Joint Project between GVCC and KIET

Chapter 1: Global Value Chains and Economic Development

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1. Global Value Chains and Economic Development

1.1. Introduction

Since the early 1990s, profound changes in the structure of the world economy have reshaped global production and trade, altering the organization of industries and national economies (Gereffi & Sturgeon, 2013). These changes have been driven by heightened international competition from trade liberalization and improvements in transport and telecommunications technologies. The resulting reconfiguration of industries has led to the geographic fragmentation of production and an increase in vertical specialization in supply chain activities by different firms at the national, regional and global levels (Gereffi, 2014). These changes began in labor-intensive industries such as apparel and electronics (Bair & Gereffi, 2001; Gereffi, 1994, 1995), but were closely followed by more advanced manufacturing sectors like automotive (Sturgeon et al., 2007). Today, most major industries, including agriculture and services, are organized as GVCs (UNCTAD, 2013).

These changes have been documented in the extensive and rapidly growing global value chain (GVC) literature (Gereffi et al., 2001; Gereffi & Lee, 2012).[2] The GVC framework has been developed over the past two decades by a global network of researchers from diverse disciplines in order to understand the phenomenon of globalization (Barrientos et al., 2011; Gereffi, 1999, 2005; Gereffi et al., 2005; Humphrey & Schmitz, 2002; Kaplinsky, 2004, 2010). It allows one to understand how industries are organized by examining the structure and dynamics of the different actors involved. This framework originated as "global commodity chains" research in the 1990s, which primarily focused on understanding how companies were reconfiguring their supply chains to source from lower cost locations around the world (Gereffi, 2011). This gave way to the broader GVC framework as researchers sought to understand the distribution of value creation and value capture across all possible chain activities, firms and countries involved in the production of goods and services.[3]

Central to this framework is the ***value chain concept***. The value chain describes the full range of activities that firms and workers around the globe perform to bring a product from conception to production and end use (Gereffi & Fernandez-Stark, 2016; Kaplinsky, 2000). This includes both tangible and intangible value-adding activities, such as research and development (R&D), design, production, distribution, marketing and support to the final consumer. Global value chains thus consist of cross-border, inter-firm networks that bring a good or service to market. Value chain analysis examines the labor inputs, technologies, standards, regulations, products, processes, and markets in specific industries and international locations, thus providing a holistic view of industries both from the top down and the bottom up. The key concept for the top-down view is the governance of GVCs which focuses mainly on lead firms and the organization of global industries; while the main concept for the bottom-up perspective is upgrading, which

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[2] For a review of this literature, see the links and more than 800 publications listed at the Global Value Chains website, https://globalvaluechains.org/publications.

[3] A parallel body of work on global production networks (GPN) has evolved at the same time. While GPNs and GVCs are terms often used interchangeably, the GPN literature has focused more on the local institutional context in which these networks are embedded, while the GVC literature has maintained firm analysis as the central element. See Yeung and Coe (2015) for a discussion of the differences between these frameworks.

focuses on the strategies used by countries, regions and other economic stakeholders to maintain or improve their positions in the global economy (Gereffi & Fernandez-Stark, 2016).

Governance shows how corporate power can actively shape the distribution of profits and risks in an industry, and it identifies the actors who exercise such power. Powerful lead firms determine how resources and knowledge are generated and distributed through the chain (Gereffi, 1994; Humphrey & Schmitz, 2002). In the past, the large flow of information regarding production processes between these lead firms and suppliers helped to facilitate development of capabilities, and expertise of the latter were important drivers for upgrading in developing countries (Gereffi, 1999). These lead firms source their products from a global network of suppliers in cost-effective locations to make their goods. The most notable form of 'supplier power' comes via platform leadership (e.g., firms that exhibit marketing or technological dominance, which allows them to set standards and get higher returns for their products), although supplier power typically is not associated with the explicit coordination of buyers or other downstream value chain actors (Frederick & Gereffi, 2009; Sturgeon, 2009).

