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# Innovation, upgrading, and governance in cross-sectoral global value chains: the case of smartphones

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## Abstract

The fourth industrial revolution challenges the existing understanding of innovation and upgrading in the global economy. It blurs traditional sectoral boundaries based on distinctive products and technologies and calls into question a traditional global value chain (GVC) perspective, which, similar to the sectoral systems of innovation approach, examines innovation and upgrading from a sector-based orientation. Building upon the recent reformulation and extension of GVC governance theory, this article proposes the notion of cross-sectoral GVC governance to capture the new stage of platform-based industrial development. It specifies the conceptual dimensions of cross-sectoral GVC governance in terms of the mode of governance (i.e., driving, linking, and normalizing), the overall GVC structure in terms of polarity, and firm strategies of managing GVCs. The proposed framework is illustrated using the case of smartphones as a platform product, focusing on four lead firms—Samsung, Apple, Huawei, and Google—to showcase divergent firm strategies for governing cross-sectoral linkages related to innovation and upgrading.

**Key words:** L1, L6, O1, O3

## 1. Introduction

The global value chain (GVC) perspective has become one of the preeminent approaches to investigate the contemporary structure and dynamics of the global economy. It is widely used to examine the growing fragmentation and dispersion of production through offshoring and outsourcing and to develop policy measures for upgrading that are aligned to the changing reality of global and regional flows of trade, production, and investment (Taglioni and Winkler, 2016; Gereffi, 2018; Ponte *et al.*, 2019a).

Innovation is generally considered an important pathway to industrial upgrading in GVCs. In a path-breaking formulation of global commodity chains (GCCs), a conceptual precedent of GVCs, Gereffi *et al.* (1994: 4) argue that "patterns of competition and innovation are crucial to understanding the organization and transformation of GCCs." For firms in developing countries, integration to GVCs plays a crucial role in their access to knowledge and innovation (Morrison *et al.*, 2008; Pietrobelli and Rabellotti, 2011; Lema *et al.*, 2018; Fransen and Knorringa, 2019). Yet, the roles of learning and innovation are not systematically interrogated in the GVC literature but usually addressed in a subtle and implicit way. Meanwhile, the sectoral systems of innovation (SSI) approach provides a conceptual framework to understand sector-specific patterns of innovation (Malerba, 2002) and catchup in developing economies (Malerba and Mani, 2009; Malerba and Nelson, 2011, 2012). Despite their common interest in analyzing sector-based, actor-centered networks of production and innovation, the GVC and SSI streams of literature have very limited interaction with each other.

The onset of the fourth industrial revolution, the digital economy, and new platform companies challenge both SSI and GVC approaches that understand innovation and upgrading based on traditional sectoral boundaries. Increasingly, contemporary innovation cuts across sectors, and occurs at the intersections of hardware and software as well as manufacturing and services. Smartphones, a gateway product to the digital economy, link multiple sectoral value chains and innovation systems, such as mobile telecommunications, semiconductors, flat panel displays (FPD), and camera and optical technologies (WIPO, 2017). Similarly, electric vehicles create new linkages between the traditional automotive sector based on mechanical engineering and the electric battery sector based on electrochemical technologies (Stephan *et al.*, 2017). This prompts rethinking of innovation and upgrading in a broader cross-sectoral and platform-based context.

Building upon recent reformulations and extensions of GVC governance theory, this article proposes the notion of cross-sectoral GVC governance and specifies its conceptual dimensions to capture the new platform-based stage of industrial development. These center on different modes of GVC governance (driving, linking, and normalizing), the overall GVC structure in terms of polarity (uni-, bi-, or multi-), and multinational enterprise (MNE) strategies for managing cross-border activities and competing for architectural advantage in GVCs (Jacobides *et al.*, 2006; Humphrey, 2018; Ponte *et al.*, 2019b; Pananond *et al.*, 2020). Our article illustrates this conceptual framework via the smartphone GVC, a platform product that integrates multiple technological and market sectors, that is, hardware, software, and services.

Our article is organized as follows. We introduce the GVC approach and highlight its commonalities and differences with the SSI perspective in Section 2. To capture the cross-sectoral nature of the fourth industrial revolution, we propose and define cross-sectoral GVC governance and discuss its conceptual dimensions mainly in relation to GVC governance in Section 3. The cross-sectoral conceptual framework is illustrated in Section 4 using the global smartphone sector, focusing on four lead firms—Samsung, Apple, Huawei, and Google—and their divergent strategies of managing linkages across sectors. In Section 5, we discuss the article's theoretical and empirical implications and possible extensions in future research before our concluding observations in Section 6.

## 2. The GVC framework: its commonalities and differences with the SSI approach

The GVC approach has various commonalities with the SSI approach. Despite their rare interaction, the two focus on sectors as the unit of analysis to examine the roles played by heterogeneous actors connected through production and innovation networks or supply chains. They both address the importance of knowledge and learning in innovation or upgrading.

First, the GVC and SSI approaches *both focus on a sector defined by specific products* as a unit of analysis. Products are central to the SSI, defined as "a set of new and established products for specific uses and the set of agents carrying out market and nonmarket interactions for the creation, production and sale of those products" (Malerba, 2002: 248). A sector is a basic unit of analysis to understand how and why diverse factors affect learning and innovation in different sectors, and why a country can catchup in some sectors but not in others (Malerba and Nelson, 2011; Lee and Malerba, 2017; Li *et al.*, 2019). Similarly, the GVC refers to "the full range of activities that firms and workers perform to bring a specific product from its conception to its end use and beyond" (Gereffi and Fernandez-Stark, 2016: 7). GVC analysis examines a sector but often focuses on more specific areas of competition and innovation such as industries or products (e.g., blue jeans; smartphones) and their social relations to understand how different value chains are organized and governed in terms of value-adding activities, supply chain stages, end markets, and supporting environment (Frederick, 2019).

Second, both approaches are centered on *actors embedded in networks* with distinctive roles and capabilities. The key components of a SSI are actors, including firms, non-firm organizations (e.g., universities, research institutes, and industry associations), and even individuals such as scientists, entrepreneurs, and consumers (Malerba and Adams, 2013). The GVC approach also emphasizes firms as actors, specifically suppliers and buyers in value chains, although the roles of the state and civil society organizations can be significant as well (Horner and Alford, 2019). These approaches illuminate the heterogeneity of actors and their interdependence. They play specialized roles across a bigger network with distinctive capabilities and knowledge bases, but they are interdependent in innovation and upgrading (Morrison *et al.*, 2008; Malerba and Adams, 2013). Thus, both approaches look beyond the boundary of a single firm and its immediate transaction partners, and take actors outside the firm as a source of innovation or upgrading (Pietrobelli and Rabellotti, 2011; Malerba and Adams, 2013: 186). In the SSI, it is often said that "firms do not innovate in isolation" (Malerba and Adams, 2013: 187). Similarly, the GVC involves networks of firms linked through a series of supplier–buyer relationships to exchange resources, including information and knowledge (Morrison *et al.*, 2008; Pietrobelli and Rabellotti, 2011; Lema *et al.*, 2018).

