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GEOECONOMICS CENTER

Trade Flows in the Age of Automation

Global Value Chains Report

Jack Daly, Bart Oosterveld, Nick Brown, and Ole Moehr

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Executive Summary

This report evaluates how innovative digital technologies might change the nature of services trade within global value chains (GVCs) and thus disrupt the value chains themselves. The COVID-19 pandemic has caused economic devastation around the world and is putting the resilience and adaptability of global supply chains to the test. While this report was completed at the outset of the pandemic in North America, the authors believe that COVID-19 does not significantly impact their findings on how digital technologies will shape services trade in the next decade. Our analysis shows that advanced economies are well-placed to benefit from the next wave of technology. As digital technologies increase the intensity of services in value chains across a broad range of industries, from automotive manufacturing to financial services, the primary sources of comparative advantage going forward will be innovation, intellectual property, and specialized skills. Since 2007, trade in services has grown 60 percent faster than that in goods. This trend is expected to continue: The World Trade Organization (WTO) forecasts that services will comprise one-third of all trade by 2040, up from 21 percent today and just 9 percent in 1970.

How did GVCs develop?

The Industrial Revolution enabled a "first unbundling" that saw companies for the first time produce goods away from the end consumer. A revolution in information and communications technology (ICT) during the 1990s significantly reduced transaction costs for cross-border trade. The WTO estimates that international trade costs declined by 15 percent between 1996 and 2004, in part because of these technologies.[1] In turn, companies could now complete the "second unbundling" by spreading the different stages of the production process across multiple countries. Today, roughly 70 percent of global trade is in intermediate goods and services, as inputs are exchanged across borders among a web of suppliers.

What explains the fast growth in services trade?

At the macroeconomic level, the global economy is undergoing fundamental changes as China and other emerging market economies are transitioning from export-driven growth models to growth based on domestic consumption. China, where services contribute approximately 50 percent of gross domestic product (GDP), aims to transform itself into an advanced economy, such as the United States, in which the services sector represents around 80 percent of economic activity. At the company level, our data-driven global economy benefits services that are more knowledge- and ideas-intensive than goods. The trend of services outpacing goods trade is set to continue as emerging digital technologies, such as artificial intelligence and the Internet of Things, make manufacturing processes more service intensive. In some cases, these same technologies are already blurring the distinction between goods and services altogether, as the services component of traditionally tangible goods grows in importance.

Major digital technologies and their impact on GVCs

This report analyzes four digital innovations that have the potential to disrupt GVCs: the Internet of Things (IoT); blockchain; artificial intelligence (AI); and advanced manufacturing. These four innovations are grouped into communications technologies (IoT and blockchain) and information technologies (AI and advanced manufacturing). While ICT advances have largely worked in concert in the past to support the expansion and fragmentation of GVCs, the future geographical effects on GVCs caused by these innovative ICTs are unlikely to be uniform. One trend to observe is the emergence of regional value chains at the expense of global ones in response to changing political, consumer, and business pressures. Digital innovations are likely to reinforce this trend in industries that prioritize short production times as well as high labor skills over low labor costs.

Communications Technologies (the Internet of Things and blockchain)

The IoT is the most mature market of the technologies selected for study with as many as twenty-five billion IoT devices anticipated to be in use by 2020. The IoT's market value is expected reach US$1.5 trillion by 2021. It may facilitate increased trade flows in certain industries by reducing lead times to export and logistics costs. So far, there has been narrow adoption of IoT technologies and limited use of the resulting data, partially because of skills shortages but also because of a preference for human input instead of computer data in decision-making. Overall, this report concludes that the IoT will either support an expansion of GVCs or the maintenance of the status quo.

1 World Trade Organization (WTO), *World Trade Report 2018: The Future of World Trade: How Digital Technologies Are Transforming Global Commerce*, 2018, https://www.wto.org/english/res_e/publications_e/world_trade_report18_e.pdf.

Blockchain has the potential to alleviate some of the friction associated with global trade by reducing transaction costs. Blockchain's market value is a fraction of those of the other technologies discussed in this report—forecasted to be $2.3 billion in 2021. The interoperability of different systems across industries and countries is a key challenge blockchain technology must overcome to disperse widely and achieve scale.

Information Technologies (AI and advanced manufacturing)

AI and advanced manufacturing may change the sourcing decisions of lead firms by decreasing the importance of labor costs in production, potentially encouraging reshoring or nearshoring to advanced economies in sectors where proximity to market is critical. However, advanced manufacturing's low market penetration combined with China's and other emerging economies' focus on AI and automation might result in trading patterns remaining unchanged.

GVCs in advanced economies

Section 3 evaluates how these four digital technologies might impact the financial services, pharmaceutical, and automotive GVCs in advanced, service-driven economies with a specific focus on the United Kingdom (UK) and the United States.

Three Main Takeaways:

- The private sector's competitiveness will increasingly depend on an ability to collect, store, organize, and analyze data.
- Regional value chains will emerge as global trade orients more around regional poles.
- Big tech firms could disrupt GVCs, although it appears as likely that they will collaborate with existing firms in established markets.

Financial Services

Digital technologies are changing the nature of competition in financial services. Traditional factors determining competitiveness, such as asset base and human capital, will be less important in the future. Financial institutions are scaling ICT innovations to improve efficiency, reduce labor costs, and gain a competitive advantage. Blockchain has upside potential to reduce transaction costs in trade financing and other activities. Accordingly, five of the UK's six largest financial services providers are investing in ledger technology. To reach scale, the various ledger platforms under development must become compatible across borders. The financial services industry, attracted by AI's predictive and strategic value, was an early adopter of the technology. To allow the industry to harness AI's growing potential, government regulations, human capital development, and data infrastructure must keep pace with technology. Insurtech startups are investing in IoT technologies, such as telematics, which collects motor vehicle data to improve the underwriting process in collaboration with established insurance companies that have economies of scale advantages.

Across financial services GVCs, digital technologies are elevating the collection, protection, and analysis of customer data as a core activity for financial institutions. This opens the door for large technology firms with access to consumer data, including Alibaba, Amazon, and Google, to expand their footprints in the financial sector. Globally, financial services value chains are becoming more regionally oriented. Firms from China and other emerging markets are taking advantage of a lack of regulation and competition by expanding in emerging and developing economies. To remain the two leading exporters of financial services in the world, the United States and the UK must continue to adapt to the changing composition and geography of the financial services GVCs. Educational programs that blend computer science, finance, and other skills, as well as a regulatory framework that evolves with the technologies, will be key to achieving that goal.

Pharmaceuticals

Research capacity and funding to adapt to technological innovations will determine winners and losers in the pharmaceutical GVCs. IoT and AI technologies offer significant potential to drive process upgrades in drug development, reduce bottlenecks in clinical trials, and lower costs. Most technological applications are still in a proof-of-concept stage without clear empirical evidence about any potential benefit. However, companies, such as US-based IQVIA, already employ IoT and AI developments to use smarter online patient databases for quantifiable gains across each stage of the clinical trial process, including fourfold increases in precision rates for screenings for Alzheimer's. Using AI to process personal data faces privacy and cybersecurity constraints. A lack of uniform regulatory frameworks across markets limits interoperability between systems. The information technology skills that are necessary to use AI and the IoT are in short supply in the pharmaceutical industry.

Continuing a historical trend, the United States and the UK are among the leading countries for pharmaceutical research and development (R&D) expenditures in IoT and AI solutions. UK-based GlaxoSmithKline is one example of a company that has invested almost $100 million to use AI to automate drug design processes. Therefore, it seems unlikely that digital innovations will reconfigure the geography of pharmaceutical GVCs to the detriment of advanced economies. Increasing Chinese and Indian investment in their R&D capacities and strong presence by Chinese companies in AI technologies create the potential that the pharmaceutical GVC will become more multipolar and regionally concentrated in the future.

Automotive

Services are an increasingly important source of value creation in the automotive GVC. Developments in AI and the IoT will spur increasing digital content as part of vehicle value chains. Car manufacturers and suppliers will need to improve their ability to glean value from software instead of hardware. Companies in the UK and United States must prioritize R&D and human capital investments, specifically in electronics and software fields, to remain competitive. The high capital intensity and significant sunk costs associated with the car industry suggest a certain durability to the automotive clusters as well as the GVC. Similarly, 3D printing is not expected to cause a large-scale reshoring of the automotive GVC in the near future. By contrast, emerging technologies, such as electric vehicles and autonomous driving, could accelerate current trends affecting the automotive GVC. For instance, by localizing parts production in countries like China, Tesla and other electric car manufacturers are strengthening the role of regional value chains within the automotive GVC. Industry dynamics associated with emerging technologies, including autonomous driving, are not settled. This is allowing new entrants, such as Google, to experiment with driverless cars. It is unclear whether tech firms will serve as competitors or partners to major vehicle manufacturers. Policy makers must play a key supporting role by crafting multilateral agreements that set standards for these emerging technologies. Possible GVC scenarios include a new era of “modular” vehicle design and industry standards that might end the largest automakers’ dominance as well as create opportunities for chain entry in both design and production.

Policy recommendations

As GVCs become more knowledge- and services-intensive, advanced economies should be prime beneficiaries overall. The UK and the United States should be the leaders in adopting digital technologies and establishing global rules and standards to maximize their benefit. It would be the wrong time for these countries to turn their backs on the global trading system.

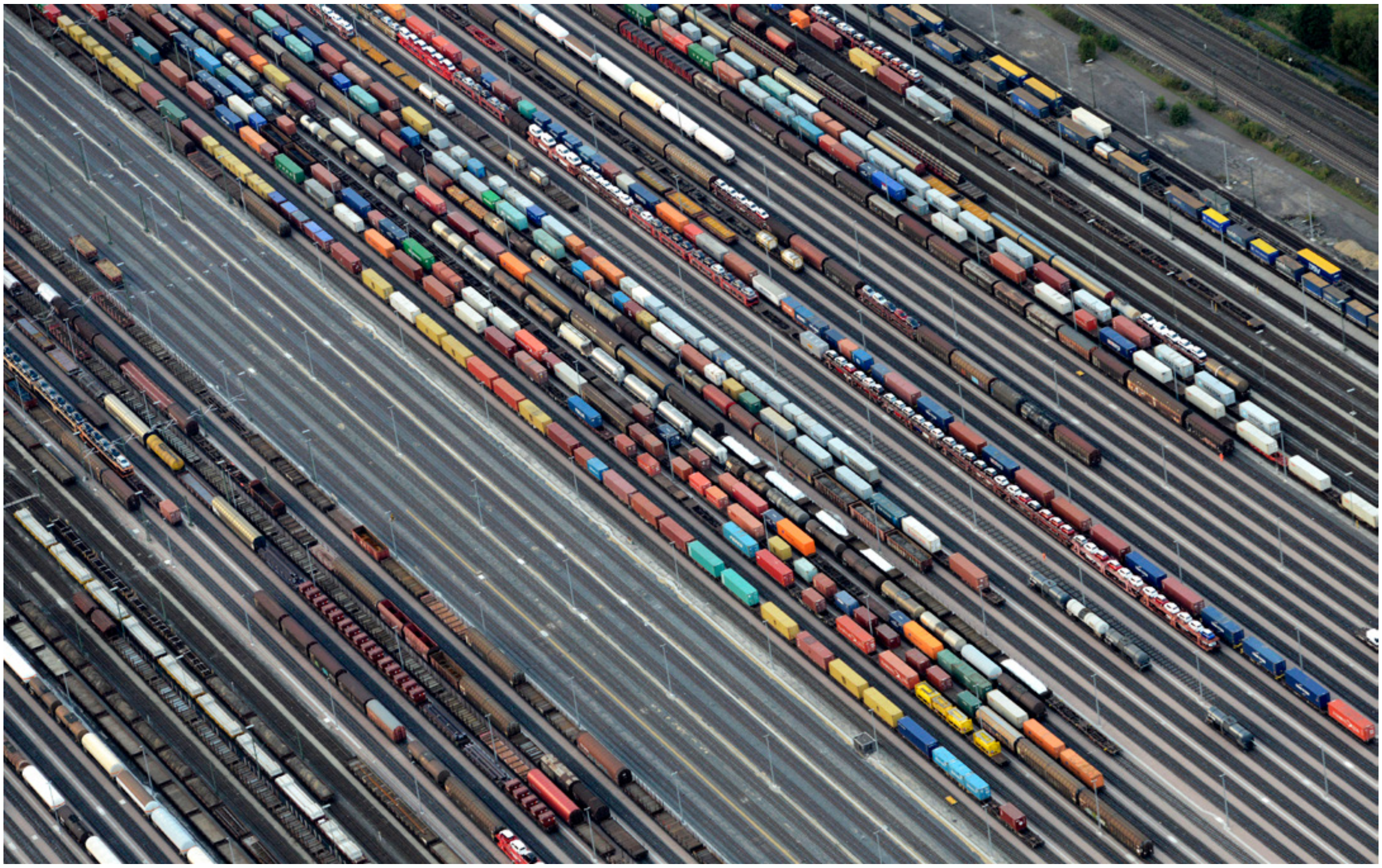
UK Domestic Recommendations

To preserve the UK’s advantage in services-intensive trade, the UK government must focus on strengthening education in technological skills from a young age to buttress the existing pipeline of science, technology, engineering, and mathematics (STEM) talent. As part of that effort, funds must go toward efforts to attract more British children, especially females, to STEM subjects both in secondary school and in higher education. The UK should explore implementing a skills wallet scheme, pioneered by its French neighbors, as a means of tackling the skills shortage through lifelong learning, to ensure all workers can respond to technological disruption swiftly, and transition to new employment when necessary. More sweeping policies, such as a universal basic income, may require proper consideration given the anticipated scale of the disruption. On migration, the UK must ensure it retains access to the best foreign talent. After Brexit, the UK has an opportunity to construct a truly global immigration system that is needs based, straightforward, and rapid.

R&D spending is an ecosystem, with mutually reinforcing effects between industry, academia, and government. The UK’s commitment to raise its total R&D investment to an above-OECD (Organisation for Economic Co-operation and Development) average of 2.4 percent of GDP by 2027 is an encouraging sign. The government should revisit its incentive structure for corporate R&D and ensure that any research that is benefitting from European Union (EU) funding or collaboration is adequately supported. Government spending on digital-enabling infrastructure, such as the roll-out of high-speed 5G internet, will be more important to address crucial bottlenecks in mobile connectivity. Finally, the UK government should prioritize deepening its laudable regulatory partnerships with industry groups to promote emerging technologies both domestically and around the world.