Economic upgrading involves increasing the value generated from a country's engagement in the chain, using either the firm or the industry as the unit of analysis. As cheaper locations vie to join chains, those already participating must develop strategies to sustain their inclusion, such as increasing their total factor productivity, specializing in higher value operations or niche sectors that are more insulated from competition (Humphrey & Schmitz, 2002). Upgrading trajectories can be analyzed at both the firm and the country levels. In general, a country upgrades when a critical mass of firms located within its borders achieves upgrading. Upgrading depends considerably on how firm strategy leverages local competitive advantages such as qualified labor, presence of suppliers, geographic location and regulatory conditions. The GVC analytical framework thus provides a typology for identifying potential upgrading trajectories; the most commonly pursued strategies are highlighted in Table 1-1.

Table 1-1. Upgrading Trajectories

Type of Upgrading	Description
Process Upgrading	Improvements in productive efficiency leading to higher productivity, such as the use of more sophisticated technology, or the incorporation of lean manufacturing techniques
Product Upgrading	Shift into the production of a higher value product
Functional Upgrading	Movement to new higher value segments in the supply chain
Chain/Intersectoral Upgrading	Leveraging capabilities developed in one chain to move into an entirely new sector
End Market/Channel Upgrading	Incursion of firms into new end market segments, either industrial (e.g., from textiles to medical devices) or geographical (e.g., regional markets in Asia to Europe)
Upgrading into Production Technologies	Moving into the design/fabrication of production machinery and capital equipment. This requires in-depth knowledge of production process.

Source: Authors; adapted from Humphrey and Schmitz (2004).

1.2. The Development Implications of Global Value Chains

The use of the GVC analytical framework has broadened over time from a research agenda to an active policy tool as the emergence of GVCs has redefined how we conceptualize economic development. For most early industrializers (pre-1990), including the US, Germany and Japan, as well as later ones such as Korea, industrialization meant building relatively complete supply chains at home. The core idea was that no nation could become globally competitive without a broad and deep industrial base, and thus considerable effort was dedicated to bring together the capital, technology and labor needed to create new industries (Gereffi, 2014). In the past twenty-five years, however, the fragmentation of production associated with the rise of GVCs now allows firms in different countries to engage in international trade without developing the full range of vertical capabilities across the value chain.

As such, GVCs have thus ushered in a new paradigm of thinking regarding industrial development (Gereffi, 2014; Taglioni & Winkler, 2016). The development trajectory of the 'old' or traditional paradigm was to move from agriculture into manufacturing and finally into services. Upgrading in a GVC-oriented world today, essentially means moving into higher value segments of the industries in which countries have already established expertise. GVC-oriented industrial policy is therefore based on specialization in specific functions. This shift in development thinking has important implications for developed and developing countries alike.

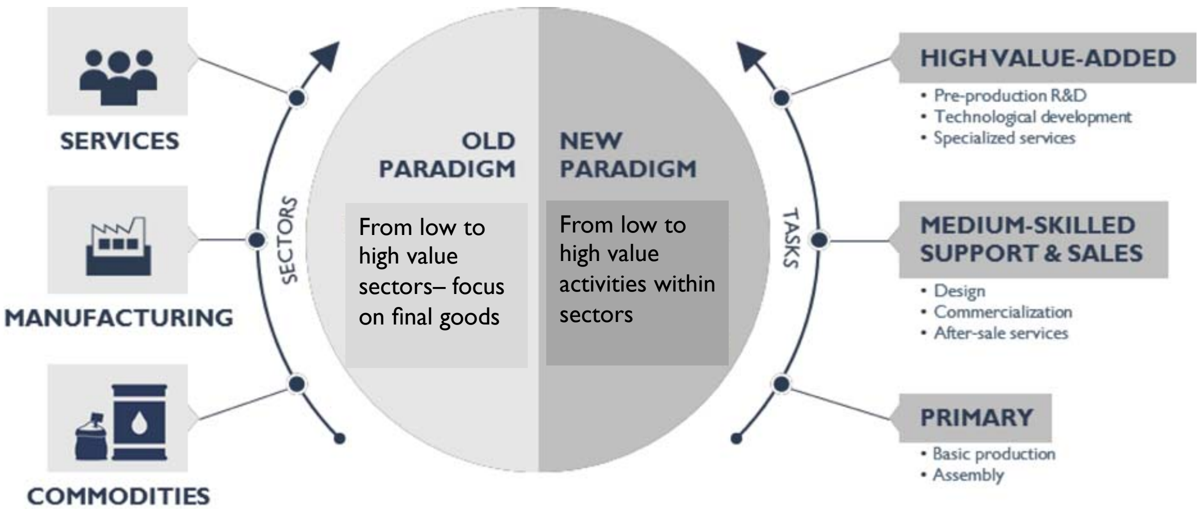
First, countries develop competencies along the supply chain of a given GVC, breaking the preconceived notion of how 'industries' understood in industrial classification systems. This is particularly relevant for the top producing and exporting countries that manufacture in large volumes. For example, in the apparel industry countries often start by assembly of final products, however as they have enough demand, they move backwards into fabric production (first knit and then woven), yarn production, man-made fibers, and finally into the actual production equipment needed to produce these products. At each stage of the chain, countries improve their productivity and the quality of their output to remain competitive.