Third, the role of *knowledge, learning, and innovation* is critical in both approaches. For the SSI approach, each sector has a knowledge base and specific technologies used to transform inputs to outputs. The difference of technological knowledge in terms of specificity, tacitness, complexity, complementarity, and interdependence leads to distinctive processes of learning and innovation, and eventually different SSIs (Malerba and Adams, 2013). While more subtle and implicit (Morrison *et al.*, 2008), the importance of various forms of organizational learning in upgrading is acknowledged in many GVC studies (Gereffi, 1999). Learning by exporting, learning from suppliers, and learning from foreign buyers all underscore how GVC participation affects firms' access to knowledge and technologies (Schmitz and Knorringa, 2000; Pietrobelli and Rabellotti, 2011; Hsieh, 2015). Furthermore, supplier–buyer governance relationships are affected by the complexity and codifiability of information and knowledge and diverse levels of supplier competence, and *vice a versa* (Pietrobelli and Rabellotti, 2009, 2011; Fransen and Knorringa, 2019).

Notwithstanding these similarities, the GVC approach has distinctive features from the SSI approach. First, *geography* is one of the key elements of the GVC concept along with its input–output structure, governance, and institutions (Gereffi and Fernandez-Stark, 2016). Value chain activities have geographic footprints. They can be concentrated in a country or region, or dispersed worldwide. In recent decades, significant portions of manufacturing GVCs are concentrated in Asia (Lee and Lim, 2018; Gereffi, 2020; Gereffi and Wu, 2020). As GVC geography shifts, firms and workers at different locations become articulated or disarticulated as they join and leave GVCs (Werner and Bair, 2019). The geographic configuration of GVCs has an impact on the value each country or region can capture because value is unevenly distributed along the chain, as highlighted by the notion of the smile curve (Mudambi, 2008; Linden *et al.*, 2009).

A second important feature of the GVC perspective is its emphasis on *value creation and capture*, and the focus on *upgrading*. From an economic and industrial aspect, upgrading is defined as countries or firms moving up to higher value-added activities via process, product, functional, and interchain upgrading (Humphrey and Schmitz, 2002, 2004; Gereffi, 2019). From the GVC perspective, product and process upgrading matter because they lead to value creation and capture in relatively high-value activities, and functional and chain upgrading contribute to industrial diversification through forward and backward linkages (Gereffi, 2019). Upgrading is a relative concept; firms need to advance faster than their competitors in order to moderate competition and capture greater value or rents (supranormal profits) (Morrison *et al.*, 2008; Kaplinsky, 2019).[1]

This view of upgrading is associated with the broader interest of GVC scholarship in *development*. Development studies are the genesis for the GVC concept (Lee, 2010; Gereffi, 2018). In terms of innovation and knowledge generation, developing countries have different conditions from developed ones. They rely less on indigenous knowledge, but more on foreign and imported knowledge (Pietrobelli and Rabellotti, 2011). This highlights the role of GVC linkages in learning and innovation and the interaction of GVCs and innovation systems in developing countries (Lema *et al.*, 2018; Fransen and Knorringa, 2019).

A third, and final, distinctive feature of the GVC approach is that it explicitly addresses the role of *coordination, control, and power* dynamics in value chains (Dallas *et al.*, 2019). A central concept is *governance*, defined as "authority and power relationships that determine how financial, material, and human resources are allocated and flow within a chain" (Gereffi, 1994: 97). Governance can be analyzed from three different angles: driving, linking, and normalizing (Ponte and Sturgeon, 2014). Governance as *driving* is inherent in the distinction between producer- and buyer-driven chains, where lead firms set the overarching performance criteria as well as the conditions for supplier upgrading (Gereffi, 1994); governance as *linking* is reflected in the fivefold typology of GVC governance—market, modular, relational, captive, and hierarchy—that identifies varied governance forms even within a single

1 Morrison *et al.* (2008) point out the conceptual ambiguity of upgrading in relation to innovation. Upgrading is sometimes considered as anything good that happens in a buyer–supplier relation.

value chain (Gereffi *et al.*, 2005); and governance as *normalization* sheds light on the role of standards—product, quality, social, and environmental—that shape the conditions of GVC participation and upgrading (Gibbon *et al.*, 2008; Ponte and Sturgeon, 2014).

Different governance structures affect the supplier's ability to access knowledge, technologies, and learning mechanisms. Pietrobelli and Rabellotti (2009, 2011) use the fivefold GVC governance typology to illustrate the impact of all five governance types on learning: (i) *market* (arm's-length) governance, where general learning mechanisms such as knowledge spillover and imitation are used; (ii) *modular* governance, where suppliers learn from international standards and codifiable transactions; (iii) *relational* governance (similar to industrial districts), where mutual learning occurs through face-to-face interactions; (iv) *captive* governance, typified by complex transactions, low supplier competence, and deliberate knowledge transfer from lead firms (Navas-Alemán, 2011); and (v) *hierarchical* governance (vertical integration), where knowledge transfer and learning are supported by intra-firm measures, such as management transfer and internal training. In this way, governance structures affect how suppliers can access knowledge and learn from GVCs, with significant implications for innovation and upgrading.

## 3. Cross-sectoral GVC governance in the fourth industrial revolution

The fourth industrial revolution refers to a new phase of industrial development and hyper-connectivity based on technologies like artificial intelligence (AI), big data, robotics, and the Internet of Things (IoT) (Schwab, 2017). One of the notable features is that it blurs the boundaries between physical, digital, and biological elements through the "integration of cyber-physical systems" (Tavares-Lehmann, 2019) and makes traditional sectoral boundaries based on distinctive products and technologies less relevant. A case in point are digital platforms, a key driver of the digital phase of industrial development, also known as Industry 4.0 and digital transformation (UNCTAD, 2017; Brun *et al.*, 2019). Digital platforms cut across manufacturing and services, and hardware and software, and merge formerly distinct value chains into a bigger business ecosystem (Jacobides *et al.*, 2018; Sturgeon, 2019).