Multilateral Recommendations

This report’s core argument is that multilateral cooperation is required to fully realize the potential of these digital technologies within GVCs. Globally, despite high structural hurdles, efforts must be targeted at liberalizing services trade through new international agreements and establishing modern, uniform standards for the use and exchange of these digital technologies. Multilateralism will be more important than ever in facilitating digital trade flows, given the necessity for interoperable regulatory environments for blockchain as well as the other technologies. The UK must continue to work with the EU, the United States, Japan, and others to revive the WTO and reinvigorate the stalled Trade in Services Agreement (TiSA), which attempts to build upon the WTO’s unique capacity and credibility to craft a global pact to liberalize services trade. TiSA lowers trade barriers including technical standards, licensing, permits, and qualification requirements. A strong TiSA could set global standards and create a more level playing field as emerging economies, such as China, are growing their services exports. To revive TiSA and other dormant WTO



Containers and cars are loaded on freight trains at the railroad shunting yard in Maschen near Hamburg September 23, 2012. REUTERS/Fabian Bimmer/File Photo

agreements, the industrial countries must build a strong coalition that includes developing economies. Digitally enabled services rely less on physical infrastructure and geography and therefore benefit developing economies, which typically lag behind in these areas. Advanced economies must underscore the promise of digital services trade to assuage fears by developing countries that gains from liberalizing services trade will disproportionately accrue to industrial countries.

While pushing for an ambitious TiSA agreement, the UK and the United States should begin bilateral negotiations more immediately in mutually beneficial areas, such as norms around data privacy, cybersecurity, and intellectual property protection, to become standard-setters for others to follow. The two countries should start small, focusing on regulatory areas in which there is already close policy convergence before tackling the more contentious issues. Both countries should target issues surrounding the new digital technologies first, such as safety standards for autonomous vehicles, where domestic rules and political priorities have not yet become entrenched. Put simply, emerging technologies should serve as the focal point for a modern agreement on digital services trade.

1. Introduction

The World Trade Organization (WTO), which was built to undergird the global rules-based trading system, is under severe pressure from the United States and other countries for being unable to police countries violating the organization's rules. The criticisms generally revolve around three main topics: WTO member countries with emerging or advanced economies declaring themselves as "developing" countries to receive special treatment, the lack of functioning of the WTO notification system around topics such as government subsidies, and finally the rulings of the organization's Appellate Body. In response, the United States is blocking new appointments to the Appellate Body, such that it has lacked the three-judge quorum—and thus has not been functioning—since December 2019.

Efforts toward comprehensive or even partial reform and modernization of the WTO are few and far between. A new multilateral framework governing fishing subsidies—a high-profile and sensitive topic in many member states—is being negotiated. In addition, there is an effort by Japan, the European Union (EU), and the United States to address excess capacity, forced transfer of technology, subsidies, and other issues that mainly concern China's behavior in global markets. Since 1995, WTO members have undertaken plurilateral negotiations to reduce barriers to services trade by addressing member countries' onerous domestic regulations. Most recently, in May 2019, a group of fifty-nine WTO members committed to advance the negotiations with the goal of achieving an agreement ahead of the Doha Round's twelfth Ministerial Conference in June 2021. Finally, and most important for the scope of this paper, there is progress on the discussion within the WTO framework on digital trade policy and electronic commerce. Currently, negotiating positions are far apart, reflecting different regulatory approaches. In addition, certain major economies are not participating in the discussions, raising questions on eventual conclusions and timing.

More generally, an increase in bilateral and other smaller trade agreements has resulted in a patchwork of rule-setting and arrangements. Partially reflecting a frustration with the lengthy and complex negotiations within the WTO framework, modernized agreements such as the United States–Mexico–Canada Agreement, the European Union–Japan Economic Partership Agreement, and the updated understandings between the United States and Brazil make rules on a number of issues of global importance such as the environment, intellectual property, market access, and designation as a developing country within the WTO framework.[2]

In addition to the global tensions affecting the functioning of the WTO, the global economy is undergoing fundamental changes based on the maturing of China and other emerging market economies and their concurrent transitions from export-driven growth models to growth based on domestic consumption. In the case of China in particular, this transition represents a seismic shift in its model, as for decades its growth has been based on an ever-expanding manufacturing sector. The services sector in China has only in recent years reached 50 percent of gross domestic product (GDP). The size of the transformation and the growth potential can be gauged by considering that the services sector represents around 80 percent of advanced industrial economies like the United States and France. These dynamics taken together would indicate gradually decreasing growth in trade intensity of most goods-based value chains, while increasing the importance of trade in services and data.

A global value chain (GVC) "includes all the activities and inputs used to create a final good or service."[3] The term refers to the economic phenomenon in which different stages of the production process are spread across multiple countries. Multinational corporations use offshoring and outsourcing to exploit a region's comparative advantage, such as raw material abundance, technical expertise, cheap labor, a favorable regulatory and tax environment, or proximity to consumers. It is common for design, marketing, production, and distribution functions to be entirely separate in a firm's operation. Each step in this chain adds value to the finished product.

The smartphone industry illustrates a highly sophisticated GVC. A Chinese-produced phone "may include graphic design elements from the United States, computer code

2 See, e.g., United States–Brazil in which Brazil gives up self-designation at the WTO in return for support for its OECD application. William Alan Reinsch and Jack Caporal, "Trade Outcomes from the Trump-Bolsonaro Meeting: More than Meets the Eye?" CSIS, March 20, 2019, https://www.csis.org/analysis/trade-outcomes-trump-bolsonaro-meeting-more-meets-eye.

3 McKinsey Global Institute, "Globalization in Transition: The Future of Trade and Value Chains," Executive Summary, January 2019, https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Innovation/Globalization%20in%20transition%20The%20future%20of%20trade%20and%20value%20chains/MGI-Globalization-in-transition-The-future-of-trade-and-value-chains-Executive-summary.ashx.

Roberto Azevedo, Director-General of the World Trade Organization (WTO), leaves after attending a news conference after a General Council meeting in Geneva, Switzerland, July 23, 2020. REUTERS/Denis Balibouse

from France, silicone chips from Singapore, and precious metals from Bolivia."[4] Apple's iPhone, for example, relies on a network of more than two hundred suppliers across forty-three countries and six continents.[5]

Value chains are typically understood in the context of goods. However, the concept is equally applicable to the production of services. While the former resembles a sequential process—with each incremental step building upon the previous one—the latter is better conceived as a network. The various inputs combine simultaneously to provide the final service.

A financial trader in Switzerland, for instance, may execute a buy order for a stock using Chinese computer hardware, financial software from an American company, and equity research from an investment bank based in the United Kingdom (UK), while taking advantage of high-speed connectivity provided by a domestic telecommunications firm, all on behalf of a client on the other side of the globe, who in turn may have been procured for the trader by an external broker. Service industry value chains can therefore be as diffuse as those for goods.

This "international fragmentation of production" is unique to the modern economy.[6] Historically, a company's supply chain—insofar as it existed at all—would be less complex and more geographically concentrated. In the late nineteenth century, the Industrial Revolution catalyzed a dramatic fall in the costs of transportation like shipping and rail, allowing for the "first unbundling," whereby companies could for the first time establish production away from the

4 Organisation for Economic Co-operation and Development, "Global Value Chains and Trade," accessed 2020, https://www.oecd.org/trade/topics/global-value-chains-and-trade/.

5 Magdalena Petrova, "Inside an Apple iPhone: Where Parts and Materials Come From," *CNBC*, December 14 2018, https://www.cnbc.com/2018/12/13/inside-apple-iphone-where-parts-and-materials-come-from.html.

6 World Bank, "Global Value Chains," https://www.worldbank.org/en/topic/global-value-chains.

end consumer.[7] Yet the production process itself remained very localized.

The "second unbundling" that has occurred since the 1990s has enabled the various stages, or nodes, of the process to be geographically dispersed too. This disaggregating of production has been facilitated by the revolution in information and communications technologies that has driven globalization more broadly. These innovations, such as the internet, online marketplaces, and mobile telephony, dramatically reduced transaction costs for cross-border trade by improving communication and coordination. The WTO estimates that international trade costs declined by 15 percent between 1996 and 2004, in part because of these technologies.[8] As a result, they made truly global production viable on a large scale for the first time. "The first unbundling allowed the spatial separation of factories and consumers. The second unbundling spatially unpacked the factories and offices themselves."[9]

Today, the centrality of GVCs in the world economy is one of globalization's most visible manifestations. The Organisation for Economic Co-operation and Development (OECD) estimates that roughly 70 percent of global trade is in intermediate goods and services, as inputs are exchanged across borders among a web of suppliers.

One of the most interesting aspects of this second unbundling—and the focus of this report—is the growing importance of services both to GVCs and to world trade more broadly. Since 2007, trade in services has grown 60 percent faster than that in goods.[10] Sectors such as business and information technology (IT) services have expanded particularly fast. This trend is expected to continue: The WTO forecasts that services will comprise one-third of all trade by 2040, up from 21 percent today and just 9 percent in 1970.[11] Services are typically more knowledge- and ideas-intensive than goods. It is understandable, therefore, why trade in these sectors has benefitted disproportionately from the rise of these data and communications technologies.

Further, it is likely that these statistics are underestimating the full significance of services in global trade. Intangible assets, such as intellectual property and brand awareness, are rarely measured, for instance. In addition, standard data do not capture the myriad free digital services, such as email and social media, which underpin modern economies and are used extensively by consumers and firms alike.

Services comprise a significant fraction of the value of manufactured goods—as much as a third by some estimates.[12] Research and development (R&D), logistics, sales, and finance are crucial components of most modern GVCs. Trade in goods is facilitated in large part by these inputs. As this report explores in Section 3, for the automotive and pharmaceutical industries, the production of goods is likely to become more services-intensive with the emerging technologies.

Indeed, in some cases technological innovations are already blurring the distinction between goods and services altogether, as the services component of traditionally tangible goods grows in importance. The music industry is a good example: Streaming audio files has displaced physical compact discs as the primary means of consuming the product. Likewise, as the automotive industry moves toward autonomous transportation, the software within a car is accounting for a greater share of its value.

7 Richard Baldwin, *Globalisation: The Great Unbundling(s)*, September 20, 2006, file:///Users/nickbrown94/Downloads/Baldwin_06-09-20%20(1).pdf.
8 WTO, *World Trade Report 2018*, 5.
9 Ibid.
10 McKinsey Global Institute, "Globalization in Transition," 5.
11 WTO, *World Trade Report 2018*, 5.
12 McKinsey Global Institute, "Globalization in Transition," 5.

2. How Will the Next Wave of Technological Development Affect Global Value Chains?

There is the belief that globalization is about to enter a new phase, with technology advancements and wage arbitrage in service industries serving as catalysts.[13] While there are a variety of terms used to describe the nascent innovations,[14] most share an interest in incorporating digital technologies into products, operations, and business models. The WTO has identified four innovations that are part of the broader digital economy that have the potential to disrupt GVCs: artificial Intelligence (AI); the Internet of Things (IoT); 3D and additive printing; and blockchain.[15] Table 1 presents definitions and salient facts about each. The term "advanced manufacturing" is used to describe both 3D and additive printing and automation.

While there is divergence on estimates for the market size associated with the digital economy, there is consensus on its potential. Exports of information and communications technology (ICT) services increased 40 percent from 2010 and 2015, part of a larger trend where global ICT trade has tripled in a twenty-year span, reaching US$1.6 trillion in 2016.[16] The four selected technologies all conform with the larger growth trends.[17]

Despite the optimism, the geographical effects on GVCs are unlikely to be uniform. Some advancements may facilitate increased trade flows in certain industries by reducing lead times and logistics costs. Others may change the sourcing decisions of lead firms by decreasing the importance of labor costs in production, potentially encouraging reshoring or nearshoring in sectors where proximity to market is critical. Others may arrive on such a delayed timeframe as to facilitate little discernible change for the foreseeable future.

At the same time, there are still other forces that are already altering the shape and contours of value chains. Trade is becoming more regionally oriented, partially in response to changing political, consumer, and business pressures. Services are increasingly significant value propositions for lead firms, even for those active in manufacturing value chains. Digital technologies have supported both trends and are likely to continue to do so moving forward.

This section of the report discusses the implications of the selected technological innovations on GVCs. It first examines each of the four advances individually, distinguishing between the potential of the IoT and blockchain versus AI and advanced manufacturing. After offering some perspective on the push-and-pull dynamics associated with each, it concludes with a brief explanation of some of the important structural changes already active within GVCs.

2.1. Digital Technologies and GVCs

The push-and-pull potential of ICT technologies on GVCs has been the source of recent scholarly interest. The available empirical data are limited and do not present a consistent picture for implications on trade. However, theoretical exercises have generally offered bipolar scenarios associated with potential of structural change. De Backer and Flaig labelled one extreme "business as usual" and the other "new normal."[18] Rehnberg and Ponte similarly saw both "complementarity" and "substitution" scenarios with technology adoption.[19] Others echoed the theme that the potential impact on GVCs is ambiguous and dependent on industry-specific characteristics.[20]

13 Richard Baldwin, "If This Is Globalisation 4.0, What Were the Other Three?" Vox CEPR Policy Portal, December 19, 2018, https://voxeu.org/content/if-globalisation-40-what-were-other-three.

14 "Industry 4.0," "digital economy," and "information economy" are some of the more common.

15 WTO, *World Trade Report 2018*.

16 Ibid.; United Nations Conference on Trade and Development (UNCTAD), *Information Economy Report 2017: Digitalization, Trade and Development*, September 2017, https://unctad.org/en/PublicationsLibrary/ier2017_en.pdf.

17 McKinsey & Company, *The Internet of Things: How to Capture the Value of IoT*, May 2018, https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20Internet%20of%20Things%20How%20to%20capture%20the%20value%20of%20IoT/How-to-capture-the-value-of-IoT.ashx; Deloitte, *Exponential Technologies in Manufacturing: Transforming the Future of Manufacturing through Technology, Talent, and the Innovation Ecosystem*, 2018, https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-mfg-advanced-manufacturing-technologies-report.pdf. To highlight some of the more notable forecasts: The IoT could have an annual economic impact of as much as US$11.1 trillion by 2025; AI is expected to post a compound annual growth rate of 55 percent from 2016 to 2021 in the United States alone.

18 Koen De Backer and Dorothée Flaig, *The Future of Global Value Chains: Business as Usual or a "New Normal?"* OECD Policy Papers, No. 41, 2017, http://www.iberglobal.com/files/2017-2/GVCs-_future_OECD.pdf.

19 Martha Rehnberg and Stefano Ponte, "From Smiling to Smirking? 3D Printing, Upgrading and the Restructuring of Global Value Chains," *Global Networks*, vol. 18, no. 1 (2017): 57-80.

20 Andre Laplume, Bent Petersen, and Joshua Pearce, "Global Value Chains from a 3D Printing Perspective," *Journal of International Business Studies*, vol. 47, no. 5 (2016): 595-609; Katherine Stapleton, *Automation, Global Value Chains and Development: What Do We Know So Far?* Pathways for Prosperity Commission, Background Paper Series, No. 26 (Oxford, United Kingdom: Pathways for Prosperity Commission, 2019).