Second, countries tend to move from production activities into service activities for any given industry. Countries often enter in production operations and over time move into distribution and sourcing, design, marketing, branding, retail and/or after-sales services. This is called 'functional upgrading' in GVCs; this is considered the pathway to GVC leadership. In many GVCs and countries, as capabilities in these higher-value segments improve, the country may move out of production and solely focus on the services segment as a result of a changes in its relative competitiveness, such as labor and/or technology costs.

Third, while countries have a tendency to upgrade within a given GVC, given the focus on specialization of functions, skills developed for one industry are often transferable to other industries. Traditional manufacturing centers including the US and the United Kingdom (UK) have been able to keep their industrial sectors alive by constantly shifting into an ever-evolving array of new, higher technology and more sophisticated sectors. Today, the sectors at the forefront include bio- and nanotechnology and artificial intelligence. In GVC chains, this is referred to as chain or intersectoral upgrading.

Finally, the more advanced a country or firm's participation along these value chains, the closer they are to the global knowledge and technology frontier. These firms define the technologies, standards, and pathways for development of these new sectors.

Figure 1-1. Rise of GVCs: Old versus New Paradigm for Development



Source: Taglioni and Winkler (2016, p. 23)

For *developing regions of the world,* this has essentially "compressed" the development experience and made non-linear catch up possible (Sturgeon & Memedovic, 2010). In the process, GVCs have allowed countries from all over the world to participate in a range of low to very high-tech sectors. For example, this has allowed Vietnam to enter the semiconductor sector, the Philippines into aerospace, and even small countries such as Costa Rica into medical devices (Bamber, Frederick, et al., 2016a; Bamber & Gereffi, 2013). This has provided emerging economies the opportunity to support their development goals by driving employment creation, adding value to their local industries and diversifying their economies. Policymakers in these countries thus have been focused on providing overall conditions for participation and upgrading, such as increasing liberalized trade, flexible labor regimes and improved infrastructure (Bamber et al., 2013).[4]

For *developed regions*, the rise of GVCs and the entry of developing countries into these sectors have provided significant opportunities, but also pose important challenges for policymakers. On one hand, firms from these regions have successfully used lower cost locations to increase their competitiveness, offshoring and outsourcing routinized codifiable tasks such as those in labor-

[4] Due to the complexity faced by many developing countries in achieving progress along these multiple policy dimensions, special economic zones, or Economic Processing Zones (EPZs) have been developed as a key instrument in facilitating entry and upgrading in GSCs. These zones, which often operate as separate jurisdictions, buffer companies involved in GSCs from poor infrastructure, bureaucratic procedures, and other challenges of operating in developing countries (Farole, 2011). In some cases, these EPZs may also operate under different labour codes than the host economy (Cairola, 2015).

intensive assembly operations while maintaining "core competencies" and high value adding activities such as branding and R&D at home. This combination of offshoring and outsourcing has allowed them to reduce their costs, enter new markets and, more recently, also access new technologies.