The digital revolution challenges sector-based approaches, such as SSI and GVC alike. Through a platform, be it a product or service, different sectoral value chains are not only connected but they also influence and reconstitute one another. Increasingly, innovation occurs through cross-sectoral interaction. One sectoral chain can be a critical source of innovation for firms in other sectors.[2] This interdependence between sectoral GVCs illuminates the cross-sectoral nature of innovation, capability development, and upgrading.

In an effort to capture this novel dynamic in GVCs, we propose the concept of 'cross-sectoral GVC governance.' We build upon Gereffi's (1994: 97) seminal definition of governance as "authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain." In the current context, value is created and captured *within* and *across sectoral GVCs*. Exerting power is not limited to direct, intended actions but it also has a more diffuse and collective dimension (Dallas *et al.*, 2019). Cross-sectoral governance is nothing new to GVCs. Social and environmental issues involve stakeholders from different societal sectors, which have generated multiple types of governance: public (e.g., governments); private (e.g., firms and business associations); and social (e.g., consumer activism and the role of nongovernmental organizations or NGOs) (Moog *et al.*, 2015; Gereffi and Lee, 2016). The notion of cross-sectoral governance recognizes that actors in different sectors have distinct interests, resources, and capabilities shared within their own sectors but not readily available to others.

Extending the concept of GVC governance to a cross-sectoral level enables us to investigate a novel set of questions. How do firm and non-firm actors in different sectors interact at different stages of a product's value chain? What type of cross-sectoral governance is in place, and who drives it? Are platform leaders digital MNEs or information and communication technology MNEs (UNCTAD, 2017)? How are the cross-sectoral flows of tasks and resources managed and the relationships among actors coordinated by lead firms? How do lead firms drive innovation outside as well as beyond their own sectoral boundaries to create and capture more value? What type of power and

2 There are many current examples of this process. The rapid advancement of FPD technology enables electronic manufacturers to experiment with novel devices, such as foldable smartphones. At the same time, the popularity of portable smart devices spurs the market growth in the digital display sector (Hayase, 2015). Similarly, thin, light, and damage-resistant glass, such as Corning's Gorilla Glass (first adopted by the iPhone in 2007), plays a critical role in the popularity of portable electronic devices. In turn, the introduction of foldable smartphones intensifies innovation among glass makers (GSMARENA, 2019).

institutional resources do they utilize to establish and maintain leadership in the cross-sectoral platform system? These questions are increasingly relevant to emerging and also revamped industrial sectors in the fourth industrial revolution.

Additional building blocks for our cross-sectoral framework come from recent efforts to reformulate GVC governance theory. First, Humphrey and his colleagues (Humphrey, 2018; Humphrey *et al.*, 2018) build a bridge between GVCs and the study of technology platforms.[3] In the latter, platforms are conceived as "modular technological architectures" (Gawer, 2014: 1239), which have no value until being connected with other components, so-called complementors. Thus, a critical task for a platform leader is "maintaining control over the platform and simultaneously promoting innovation by complementors" who are often outside their own sectoral system or value chain (Humphrey, 2018: 8).

Three key challenges emerge in governing a cross-sectoral platform: integrity, change, and leadership (Gawer and Cusumano, 2002). First, the platform leader must retain enough control to guarantee the integrity of the platform so that all the complementors are connected and operate in a reliable manner. Platform-wide rules and standards can be used for this purpose. Second, platforms grow and evolve over time to advance their functionality and incorporate new innovations. The changes require coordination between the platform leader and its complementors. Finally, the platform leader should ensure its leadership within its platform system to maximize value capture by striking a balance between control and innovation.

This final leadership challenge in cross-sectoral governance invites a rethinking of governance and power from a GVC perspective. The central question is who controls the flow of tasks and resources and thereby shapes the opportunities (and constraints) for innovation, upgrading and value capture for platform participants. The three dimensions of GVC governance (i.e., driving, linking, and normalizing), synthesized by Ponte and colleagues (Ponte and Sturgeon, 2014; Dallas *et al.*, 2019) can be applied to cross-sectoral governance. That is, who drives the governance of a platform as a cross-sectoral interface and architecture? How are individual linkages across sectoral boundaries managed, that is, vertically integrated, governed in a relational or modular manner, or managed through arms' length ties? Finally, who sets the rules to maintain the integrity of the platform and keep the participants' expectations and actions aligned?

Our final conceptual building blocks introduce a strategic and competitive dimension. Pananond *et al.* (2020) provide a typology of MNE strategies for managing cross-border activities of GVCs. In the network optimization strategy, MNE lead firms are "orchestrators" in a complex interfirm and cross-sectoral network. The strategic coevolution approach, by contrast, is a supplier-centered approach in which suppliers or complementors in a cross-sectoral platform interact and coevolve with lead firms, while simultaneously seeking an opportunity to reconfigure GVC governance to their advantage. This is particularly relevant to the expanding role of MNEs from emerging economies like China, which challenge the existing governance pattern and power dynamics in GVCs (Horner and Nadvi, 2018; Wu and Gereffi, 2019).

A more structural view of firm strategies in a cross-sectoral GVC setting is found in the concept of industrial architecture by Jacobides *et al.* (2006). As "a sector-wide construct that defines the terms of the division of labor," it provides sector-wide rules to delimit the roles and interactions of co-specialized firms (i.e., complementors) and divide surplus in a platform system. Lead firms can configure a cross-sectoral architecture to leverage their distinctive resources and capabilities and at the same time stifle the challenges from other lead firms or suppliers to obtain "architectural advantage" (Jacobides *et al.*, 2006). They restrict entry and competition in the value chain nodes they occupy to create a 'bottleneck' (a position with scarce supply), while promoting competition and replaceability in the others. Any discontinuity or disruption in technology, institutions, regulation, or market demand provides a window of opportunity for new entrants to challenge and replace an incumbent architecture with a new one.

Based on the discussion above, Table 1 presents an overview of the key conceptual components of cross-sectoral GVC governance, which frames our empirical investigation of the smartphone GVC in the following section.

## 4. The smartphone GVC and contending lead-firm strategies for cross-sectoral governance

The smartphone provides an excellent lens through which to examine cross-sectoral governance. It has evolved from a voice-only communication tool into a portable device with a computing power matching that of the personal

3 Note that there is a difference between a market platform like Amazon (two-sided or multi-sided markets) and technology platforms (e.g., Intel chipsets), discussed in Gawer (2014).