Table 1. Selected Digital Technologies and Potential Implications for Global Value Chains

Technology	Definition	Notable Metric	Challenges for Adoption	Industry Outlook	Outlook for Trade Patterns
Communications Technologies					
Internet of Things	Advanced software and network connections that link physical objects via the internet	Estimates suggest there may be 25 billion IoT devices by 2020	■ Privacy and security concerns ■ Human capital ■ Bias against computer-generated insights	Discrete manufacturing and healthcare/pharmaceuticals have had highest adoption rates	■ Reduction in trade costs and friction ■ Elevation of value of service activities
Blockchain	Tamper-proof, decentralized digital record of transactions	Forecasted to post a 62% CAGR in the United States from 2016 to 2021	■ Low e-commerce rates in many markets ■ Storage space and computational power	Largest benefit for banking and financial services	Reduction in transaction costs
Information Technologies					
Artificial Intelligence	Ability of computer systems to perform human-like tasks (machine learning)	AI patent applications were more than two times higher in 2017 than they were as recently as 2013	■ Expense of machinery ■ Scale potential ■ Human capital ■ Access to data ■ Competition with low labor costs for production and processing activities in selected locations	■ Increased AI adoption across sectors ■ Advanced manufacturing has highest potential in manufacturing GVCs and production of industrial equipment	■ Selected industries might see some changes in trade patterns as AI facilitates onshoring or nearshoring ■ Those who rely on low-cost labor or have less incentive to automate production
Advanced manufacturing	Automation and 3D and additive printing	Worldwide shipment of 3D printers expected to increase from 450,000 in 2016 to 6 million in 2020			

Note: CAGR stands for compound annual growth rate.

Sources: Authors, based on World Trade Organization, *World Trade Report 2018: The Future of World Trade: How Digital Technologies Are Transforming Global Commerce*, 2018, https://www.wto.org/english/res_e/publications_e/world_trade_report18_e.pdf; United Nations Conference on Trade and Development, *Information Economy Report 2017: Digitalization, Trade and Development*, September 2017, https://unctad.org/en/PublicationsLibrary/ier2017_en.pdf; Organisation for Economic Co-operation and Development, *OECD Science, Technology and Industry Scoreboard 2017: The Digital Transformation* (Paris: OECD Publishing, 2017), https://doi.org/10.1787/9789264268821-en; Koen De Backer and Dorothée Flaig, *The Future of Global Value Chains: Business as Usual or a "New Normal?"* OECD Policy Papers, No. 41, 2017, http://www.iberglobal.com/files/2017-2/GVCs-_future_OECD.pdf; McKinsey & Company, *The Internet of Things: How to Capture the Value of IoT*, May 2018, https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20Internet%20of%20Things%20How%20to%20capture%20the%20value%20of%20IoT/How-to-capture-the-value-of-IoT.ashx; Deloitte, *Exponential Technologies in Manufacturing: Transforming the Future of Manufacturing through Technology, Talent, and the Innovation Ecosystem*, 2018, https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-mfg-advanced-manufacturing-technologies-report.pdf.

Distinguishing between technologies is necessary to anticipate possible effects. While ICT advances have largely worked in concert in the past to support the expansion and fragmentation of GVCs, they may move in conflicting directions in the future. De Backer and Flaig separate the potential of information technologies and communications technologies while advancing the "business as usual" and "new normal" scenarios.[21] The IoT and blockchain are considered communications technologies while AI and advanced manufacturing (both automation and 3D and additive printing) are considered information technologies. This report uses the distinction as a useful heuristic.

2.1.1. Communications Technologies

The Internet of Things describes physical objects with sensors, networks, and processors that are linked through the internet.[22] Though the IoT is segregated from cloud computing and data analytics in taxonomies of the digital economy, it should be considered a component part of a larger unit—IoT devices are sending information through the internet that can be processed and stored in the cloud, where companies access and use the data to invest in strategies to reduce costs.[23] Combined, the three form the foundation for the digital economy that make AI and advanced manufacturing possible.

The IoT has the most mature market of the technologies selected for study. With as many as twenty-five billion IoT devices anticipated to be in use by 2020, virtually every metric associated with global connectivity is accelerating.[24] Although much of the available data indicate that developed countries lead on most measures,[25] there is appetite for the IoT in middle- and low-income nations. As much as 40 percent of the value in the IoT economy could be generated in developing countries by 2025, with the greatest benefits associated in markets with concentrations for cities, factories, and workplaces.[26]

This is not to suggest that there are not reasons for caution. Privacy and security concerns abound, with recent malware attacks of US municipalities highlighting some of the risks.[27] Survey results from interviews with executives from major companies also indicate that there has been narrow adoption of IoT technologies and limited use of the resulting data, partially because of skills shortages but also because of a preference for human input instead of computer data in decision-making.[28]

Aggregated, these dynamics suggest that the IoT will either support an expansion of GVCs or the maintenance of the status quo. When modeling the potential of technology developments to reduce trade costs, the WTO focuses on the effects on the following variables: 1) lead time to export as measured by customs procedures; 2) logistics efficiency as measured by shipping connectivity; 3) credit information indexes; and 4) shared languages.[29] The IoT has the potential to reduce costs and time associated with almost all of these factors. GPS (Global Positioning System) and radio frequency identification technology allow for the monitoring of physical objects across the supply chain, which can help producers and buyers identify transit and route bottlenecks.[30] Enhanced connection and communication throughout the supply chain can also support more efficient planning and predictive abilities throughout the production process. It is also conceivable that IoT and software services can assist with real-time translation when there are communication barriers between markets.

21 De Backer and Flaig, *The Future of Global Value Chains*.

22 WTO, *World Trade Report 2018*.

23 UNCTAD, *Information Economy Report 2017*.

24 The World Bank, "Individuals Using the Internet (% of Population)," accessed August 2020, https://data.worldbank.org/indicator/IT.NET.USER.ZS?most_recent_value_desc=false; UNCTAD, *Information Economy Report 2017*. Worldwide, 49 percent of individuals reported using the internet in 2017, up from 34 percent in 2012, while the number of countries where at least 80 percent of the population had access to the internet (53) reached an all-time high in 2017. There are other ways to quantify the trends, from OECD databases that chart businesses' use of the internet and cloud computing to UNCTAD databases that track the proportion of businesses in different locations that are using the internet for financial services. All point to expansion of the market.

25 Power in digital economy value chains is especially concentrated among companies based in the United States. Roughly two-thirds of the top one hundred digital multinational enterprises included in UNCTAD's 2017 ranking were based in the United States, which is an unusually high percentage. See UNCTAD, *World Investment Report 2017: Investment and the Digital Economy*, 2017, https://unctad.org/en/PublicationsLibrary/wir2017_en.pdf; Stacey Frederick, Penny Bamber, and Jaehan Cho, *The Digital Economy, Global Value Chains, and Asia*, 2018, https://gvcc.duke.edu/wp-content/uploads/DigitalEconomyGVCsAsia2018.pdf.

26 McKinsey Global Institute, "The Internet of Things: Mapping the Value beyond the Hype," Executive Summary, June 2015, https://www.mckinsey.com/~/media/McKinsey/Industries/Technology%20Media%20and%20Telecommunications/High%20Tech/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/Unlocking_the_potential_of_the_Internet_of_Things_Executive_summary.ashx.

27 Manny Fernandez, David Sanger, and Marina Trahan Martinez, "Ransomware Attacks Are Testing Resolve of Cities across America," *New York Times*, August 22, 2019, https://www.nytimes.com/2019/08/22/us/ransomware-attacks-hacking.html.

28 Deloitte, *Exponential Technologies in Manufacturing*.

29 Transport costs account for the highest variance between countries in the trade of goods, followed by information and transaction and then logistics. For trade of services, information and transaction costs are highest. WTO, *World Trade Report 2018*.

30 Logistics companies such as Maersk have invested in solutions that combine the IoT, cloud computing, and data analytics to allow for enhanced monitoring of container ships, facilitating faster customs and port procedures while allowing for improved environment control for sensitive cargo. WTO, *World Trade Report 2018*.

Blockchain also holds the potential of alleviating some of the friction associated with global trade by reducing transaction costs. The ledger technology guarantees tamper-proof digital records of transactions. Its market is a fraction of the other technologies discussed in this report—the total size is forecasted to be only $2.3 billion in 2021 compared with $1.5 trillion for the IoT.[31] Part of the reason for the more limited dispersion can be attributed to different preferences associated with digital payments versus cash. In Egypt, for instance, roughly 90 percent of e-commerce transactions are paid in cash on delivery, and less developed economies rely on physical currency to an even higher degree.[32]

2.1.2. Information Technologies

Artificial intelligence is the ability of computers or robots to perform human-like tasks such as reasoning, generalization, and learning from past experiences.[33] **Advanced manufacturing** includes automation and 3D and additive printing.[34] Both AI and advanced manufacturing can be differentiated from the IoT and blockchain as information technologies.[35]

There is evidence of the increased dispersion of these technologies. Global sales of industrial robots increased 30 percent in 2017, capping a stretch from 2012 to 2017 when the compound annual growth rate (CAGR) of sales was 19 percent per year.[36] Applications for patents to the US Patent and Trademark Office containing the term "artificial intelligence" were more than two times higher in 2017 than they were as recently as 2013.[37] Finally, the size of the market for 3D-printed components increased by a factor of 5.5 from 2010 to 2017.[38]

As the new technologies are implemented, there could be geographical changes in the supply chains of manufacturing industries. As AI or advanced manufacturing technologies become available, production could become more mobile, and firms might consider reshoring or nearshoring many of their facilities, especially in industries where speed to market or skilled human capital are as important as labor costs.[39]

There are, however, reasons for some skepticism that there will necessarily be alterations in trading patterns. Sales of 3D-printed components still comprise less than one-tenth of 1 percent of the global market, and industry robotics purchases are concentrated in certain industries (automotive and electrical/electronics) in certain markets (China).[40] China is already the world's manufacturing hub in many industries–instead of revitalizing concentrated production in European and North American markets, the dispersions of information technologies may allow China to further increase its clout in industries where it already has a presence. As its workforce sharpens its skills base, its power may rise as its capacity rises in high-value service activities.

It is thus not surprising that the theoretical perspective offers significant nuance. Stapleton summarizes the scant body of research and reiterates that there is a high degree of uncertainty.[41] While it is reasonable to assume firms will have less incentive to locate in low-cost countries if advanced manufacturing at home is a feasible option, capital costs will also play a significant role. Automating a production process typically occurs for any number of reasons, such as when labor is expensive; handling the product might lead to contamination; the activity is repetitive; or input materials can be gripped and manipulated by machines. For industries such as apparel that helped spark the recent waves of globalization by seeking low-cost labor locations in Southeast Asia or elsewhere, it is not obvious that there will be incentive to move supply chains back closer to home, especially since backward linkages in many of those markets have matured to form distinct regional value chains.[42] Moreover, the geography

31 Deloitte, *Exponential Technologies in Manufacturing*.

32 UNCTAD, *Information Economy Report 2017*.

33 WTO, *World Trade Report 2018*.

34 Automation describes machines performing the work of humans during the production process; 3D printing and additive printing describe the generation of a three-dimensional output from a digital model.

35 De Backer and Flaig, *The Future of Global Value Chains*.

36 International Federation of Robotics, "World Robotics 2018 Industrial Robots," Executive Summary, 2018, https://ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf.

37 Jason Furman and Robert Seamans, "AI and the Economy," *Innovation Policy and the Economy*, vol. 19 (2019): 161-191.

38 Economist Intelligence Unit, "Adding It Up: The Economic Impact of Additive Manufacturing," October 10, 2018, https://eiuperspectives.economist.com/sites/default/files/Addingitup_WebVersion.pdf.

39 Duke University Professor Gary Gereffi frames the dynamic as shifting from a race to the bottom, where companies prioritized locating their supply chains in countries where wages were lowest, to a race to the top, where firms are increasingly interested in moving production to places with skill capacity to produce advanced-technology products. See Gary Gereffi, *Global Value Chains and Development: Redefining the Contours of 21st Century Capitalism (Development Trajectories in Global Value Chains)* (Cambridge: Cambridge University Press, 2018), doi:10.1017/9781108559423.

40 Economist Intelligence Unit, "Adding It Up"; International Federation of Robotics, "World Robotics 2018 Industrial Robots."

41 Stapleton, *Automation, Global Value Chains and Development*.

42 Stacy Frederick and Jack Daly, "Pakistan in the Apparel Global Value Chain," Duke Global Value Chains Center, July 2019, https://gvcc.duke.edu/wp-content/uploads/Pakistan_Apparel_GVC_Report_2019.pdf.

of GVCs is determined by a range of factors, including scale economies, transportation times, logistics costs, and trade barriers.

As a final note, the distinctions between "buyer-driven" and "producer-driven" chains are useful when differentiating between how technological developments might affect value chains. The apparel sector is an example of a buyer-driven chain, where lead firms are retailers or brand owners that do not own manufacturing sites; instead, they purchase their products from a capable network of global suppliers. Lead firms in producer-driven chains own final assembly or production facilities that require significant capital and technology investments and skilled labor to compete with peers. The automotive industry is an archetypical example. With lead firms in buyer-driven chains concentrating on higher-value activities such as design and marketing, they have demanded that their suppliers provide cost advantages, which has led to sourcing in low-cost locations. As such, they might have limited demand for expensive technological advancements. Producer-driven chains are capital-, scale-, or skill-intensive and have been more likely to maintain operations in high- or medium-income countries, sourcing cheaper, more generic goods from a distance while maintaining closer access to skilled workers. As such, they could pursue technological advancements that yield efficiency gains with higher zeal.

2.2. Technology and Other Recent Shifts in GVCs

There are two additional considerations when evaluating the potential of digital technologies to effect structural changes in GVCs. Both are trends that have been observed in GVCs in recent years. And both are likely to work in combination with technological advances to determine the geography and distribution of value within industries.

The first is the emergence of **regional value chains** at the expense of global ones. From 2000 to 2012, the share of trade between countries in the same region decreased from 51 percent of total world trade to 45 percent; however, that trend has reversed more recently, with intra-regional trade increasing by 2.7 percentage points since 2013.[43] Regional networks can be seen across industries—Canada, Mexico, and Central American countries feeding into the American automotive sector; various European markets feeding into Airbus's supply chain in aerospace; and Taiwan, Singapore, and Malaysia all serving as inputs for Chinese electronic production. Not only are technology advancements unlikely to disrupt this regional reorientation where it exists, but they may reinforce it, especially in industries that prioritize short lead times as well as high labor skills over low labor costs. Additionally, China's rising consumer power is likely to put its firms at the head of supply chains that are oriented toward its market. Many of the country's investments in countries with material riches (e.g., Africa and rare earth metals, Pakistan and textiles and cotton) are exported back to China, where they are used as intermediate goods by Chinese state-owned enterprises and private companies.

The second is technology's amplification of the **value of services.** One can get a sense of this dynamic partially from trade statistics. The share of services exports in global trade is expected to grow from 21 percent in 2017 to 25 percent by 2030, and trade in services has grown 60 percent faster than trade in goods over the last decade, with sectors such as IT and business services showing particularly strong gains.[44] Yet export data have not historically captured the complete picture since manufactured outputs include a range of service-supported activities such as R&D and sales and marketing, which contribute to the value of goods but are not precisely measured in trade statistics.