On the other hand, these changes have altered the demands on policymakers in more industrialized countries. In particular, as they see their competitive advantages in production erode, developed countries have been forced to re-focus their growth models, emphasizing sectors and activities that leverage their comparative advantages in knowledge and innovation. The past emphasis on production efficiencies has been supplanted by the need to foster an environment where innovation can thrive, supported by highly skilled labor and intellectual property protection, while gaining access to new manufacturing hubs through the reduction of tariff and non-tariff barriers on intermediates (OECD, 2014). In doing so it has raised the question of how to remain innovative without a manufacturing base (Gereffi, 2014). Combined, globalization and the logic of value-added production mean that industries are "hollowed out" (Goos & Manning, 2007; Goos et al., 2009, 2014). This has had important implications on labor. The concentration on higher value activities has meant fewer, albeit highly skilled, jobs while this has had positive outcomes for many, unskilled and semi-skilled labor in these countries has suffered (Bacchetta & Jansen, 2011). In numerous communities this has led to pressure for more protectionist policies against this offshoring of jobs.

1.3. Current Trends in Global Value Chains

While GVCs have fundamentally reshaped international trade since the 1990s, the chains themselves are dynamic and constantly evolving in response to shifts in demand, changes in national and international trade and investment policy, and technological advances. Most recently, in the aftermath of the 2008-2009 global financial crisis, four broad changes have begun to change alter existing GVC dynamics: (1) rationalization, (2) reorientation towards Asia, (3) automation/additive manufacturing, and (4) servicification. The latter two are based on changes being ushered in by "Industry 4.0"; automation/additive manufacturing affects tangible production operations, while servicification covers a new series of intangible operations in chains. Each of these trends is addressed below.

First, global lead firms are more actively consolidating their supply chains to include fewer, but more technologically capable and strategically located suppliers (Gereffi, 2014, p. 15). This organizational rationalization of the supply base has been driven by the need to reduce transaction costs. A handful of suppliers were increasingly delivering the majority of value; and lead firms found that supply chain management could be done more efficiently and frequently if a fewer number of highly capable suppliers were engaged. Although consolidation was growing at both the country and supply chain levels in a number of hallmark global industries pre-crisis, such as apparel (Gereffi & Frederick, 2010), automobiles (Sturgeon & Van Biesebroeck, 2011; Sturgeon et al., 2008) and electronics (Brandt & Thun, 2011; Sturgeon & Kawakami, 2011), it has subsequently gained pace. Two noteworthy consequences of this consolidation is the growth of very large GVC suppliers and intermediaries (Gereffi, 2014), and the subsequent crowding out of smaller firms from participating in these global industries (Bamber et al., 2013; Bamber, Frederick, et al., 2016a). These changes have been particularly prevalent in bulk/volume segments, or where large scale is required; niches based on high levels of customization, and smaller volumes provide opportunities for smaller firms to participate.

A second trend in GVCs is a notable reorientation of chains towards Asia, as a result of shifting patterns of both demand and supply. The region's low cost labor and growing industrial base combined with its rapidly growing local demand is increasingly concentrating trade into regional value chains in a number of industries, including apparel, chemicals, electronics and shipbuilding (Bamber, Frederick, et al., 2016b). This shift towards markets in Asia is also evident by the growth in trade between emerging regions. While the general pattern of trade throughout the 20th and 21st centuries has been between countries in the northern hemisphere and between countries in the northern and southern hemispheres, today, the fastest growing corridors of trade are between Asia and Middle East North Africa, Asia and Sub-Sahara Africa, and Asia and Latin America (WTO, 2013). The Asian Development Bank projects these trade patterns could increase from 33% in 2004 to 55% in 2030, and that the South's share of global trade could overtake that of traditional trade leaders in the northern hemisphere by 2030 (Anderson & Strutt, 2011). Regionalization, of course, is not new to global value chains or international trade (Gereffi, 2014). In the past, this has often been the outcome of trade agreements such as the European Union and NAFTA. This reorientation to Asia is perhaps more striking as it is being driven by a significant shift in demand and supply.