**Table 1.** Cross-sectoral GVC governance: key conceptual dimensions

| Dimension | Description | Reference |
|---|---|---|
| Driving | | |
| Chain driver | The type of firms driving the cross-sectoral platform system | Gereffi (1994) |
| Linking | | |
| Cross-sectoral linkage | The ways cross-sectoral linkages are managed (market, modular, relational, captive, hierarchy) | Gereffi *et al.* (2005) |
| Normalizing | | |
| Platform-wide rules and standards | Governance tools to maintain the integrity of the platform and keep the participants' expectations and actions aligned | Gibbon *et al.* (2008) |
| Overall structure | | |
| Polarity | Unipolar, bipolar, multipolar | Ponte and Sturgeon (2014) |
| Firm strategies | | |
| Network optimization | Lead firm strategy of shaping and capitalizing on the division of labor. and resource independence among platform participants | Pananond *et al.* (2020) |
| Strategic coevolution | Supplier strategy of interacting and coevolving with lead firms, establishing its own platform system and reconfiguring GVC governance | Pananond *et al.* (2020) |
| Architectural advantage | A set of strategies for managing the platform architecture in a way to create and occupy the bottleneck of the system | Jacobides *et al.* (2006) |

Source: Authors.

computer. It is compatible with a plethora of applications and services used in both personal and work settings. The latest fifth-generation (5G) mobile networks mark another important milestone of smartphones as a gateway to digital transformation (Jorge *et al.*, 2019).

The smartphone is a platform product with a modular technological architecture that connects hardware, software, applications, and services. As illustrated in Figure 1, it consists of the input–output activities of the focal product (gray boxes at the vertical center) and the complementary sectors that are connected to it (white boxes and circles at the left and right sides). The latter include a wide array of electronics components like semiconductors, FPD, camera and battery, contract manufacturing, mobile network infrastructure, a software-based operating system (OS) and applications, and digital content and service. Each sector provides specialized and complementary assets at different phases of the value chain to make the smartphone an indispensable portal to the digital economy.

The rise and fall of smartphone lead firms illuminates the dynamic nature of innovation, upgrading, and competition in the sector, exemplified by once mighty but now vanishing brands like Nokia, Motorola, and Blackberry (Doz and Wilson, 2017). The entire sector has been a hub of innovation. About 35% of all patents filed worldwide over the last three decades relate to smartphones (WIPO, 2017: 94). In 2015–2016, five out of the world's top 10 R&D-spending firms were connected to smartphones—that is, Samsung Electronics, Intel, Alphabet (Google's parent company), Microsoft, and Huawei. Intense competition among lead firms is based on different industrial architectures that combine various sources of capabilities and innovation, as we will discuss below.

The production of smartphones is highly specialized and mainly organized through GVCs (Dedrick and Kraemer, 2017; Lee and Lim, 2018). Many smartphones are still developed and designed in-house by lead firms, typically headquartered in advanced economies. But production is concentrated in emerging economies like China, India, and Vietnam. Production is frequently carried out by third-party contract manufacturers, such as Foxconn and Flex. While geographically and organizationally fragmented, the entire production process is tightly integrated and governed by dynamic lead firms.

The world's smartphone market is highly concentrated. As shown in Table 2, the top three lead firms have consistently represented over 40% of total smartphone sales since 2012, and Samsung, Huawei, and Apple accounted for 1.5 billion units of sales (47%) in 2019 (Gartner, 2020). Samsung and Apple have been the two leading brands since the early 2010s when the smartphone market took off. Apple's iPhone created a new product segment versus the feature phone segment dominated by Nokia. Samsung made a successful transition to the new segment by quickly adopting Google's Android OS to emerge as the world's largest smartphone producer. Huawei, a Chinese latecomer,

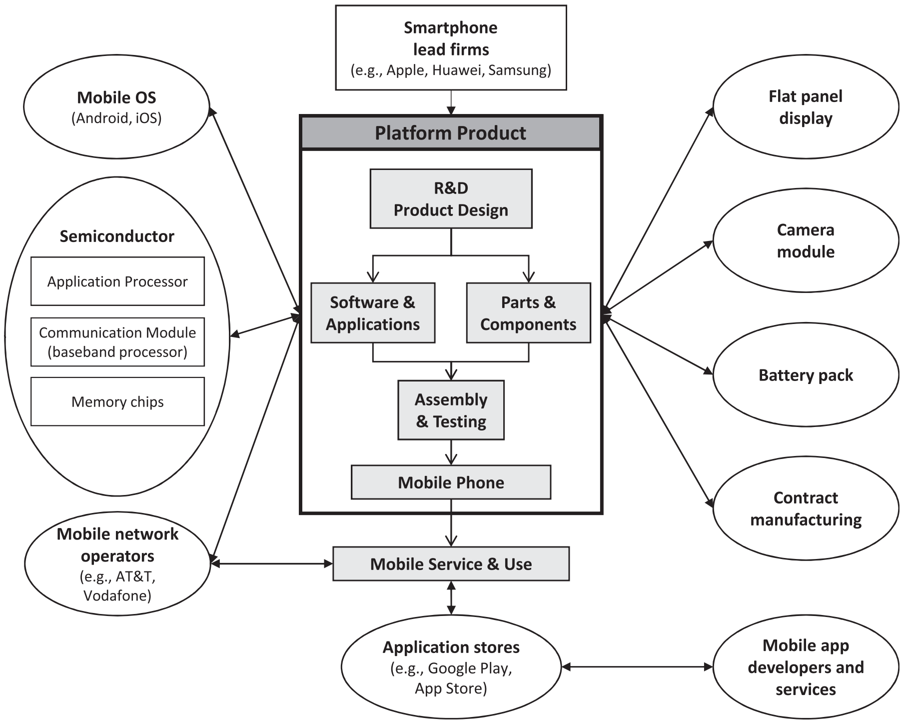


**Figure 1.** Smartphone as a cross-sectoral platform product.

**Table 2.** Leading smartphone brands and their market share, 2012–2019 (unit: %)

| 2012 | | 2014 | | 2016 | | 2019 | |
|---|---|---|---|---|---|---|---|
| Samsung | 30.3 | Samsung | 24.7 | Samsung | 20.5 | Samsung | 19.2 |
| Apple | 19.1 | Apple | 15.4 | Apple | 14.4 | Huawei | 15.6 |
| Huawei | 4.0 | Lenovo[a] | 6.5 | Huawei | 8.9 | Apple | 12.6 |
| LG | 3.8 | Huawei | 5.5 | Oppo | 5.7 | Xiaomi | 8.2 |
| Lenovo | 3.2 | Xiaomi | 4.5 | Vivo | 4.8 | Oppo | 7.7 |
| Others | 39.6 | Others | 43.4 | Others | 44.6 | Others | 36.7 |
| CR3[b] | 53.4 | CR3 | 46.6 | $CR_3$ | 43.8 | CR3 | 47.4 |

*Sources:* Gartner (2013, 2015, 2017, 2020).
[a]Including the sales of Motorola, acquired by Lenovo in 2014.
[b]Three-firm concentration ratio (the total market share of the three largest firms).

has gradually undermined the market of the two leaders to become the world's second largest producer in 2019. While the rapid expansion of the Chinese market, the world's largest for smartphones, spurred the company's growth, the recent China–US trade war has hit Huawei's entire supply chain very hard (Fitch and Strumpf, 2019).