Digital technologies are expanding the value-generation opportunities in GVCs even further. In their research of the digital economy value chain, Frederick et al. found that services were creating new segments in manufacturing GVCs while redistributing value within existing stages.[45] New, high-value services are emerging as new growth areas for leading capital equipment manufacturers, particularly in data analytics as firms shift their business models to renting rather than selling equipment. Leading equipment companies traditionally viewed as manufacturers such as GE and Rolls-Royce earned nearly 50 percent of their revenues from services in 2017.[46] Rehnberg and Ponte observed similar dynamics when considering the potential for the adoption of 3D printing technologies.[47] In both the "complementarity" and "substitution" scenarios, digital services account for the majority of the high-value activities.

43 McKinsey Global Institute, "Globalization in Transition." There are many reasons for the shift toward regional value chains, including rising protectionism associated with electoral pressures in many developed economies as well as firms' emphasis on just-in-time delivery models and the rising importance of the Asian consumer.

44 WTO, *World Trade Report 2018*; McKinsey Global Institute, "Globalization in Transition."

45 Frederick, Bamber, and Cho, "The Digital Economy, Global Value Chains, and Asia."

46 Ibid.

47 Rehnberg and Ponte, "From Smiling to Smirking?"

3. Global Value Chains in Advanced Economies

The financial services, pharmaceutical, and automotive sectors are three pillars of the UK economy, employing millions of people and generating billions in export revenue. While there are important differences across the three industries, developed economies such as the UK and the United States have structural advantages that help explain their competitive positions, including skilled workforces, large quantities of capital, favorable regulatory regimes, and robust institutional support. At a time when service activities are increasingly generating the highest returns across a multitude of value chains, these supporting features offer the potential for continued success.

Technological innovations such as advanced manufacturing, AI, blockchain, and the IoT hold the potential for disruptions in each of these sectors. While the ultimate prognosis for how each technology might alter trading patterns is not uniform, the innovations are changing the way firms and markets interact with one another. Some of the most immediate ways the technological advances are influencing the GVCs in each industry include the following:

- The competitive environment in the financial services GVC increasingly revolves around digital innovations that allow companies to scale ICT to improve efficiency. While the United States has been an early leader in pursuing financial technology ("fintech"), allowing its firms to increase market share within certain product categories, the UK has taken steps to produce a supportive environment through the creation of an Open Banking regulation and other measures.

- Research capacity is a critical determinant of firm competitiveness in the pharmaceutical industry. While there is still substantial uncertainty associated with the future diffusion of IoT and AI technologies, each holds significant potential to drive process upgrades. With firms in major markets such as the UK and the United States investing in the new technologies, the geography of the chain is unlikely to change dramatically in the near future, although it is possible Chinese firms will emerge in certain regional markets.

- In the automotive GVC, services are increasingly important sources of value creation. That is likely to continue as the industry, spurred by AI and the IoT, undergoes a shift with the increasing digital content in vehicles as well as the push toward automated or autonomous driving. While it would not be expected that lead firms would abandon assembly capabilities—the high capital intensity and significant sunk costs associated with the industry suggests a certain durability to automotive clusters—there might be opportunities for new market entrants, especially with emerging technologies such as electric vehicles.

This section analyzes how technological changes have the potential to change the three selected GVCs. Each case study proceeds by first introducing how the industry is interacting with the new technologies before pivoting to potential outcomes. Each concludes with the potential implications for the GVC.

3.1. Financial services

Financial services are one of the industries driving the increasing importance of services in world trade.[48] The value of global exports increased from $383 billion in 2012 to $489 billion in 2018, a rise of almost 28 percent that helped put the sector fifth behind tourism and others in terms of services trade.[49] The United States and the UK are the largest single sources of financial services for the worldwide market, accounting for a combined 40 percent of global exports in 2018. The UK was the largest net exporter of financial services in the world, with a trade surplus of $88 billion in 2017.[50] The country has an entrenched advantage over its closest peers—not only has it maintained a trade surplus each year for the last decade, but the combined surplus of the next three exporters failed

48 The discussion in this section includes the broadest conception of "financial and insurance services" as captured by the UK Standard Industrial Classification and WTO hierarchies. Financial services include monetary intermediation (banking) and other related activities. Insurance includes insurance and pension funding. Data points collected by the UK Office of National Statistics and WTO generally disaggregate financial services and insurance services data—these distinctions are clearly delineated in the text. Notably, neither definition includes accounting or tax services.

49 WTO, "World Trade Organization Statistics Database," accessed August 2020, https://data.wto.org/.

50 TheCityUK, *Key Facts about the UK as an International Financial Centre 2018*, October 2018, https://www.thecityuk.com/assets/2018/Reports-PDF/94053cfc7b/Key-facts-about-the-UK-as-an-international-financial-centre-2018.pdf.

to match the UK's.[51] The EU and the United States are the largest importers of the UK's financial services, with 43 percent destined for EU member states and 19 percent for the United States.[52]

The presence of multiple UK-based businesses at the top of the financial services GVC puts them in direct contact with forces driving change in the industry.[53] Technology change is among the most prominent. While the industry historically has been more dependent on skilled labor and strong legal and regulatory frameworks than capital investments, competitiveness is increasingly driven by innovations that allow companies to scale ICT developments to improve efficiency and reduce labor costs.

There is geographical variance associated with the pursuit of new technologies. US banks were projected to spend an aggregate $105 billion on technology in 2019 compared with the $77 billion outlay by European peers.[54] Viewed from an alternative perspective, North American banks spent 33 percent of their IT budgets on new investments in 2018 compared with 24 percent for European institutions. The spending may be correlated to the fact that US banks increased their share of global investment banking fees from 53 percent in 2011 to 62 percent in 2018.[55]

Stakeholders in other markets are taking proactive steps to maintain competitiveness. Part of the United States' recent advantage has been the light regulation associated with consumer data—developers have been able to build targeted financial products by using the trove of information collected by companies such as Amazon and Paypal. To encourage greater innovation through increased access to consumer information, the UK implemented an Open Banking regulation that came into force in 2018. The law, which mandates that firms share financial transaction data with third parties in standardized form, is only one part of the UK's broader approach to support the market. Others include updating anti-competitiveness laws to better cover digital markets and the UK Financial Conduct Authority developing a regulatory sandbox, which allows for real-world testing of innovative services in a controlled environment, to encourage experimenting and testing of new technologies. Combined with other entrenched advantages—skilled human capital, clusters of savvy firms and clients—the measures appear to have had early success. There are 1,600 fintech firms in the country, a number that is expected to double by 2030. In total, 76,500 people work in fintech, and the country's fintech adoption rate of 42 percent is higher than the global average of 33 percent.[56]

In an environment where the determinants of firm competitiveness are changing to a degree, three of the emerging technologies described in the previous section can be expected to influence the financial services' GVC over the near term to various degrees: blockchain, AI, and the IoT. The implications of all three are examined below before the subsection concludes with forward-looking analysis about how the value chain might change.

3.1.1 Blockchain

Financial services companies have been especially interested in blockchain.[57] Five of the UK's largest six companies have invested in businesses that are working to develop ledger technology, with HSBC and Barclays both financing multiple startups. UK firms' blockchain profile mirrors the footprint of companies in the United States, where Citigroup (nine investments) and CME Group (eight) have

51 The United States, Switzerland, and Luxembourg rank second through fourth in the world in trade surpluses for financial services. Their aggregated trade surplus in 2017 was US$87 billion.

52 TheCityUK, *Key Facts about the UK as an International Financial Centre 2018*.

53 The UK's robust export profile is supported by many prominent companies: HSBC, Standard Chartered, and Barclays are ranked among the most geographically diversified financial services firms in the world. If one considers the world's largest banks by asset size, Lloyds Banking Group (twenty-third) and the Royal Bank of Scotland (twenty-ninth) are in the top thirty. See UNCTAD, "Annex Table 21. The Top 50 Financial TNCs Ranked by Geographical Spread Index (GSI)," 2017, https://unctad.org/Sections/dite_dir/docs/WIR2018/WIR18_tab21.xlsx; S&P Global Market Intelligence, "Data Dispatch: The World's Largest 100 Banks," April 6, 2018, https://platform.mi.spglobal.com/web/client?auth=inherit#news/article?id=44027195&cdid=A-44027195-11060.

54 Rachel Toplensky, "Technology Is Banks' New Battleground," *Wall Street Journal*, September 10, 2019, https://www.wsj.com/articles/technology-is-banks-new-battleground-11568114378. JP Morgan and Goldman Sachs have proven to be particularly aggressive in investing in fintech. To cite one example: JP Morgan's new software analysis programs, implemented in 2017, allow the company to save hundreds of thousands of hours in lawyer fees, increasing cashflow that can be used for further process upgrades.

55 Liz Hoffman and Telis Demos, "U.S. Banks' Influence Grows in Global Financial System," *Wall Street Journal*, September 5, 2019, from https://www.wsj.com/articles/how-u-s-banks-took-over-the-world-11567589403.

56 UK Department for International Trade, *UK FinTech: State of the Nation*, May 15, 2019, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/801277/UK-fintech-state-of-the-nation.pdf.

57 S&P Global Market Intelligence tracked the mentions of "blockchain" in quarterly earnings calls and other public events of publicly traded companies in the United States. There were ten companies whose officials mentioned the term "blockchain" at a minimum of ten events: Nasdaq (thirty-two); International Business Machines Corporation (twenty-three); Broadridge Financial Solutions (eighteen); Overstock.com (seventeen); SAP (sixteen); Mastercard (sixteen); Visa (fifteen); SBI Holdings (fourteen); Luxoft Holding (twelve); and Bank of New York Mellon Corporation (eleven). At least six are involved in the financial services value chain. See Katie Darden, Nimayi Dixit, and Tom Mason, *2018 US Fintech Market Report*, S&P Global Market Intelligence, 2018, https://www.spglobal.com/marketintelligence/en/documents/2018-us-fintech-market-report.pdf.

Table 2. Leading UK Financial Transnational Corporations' Investments in Blockchain

Company	IT's Share of Total Company Investments	Blockchain Investments*			
		Recipient Company	Date	Country	Amount (US$)
HSBC	10%	R3	December 18, 2018	United States	—
		R3	May 13, 2017	United States	$107 million
		Axoni	November 13, 2018	United States	$4 million
Barclays	12%	Fnality International	June 3, 2019	United Kingdom	$63.2 million
		SendFriend	February 11, 2019	United States	$1.48 million
		R3	May 23, 2017	United States	$107 million
		R3	September 15, 2015	United States	—
Royal Bank of Scotland	15%	R3	May 23, 2017	United States	$107 million
		R3	September 15, 2015	United States	—
Standard Chartered	5%	Ripple Labs	September 15, 2016	United States	$55 million
Lloyds	7%	Fnality International	June 3, 2019	United Kingdom	$63.2 million

Note: Organized by company and then date of investment. Blockchain investments were identified by using the terms "blockchain," "ledger," "crypto," and "currency" independently in the four databases. IT stands for information technology.

Source: Authors, based on CB Insights, S&P Global.

been the most active.[58] Table 2 summarizes details of the blockchain transactions.

These efforts appear to be transitioning from proof-of-concept to piloting and implementation. What has been described as an investment "bubble" appears to have peaked, with overall global investments in blockchain remaining relatively flat since 2015 ($550 million).[59] HSBC claimed that it completed the first blockchain-supported trade-finance transaction in 2018 when it processed a letter of credit for Cargill for a shipment of soybeans from Argentina to Malaysia.[60] Corda, the platform used to execute the deal, was developed by R3, which is a consortium of at least three hundred companies and seventy global banks—including HSBC, Barclays, and the Royal Bank of Scotland—across multiple sectors that have invested in the technology.[61] Similarly, both Lloyds and Barclays have supported Fnality International, which is working to develop a coin platform to facilitate the issuance of blockchain-based currencies in commercial and central banking sectors.

58 Thomas Mason, "Less Hype Could Be Positive for Blockchain Technology," S&P Global Market Intelligence, June 26, 2019, https://www.spglobal.com/marketintelligence/en/news-insights/research/less-hype-could-be-positive-for-blockchain-technology.

59 Douglas Miller, Peter Mockel, Gordon Myers, Marina Niforos, Vijaya Ramachandran, Thomas Rehermann, and John Salmon, *Blockchain: Opportunities for Private Enterprises in Emerging Markets*," IFC Publications, January 2019, https://www.ifc.org/wps/wcm/connect/2106d1c6-5361-41cd-86c2-f7d16c510e9f/201901-IFC-EMCompass-Blockchain-Report.pdf?MOD=AJPERES&CVID=mxYj-sA.

60 Don Weinland, "HSBC Claims First Trade-Finance Deal with Blockchain," *Financial Times*, May 13, 2018, https://www.ft.com/content/c0670eb6-5655-11e8-bdb7-f6677d2e1ce8.

61 Banco Bradesco, Bangkok Bank, Bank of America, Merrill Lynch, CTBC Bank, Daiwa Securities Group, Intel Capital, Itaú Unibanco, Mizuho Financial Group, Ping An Insurance, SBI Group, and Temasek were among the other investors in the R3 consortium on the same dates as HSBC and Barclays. See "The Future of Clinical Trials: How AI & Big Tech Could Make Drug Development Cheaper, Faster, & More Effective," CBI Insights, August 7, 2018, https://www.cbinsights.com/research/clinical-trials-ai-tech-disruption/.

3.1.2. Artificial Intelligence/Big Data

Definitions of AI in the financial services sector can vary, posing challenges for analysis on potential implementation.[62] While Section 2 advanced a narrow conception ("machine learning") and distinguished it from big data and the IOT, the three concepts are sometimes used interchangeably or to describe similar innovations. If one considers AI in its most expansive sense and includes tasks such as pattern detection and probability analysis, the technology can be expected to have substantial influence in the financial services GVC in the next decade.

The industry has already been credited as being an early adopter of AI.[63] Early applications have generally involved customer-facing operations where companies use predictive technologies to determine if consumers might be interested in new products based on analysis of existing portfolios. There are other areas where AI has current or near-term potential, including in assessing back-end operations processes, maintaining functions for computer programs, and helping to guide systematic investment strategies.

