business, 2013).
6. Suppliers are located in places as diverse as the United States, Mexico, Brazil, Viet Nam, Malaysia, India, China, and various locations in Europe. On the ICT services side, countries such as India, Philippines, and Ukraine provide routine software coding and the provision of remote ICT-enabled services.
7. There are two main reasons for the delinking of production from design and innovation activities. First, the deep technical, management, and financial expertise needed to develop and launch new products and alter the technological trajectory and evolution of knowledge-intensive industries takes a long time to develop and therefore tends to be place-specific. Second, because of fragmentation in GVCs, traditional design clusters have been able to maintain, and even strengthen, their roles in GVCs, thanks to the fact that first-tier suppliers have co-located with lead firms.
8. From the beginning, the industry has had close links with the development of military technology; hence, the standardization of its major product lines was advanced under strong military influence. Product standardization was further facilitated by the introduction of computer-aided design systems, which allowed information on product designs and specifications to be digitized and stored for repeated use in the industry. In addition, the Information Technology Agreement, a high-level plurilateral free-trade agreement, was adopted by many countries including emerging economies, and thus became another important driver of standardization and modularization of the industry's value chains.
9. Platforms can exist at all levels of a value chain and in all industries, and are ideal to help latecomers to join capital- and skill-intensive value chains. Platforms provide a wide range of functionalities and flexibility. As such, platforms have played a key role in disrupting various industries, from consumer electronics such as LCD TVs to special industrial machinery such as numerically-controlled machine tools. In the PC industry, the most prominent example is "Win-tel", which is a coinage from Microsoft's operating system Windows and chip designer/vender Intel.
10. According to Shiu and Imai (ibid.), sales promotion through blueprint bundling is known to have originated in the business model of US/European chip vendors who sought marketing opportunities in China. However, the production guidelines in the blueprints of the US and European vendors covered only basic aspects of terminal assembly. Lacking detailed explanations, these blueprints were not sufficiently user-friendly for Chinese manufacturers with limited experience in the production of high-tech equipment such as mobile phones. In contrast, MediaTek from Chinese Taipei provided full guidelines for every aspect of assembly tasks, even covering multimedia functions for music/video playback, and offered a package with a considerably cheaper license fee than those of US/European rivals. As a result, MediaTek contributed to Chinese manufacturers' ability to produce at low cost while still providing highly appealing products for local consumers.
11. In a general equilibrium perspective, the price competition benefits downstream users, especially final consumers. Here, we consider costs and benefits only from the viewpoint of mobile phone producers in relation to their development potentials.
12. The case of MediaTek illustrates how a platform leader can use its leadership position to impose a closed system of governance on the resulting ecosystem (as opposed to allowing it to be open source). When this happens, the platform leader can impose structural constraints on the design and specification of other auxiliary components, with the effect that suppliers and other firms in the platform ecosystem may be forced to produce products whose designs are highly subordinate to the platform's interface specification. The platform leader can also completely "black-box" the interior of the platform module itself, which gives it potentially an overwhelming power to influence the way supply chains are organized in the industry.
13. To capture consumers' attention, local manufacturers rushed to introduce multiple models with very similar functionalities. As a result, the market was flooded with undifferentiated products and the industry's

profitability declined significantly. The emergence of MediaTek provided local manufacturers with the opportunity to produce high-tech mobile-phone terminals, but also induced the side-effect of rapid commoditization of the industry. Commoditization of mobile phones into undifferentiated products significantly lowered the complexity of transactions between parties.

14. As discussed in the text, the value chain of the shanzai sector is typically arm's length, prone to feature numerous undifferentiated products, i.e. characterized by a highly disintegrated market, with dozens of independent firms specializing in the same narrow and low-value added segments of production and competing with each other harshly on prices.
15. The "G"s of 3G and 4G stand for a generation of mobile phone technology, and hence the terminals with 4G generally assume higher performance than those with 3G in terms of data transmission speed and reliability. For the previous generations, 1G was analogue technology, which turned into digital technology from 2G. Today, we are now talking about 5G, which is considered to have a significant impact on the way of our life. Compared to the earlier technologies, 5G realizes greater speed, lower latency, and simultaneous connection to larger number of devices. Such features brought a wider prospect for the high level of applications in the areas of Internet of Things, remote services, self-driving systems, virtual/augmented realities, and so on.
16. Also, Qualcomm's unique patent licensing model, based on a revenue-sharing scheme, provided its own incentive to care about the performance of its customers, thus making further motivation to closely collaborate with them.
17. Ding and Hioki (2017) do not consider this form of new value chains as relational since it does not involve asset-specific transactions. However, one might consider that the human/organizational relationships developed through collaboration are specific (intangible) assets, as frequently observed in Japanese firms' practices in keiretsu networks.
18. These two firms together assemble about 22 percent of their handsets in the Republic of Korea, and rely on Viet Nam and Indonesia as secondary sources to China. Only HTC, from Chinese Taipei, and a relatively minor player, produces entirely at home. India and Brazil are significant assembly locations for many brands, in part to meet strong local content requirements in these large markets.
19. Note that this finding was also captured by the earlier work of Santoni and Taglioni (2016). Also, the demonstrated empirical result is consistent with Criscuolo and Timmis's (2017) based on large-scale multi-country firm-level data collected from the ORBIS. Although the ORBIS data include Japanese and Chinese firms, the coverage of these Asian firms is not large in the analysis by Criscuolo and Timmis (2017) mainly because the value added information is not available for many Asian firms. Therefore, the firm-level data used by Criscuolo and Timmis (2017) cover more European firms than Asian firms such as Japanese and Chinese firms. In Nakano, Nishimura, and Kim (2018), a parallel approach is projected to address the issue of technological diffusion by employing a general equilibrium framework, again using input-output accounts. The technological diffusion is considered to transform the input substitution structure as prompted by the change in relative prices of products. Such "structural propagation" was quantified by using a system of various cost functions whose parameters were estimated via two timely-distant input-output accounts and deflators.
20. Fujita (2017) presents a case of the motorcycle industry in Viet Nam in which Chinese suppliers chose to engage in the relations with local Vietnamese manufacturers without strong technological bases. See Box 4.1 for the motivation of the strategy and its consequences.
21. The well-known theories of Vernon's "product life-cycle" and Akamatsu's "flying geese" depict a process in which technologies originating in advanced economies become obsolete and are passed on to less-developed countries, thereby promoting their economic development.
22. Measured as the stock of industrial robots per 1000 persons employed.
23. This sector-level data obfuscates the fact that certain tasks even in these highly automated sectors will continue to be labor-intensive.
24. Even though these two industries are highly prominent in GVCs, it is also interesting and worthwhile to consider how representative they are in terms of their development experience vis-à-vis other industries, especially those relevant for developing countries such as apparels or agro-business. This will be the topic of future research.
25. This annex is reprinted from *GVC Development Report 2017*, chapter 1.

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