Last but not least, Google is the newest lead firm in the smartphone GVC as a cross-sectoral system. While the company is not a major player in the hardware segment, it has a significant influence in the smartphone GVC via its OS and application distribution channel. Platform leadership is anchored in its Android system, an open and free mobile OS accounting for more than 80% of world's mobile OS market, and Google Play, the world's largest mobile application distribution platform. The company also has a distinctive approach to cross-sector management in the smartphone GVC through its complementary and competitive relationships with the other three lead firms.

As seen in Table 3, each of the four smartphone lead firms has a distinctive model of governing its own cross-sectoral value chain. To clarify their strategic differences, we examine a wide array of cross-sectoral linkages

**Table 3.** Lead firms in smartphone GVCs and their cross-sectoral governance models

| | Samsung | Apple | Huawei | Google |
|---|---|---|---|---|
| **Lead firm type** | Global Producer supported by open OS/service | Global Integrator with proprietary OS/ service | National Champion with restricted access | Global Innovator with open OS and own service |
| Architectural advantage | Internalized manufacturing and close partnership with open OS/service (Google) | Strong control of the entire platform system and tight product-service integration | Strong tie to the world's largest smartphone market (China) and Asian supply chains | Open OS platform (Android) and strong application ecosystem (Google Play) |
| Focal sector | Hardware and global market | Hardware, OS/service, and global market | Hardware, OS/service, and local market | OS/service and global market |
| Polarity | Bi-polar | Uni-polar | Bi-polar → Uni-polar | Uni-polar / Bi-polar |
| **Hardware segment** | **High internalization** | **High externalization** | **Medium internalization** | **High externalization** |
| Key components[a] *Internalization/ Localization* | High/high | Low/low | Low/high | Low/medium |
| Assembly *Own vs. ODM/EMS* | Own (90%) | EMS (100%, Foxconn and Pegatron) | Own (70%) | EMS (100%, HTC) |
| **OS/service segment**[b] | **Open; third-party platform** | **Proprietary platform** | **Open; own platform** | **Open; own platform** |
| Mobile OS *Own vs. third-party/ Open vs. proprietary* | Third-party and open (Google Android and Google Mobile Service) | Own and proprietary (iOS) | Third-party and open (Google Android) → Own and open (Harmony OS and Huawei Mobile Service) | Own and open (Google Android and Google Mobile Service) |
| App distribution *Own vs. third-party* | Third-party (Google Play) | Own (Apple App Store) | Own (Huawei AppGallery) | Own (Google Play) |
| **Market segment** | **Global variety** | **Global standard** | **Local variety** | **Global standard** |
| End market | Global | Global | Domestic and regional | Global |
| Product variety[c] | High (22 new models) | Low (3 new models) | High (25 new models) | Low (not available) |

*Sources:* Compiled from various sources of information, including industry reports.
[a]See Table 4 for more information.
[b]OS means "operating system."
[c]The number of newly introduced smartphone models in 2017 is in parenthesis, according to Richter (2018).

anchored in three distinctive segments of the smartphone GVC: (i) hardware (component manufacturing and smartphone assembly); (ii) OS and application distribution; and (iii) consumer markets (geographic scope and product variety). Below we analyze their strategies, focusing on how each lead firm manages and governs the three major segments in the GVC to create an architectural advantage and to ensure its leadership at a platform level. We also compare the composition of component suppliers for each lead firm's flagship model based on publicly available teardown and bill-of-materials (BOM) data to analyze its linkages to the hardware component sector.[4]

4 A teardown and BOM analysis refers to a series of activities including disassembling a product, identifying all of its components and their manufacturers, and estimating their part values. For Table 4, the flagship model for each firm was selected based on the time of its release and the availability of BOM data. The former allows us to compare the models competing in the market around the same time with similar technical specifications, and the latter is important because BOM data are not publicly available for all the models. Due to data limitations, Huawei P30 Pro (released in March 2019) instead of P20 Pro (March 2018), and Google Pixel XL (October 2016) instead of the succeeding models, were selected, which restricts a full comparison of the models chosen.

### Samsung: global producer supported by open OS/service

This Korean MNE internalizes most of its own hardware supply chains and related complementors. Samsung develops, designs, and manufactures most of its smartphones in-house. Part of Samsung Group, the largest conglomerate in Korea, Samsung Electronics also develops and makes key components in-house or through its related firms, including memory chips, touchscreen displays, camera modules, and battery packs (Lee and Lim, 2018). As shown in Table 4, 36% and 42% of the total BOM cost for its flagship model, Galaxy S9+, are accounted for respectively by Samsung affiliates (internalization ratio) and by Korea-based suppliers (home-country ratio), indicating a high level of internalization and localization of its cross-sectoral GVC.

In its OS/service sectors, Samsung critically depends on an open third-party platform supported by Google. Most of its smartphones are run on custom versions of Google Android with a suite of Google applications pre-installed, and Google Play is the leading source of application downloads for Samsung-branded phones.[5] The company's early adoption of the Android system and mass-marketing campaigns set Samsung up as a rival to Apple, and helped carry over its market-leading position to the smartphone segment (Cain, 2020). Samsung tried to develop its own mobile OS, which was not successful. It also runs its own application outlets, that is, Galaxy Store, but it is no match for Google Play as the major source for Samsung smartphone users to download applications.

The company enjoys worldwide sales with extensive product variety. In 2017, Samsung introduced 22 new smartphone models. This was less than the 25 models offered by Huawei, but much greater than Apple, which only released three new models (Richter, 2018). Samsung's key competitive advantage is its tight integration of design and manufacturing, and mass production with significant product variety (Nam, 2009). Thus, its cross-sectoral governance model features high internalization and localization in hardware, but reliance on Google's OS and service platform for the global presence of its smartphones.