The third trend is the rise of new disruptive technologies in the manufacturing process. Heralded as part of Industry 4.0 (Schwab, 2017),[5] this includes automation, human to machine interface, and additive manufacturing (see Box 1.1) (Baur & Wee, 2015; Manyika et al., 2015; Rüßmann et al., 2015).[6] This collection of technologies is expected to change the way things are manufactured. The overall vision of these systems is to automate and integrate production lines, design and produce collaboratively and virtually, and improve the efficiency with which these are delivered to the client/consumer. Automation is already being increasingly incorporated into scale operations, while 3D printing has begun to be used in niche, high value manufacturing operations. The cost of these technologies is decreasing rapidly, with reductions up to 90% over the past four years.[7] As costs have declined, technology adoption has increased; estimates of additive manufacturing adoption are that it has increased four times what it was ten years ago (Manyika et al., 2013). 3D printing is already expanding from consumer use to direct product manufacturing, and tool and die manufacturing. Physical components can be produced near the assembly site in the country of consumption, further reducing the number of suppliers and inventory required. General Electric's new LEAP engine, for example, is equipped with 3D-printed fuel nozzles in alloyed metal – extending the product lifetime by a factor of five, decreasing weight by 25%, and reducing its assembly from 18 parts to one (Rehnberg & Ponte, 2016). Although the current range of products able to be produced by the various techniques of additive manufacturing is limited to complex, low-volume, highly customizable parts like

[5] See Table 1-A1 in the Appendix for an overview of the different definitions.
[6] Manyika et al. (2013) identify twelve technologies that are part of Industry 4.0. In general, they overlap later efforts at defining Industry 4.0, such as those by Rüßmann et al. (2015) and Baur and Wee (2015), although they also include genomics and energy related technologies (storage, enhanced oil/gas exploration & recovery, and renewable technologies), which are now not considered as part of Industry 4.0 technologies.
[7] Adopting productivity enhancing technologies will require a 35% capital investment increase over the next five to ten years, but is expected to yield 30% reductions in labor, operating, and overhead costs, and 50% reductions in logistics costs (Rüßmann et al., 2015).

aircraft fuel nozzles, the electronic proliferation of tool and die specifications needed to make components through traditional manufacturing techniques could significantly affect the location of manufacturing activity (Manyika et al., 2013; Rehnberg & Ponte, 2016).

Box 1-1. Supply Chain Digitalization: Industry 4.0

Supply chain digitalization is defined as the use of advanced data analytical tools and physical technologies to improve the digital connectivity and technological capabilities of supply chains (Mussomeli et al., 2016). Advanced data analytical tools include visualization, scenario analysis, and predictive learning algorithms, typically called information technology (IT). Advanced physical technologies include robotics, drones, additive manufacturing (3D printing), and autonomous vehicles, typically called operations technology (OT). The combination of IT and OT, made possible by improved processing capabilities, increased computing power, and reduced costs of computing, storage, and bandwidth over the past 15 years has allowed for real-time access to data, analysis, and optimization in the production system. These key areas include:

- Big Data and Analytics are used to collect and evaluate data from production equipment and systems, enterprise and customer-management systems to support decision-making.
- Autonomous robots are developing to become flexible and cooperative with one another and able to learn and work with humans; robots will cost less and have a greater range of capabilities than those that currently exist in manufacturing sites.
- Simulations: real-time virtual model of machines, products, and humans mirroring the physical world. These virtual models allow operators to test and optimize machine settings for the next product in line before a physical changeover, reducing machine set-up times and improving quality.
- The industrial Internet of Things will increase the connectivity of machines and products through distributed systems, allowing real-time response.
- Cybersecurity will become more important as increased connectivity and use of standard communications protocols by industrial and manufacturing systems will require secure, reliable communications, identity, and access management systems.
- The Cloud will increase connectivity and data sharing across sites and company boundaries as part of the Internet of Things. It will improve to also hold monitoring and control processes.
- Additive Manufacturing will go beyond prototypes and individual components to small batches of customized products that can be produced onsite reducing transportation distances and inventory.
- Augmented Reality support parts selection in warehouses and sending repair instructions. Although currently in its infancy, augmented reality may allow workers to receive repair instructions in real-time while looking at the system needing repair. Virtual training through augmented reality may also be used increasingly.