Specific company examples provide context. In conjunction with the Open Banking standard discussed earlier, Lloyds Banking Group has invested $4.1 billion in AI and other digital technologies to position itself as a guardian of customer data, developing a program called "The Rat" to identify potential incidents of fraud.[64] HSBC, meanwhile, announced a partnership with Element, a Canadian software company, to develop AI software that will be able to analyze client data from its Global Banking and Markets Division.[65]

3.1.3. Internet of Things

The implications of advancements associated with the IoT can be examined by looking at the insurance sector, which is a component of financial services. Investments in insurance technology (insurtech) historically have trailed those in the banking sector, although there has been a shift in recent years as some of the technologies in banking mature.[66] Estimates suggest that as much as $1.8 billion flowed into insurtech in the United States in 2018, which surpassed all technologies for financial services categories save for mobile payments.[67] While many of the projects are still in their early phases, most innovations have focused on innovating policy design, user experience, and data.[68]

The reasons for the investor interest can be tied both to demand- and supply-side features. Insurance penetration rates for OECD countries is 8.9 percent, and individuals and businesses in non-OECD countries are believed to pursue coverage even less frequently.[69] The reasons for limited global popularity of formal insurance include the following: limited purchasing power; poor understanding of products and concepts; deficits in trust in agents and offerings; products that do not match market needs; ineffective distribution networks; and inefficient business models.[70]

Digital technology provides an opportunity to ameliorate some of these concerns. The International Association of Insurance Supervisors recognized at least eight insurtech innovations that might effect change in the industry; most relate to the IoT in one form or another.[71] Other organizations have identified similar opportunities in the insurance sector,[72] with the World Bank highlighting the potential of two IoT advances: 1) *telematics* for automotive insurance, and 2) *wearable devices* for health and life insurance.[73]

62 To wit, from a World Economic Forum report tasked with investigating the issue: "There is a marked lack of clarity around the definition of AI, which frequently leads to confusion and outright disagreement. In our interviews with stakeholders we found slight and sometimes not so slight variations in experts' definitions of AI, irrespective of their technical background or formal education in computer science and computer engineering." See World Economic Forum, *The New Physics of Financial Services: Understanding How Artificial Intelligence Is Transforming the Financial Ecosystem*," August 2018, http://www3.weforum.org/docs/WEF_New_Physics_of_Financial_Services.pdf, 10.

63 McKinsey & Company, "Artificial Intelligence: The Next Digital Frontier?" June 2017, https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx.

64 World Economic Forum, *The New Physics of Financial Services*.

65 John Murawski, "HSBC Teams Up with Element AI on Big Data," *Wall Street Journal*, June 18, 2019, https://www.wsj.com/articles/hsbc-teams-up-with-element-ai-on-big-data-11560850200.

66 International Association of Insurance Supervisors (IAIS), *FinTech Developments in the Insurance Industry*, February 21, 2017, https://www.iaisweb.org/file/65625/report-on-fintech-developments-in-the-insurance-industry.

67 Darden, Dixit, and Mason, *2018 US Fintech Market Report*.

68 Ibid.

69 OECD.Stat, "OECD Database: Insurance Indicators: Penetration," accessed 2020, https://stats.oecd.org/Index.aspx?QueryId=25444.

70 Peter Wrede, *How Technology Can Make Insurance More Inclusive*, World Bank Group, 2018, http://documents.worldbank.org/curated/en/583381531209953337/pdf/128157-9-7-2018-11-49-10-FintechNotesTechnologyInsuranceInclusiveFinalLowRes.pdf.

71 The eight were digital platforms (internet, smartphones); the IoT; telematics; big data and analytics; comparators and robo-advisors; machine learning and AI; blockchain and ledger technology; and peer-to-peer, usage-based, and on-demand insurance. See IAIS, *FinTech Developments in the Insurance Industry*.

72 World Economic Forum, *The New Physics of Financial Services*.

73 World Bank Group and International Monetary Fund, *Fintech: The Experiences So Far*, 2019, http://pubdocs.worldbank.org/en/361051561641115477/pdf/Fintech-executive-summary.pdf.

A staff member, wearing a face mask following the coronavirus disease (COVID-19) outbreak, looks at a robot at the venue for the World Artificial Intelligence Conference (WAIC) in Shanghai, China July 9, 2020. REUTERS/Aly Song

Telematics collects motor vehicle data that can be used to improve the underwriting process. UK insurance firm Ingenie uses the technology to assess drivers in four areas: speed, braking, acceleration, and cornering.[74] The company provides consumers with performance data via their mobile app, offering points for improvements that help lower the costs of insurance. The technology has the potential to be an important process upgrade as models using IoT data sources have been shown to be more effective than traditional predictive analysis.[75]

Wearable devices are a second area for the implementation of IoT technology. John Hancock made news when it announced in 2018 that it would sell life insurance only via interactive policies that track fitness and health data through smartphones, an Apple Watch, or another platform.[76] Yet the company is in some ways following the lead of other life insurance providers. Vitality has partnered with Apple for discounts on Apple Watches to help count steps; the UK-based business also offers consumers other rewards such as entertainment tickets, discounted flights, and cheaper policies based on points earned for healthy habits.[77]

3.1.4. Potential Outcomes

Blockchain, AI, and the IoT are examples of emerging technologies that will influence the financial services sector for the foreseeable future, albeit to different extents. Trade financing activities are an area where blockchain appears

74 Lloyds, *Networked World: Risks and Opportunities in the Internet of Things*, 2018, https://www.lloyds.com/~/media/files/news-and-insight/risk-insight/2018/internet-of-things/interconnectedworld2018-final.pdf.

75 Philippe Baecke and Lorenzo Bocca, “The Value of Vehicle Telematics Data in Insurance Risk Selection Processes,” *Decision Support Systems*, vol. 98 (2017): 69-79.

76 Suzanne Barlyn, “Strap on the Fitbit: John Hancock to Sell Only Interactive Life Insurance,” *Reuters*, September 19, 2018, https://www.reuters.com/article/us-manulife-financi-john-hancock-lifeins/strap-on-the-fitbit-john-hancock-to-sell-only-interactive-life-insurance-idUSKCN1LZ1WL.

77 A. Spender, “Wearables and the Internet of Things: Considerations for the Life and Health Insurance Industry,” *British Actuarial Journal*, vol. 24 (2019): E22.

most promising. Broadly, the technology appears supportive of increasing global trade–ledger technology has the potential to reduce transactions costs and processing times associated with paper documentation. Trade finance is generally considered a division of transaction banking, which falls under the larger commercial bank category. It is a lucrative activity for companies such as HSBC, which is one of the largest three banks in the world in transaction banking, earning $2.5 billion in trade finance revenue in 2018.[78]

Despite the potential in certain product categories, blockchain also faces barriers for more widespread adoption over the next decade. The R3 and Fnality initiatives highlight one of the challenges associated with blockchain: the importance of the interoperability of different systems. For the technology to disperse widely and achieve scale, the various platforms under development will have to be compatible across industries and countries. While the R3 consortium addresses some of these concerns for the private sector, there will have to be multilateral cooperation between different governments and regulators in different markets. Other concerns include those surrounding cybersecurity and data privacy, finding and developing qualified human capital, and a regulatory environment that can keep pace with digital innovations.[79]

AI advances are likely to continue to accelerate, with both firms and consumers attracted by its predictive and strategic value. Many of the challenges are similar to blockchain's: Regulations must keep pace with technology; there must be ample pools of qualified human capital; data must be accessible, standardized, and accurate; and technical infrastructure must be supportive. Moreover, AI is likely to change the value proposition of many leading firms, which is one reason that Lloyds Banking Group has positioned itself as a custodian of customer data–data, in effect, are the critical currency.

With respect to the IoT and insurance, some of the systematic features of the industry suggest it is resistant to change. It should be stressed that traditional carriers have substantial economies of scale advantages, allowing them to pool resources and hedge against risk.[80] Insurtech startups have generally decided not to fight against these dynamics, relying on the incumbents for their underwriting abilities. The established firms have also been open to collaboration rather than competition, pursuing partnerships with the insurtech startups to improve some of the supply and demand bottlenecks identified earlier.

3.1.5. Implications for the Financial Services GVC

All three examples provide clues as to how digital technologies can be expected to change the financial services GVC moving forward. It is worth reiterating that the governance associated with the industry is evolving. Whereas firm-level dynamics such as size of asset base or country-level factors such as legal and regulatory environment or availability of skilled human capital were critical determinants of competitiveness in the past, a company's—or country's—capacity for investing in emerging technologies is increasingly vital. Moving forward, the collection, protection, and analysis of customer data will be a core activity for financial institutions.

The shifting emphasis has implications for both the future composition and geography of the chain. The United States and the UK, the two leading exporters of financial services in the world, have both taken steps to maintain their competitive positions. While American firms have enjoyed a head start, the UK has taken meaningful steps to catch up with its regulatory advances. Provided stakeholders in those markets continue to provide oxygen to the entire innovation ecosystem–to wit: educational programs that blend computer science, finance, and other skills; and a regulatory framework that can address emerging issues in a coherent and collaborative manner–both countries can be expected to continue to adapt to technological change.

There is potential for new market entrants to dislodge traditional powers, although it is not uniform across markets and product categories. Large technology firms derive their power in part from their access to consumer data; with the increasing primacy associated with data in the financial services GVC, it is possible companies such as Google, Amazon, Apple, and Alibaba might expand their footprints in the sector. Many already offer financial products to varying degrees, with payments, money market funds and insurance products, and credit provision being three of the most common. Overall, financial services accounted for 11 percent of the revenue of a sample of twelve major technology companies in 2018.[81]

78 Weinland, "HSBC Claims First Trade-Finance Deal with Blockchain"; Sanne Wass, "Trade Finance Distribution Poised to Grow to $3 Trillion Market for Investors," *S&P Global Market Intelligence*, February 12, 2020, https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/trade-finance-distribution-poised-to-grow-to-3-trillion-market-for-investors-56796936.

79 Miller, Mockel, et al., *Blockchain: Opportunities for Private Enterprises in Emerging Markets.*

80 World Economic Forum, *The New Physics of Financial Services*.

81 The sample included Alibaba, Alphabet, Amazon, Apple, Baidu, Facebook, Grab, Kakao, Mercado Libre, Rakuten, Samsung, and Tencent. Revenue share by segment for the sample was IT (46 percent), consumer goods (22 percent), communication services (15 percent), and financial services (11 percent). See Jon Frost, Leonardo Gambacorta, Yi Huang, Hyun Song Shin, and Pablo Zbinden, "BigTech and the Changing Structure of Financial Intermediation," BIS Working Paper No. 779, April 8, 2019, https://www.bis.org/publ/work779.pdf.

The demand- and supply-side factors that encourage technology firms to enter financial services include unmet consumer demand and preferences, lack of regulation, and lack of competition.[82] Optimal conditions most often exist in China and emerging economies such as those of Southeast Asia, East Africa, and Latin America, which is a major reason why technology firms have had success launching payment services and other products in these locations.[83] In North American or European markets where established players are entrenched or regulatory frameworks are more developed, technology firms have been more likely to partner with existing actors.

Overall, this emerging dynamic—disparate networks of businesses that serve different end markets—conforms with one of the prominent recent trends in value chains that was highlighted in the previous chapter: the emergence of regional trading patterns at the expense of global ones. Technology advancements are likely to contribute to a similar profile in the sector: technology and financial services companies in the United States and UK will partner with each other to allow banks, insurance companies, and other businesses to use investments in blockchain, the IoT, and AI to enhance core competencies in North America, Europe, and other developed countries; Chinese and upstarts in other emerging market locations will look to harness new technologies to operate in local and underserved markets.

3.2. Pharmaceuticals

Research and development and the ability to complete clinical trials successfully are critical barriers to entry in the pharmaceutical GVC. The industry's different outputs can be partially distinguished based on the R&D strategies of the producer. Firms that generate the branded products that yield the highest returns historically have integrated R&D and production operations, which allows them to control the entire lifecycle of product development. By contrast, other categories of outputs (quality generics and low-value generics) have more segmented operations, with R&D and production and marketing activities often separated.[84]

The United States, Japan, and the UK lead the world in pharmaceutical R&D spending, although the trendlines for the United States (58 percent in 2016 compared with 51 percent in 2011) and Japan (13 percent in 2016 compared with 15 percent in 2011) are heading in different directions. The UK ranks third behind the United States and Japan–pharmaceutical firms in the UK spent UK£4.3 billion on R&D activities in the country in 2017, which is the most of any sector and 18 percent of the UK's $30.2 billion total.[85] GlaxoSmithKline (GSK) and AstraZeneca are the largest two UK-based pharmaceutical firms as measured by sales, employees, and foreign assets—each spent $6 and $5.4 billion on R&D, respectively, across their entire corporate umbrellas in 2018, which are the seventh- and eighth-highest totals for all pharmaceutical companies in the world.[86]

The importance of R&D is only one of the more prominent characteristics of the industry. A related structural feature is the time and costs associated with drug development. Estimates indicate the lifecycle can take up to fifteen years and cost as much as $2 billion to bring a single new drug to market.[87] Despite pharmaceutical companies' investments in R&D, there have not been industry-wide gains to reduce the expenditures–the number of new drugs gaining regulatory approval per $1 billion spent has fallen by 50 percent every nine years in the recent past.[88]

Clinical trials are a substantial bottleneck. R&D can be divided into two stages: 1) drug discovery and development; and 2) clinical trials, which include pre-clinical testing, Phase I and Phase II trials, and then the Phase III trials that occur before regulatory approval.[89] Clinical trials absorb as much as 50 percent of the total R&D investment, with Phase III trials accounting for 60 percent of the cost of clinical trials. Yet only close to 9 percent of drugs that start the clinical trial phase are submitted for regulatory approval,

82 Ibid.

83 Ibid.

84 Stine Jessen Haakonsson, "The Changing Governance Structures of the Global Pharmaceutical Value Chain," *Competition & Change*, vol. 13, no. 1 (2009): 75–95, https://doi.org/10.1179/102452909X390574.

85 UK Office of National Statistics, "Business Enterprise Research and Development, UK: 2017," November 21, 2018, https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/businessenterpriseresearchanddevelopment/2017#pharmaceuticals-rd-increases-and-leads-the-way-for-uk-rd.

86 UNCTAD, "Annex Table 24. The World's Top 100 Non-financial MNEs, Ranked by Foreign Assets, 2015," accessed August 2020, https://unctad.org/Sections/dite_dir/docs/WIR2016/WIR16_tab24.xlsx; Barry Jaruzelskim, Robert Chwaik, and Brad Goehle, *The 2018 Global Innovation 1000 Study*, PwC, 2018, https://www.strategyand.pwc.com/gx/en/insights/innovation1000.html.

87 CB Insights, *The Future of Clinical Trials: How AI & Big Tech Could Make Drug Development Cheaper, Faster, & More Effective*, August 7, 2018, https://www.cbinsights.com/research/clinical-trials-ai-tech-disruption/.

88 Stefan Harrer, Pratik Shah, Bhavna Antony, and Jianying Hu, "Artificial Intelligence for Clinical Trial Design," *Trends in Pharmacological Sciences*, vol. 40, no. 8 (2019); 577-591.

89 Vivek Wadhwa, Ben A. Rissing, G. Gereffi, John Trumpbour, and Pete Engardio, "The Globalization of Innovation: Pharmaceuticals: Can India and China Cure the Global Pharmaceutical Market," *SSRN* (2008), https://ssrn.com/abstract=1143472.

Employees of Biocon Ltd work inside the company's research and development centre in Bengaluru, India, October 16, 2015. India, which has dominated the generic drugs industry for decades, is falling behind in the race to make copies of complex biotech drugs, which are expected to generate tens of billions of dollars in sales in the coming years. REUTERS/Abhishek N. Chinnappa

which means the loss per failed trial is somewhere between $800 million and $1.4 billion for each drug.[90] By the time Phase III trials typically conclude, it is as many as thirteen years after the drug development process started.

Technology holds the potential of major change, with the IoT and AI serving as two of the more prominent areas. New developments associated with each are outlined in the subsection below, followed by a concluding perspective on the possible outcomes and expected changes to the larger pharmaceutical GVC.