### Apple: global integrator with proprietary OS/service

The US-headquartered company has its own mobile OS, called iOS, and develops and designs its entire suite of smartphone products. Apple focuses on integrating its hardware products to its OS and other innovative service features. In hardware sectors, the company scores low in both internalization and localization indicators, 7% and 17%, respectively (see Table 4). Yet, it designs its own application processors and fully controls the integration of the chips with its hardware and software, while chip fabrication is outsourced to a foundry like Taiwan-based TSMC, the world's largest semiconductor foundry (Barrett, 2020).[6]

Similarly, manufacturing of the iPhone is outsourced to contract manufacturers such as Foxconn and Pegatron, which allow Apple to utilize low-cost, mass-scale manufacturing in China (Lee and Lim, 2018: 210–215). Despite the US–China trade war, there is little indication that Apple's regional reliance on Asian suppliers is declining (Li and Cheng, 2020). While Apple's linkages with hardware sectors are featured by high externalization, it is well-known that the company tightly manages its supply chains through close relationships with a few highly capable suppliers and exercises its power through tough bargaining with suppliers to cut production costs and ensure quality (Lee and Ke, 2018).

Its own mobile OS, App Store, and integrated service are a key part of Apple's business model. Unlike open source-based Android, iOS is proprietary and only available to Apple products. Apple also tightly manages its app distribution channel. Unlike Samsung, Apple smartphone products are standardized worldwide and its product line is very streamlined, with little modification by market segment, emphasizing the users' seamlessly integrated experiences across the company's products and services (Rothaermel and King, 2017). Apple's tight control of the upstream and downstream segments of its GVC across various sectors enables it to capture the majority of value from its smartphone products (Dedrick *et al.*, 2010).

### Huawei: national champion with restricted access

As a latecomer, Huawei shares some similarities with Samsung and Apple, but also has unique features in organizing its cross-sectoral GVCs. In hardware design, component production, and assembly, Huawei is a mix of Samsung and

5 Samsung is the world's leading manufacturer of Android-based smartphones, and Google Play accounted for 72% of total downloads in 2018, according to statistics on app downloads (Iqbal, 2020).

6 Samsung had partnered with Apple in designing and manufacturing application processors for early models of iPhones until their relationship soured amidst the rise of Samsung as a rival in smartphones and a patent dispute dating from 2011 (Kim, 2012).

**Table 4.** Key component suppliers for lead firm's flagship smartphone models

| Samsung Galaxy S9+ | | | Apple iPhone X | | | Huawei P30 Pro | | | Google Pixel XL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Released on | March 2018 | | | November 2017 | | | March 2019 | | | October 2016 | |
| Total BOM cost | $375.80 | | | $370.25 | | | $363.83 | | | $285.75 | |
| Supplier | Est. cost ($) | % of cost | Supplier | Est. cost ($) | % of cost | Supplier | Est. cost ($) | % of cost | Supplier | Est. cost ($) | % of cost |
| *Application processor* | | | | | | | | | | | |
| Qualcomm (US) | 67.00 | 18% | Apple (US) | 27.50 | 7% | HiSilicon (China) | 30.00 | 8% | Qualcomm (US) | 50.00 | 17% |
| *Baseband processor/IC* | | | | | | | | | | | |
| Qualcomm (US) | Incl. above | – | Qualcomm (U.S) | 18.00 | 5% | HiSilicon (China) | 5.25 | 1% | Qualcomm (US) | Incl. above | – |
| *Radio frequency (RF)/power amplifier (PA)* | | | | | | | | | | | |
| Qualcomm, Broadcom, Skyworks (all US) | 19.00 | 5% | Broadcom, Skyworks (all US) | 16.60 | 4% | Qorvo, Skyworks (all US); TDK, Taiyo Yuden, Kyocera (all Japan) | 16.75 | 5% | Qualcomm, Broadcom, Skyworks (all US); Sony (Japan) | 19.50 | 7% |
| *Memory (NAND flash/DRAM)* | | | | | | | | | | | |
| Toshiba (Japan), Samsung (Korea) | 57.00 | 15% | Toshiba (Japan), SK Hynix (Korea) | 33.45 | 9% | Micron (US), Samsung (Korea) | 69.12 | 19% | Samsung, SK Hynix (all Korea) | 26.50 | 9% |
| *Display/touchscreen* | | | | | | | | | | | |
| Samsung Display (Korea) | 79.00 | 21% | Samsung Display (Korea) | 110.00 | 30% | BOE, Shenzhen Goodix (all China); Alps Electric (Japan); Corning (US) | 92.00 | 25% | Samsung Display (Korea) | 58.00 | 20% |
| *Camera module* | | | | | | | | | | | |
| Unknown[a] | 44.95 | 12% | Unknown[a] | 35.00 | 9% | Sony (Japan) | 34.91 | 10% | Unknown | 17.50 | 6% |
| *Battery pack* | | | | | | | | | | | |
| Samsung SDI (Korea) | 4.90 | 1% | Sunwoda (China) | 6.00 | 2% | Amperex (Hong Kong) | 8.00 | 2% | LG Chemical (Korea) | 4.00 | 1% |
| *% total BOM cost* | | *72%* | | | *67%* | | | *70%* | | | *61%* |
| *% internalization*[b] | | *36%* | | | *7%* | | | *10%* | | | *0%* |
| *% home country suppliers*[b] | | *42%* | | | *17%* | | | *33%* | | | *23%* |
| *% Asian suppliers*[b] | | *49%* | | | *50%* | | | *48%* | | | *32%* |

*Sources:* Compiled by the authors based on the following sources: Samsung (https://technology.informa.com/601100/galaxy-s9-materials-cost-43-more-than-previous-versions-ihs-markit-teardown-shows); Apple (https://news.ihsmarkit.com/prviewer/release_only/slug/technology-iphone-x-costs-apple-370-materials-ihs-markit-teardown-reveals); Huawei (https://asia.nikkei.com/static/vdata/huawei-supply-chain/newsgraphics/huawei-supply-chain/index.html); Google (https://technology.informa.com/584911/google-pixel-xl-manufacturing-cost-is-in-line-with-rival-smartphones-ihs-markit-teardown-shows).

*Note:* BOM, bill of materials.

[a]Multiple separate sources indicate that Samsung Electro-Mechanics and LG Innotek, both from Korea, were the leading camera module suppliers to Galaxy S9 models, and LG Innotek and Sharp (Japan) were two major suppliers of the component to Apple iPhone models.

[b]The actual cost for each supplier in the same component category is counted wherever that information is available. When two suppliers are listed for the same component category and the cost information for an individual supplier is unavailable, 50% of the category's total cost is counted as each supplier's cost.

Apple; it designs and assembles the majority of its smartphone products in-house, but also outsources about 30% of production to third-party contractors. Like Apple, the company relies on third-party suppliers for many key components, mostly located in China, Korea, and Japan, as its high localization (33%) and Asian supplier ratios (48%) indicate for its P30 Pro model (see Table 4).