Importantly, the incorporation of these technologies has huge potential pay offs. Manufacturing processes are becoming more automated and flexible to allow for smaller lot sizes and to allow for learning, self-optimization, and adjustment, and automated logistics will use autonomous vehicles and robots to adjust automatically to production needs (Rüßmann et al., 2015). By optimizing functions across the value chain, Industry 4.0 tech can result in increased productivity, reduction of waste and energy consumption and a further decrease in transaction costs. Supply chain partners are connected when and where necessary, reducing capital requirements necessary for efficient production, resulting in on-demand supply, which may permit smaller firms to compete on a more equal footing with larger firms. In manufacturing, companies can gather more information and make better use of it, particularly on technologies focused on process and resource efficiencies that can be enhanced through better technology.

Sources: Baur and Wee (2015); GTAI (2017); Manyika et al. (2015) and Mussomeli et al. (2016).

Finally, ***servicification*** or the increasing role of services in the GVCs; this has been particularly evident in manufacturing sectors (Low & Pasadilla, 2016). First, due to the rapidly changing technology, **pay-by-use and subscription services** are becoming more common. This has already begun in sectors characterized by high capital expenditure, at both the individual consumer and firm level. Rather than focus on selling a product to a customer, the focus is on selling a capability to a customer on a subscription or per-use basis. In transportation services, for example, car manufacturers are investing in ride sharing operations such as Lyft and ZipCar (Gauger et al., 2017; Porter & Heppelmann, 2014). The benefit for the customer is that they no longer own and maintain a car that is idle 90 percent of the time (Morris, 2016) and which uses 25 percent of disposable income (Hodges-Copple, 2017), while getting on-demand transportation services. The benefit for the manufacturer is the ability to deploy a single system for multiple customers who are all paying fees for the privilege of the service. Likewise, this is occurring where capital equipment is even more costly – including aerospace and extractive industries; essentially turning capital expenditures into operational expenditures (Baur & Wee, 2015; Mussomeli et al., 2016; Porter & Heppelmann, 2014). The model means that some manufacturers no longer own their production equipment but rather pay either a fixed subscription cost or variable "per-use" fee to equipment manufacturers to use and maintain the equipment; these manufacturers now redefine themselves as capability and service providers.

These changes are occurring across a wide range of sectors, facilitated by the rise of the Industry 4.0 technologies, generally referred to as the **"Internet of Things" and "Big Data**". As sensors and communication capabilities are embedded in products, they are being used to create system platforms of similar products, optimize their individual or combined use, or sold to develop new information products to new customers (Porter & Heppelmann, 2014). By opening the door for new analytical services, these tools allow traditional manufacturers to enter high value knowledge economy activities.[8] For example, data about the fuel efficiency of a vehicle under different operating conditions and the current driving conditions on roads could be valuable to a number of potential customers, including other drivers, transportation and logistics companies, and insurance companies. Data about how, when, and where the product is used could be valuable to product manufacturers to segment customers, customize features and provide specialized service plans or discounts for additional products to highly specific niche customers (Porter & Heppelmann, 2015). Manufacturers are beginning to develop new businesses that monetize their production expertise and data (Baur & Wee, 2015; Porter et al., 2014).