3.2.1. Internet of Things and Artificial Intelligence

Clinical trials fail for many reasons, but two of the more common are patient cohort selection and insufficient technical infrastructure to maintain and analyze the volumes of data collected.[91] The IoT and AI offer the potential of process upgrades. Cohort selection can be improved with more efficient connections between eligible candidates and experimental drugs by linking patient records and national databases of active trials. There is also a predictive element. There is hope that AI might drive efficiency gains through advanced pattern recognition to anticipate possible failures or successes.[92] Machine learning can also allow for higher-powered experiments with how molecules will interact with each other, potentially saving both time and money.

Intrigued by the possibilities, healthcare companies have invested in the IoT and AI to significant degrees. The most ambitious initiatives—especially with respect to AI—are still in proof-of-concept phases and years away from deployment, but the market for the IoT in the healthcare and pharmaceutical industry has been projected to be as high as $154 billion by 2025, which is higher than discrete

90 Harrer, Shah, et al., "Artificial Intelligence for Clinical Trial Design."

91 Ibid.

92 Andrew Bate and Shahid Hanif, *A Perspective on Machine Learning in the Pharmaceutical Industry*, Association of the British Pharmaceutical Industry, March 15, 2017, https://abpi.org.uk/media/3462/a_perspective_on_machine_learning_in_the_pharmaceutical_industry.pdf.

manufacturing ($105 billion); oil, gas, and mining ($62 billion); telecommunications ($55 billion); and the public sector ($53 billion).[93] AI has had similar interest–from 2014 to 2018, there was more money ($6 billion) invested globally in AI startups with products that will serve the healthcare sector than any other industry.[94]

Firms in developed markets are driving the spending. The number of investment deals involving UK-based startups pursuing AI solutions to healthcare challenges increased from two in 2014 to twenty-four in 2018 as funding jumped from $64 to $241 million during the same time period.[95] The firms involved are mostly using AI and IoT technologies to support drug discoveries, although predictive analysis and risk scoring, virtual assistants, and diagnostics are other applications. The UK's leading pharmaceutical companies have been particularly active in funding startups. GSK has placed an emphasis on building its AI capacity as part of a multipronged strategy to improve its R&D fortunes, partially as a response to the fact that its returns on R&D investments have historically been among the lowest in the industry.[96] Part of the initiative has involved personnel changes and the recruitment of AI experts; another component has been $94 million investments in Insilico Medicine and Exscientia, two companies using AI in the drug discovery process.[97] Meanwhile, AstraZeneca has initiated similar efforts to use AI to automate existing data and drug design processes. In 2014, it acquired Definiens, an AI company based in Germany, which is attempting to use machine learning to evaluate tumor microenvironments in cancer treatments.[98]

IQVIA provides a company example of where IoT and AI technologies have already made concrete inroads. The US-based company specializes in big data and advanced analytics to improve drug discovery and development. The firm has data on treatments and outcomes of more than six hundred million anonymous patients. In 2019, IQVIA credited AI and AI-adjacent technology (e.g., automation, the IoT) for quantifiable gains across each stage of the clinical trial process, including fourfold increases in precision rates for screenings for Alzheimer's and improvements in how trials are monitored, including examining as many as 70 percent of drug reactions without the need for human intervention and enhancing accuracy in identifying outliers.

3.2.2. Potential Outcomes

Despite its clear potential, there is still uncertainty about the medium- and long-term outcomes of AI for the pharmaceutical sector. Hype notwithstanding, researchers have been explicit that the technology should be not viewed as a "magic bullet."[99] Given that advanced technologies are still in the proof-of-concept stage and that drug development and clinical trials take time, it will likely be up to a decade before there is clear empirical evidence about any potential benefit. More widespread adoption would follow thereafter. Some of the IoT/AI developments promising process improvements with clinical trials—connecting patients with experiments through smarter online databases—are expected to happen on a faster timeline, as evidenced by IQVIA's experience. However, these are more modest upgrades than the drug development investments that might be facilitated by Insilico Medicine, Exscientia, and Definiens.

Beyond the fact that there is not yet proof that computers can create a molecule that will stand up to clinical scrutiny and provide benefits for businesses, there are other technical and regulatory challenges. Increased transparency of research methodologies will be necessary for regulatory approval to ensure the reproducibility and replicability of results.[100] In addition to undergoing the review process at the US Food and Drug Administration, the UK Medicines and Healthcare products Regulatory Agency, or the European Medicines Agency, companies must conform

93 McKinsey & Company, "The Internet of Things."

94 CB Insights, *The Future of Clinical Trials*. CB Insights combines pharmaceuticals with the larger healthcare industry. Additionally, its AI dataset includes software innovations that would be accurately classified as IoT or data analytics using the definitions outlined in Section 3 of this report. The blurring of IoT and AI concepts does not detract from the larger takeaway of industry interest.

95 Ibid.

96 GlaxoSmithKline, *Annual Report 2018*, March 11, 2019, https://www.gsk.com/media/5349/annual-report-2018.pdf; James Paton, "GlaxoSmithKline Builds AI Team with Another Hire from Biotech Hotbed," *Bloomberg*, July 9, 2019, https://www.bloomberg.com/news/articles/2019-07-10/glaxo-builds-up-ai-team-with-another-hire-from-biotech-hotbed?sref=a9fBmPFG. As measured by comparing operating profit against research and development expenditures.

97 CB Insights, *The Future of Clinical Trials*. Exscientia has a proprietary Centaur Chemist platform that is designed to improve drug efficacy. The company describes it thusly: "New compounds are automatically designed and prioritized for synthesis by its AI systems, which rapidly evolve compounds towards the desired candidate criteria for clinical development. Exscientia systems learn from both existing data resources and experimental data from each design cycle. The principle is similar to how a human would learn, but the AI process is far more effective at identifying and assimilating data." Insilico Medicine is a Hong Kong–based AI firm that is developing generative adversarial networks and reinforcement learning approaches to generate synthetic data.

98 AstraZeneca, *Annual Report 2018*, 2018, https://www.astrazeneca.com/content/dam/az/Investor_Relations/annual-report-2018/PDF/AstraZeneca_AR_2018.pdf.

99 Harrer, Shah, et al., "Artificial Intelligence for Clinical Trial Design."

100 Bate and Hanif, *A Perspective on Machine Learning in the Pharmaceutical Industry*."

with EU or US cybersecurity and privacy regulations surrounding the processing of personal data used for AI.[101] Furthermore, there are not uniform regulatory frameworks across markets for data collection that serve as an input for electronic health records, which limits interoperability between systems.[102] Then there is the skills gap. Similar to financial services, there is a need for hybrid training programs as the use of machine learning requires mathematical and computer skills that are already in short supply in the pharmaceutical industry.

3.2.3. Implications for Pharmaceutical GVC

Even if one assumes advanced technologies bridge these barriers, it seems unlikely they reconfigure the geography of pharmaceutical GVCs to the detriment of established players. Research capacity is a critical determinant of competitiveness in the industry. The United States and the UK have historically been among the leading countries for pharmaceutical R&D expenditures; true to form, firms in each market have aggressively pursued IoT and AI solutions. IQVIA has been especially proactive in implementing advanced software solutions, while GSK—a company that does not have a particularly distinguished recent history in effectively using its R&D department—has nonetheless made AI part of a three-pronged effort to reestablish its research credentials. These and other initiatives should help ensure companies in these markets are not caught flat-footed by nascent advances.

There is the potential that the pharmaceutical GVC will become multipolar in a way that mimics financial services and a host of manufacturing industries. While the upgrading trajectories of emerging markets such as China and India have included significant increases in their R&D capacities, the firms in those countries have mostly targeted local or regional markets.[103] Partnering with some of the same technological firms that have also entered into financial services (e.g., Alibaba, Tencent), Chinese companies have invested in AI technologies to help maintain competitiveness in markets where they have existing share.

Given the dynamics associated with technology, the geographic composition of the supply chain for pharmaceutical R&D trials could become more concentrated. Site selection is an entrenched challenge, with trials often failing to meet enrollment targets. AI offers the potential to more accurately target geographic regions that have the requisite sizes of potential pools of patients, but this will require access to standardized patient data that has consistent safeguards across markets. Locations will also need to have a supply of engineers and medical professionals with computer science or data analytics backgrounds.

Singapore is one country that has taken steps that will likely help its biomedical industry continue to flourish.[104] Its success is the result of careful attention from a variety of local stakeholders. Broadly, the government's supporting efforts can be divided into two prominent areas: 1) strengthening human capital through R&D investments to improve skills and build linkages between educational institutions and private sector actors; and 2) attracting foreign direct investment through a strong regulatory regime as well as fiscal incentives.[105]

3.3. Automotive Industry

The automotive industry is one of the world's largest manufacturing sectors, with global trade of final products and components accounting for roughly $1.5 trillion in exports in 2018. Its organization is complex and has undergone transformation in the last thirty years. Since the 1990s, it has moved from discrete national industries that tended to export final products to a globally integrated sector where value is added in multiple locations and countries focus on particular activities. Features worth accentuating include the following:[106]

101 Lincoln Tsang, Daniel A. Kracov, Jacqueline Mulryne, Louise Strom, and Nancy L. Perkins, "The Impact of Artificial Intelligence on Medical Innovation in the European Union and United States," *Intellectual Property & Technology Law Journal* (2017), https://www.arnoldporter.com/~/media/files/perspectives/publications/2017/08/the-impact-of-artificial-inteelligence-on-medical-innovation.pdf.

102 Harrer, Shah, et al., "Artificial Intelligence for Clinical Trial Design."

103 Wadhwa, Rissing, et al., "The Globalization of Innovation."

104 The country's biomedical sector—which includes pharmaceuticals and medical devices—is its second-largest cluster within manufacturing. After the country's exports of medical devices grew at an annual rate of 7.4 percent from 2013 to 2018, production is projected to increase by 8.4 percent from 2018 to 2023. While exports associated with pharmaceuticals and biological products are somewhat modest, traditional trade data do not capture the full picture. The local value addition associated with the sector is among the highest of domestic manufacturing industries, trailing only computer and electronics products in 2018. See Department of Statistics Singapore, "Yearbook of Statistics Singapore 2019," August 2019, https://www.singstat.gov.sg/-/media/files/publications/reference/yearbook_2019/yos2019.pdf.

105 Ibid. Biomedical and related sciences received the second-highest amount of R&D funding in 2017, trailing only engineering. It came from a mix of sources, with relatively proportionate shares from higher education (31 percent), the private sector (26 percent), public research institutes (24 percent), and the government (19 percent). Meanwhile, foreign companies were recruited through deductions on intellectual property registrations, labor costs, and R&D expenses while the regulatory regime was overhauled to align with frameworks developed by the US Food and Drug Administration, the European Union, the Canadian Medical Devices Bureau, and others.

106 The characteristics described here are based on the discussion of the global automotive industry contained in Timothy Sturgeon, Jack Daly, Stacey Frederick, Penny Bamber, and Gary Gereffi, *The Philippines in the Automotive Global Value Chain*, Duke Global Value Chain Center, 2016, https://gvcc.duke.edu/wp-content/uploads/2016_Philippines_Automotive_Global_Value_Chain.pdf.

- **The historical production hubs that have long been associated with the industry have shifted focus to design, engineering, and testing.** Places such as Detroit, United States; Stuttgart, Germany; and Tokyo, Japan, have long held a prominent place in the automotive industry. But whereas those locations were once dominant production centers, the largest automakers now typically concentrate on vehicle development and design there.

- **Production tends to be organized regionally or nationally in countries with access to large markets.** There are limits to how far apart parts production and final assembly can be geographically spaced: automotive parts are heavy, and the industry has embraced efforts to reduce inventory costs through just-in-time delivery methods. The result has been regional production networks, with final assembly plants with nearby access to large markets serving as hubs for dispersed parts production. There are significant costs associated with capital in the industry; once established, local automotive clusters tend to last for an extended period.

- **Lighter, smaller parts are globally oriented.** More generic inputs are often produced in locations that have capacity to produce at scale with lower labor costs (wire harnesses are an example). They are then shipped to subassembly facilities adjacent to final assembly plants, where they can be tailored and adapted to the characteristics associated with the final vehicles.

- **Services are increasingly important sources of value creation.** The automotive industry is one of the sectors driving services' expanding share of global trade. In the United States, services' value-added content contributed 38.2 percent to gross exports of motor vehicles in 2015, which was higher than the country's 29.7 percent share for all manufactured goods.[107] It also represented an increase from 2011, when services' value-added content accounted for a little more than 30 percent of the value of motor vehicle exports.[108] While design and engineering are traditional value-creation service activities, exports are expanding into new frontiers, with aftermarket products and related analytical consulting services acting as catalysts. The overall aftermarket segment of the chain–estimated to be worth $760 billion globally in 2015–is expected to grow 3 percent annually through 2030, with increases especially high in China (8.1 percent) and the rest of Asia (6.5 percent).[109]

While these properties help give the automotive GVC its shape, technological disruptions are underpinning much of the change. A fundamental issue is the increasing use of digital technologies and electronic components in both the production process and the vehicles themselves, which can be felt through the entire chain. The following subsections consider two advances: additive and 3D printing, and automated and autonomous driving. After discussing potential outcomes, the paper examines the implications for the value chain.

3.3.1. Additive and 3D Printing

The automotive industry has been a prominent consumer of industrial robots for the better part of a decade. Manufacturers' orders increased following the financial crisis in 2008/09, and between 2012 and 2017 robot sales to the industry increased by an average of 14 percent each year.[110] The purchases have been broad-based across markets, with suppliers in emerging markets and major automotive-producing nations demanding robots to promote efficiency gains. From 2015 to 2017, the automotive industry purchased more robots than any other sector.[111]

The demand for advanced manufacturing technologies is one reason the industry has been credited as being an early adopter of 3D printing. In a multi-industry study of the viability of additive printing, the manufacture of machinery and equipment was found to have the highest potential when compared with the production of basic metals, chemicals, paper products, and textiles.[112] A 2016 survey of manufacturers determined the automotive industry had the third-highest share of purchases of 3D printing equipment (15 percent), trailing only industrial machinery (19 percent) and aerospace (18 percent).[113] The interest in 3D printing

107 Services' share of value addition for the export of motor vehicles in the United States is the third-highest in the OECD, trailing only Australia (39.4 percent) and France (39.1 percent). Turkey (38.2 percent), the United Kingdom (37.2 percent), and Canada (36.3 percent) are next highest.

108 OECD, "Trade in Value Added," accessed 2020, https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm#access.

109 Dirk Breitschwerdt, Andreas Cornet, Sebastian Kempf, Lukas Michor, and Martin Schmidt, *The Changing Aftermarket Game: How Automotive Suppliers Can Benefit from Arising Opportunities*, McKinsey & Company, June 2017, https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/The%20changing%20aftermarket%20game%20and%20how%20automotive%20suppliers%20can%20benefit%20from%20arising%20opportunities/The-changing-aftermarket-game.ashx.