Huawei has invested heavily in internalizing the design of application and communication processors for its smartphones and achieved some success as shown in the P30 case. However, the recent US government's tight control of semiconductor technologies and equipment has jeopardized Huawei's entire smartphone business at home and abroad. The measure drastically limits its access to many existing key suppliers, not only American but also from other economies like TSMC, which manufactured mobile processors for Huawei on a contract basis (Cheng and Li, 2020). In its Mate 30 model, released after Huawei was included to the US Entity List on May 2019,[7] Huawei replaced US semiconductor suppliers like Skyworks and Qorvo with HiSilicon, its semiconductor subsidiary, or Japanese suppliers like Murata (Fitch and Strumpf, 2019), pushing the company further in the directions of greater internalization and localization.

Due to the Chinese government's restrictive Internet governance that blocks access in China to Google services including Google Play (Wu and Gereffi, 2019), Huawei's own AppGallery has been the major application distribution platform for Huawei users, shielding the domestic market from Google's influence. However, the recent trade ban imposed by the US government has blocked Huawei from using Google Android OS on its products, a significant blow at a time when the company eyes continued global expansion. As in the hardware sector, Huawei is trying to respond to restricted access by deploying its own mobile OS named Harmony, which is free and open-source-based, like Google's Android (Kharpal, 2019). When it comes to markets, Huawei offers a high level of product variety but its market has so far been centered on China.[8] Given the aborted internationalization drive during the trade war, the company's market access remains restricted.

### Google: global innovator with open OS and own service

The power of this US-based technology MNE and platform company to drive the smartphone cross-sectoral GVC is centered in the OS/service domain, unlike any of the previous three lead firms. Its Android OS accounted for 85% of the world market as of 2018 (IDC, 2019), and Google Play is the world's largest mobile application distribution platform.

In smartphone hardware, Google's focus is mainly on setting an example for the Android phones most tightly integrated to its OS and services. Unlike Apple's case, Google Android provides fragmented user experience since it allows manufacturers like Samsung and Huawei to customize the OS to varying degrees. While Google's own-brand smartphones are not generally the most advanced in hardware functionality compared to their competitors, what makes them distinctive is that they are one of the earliest devices running the latest version of Android OS and newly launched services.[9] For this purpose, Google designs, develops and markets most of its smartphone products, whose line-ups started with the Nexus brand in 2010 and evolved into the current Pixel line in 2016. Smartphone production (and design in some cases) has been outsourced to various Asian manufacturers, including HTC, Foxconn (Taiwan), LG (Korea), and Huawei (China). Google also relies on specialized suppliers for components, mostly from the US, Japan, and Korea in the case of its Pixel XL released in 2016. Google's emphasis on globally standardized devices is a stark contrast to Samsung and Huawei, which emphasize product variety (see Table 4).

High externalization in hardware sectors is a sharp contrast to Google's internalization focus on its own OS and app distribution platform. Unlike Apple's iOS, Google Android is a mobile OS based on open sources and licensed to



7 This US government action restricts Huawei's access to the products or services sold by American companies without a government license. The access was further limited later as the US applied the licensing rules to American software and technology used in semiconductor manufacturing (Bown and Kolb, 2020).

8 While Huawei did not provide information on its smartphone revenue by region in its annual report, 59% of its total revenue came from China in 2019, an increase from 52% in 2018 (Huawei, 2020).

9 Rick Osterloh, the head of Google's hardware unit, was quoted at the launching event of a new Pixel product in 2016 to say that "[b]uilding hardware and software together lets us take full advantage of capabilities like the Google Assistant… It lets us harness years of expertise we've built up in machine learning and AI to deliver the simple, smart, and fast experiences that our users expect from us" (Knowledge@Wharton, 2016). The Google Assistant is an AI-powered virtual assistant, mainly competing with Apple's Siri and Amazon's Alexa.

any smartphone manufacturers like Samsung to build Android-based devices. The company's strategy is to maximize the availability of Android-based devices and the number of users (Kapoor and Agarwal, 2017) in order to lock them into its own applications (e.g., Gmail, Google Maps) and Internet services (e.g., YouTube) as well as Android-based third-party applications available at Google Play. In this regard, Google's architectural advantage lies in its own fully open platform, unlike any of its competitors.

## 5. Discussion

Our article examines innovation and upgrading in the era of the fourth industrial revolution from a GVC perspective. Similar to the SSI approach, the GVC perspective adopts a sectoral or product-based value chain as its basic unit of analysis. The new platform-based stage of industrial development, however, challenges these frameworks as sectoral boundaries become blurred through the integration of physical, digital, and biological systems. A linear or sequential model implied by the chain concept in GVCs and the notion of sector-based systems of innovation are insufficient to fully address these changes. Platform products like smartphones meld traditionally distinctive domains into interconnected technological, organizational and institutional fields of larger business ecosystems (Gawer, 2014; Humphrey, 2018; Jacobides *et al.*, 2018).

First, the concept of cross-sectoral GVC governance proposed in this article raises novel questions about the structure and dynamics of innovation and upgrading. It highlights the importance of leveraging innovation from sectors connected to a platform outside a focal firm's sectoral domain. This is distinctive from the existing patterns of learning and knowledge transfer within a specific sectoral system—that is, the vertical value chain linkages between buyers and suppliers, or the interaction of horizontal and vertical systems (Gereffi and Lee, 2016). It requires a wider search for necessary capabilities, and new and creative ways of combining discrete elements of innovation. This will be an important role for lead firms in platform ecosystems.

While the SSI and GVC pay attention to the heterogeneity of actors, a cross-sectoral approach prompts us to take seriously the heterogeneity of *sectors*. Sectors are different not only in terms of resources and capabilities but also in their organizational configuration (e.g., concentrated or decentralized), power structure (e.g., more or less hierarchical), and resource dependence (public or private sources). The logic of creating innovation and organizing production is likely to vary across sectors (Apitzsch and Piotti, 2012), whose characteristics can be a source of innovation but also can lead to tensions or conflicts among actors (McColl-Kennedy *et al.*, 2020). Lead firms may combine these sectoral features in distinct ways to create their unique cross-sectoral architectures.