1.4. Potential Impacts of Changes on GVC Participation

Over the past two decades, developed and developing countries alike have competed to participate in different industries, shaping a series of policies based on the existing understanding of the distribution of value within the chain and the particular requirement of each of those stages. The development path used by many developing countries has been to attract segments of

[8] This is already happening in both the mining equipment and aerospace industries, where manufacturers are now netting over half of their revenue from life-cycle services (Bamber, Fernandez-Stark, et al., 2016; Bamber, Frederick, et al., 2016a). In mining, equipment manufacturers such as Komatsu (Joy Global) are increasingly signing performance based contracts with miners, with profits dependent on the productivity and availability of their machines (Bamber, Fernandez-Stark, et al., 2016). In aerospace, GE changed its business model from being a product and component supplier to being a power and propulsion provider in which it leased equipment on a "power by the hour" basis (Chesbrough, 2012).

GVCs utilizing comparative advantages in labor to conduct routine manual and service work in global industries at lower cost. As such, permissive labor policies, efficient and reliable infrastructure (transportation and energy), and low import tariffs, have been prioritized to enter into chains via low value assembly and production stages (Bamber et al., 2013). Developed countries have focused on research, design and technology development, in addition to branding and marketing skills, as well as negotiating trade and investment policies to leverage the benefits of low cost locations. The current trends are altering the dynamics of GVCs, affecting their value distribution, governance structure and geographic composition. As a result, the calculus for outsourcing and offshoring value chain activities by firms may change, affecting the development prospects of countries.

First, the new technologies and the rise of services **alter the value distribution within GVCs**. Automation and 3D printing could result in the re-integration of production processes, and reducing reliance on labor-intensive assembly operations, although the uptake will likely vary by industry and operation type for quite some time to come (Rehnberg & Ponte, 2016). Manufacturing related services, particularly those previously considered "after-sales" ones are becoming as important sources of revenue, if not more so, than manufacturing operations themselves (Low & Pasadilla, 2016). In some capital equipment sectors, these already account for more than 50% of manufacturing company revenues (Bamber, Fernandez-Stark, et al., 2016).

Second, they **shift the balance of power** within these chains; the shift is subtle, yet powerful and affects which firms can gain access to these chains. Traditional lead firms are being challenged by powerful suppliers with new technologies and capabilities (Gereffi, 2014); these include both large suppliers from the developing world, such as Foxconn and Li & Fung, which have gained dominant positions through rationalization and upgrading (Rehnberg & Ponte, 2016), as well as emerging, well-financed actors such as Amazon, Google, Uber and Akamai, which have successfully leveraged new services platform technologies to take on major coordination roles between buyers and suppliers.

Finally, these trends also change the **potential geographic distribution of chain activities,** with implications for which countries can participate. While automation and regionalization may foster the relocation of manufacturing activities closer to their markets, increased digitalization allows for globalization of services. Routine manufacturing tasks, such as component production and assembly, were the first portions of the value chain to be offshored due to lower relative wage rates (controlled for logistics costs). However, as a result of increased automation and digitalization capabilities, capital substitution of labor in routine manufacturing tasks is high and expected to be even greater as a result of expanded capabilities provided by Industry 4.0 technologies. As a result, the value of continued offshore production may be reduced in some manufacturing GVCs as new capital investments replace labor. **Access to large scale manufacturing GVCs will become more dependent on proximity to market, combined with expertise in automation technologies.** Countries benefiting the most from automation technologies are likely to be in the advanced industrialized world due to the need to improve productivity in the face of population declines (Bughin et al., 2017). Technology advances are likely to be slower in developing countries which have relied on their competitive labor advantage and failed to upgrade capabilities. Thus, a significant threat exists for countries and regions of the world historically using low relative costs of labor as their source of comparative advantage (Butollo, 2017).

Yet, countries may no longer have to be manufacturing hubs to participate in manufacturing GVCs; services such as data analysis for life-cycle management can be carried out anywhere in the world with the right mix of human capital availability and infrastructure. Currently, many of these activities are being carried out in the advanced industrial countries, however, the efficiency seeking ambitions that led to the first wave of unbundling in GVCs remains, and non-automated services too are being offshored to lower cost locations (Fernandez-Stark et al., 2011).