110 International Federation of Robotics, "Executive Summary World Robotics 2018 Industrial Robots," 2018, https://ifr.org/downloads/press2018/Executive_Summary_WR_2018_Industrial_Robots.pdf.

111 Ibid.

112 Laplume, Petersen, et al., "Global Value Chains from a 3D Printing Perspective."

113 ING, *3D Printing: A Threat to Global Trade*, 2017, https://www.ingwb.com/media/2088633/3d-printing-report-031017.pdf.

Table 3. Automotive Components, Technical and Economic Viability

Component	Technically Possible to Apply 3D Printing	Economically Beneficial to Use 3D Printing Instead of Traditional Production Methods
Distributor Caps	Yes	Yes
Radiators	Yes	No
Brake calipers	Yes	No
Tires	No	N/A
Brake pads	No	N/A

Source: ING, *3D Printing: A Threat to Global Trade*, 2017, https://www.ingwb.com/media/2088633/3d-printing-report-031017.pdf.

has prompted predictive analysis that it will generate 50 percent of manufactured goods by 2060, an implementation rate that could reduce global trade by as much as 25 percent in selected sectors as manufacturers have less incentive to source from countries with low labor costs.[114]

If the disruptive forecasts for twenty- and forty-year time horizons have high degrees of uncertainty, current 3D capacity offers a sense of how the technology might influence automotive production in the more immediate future. Purchases of 3D printing equipment by businesses in the automotive GVC are concentrated narrowly in selected numbers of outputs—tools, dies, molds, jigs, fixtures, and selected low-volume parts.[115] Table 3 offers examples of specific automotive parts where 3D printing offers varying levels of potential.

There are active company projects to expand additive manufacturing's footprint. While many are still concentrated in tools and parts production covered in Table 3, many firms have R&D projects related to the technology. Examples of notable initiatives include the following: BMW using 3D printing to generate inlays for interior trim and LED door sills and projectors while also investing $12.8 million in an Additive Manufacturing Campus; Ford spending $45 million in its Advanced Manufacturing Center and $65 million in a 3D-printing startup, Desktop Metal, at the same time it uses 3D-printed parts for brakes in the Ford Mustang; and Volkswagen using 3D-printed brake calipers for selected models while also opening a research center to study the technology in Germany.[116]

3.3.2. Automated and Autonomous Driving

Increasing electronics content in vehicles as part of the push toward automated and autonomous driving is an unambiguous trend in the automotive GVC. While the value breakdown between hardware and software in new motor vehicles is currently skewed heavily toward hardware (90 percent), the ratio is expected to tilt closer to an even split in the next ten to fifteen years.[117] The global market for digital components in cars–content and software for autonomous driving, apps and goods with digital and physical features, accessories for assisted driving, auto pilot and navigation, and fully autonomous vehicles–could grow from $83 billion in 2025 to $282 billion in 2030 and $558 billion by 2035, the last of which would represent 17 percent of the total automotive market in 2035.[118]

After periods of competition between automakers and technology companies, recent developments suggest meaningful collaboration between major actors in the two industries is emerging.[119] There are any number of examples, from Daimler and BMW with Apple to Hyundai with Blue Link.

114 Ibid. More aggressive models suggest the 50 percent threshold could be eclipsed by 2040.

115 Ibid.; Bill Koenig, "Automotive Industry Warms to 3D Printing," *Advanced Manufacturing*, August 1, 2019, https://advancedmanufacturing.org/automotive-industry-warms-to-3d-printing/.

116 Shashank Modi and Abhay Vadhavkar, *Advancing Additive Manufacturing into the Mobility Industry Business Case*, Center for Automotive Research, March 2019, https://www.cargroup.org/wp-content/uploads/2019/03/Advancing-Additive-Manufacturing.pdf.

117 AT Kearney, "How Automakers Can Survive the Self-Driving Cars Era," 2016, https://www.atkearney.com/documents/10192/8591837/How+Automakers+Can+Survive+the+Self-Driving+Era+%282%29.pdf/1674f48b-9da0-45e8-a970-0dfbd744cc2f.

118 Ibid. It should be noted that the 17 percent figure for digital components is more narrowly conceived than the data point for the software versus hardware distinction in the preceding sentence. The 17 percent includes only content and software related to autonomous driving; telematics for car-to-car communications and traffic management; and accessories for assisted driving, auto pilot, and navigation. Broader car software includes integrated software that communicates within the vehicle, for example, brake systems talking to steering, engines, and other systems.

119 Robert Wright, "Silicon Valley and Detroit Join Forces for Journey towards Car of the Future," *Financial Times*, January 16, 2016, retrieved from ProQuest.

The partnerships between lead firms (or original equipment manufacturers, OEMs) can be expected to accelerate into the future as OEMs seek arrangements with telecommunications and software providers to develop new technologies.

Traditional production markets have taken meaningful steps to ensure they will benefit from these trends. In the UK, for instance, the Department for Transport and the Department for Business, Energy & Industrial Strategy formed the Centre for Connected & Autonomous Vehicles (CCAV) in 2015. CCAV has initiated at least seventy projects investigating technologies associated with connected and autonomous vehicles across seven primary thematic areas: 1) vehicle technologies; 2) non-car applications; 3) communications, data, security; 4) transport environment and infrastructure; 5) test, verification, and validation; 6) trials and demonstrations of vehicles and technologies; and 7) business models, commercial environment, and new services.[120] The government has contributed $153.6 million to the projects, with an additional $87 million coming from outside actors. The list of industry partners includes leaders across sectors, including firms such as Jaguar, Ford, Airbus, Land Rover, Siemens, Huawei, and Shell.

3.3.3. Potential Outcomes

While increasing electronics components in motor vehicles is a trend that appears unlikely to recede—including the advances toward automated vehicles—widespread adoption of additive and 3D printing faces more significant hurdles. Although the automotive industry is often grouped with aerospace in terms of the viability of 3D printing, there are important differences between the two sectors. Aerospace produces a limited number of final outputs, which means the slower trickle of low-volume outputs associated with additive printing is not necessarily debilitating. For motor vehicles, it makes the technology uncompetitive. Other structural factors associated with the industry–the deep investments in capital equipment and skills in local automotive clusters, the emphasis on just-in-time delivery models–offer additional challenges. There are other business considerations such as skills shortages, intellectual property protection, and high initial investments as well as technical shortcomings, which include the ability to generate different sized outputs, the limitations on printing of mixed materials, and quality.[121]

Using the UK as a representative example, one can see that even if the more aggressive 3D adoption scenarios come to pass in the next decade, the effects on supply chains may be muted. Table 4 lists the UK's largest import categories of motor vehicle parts in 2017 by six-digit HS codes;[122] only one (brake parts; HS code 870830) has been demonstrated to be suitable for 3D printing for the foreseeable future, and even that is for specific parts within the broader category. Otherwise, the majority of the UK's imported parts appear unlikely to be reshored in the next decade on account of additive printing. Phrased in an alternative manner: Until some of the constraints listed in the previous paragraph are addressed, the share of the UK's motor vehicle parts imports where 3D printing might be applied is likely to stay under 10 percent.[123]

3.3.4. Implications for the Automotive GVC

Technological advancements are continuing the disruptions to the automotive GVC that began in the 1990s. While it is challenging to look forward and offer concrete predictions about how the industry might change further in the next decade, there are developments that seem more likely than others. It is doubtful that any large-scale reshoring will be driven primarily by 3D or additive printing. This, however, should not be interpreted as an indication that the location of automotive production will not evolve. The local content of vehicles manufactured in the UK, for example, has increased from 36 percent in 2011 to 44 percent in 2018.[124] Strong institutional support rather than technological advances played a critical role.[125]

120 Centre for Connected & Autonomous Vehicles, *UK Connected & Autonomous Vehicle Research & Development Projects 2018*, July 11, 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/737778/ccav-research-and-development-projects.pdf.

121 Modi and Vadhavkar, *Advancing Additive Manufacturing into the Mobility Industry Business Case*.

122 "The Harmonized System is a standardized numerical method of classifying traded products. It is used by customs authorities around the world to identify products when assessing duties and taxes and for gathering statistics." See US International Trade Administration, "Understanding HS Codes and the Schedule B," accessed August 2020, http://www.trade.gov/harmonized-system-hs-codes.

123 It should be noted that underdeveloped backward linkages in the local economy have implications for downstream production activities, which in turn may affect the import demand depicted in Table 4. It is possible that 3D printing may provide access to local parts that might facilitate the production of larger components or subassemblies that are not currently manufactured in the UK, thereby allowing for reshoring that does not appear likely based strictly on analysis of current trade data. However, it is worth reiterating critical features of the global industry—investments in manufacturing plants tend to be long-lived because of the capital costs, with subassembly and assembly facilities located in close geographic proximity to final markets. As a result, any large-scale shifts in production patterns would be expected over only long-term time horizons.

124 Society of Motor Manufacturers and Traders (SMMT), "SMMT Motor Industry Facts 2019," May 2019, https://www.smmt.co.uk/wp-content/uploads/sites/2/SMMT-Motor-Industry-Facts-May-2019-V2.pdf.

125 Automotive Council UK, *The International Competitiveness of the UK Automotive Industry: 2018 Report*, 2018, https://www.automotivecouncil.co.uk/wp-content/uploads/sites/13/2018/11/Automotive-Council-International-Competitiveness-of-the-UK-Automotive-Industy-2018-Report-FINAL.pdf. The Automotive Council UK and the UK government have worked together to form strategic plans such as the Industrial Strategy: Automotive Sector Deal. The Long Term Automotive Supply Chain Competitiveness program is an example of a program that has yielded benefits. Founded in 2014, it has worked with the private sector to help suppliers make process upgrades while improving research and development capacity and human capital skills.

Services will continue to be an increasingly important component of value creation in the chain. In addition to design and engineering, which will remain critical revenue-generation activities, digitization and data analytics will provide value-creation opportunities. This applies not only to planning and preproduction, but also in the aftermarket arena, where lead firms and OEMs can be expected to mirror the trend seen across manufacturing value chains and invest more resources.

It should be stressed that OEMs should not be expected to abandon assembly capabilities. Section 2 briefly introduced both buyer- and producer-driven chains; the automotive GVC is a classic example of a producer-driven

Table 4. UK's Top 10 Motor Vehicle Parts Imports, 2017

HS Code	Description	Import Value (US$ millions)	Share of Parts Imports	Major Source Markets
870899	Vehicle parts and accessories	$3,556	12%	Germany (25%), France (12%), Spain (8%)
870840	Gear boxes and parts thereof	$3,039	10%	Germany (33%), Belgium (13%), United States (12%)
870829	Parts and accessories of bodies, other than seat belts	$3,000	10%	Germany (34%), France (11%), Poland (8%)
840991	Engines, parts	$2,382	8%	Germany (39%), Poland (8%), France (7%)
401110	Rubber, new pneumatic tires	$1,967	6%	China (23%), Germany (20%), Netherlands (6%)
854430	Insulated electric conductors, ignition wiring sets	$1,653	5%	Romania (17%), Spain (14%), Morocco (11%)
840999	Engines, parts for internal combustion piston engines	$1,561	5%	Germany (27%), United States (12%), Japan (11%)
870830	Vehicle parts: brakes, servo-brakes, and parts thereof	$1,310	4%	Germany (29%), China (13%), Italy (8%)
840820	Compression-ignition internal combustion piston engines	$1,115	4%	Spain (26%), France (25%), Austria (13%)
851220	Lighting or visual signaling equipment	$891	3%	Czechia (20%), France (17%), Germany (10%)
Import Categories Where Potential of 3D Printing Has Been Highlighted				
870830	Vehicle parts: brakes, servo-brakes, and parts thereof	$1,310	4%	Germany (29%), China (13%), Italy (8%)
870891	Vehicle parts: radiators and parts thereof	$186	1%	Poland (24%), Germany (15%), China (8%)
851130	Ignition or starting equipment; distributors and ignition coils	$98	0%	Japan (38%), China (18%), Italy (13%)

Note: Six-digit HS codes for motor vehicle parts with UK as the reporter country and "World" as partner.

*Source:*United Nations Comtrade, "UN Comtrade Database", accessed 2020, https://comtrade.un.org/data/.

chain in which lead firms exert control through technological expertise, and value is created through manufacturing skills. Furthermore, the high capital intensity, significant sunk costs, and durability of automotive clusters mean that OEMs are unlikely to focus entirely on new activities.

This is not to suggest that there will not be opportunities for new entrants, especially with outputs that rely on emerging technologies. Electric vehicles (e-vehicles) provide an example. Globally, there were roughly 1.98 million e-vehicles sold in 2018, which represents a 68 percent increase from 2017.[126] China is the world's leading market, with a little more than one million automobiles sold in 2018, followed by Europe (385 thousand) and the US (361 thousand). Minimum scale requirements mean e-vehicles are not as well established as conventional engines, which has encouraged upstart businesses such as Tesla and Chinese firms to aggressively pursue e-vehicle development. Tech companies such as Google have also experimented with driverless cars. Although it does not appear imminent that tech firms will serve as competitors instead of partners to major vehicle manufacturers, there are no guarantees. It is possible new brands will emerge that break the dominance of the largest automakers.

Finally, Tier I suppliers might face difficult decisions with the new landscape. It is plausible that the likes of Bosch, Continental Temic, Denso, and Magna will have to shift their focuses away from hardware to software activities. For the UK, the largest suppliers of OEM manufacturers include GKN (drive trains, transmissions, engines), TI Fluid Systems (fluid system technologies), and Delphi Technologies (engines and electric vehicles).[127] To maintain competitiveness, these and other similar companies based in the UK will need to prioritize R&D and human capital investments, specifically in the electronics and software fields. Policy makers can also be expected to play a key supporting role, not only by supporting training initiatives, but by working together with officials in different markets to craft multilateral agreements that set standards for emerging technologies. Autonomous and electric vehicles are an example, with safety standards not fully defined on either side of the Atlantic.

3.4. Section Conclusion

The case studies discussed how technological changes might influence the GVCs of three industries: financial services, pharmaceutical, and automotive. At least three common threads can be identified:

- **Competitiveness will be predicated partially on capacity in certain key service areas that involve data management and analysis.** The increasing importance of services in world trade can be observed in all three of the industries. Moving forward, businesses in development markets such as the UK and the United States can be expected to distinguish themselves based on their ability to reap rewards from technological benefits in specific data-related areas. In financial services, companies may be distinguished by scaling ICT innovations to identify opportunity while reducing labor costs instead of by traditional factors such as asset base or having access to skilled human capital with finance backgrounds. In pharmaceuticals, enhanced R&D that is supported by the IoT or AI could reduce bottlenecks in clinical trials, which have long been plagued by high costs and low success rates. While there might not be immediate reshoring in the automotive GVC due to advanced manufacturing techniques, firms will have to react to the increasing digital components in vehicles. Lead firms can be expected to still focus on assembling vehicles, but their relationship with technology and their ability to glean value from software instead of hardware will be critical.