A key question is whether blurred sectoral boundaries will lead to an isomorphic process where sectoral dynamics and logics converge, or if diverse sectoral characteristics will persist. Furthermore, increased cross-sectoral interaction could lead to multiple and often competing logics of organizing innovation and production within a given sector (Vasudeva *et al.*, 2015). An incumbent sectoral logic may be undermined by new ways of organizing innovation and upgrading across sectoral boundaries. For instance, the introduction of electronic and autonomous driving vehicles unsettles the existing architectural design of the automotive sector. It opens an opportunity for new entrants like Tesla, BYD, and Google with distinctive capabilities from those of the incumbent automakers to reshape the source of knowledge and innovation. This contention could eventually lead to the demise of the incumbent and the rise of the challenger as a new lead firm, as shown in the contrasting fortunes of Nokia and Apple. At a field level, it could result in the replacement of one logic with another or the emergence of a hybrid model (Gereffi, 2001; Gereffi and Lee, 2016).

Second, this article extends GVC governance theory to a cross-sectoral dimension. A series of recent theoretical endeavors in the GVC literature have tried to synthesize existing frameworks (Ponte and Sturgeon, 2014) and adapt them to new realities like the digital platform economy (Humphrey, 2018; Dallas *et al.*, 2019; Pananond *et al.*, 2020). By defining cross-sectoral governance and specifying its conceptual dimensions, our article sheds new light on how innovation travels across sectoral boundaries and who coordinates and controls the flow that links vertical, cross-sectoral, and international dimensions.

From a lead firm perspective, how to strike a balance between control and integrity, on the one hand, and growth and innovation, on the other, is a more complex and important question than in a conventional dyadic relationship, since platform participants spread across both sectoral and geographic boundaries. Semiconductor manufacturers like Qualcomm, for example, deal not only with Samsung and Apple, but also Hewlett-Packard, Amazon, Microsoft, and other lead firms in the server and cloud sectors (PwC, 2019). Display manufacturers are diversifying into the automotive sector, partly in response to the saturated demand for smart devices (Higgins and Boston, 2019). As a result, lead firms in multiple sectors are increasingly linked through shared suppliers and eventually embedded in a larger business ecosystem.

One implication is that a multipolar structure is more likely to emerge in cross-sectoral systems. For instance, a modular form of interfirm governance, that is, between brand lead firms like Apple and contract manufacturers like Foxconn, attracted a great deal of attention in the electronics GVC (Sturgeon and Kawakami, 2011). A cross-sectoral perspective highlights other types of linkages that are quite new and unstudied. This includes the relationship between lead firms in different sectors, for example, Apple and Qualcomm, Huawei and BOE (China's leading FPD manufacturer), and Samsung and Google. These are all global market and technology leaders governing their own sectoral value chains. But they are also interconnected through platform products like smartphones, and such cross-sectoral connection is likely to be more critical for their business success in a platform-based digital economy.

Third, our smartphone case study suggests that cross-sectoral governance in the platform economy is central in the new stage of digitally oriented industrial development. All the lead firms (even Huawei before the recent US ban) work with a similar set of actors in the hardware sectors, largely divided between the US (semiconductor and communication) and Asian suppliers (memory, display, camera, and battery) and contract manufacturers (see Table 4). Yet, how each lead firm integrates them into its value chains, that is, OS/service and market sectors, is clearly divergent, highlighting the importance of lead firm strategies in organizing cross-sectoral linkages (Pananond *et al.*, 2020). While it is intriguing to explain why firms adopt such different strategies, an even more fundamental question from our perspective is how cross-sectoral relationships and contexts might affect the diverging choices themselves, and specifically whether the suppliers or complementors in different sectors played any role in shaping lead-firm strategies.

Our approach foregrounds novel features of cross-sectoral governance—that is, the persisting symbiosis of Samsung and Google through Android OS, a forced breakup of Huawei and Google caused by government restrictions, and an evolving, often rocky, relationship of Samsung and Apple. The recent US–China trade war and the global pandemic of Covid-19 are likely to unsettle GVCs even further (Gereffi, 2020; Van Assche and Lundan, 2020). The growing influence of government policy, from trade restrictions to public investment in home-grown innovation, is already reshaping the business environment for many of these MNEs. They are likely to adjust, if not restructure, their cross-sectoral architecture in relation to these disruptive changes and their fallout, which is another topic for future research.

Finally, expanding the scope of innovation is particularly critical in the context of cross-sectoral systems anchored around a platform product like smartphones. Technological innovation may be embedded in complementary assets provided by platform participants or intermediate goods and services imported from abroad. The cross-sectoral specialization of production and integration through platforms highlight the importance of combining external innovation and internal capabilities, whether via integrating extra-sectoral innovation to intra-sectoral capabilities, or creating synergy between innovation systems at the platform level and those within firms. Leveraging specialized complementors' capabilities can lead to more rapid catchup.

An exemplar is Apple's extensive use of contract manufacturers like Foxconn for strategic advantage by combining the latter's mass production prowess with Apple's own strengths in design, branding, and software. The rapid rise of Chinese mobile phone producers (both state-supported giants such as Huawei and startups like Xiaomi, Vivo, and Oppo) at the early stage of catchup was facilitated by the extensive use of Taiwanese and Korean original design manufacturers (ODMs) (Yang and Chen, 2013). A theoretical challenge ahead is to extend the existing work on innovation systems and interfirm governance in sectoral GVCs (Pietrobelli and Rabellotti, 2011; Lema *et al.*, 2018) to specify the process of learning and knowledge transfer mechanisms and upgrading outcomes in a cross-sectoral setting.

## 6. Conclusion

This article has examined innovation and upgrading in the context of the fourth industrial revolution, focusing on cross-sectoral governance in GVCs. The concept illuminates the importance of learning and innovation across traditional sectoral boundaries that are anchored in platform products like smartphones. The growing use of platform dynamics and new technologies like AI and IoT, and the integration of manufacturing and services in a wide range of industries (e.g., electric cars, Alibaba's e-commerce platform in apparel, or automation efforts in athletic footwear) may lead to the spread of cross-sectoral governance. But it is up to empirical research to answer whether, and to what extent, cross-sectoral governance can be applied in various sectors such as apparel, automobiles, electronics, and other GVCs (Lee and Lim, 2018; Wu and Gereffi, 2019).

From a GVC perspective, future studies need to pay more attention to intangible assets, high-value embedded services, and related institutional arrangements such as intellectual property rights as tools for value chain governance, and the ways they facilitate or inhibit firms' learning, innovation, and upgrading within and across sectors. From the SSI perspective, a wide range of rent-generating strategies, and value capture through governance and architectural advantage are relevant topics for a constructive dialogue with the GVC literature. Whether Huawei and other Chinese smartphone brands can leverage the Chinese domestic market as a niche for low-cost innovation, which was neglected by sectoral forerunners like Samsung and Apple, illustrates the kind of subject on which both GVC and SSI approaches could fruitfully collaborate.

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