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Appendix

Table A-1-1. Definitions of Current Technology Trends

Term	Definition
Industry 4.0	A term extensively used by McKinsey and Company to describe "the fourth major upheaval in modern manufacturing, following the lean revolution of the 1970s, the outsourcing phenomenon of the 1990s, and the automation that took off in the 2000s…We define Industry 4.0 as the next phase in the digitalization of the manufacturing sector, driven by four disruptions: the astonishing rise in data volumes, computational power, and connectivity, especially new low-power wide-area networks; the emergence of analytics and business-intelligence capabilities; new forms of human-machine interaction such as touch interfaces and augmented-reality systems; and improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing (Baur & Wee, 2015)."
Industrie 4.0	A German strategic initiative, described in the German Trade and Investment Ministry's 2010 "High-Tech Strategy 2020" plan, seeking a "fusion of the online world and the world of industrial production" (Merckel, 2015) as a "means to establish Germany as a lead market and provider of advanced manufacturing solutions… Cyber-physical production systems (CPPS) made up of smart machines, logistics systems and production facilities allow peerless ICT-based integration for vertically integrated and networked manufacturing" (GTAI, 2017).
4th Industrial Revolution (4IR)	Championed by the World Economic Forum and its founder Klaus Schwab, the term Fourth Industrial Revolution ("4IR") describes the range of new technologies fusing the physical, digital and biological worlds into "cyber-physical systems." The emerging technology breakthroughs in artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing and nanotechnology are a part of the 4IR. 4IR is distinguished from the first, second, and third industrial revolutions in which mechanization, electricity, and information technology, respectively, powered industrial change (Davis, 2016; Schwab, 2017).
Internet of Things ("IoT")	Embedding objects with technology that can communicate with IT systems and be detected by sensors. "The advent of the IPv6 internet protocol (which makes 600 quadrillion addresses per square millimeter of the earth's surface possible) means that all physical objects, in theory, can have their own IP address, creating a world of intelligent objects in an Internet of Things. The brave new world of the Internet of Things goes beyond simple machine-to-machine (M2M) communication; extending to machine-to-infrastructure and even machine-to-environment communication. Ordinary objects and devices in the physical world communicate independently and exchange information online thanks to increased programmability, memory storage capacity, and sensor-based capabilities (GTAI, 2017).
Digital supply network	Deloitte Consulting's term for combining information technology's (IT) advanced data analytical tools with operational technology's (OT) advanced physical technologies to improve the digital connectivity and technological capabilities of supply chains (Mussomeli et al., 2016).

Table A-1-2. Supply Chain Digitalization and Optimization Examples

Supply Chain Stage	Examples
Design process optimization	• Sensor/data-driven design enhancements
	• Open innovation/crowdsourcing
	• Rapid prototyping
	• Virtual design simulation
Product optimization	• Data as a product or service
	• Make-to-use with 3D printing
	• Ultra-delayed differentiation
Planning & inventory efficiency	• Analytics-driven demand sensing
	• Dynamic inventory fulfillment
	• POS-driven auto-replenishment
	• Real-time inventory optimization
	• Sensor-driven forecasting
Risk prevention & mitigation	• Proactive quality sensing
	• Track-and-trace solutions
	• Proactive risk sensing
Supplier collaboration	• Analytics-driven sourcing
	• Asset sharing
	• Blockchain-enabled transparency
	• Cloud/control tower optimization
	• Supplier ecosystem
Operations efficiency	• Augmented reality-enhanced operations
	• Automated production
	• Predictive maintenance
	• Sensor-enabled labor monitoring
Logistics optimization	• Augmented reality-enhanced logistics
	• Automated logistics
	• Direct-to-user delivery
	• Driverless trucks
	• Dynamic/predictive routing
Sales optimization	• Inventory-driven dynamic pricing
	• Sensor-driven replenishment pushes
	• Targeted marketing
Aftermarket sales & services	• Augmented reality-enabled customer support
	• End-to-end transparency to customers
	• Make-to-use with 3D printing
	• Predictive aftermarket maintenance

Source: Mussomeli et al. (2016)