- **The emergence of regional value chains (RVCs).** As highlighted in Section 2, global trade is orienting more around regional poles. Established markets such as the UK and the United States are anchoring one end, with North and Central American supply chains feeding into the United States, and Eastern Europe and North Africa serving as sources of inputs or intermediate goods for Europe. On the other side, African and South Asian markets are serving as strategic investments for Chinese companies, strengthening existing networks in Southeast Asia. The dynamic can be observed in the case studies. Financial services have historically been globally oriented, but the environment is changing to a degree. Backed partly by their aggressive pursuit of new technologies, American businesses claimed market share on European counterparts, forcing them to focus closer to home. Chinese firms and other companies from emerging markets have had success expanding into Southeast Asia, East Africa, and other markets. The automotive GVC has been moving toward RVCs for some time, but the emergence of new technologies is likely to accelerate things, especially as leading e-vehicle manufacturers such as Tesla look to localize parts production inside China.

126 International Energy Agency, *Electric Vehicles: Tracking Report*, May 2019, https://www.iea.org/reports/tracking-transport-2019/electric-vehicles.

127 Lindsay Chappell, "The Biggest Suppliers Gear Up for Change, *Automotive News,* June 24, 2019, https://s3-prod.autonews.com/data-protected/062419-2019TopSuppliers-062419.pdf?djoDirectDownload=true.

Toyota Motor Corp's uBox concept vehicle is seen during an event at the annual Society of Automotive Engineers world congress in Detroit April 12, 2016. The uBox was designed with students from Clemson University to test a design Concept for an electric vehicle aimed at younger buyers, and certain manufacturing techniques. Parts of the vehicle were made using 3-D printing techniques, Toyota said. REUTERS/Joe White

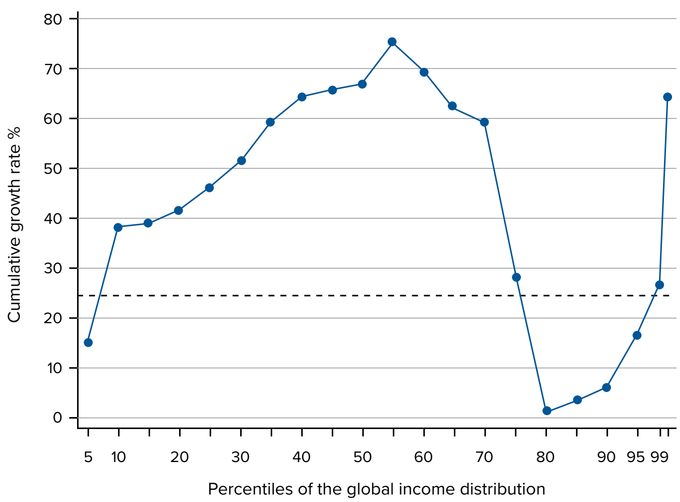
- **Big tech firms could be potential disruptors**, although it appears as likely that they will collaborate with existing firms in established markets. Big tech firms have the advanced software and data analytics capabilities that are increasingly in demand in the case studies. But while companies such as Apple, Google, and Alibaba have demonstrated some interest in moving into financial services (11 percent market share in 2018) and motor vehicles (Google has been attempting to develop driverless vehicles), it seems more likely that they will form partnerships with leading firms, especially in leading countries. Economies of scale considerations are one prominent reason why, and tech firms have not demonstrated an appetite for spending the resources to conform with regulations in financial services or pharma. There are potential exceptions, including financial services, where big tech companies have had success with some products such as payment platforms in underserved and underregulated markets. Moreover, the industry dynamics associated with e-vehicle production are not settled, which potentially opens the door for new entrants.

The firm- and country-level considerations that will determine success are also likely to evolve. Sectors such as financial services and pharmaceuticals that have focused heavily on investing in human capital are still likely to prioritize talent, even as they spend on new technologies. The overall paradigm for R&D and training and education might shift to more specialized skills that allow companies to scale new technologies, with computer science and data analytical programs being paired with finance, life science, or engineering. Regulatory and legal frameworks will need to adjust to the privacy and security concerns raised by many of the advances, working collaboratively to determine the appropriate approach to data collection and sharing. Finally, internet and 5G infrastructure are likely to be as critical as roads and airports.

4. Policy Recommendations

This report's analysis has shown how advanced economies are well-placed to benefit from the next wave of technology. As digital technologies increase the intensity of services in value chains across a broad range of industries, from automotive manufacturing to financial services, the primary sources of comparative advantage going forward will be innovation, intellectual property, and specialized skills. The WTO estimates that services value-added already account for nearly 50 percent of the value of the international goods and services trade. Owing to services' growing importance in value chains, their share of global trade could increase by 50 percent by 2040.[128]

Figure 1. Global Growth Incidence Curve, 1988-2008



Source: The World Bank Economic Review, Volume 30, Issue 2, 2016, Pages 203–232, https://doi.org/10.1093/wber/lhv039

At the same time, digitalization is making it easier to exchange services across borders. This next wave of globalization should thus be welcomed by advanced economies like the United Kingdom and United States. A central trend of recent decades, as discussed in Section 1, has been the fragmentation of value chains in search of cheaper production, particularly low-cost labor. As a result, developing economies have benefitted disproportionately from globalization since the 1980s—as famously depicted by Branko Milanovic's "elephant curve" (Figure 1).[129] The coming decades, in contrast, should see stronger income gains for the middle class in the developed world if suitable compensatory policies are enacted. As GVCs become more knowledge- and services-intensive, advanced economies should be prime beneficiaries overall. The UK and United States should be the leaders in adopting digital technologies and establishing global rules and standards to maximize their benefits. It would be the wrong time for these countries to turn their backs on the global trading system.

Drawing on this report's work, this section highlights key areas for policy focus. Domestically, the UK government should focus on alleviating the digital skills shortage, stimulating R&D and investment in digital infrastructure, and deepening its laudable regulatory partnerships with industry groups as they seek to promote emerging technologies both domestically and around the world. Globally, efforts must be targeted at liberalizing services trade through new international agreements and establishing modern, uniform standards for the use and exchange of these technologies within GVCs. Multilateralism will be more important than ever in crafting services pacts that harness digital trade, given the necessity for interoperable regulatory environments. The UK and others must seek to revive the WTO and reinvigorate dormant agreements, such as TiSA, that attempt to build upon the WTO's unique capacity as a forum for universal trade negotiations.

4.1. UK Domestic Recommendations

The previous section highlighted the hurdles as well as opportunities that the UK's financial services, automotive, and pharmaceutical industries face from emerging technologies. Several commonalities stand out, and it is at these friction points that domestic policy should be adjusted. Most important, industry associations across the three sectors emphasize their concern about a technology skills shortage and inadequate spending on digital infrastructure and R&D.

4.1.1. Addressing the Skills Shortage

A strong pipeline of science, technology, engineering, and mathematics (STEM) talent will be essential for preserving

128 WTO, *World Trade Report 2019: The Future of Services Trade*, 2019, https://www.wto.org/english/res_e/booksp_e/00_wtr19_e.pdf.

129 There has been much debate about the precise shape of the curve. See this Vox discussion, for instance: Dylan Matthews, "The Global Top 1 Percent Earned Twice as Much as the Bottom 50 Percent in Recent Years," VOX, February 2, 2018, https://www.vox.com/policy-and-politics/2018/2/2/16868838/elephant-graph-chart-global-inequality-economic-growth. However, there is wide agreement that the middle classes in the developing world have seen significantly greater real income growth than their equivalents in advanced economies.

the UK's advantage. The UK is starting from a solid base, with a strong education system led by world-leading universities and close collaborations among industry, academia, and government. Nonetheless, the case studies raise some warning signs. There is a scarcity of automotive engineers, for instance. Less than 10 percent of UK students graduate with engineering or related degrees, compared with roughly 17 percent in Germany and 15 percent in France. The UK has fewer "skilled industrial employees" than Romania.[130] Similarly, pharmaceutical industry participants are increasingly citing the lack of computational skills.[131] Bodies in the three sectors mention the importance of skilled migration to complement domestic workers; uncertainty surrounding the UK's future relationship with the European Union is thus a further concern.

The statistics support this anecdotal evidence. In the UK's most recent Employer Skills Survey, businesses identified 226 thousand vacancies (22 percent of total vacancies) that they could not fill due to a lack of required skills among applicants. Digital skills in particular were highlighted as a problem.[132] This skills shortage is a phenomenon across the developed world. It is therefore concerning that among OECD countries, public spending on workforce training programs has fallen considerably since the 1970s.[133] Multilateral organizations, such as the OECD, should prioritize reversing this trend among their members.

The UK must focus on strengthening education in technological skills from a young age, such that all children leave school digitally literate. Digital literacy should be seen as a core skill alongside English and mathematics.[134] The government should fund efforts to attract more British children, especially females, to STEM subjects both in secondary school and in higher education. The recently launched Youth Industrial Strategy Competition is an excellent start in this regard.

The UK government's focus on skills acquisition beyond higher education is laudable. While policies to encourage a greater number of STEM graduates will ensure that the UK remains competitive, they do nothing to address the many individuals who do not attend university—many of whom will be most vulnerable to displacement. Moreover, higher education policies offer no support to people already in the workforce. Instead, there must be a greater emphasis on lifelong learning and apprenticeships.

Effective lifelong learning policies provide the resources for individuals to continue to acquire skills throughout their working lives. This ensures workers can respond to technological disruption swiftly, and transition to new employment where necessary. The government's national retraining scheme, announced in 2018 and due to be fully rolled out in England in 2020, should be a key pillar of industrial policy going forward. Assuming testing is successful, its eligibility should be expanded to include employees with degrees and those earning above the current wage threshold—given the scope of workforce re-skilling that will be required. However, the UK has work to do: A 2012 study suggested that Britain ranks third worst in the OECD for work-based nonformal training for older workers, above only Slovenia and Turkey.[135]

The UK and other advanced economies must therefore go further still. Recent policy initiatives in France are particularly enlightening in this regard. Its Compte Personnel de Formation (Personal Training Account), implemented in 2015, is the first national individual learning account.[136] It allows all labor force participants to accumulate a "wallet" to spend on training courses as and when they desire. Workers can save up to $6,400 in these accounts, financed by a training levy on firms. These credits can be spent only on courses authorized by the government to ensure the scheme is used to acquire relevant skills. Its most significant innovation is the portability of this wallet between employers. Workers are therefore not reliant on their employers to offer training programs. This is more appropriate for the modern economy, where workers move between jobs more regularly, and many increasingly work independently. The UK should explore implementing a similar skills wallet scheme as a means of tackling the skills shortage through lifelong learning, to ensure all workers can participate in the new economy.

On migration, the UK must ensure it retains access to the best foreign talent. After Brexit, the UK has an opportunity to construct a truly global immigration system that is needs based, straightforward, and rapid. It should also seek to agree to reciprocal arrangements with the EU that facilitate

130 Automotive Council UK, *The International Competitiveness of the UK Automotive Industry: 2018 Report*.

131 Association of the British Pharmaceutical Industry, "Worldwide Pharmaceutical Company R&D Spending by Country," accessed 2020, https://www.abpi.org.uk/facts-and-figures/science-and-innovation/worldwide-pharmaceutical-company-rd-expenditure-by-country/.

132 UK Department for Education, *Employer skills survey 2017: UK findings*, August 2018, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/746493/ESS_2017_UK_Report_Controlled_v06.00.pdf

133 OECD, "OECD Database: Insurance Indicators: Penetration."

134 UK Department for Business, Innovation & Skills, *Digital Skills for the UK Economy*, January 2016, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492889/DCMSDigitalSkillsReportJan2016.pdf, 5.

135 OECD, *Education at a Glance 2012*, 2012, https://www.oecd.org/education/highlights.pdf.

136 OECD, "OECD Database: Insurance Indicators: Penetration."

ease of movement for the bloc's highly skilled workers—including extending existing systems for non-European countries, such as the intra-company transfer process, to the European Economic Area after the transition period expires in late 2020. Finally, the UK Home Office should review its shortage occupation list more frequently to ensure it is prioritizing the emerging digital skills required by the newly configured GVCs.

4.1.2. Transitioning Workers

Even with the most effective skills-based policies, it is inevitable—given the scale of disruption—that workers in some pockets of the economy will suffer through wage stagnation, insecure work, and long-term unemployment. Winners in today's economy will likely remain the major winners in tomorrow's, given the premium on individuals with high levels of education and skills, or the capacity (financial and otherwise) to obtain them. Demand for high-wage occupations will increase, while that for middle-wage occupations will fall. Labor in some sectors, such as pharmaceuticals and sophisticated financial services, will reap large rewards. Other industries, such as traditional automotive manufacturing, will experience dramatic upheaval. It is estimated that 15 percent of jobs globally could be replaced by automation (specifically AI and robotics) by 2030, with as many as 375 million workers having to switch occupations. Advanced economies like the UK and United States are particularly vulnerable to pressures to automate given the incentive of reducing high labor costs.[137]

The United States' Trade Adjustment Assistance (TAA) program is a case in point. It was designed precisely to support those workers in industries that lost out because of international trade, through retraining and expanded unemployment benefits. In theory, this policy is praiseworthy. Indeed, for those that managed to obtain help through this initiative, the economic gains were real and significant.[138] However, the scheme has been consistently underused—in part due to the complex and inconsistent Department of Labor petitioning process—and underfunded. Studies have shown that in regions most affected by trade, average TAA per head amounted to just 23 cents, compared with an income loss of $549.

Some have argued for a revamp of TAA, modeled on the more ambitious GI Bill. In addition to improving access to the program, TAA could provide more expansive reeducation grants (such as full tuition and housing stipends for public universities, as the GI Bill does) and extended unemployment insurance. Moreover, given the local market effects of trade disruption, assistance could be made more generous in those regions most impacted by trade.[139]

As discussed, ensuring UK workers—both new and existing—have the necessary skills to participate in this new economy will therefore be paramount. But the government must ensure that adequate protections are in place to support those for whom these policies fail to assist. Governments must ensure their unemployment insurance programs are sufficient to support workers transitioning between jobs. Tax credits and wage subsidies can complement low wages in disrupted corners of the economy. More sweeping policies, such as a universal basic income, are being piloted in some countries; the scale of disruption may require proper consideration of such bold reforms.

4.1.3. Stimulating Investment in Digital Infrastructure and R&D

The case studies highlighted several instances of insufficient investment in digital-enabling infrastructure and innovative R&D. The former is concerning given the importance of this infrastructure as a complement to these technologies. Meanwhile, trends in UK R&D spending are worrying. In 2017, total R&D expenditure represented 1.69 percent of GDP, well below the EU average of 2.07 percent; the UK ranked just eleventh among EU countries on this measure.[140] The UK pharmaceutical sector accounts for the largest share of expenditure, but its investment peaked in 2011 and has trended downward since. As that case study showed, this is a concern in a knowledge-intensive sector for which R&D is pivotal. Meanwhile, the financial services section (3.1.) explained how European banks have been consistently outspent by their American counterparts on technology, likely contributing to their falling market share.

Direct investment in R&D by governments is "a critical factor in stimulating R&D investment by industry across all sectors."[141] R&D spending is an ecosystem, with mutually reinforcing effects between industry, academia, and government. In this regard, it was encouraging to see the UK government take the initiative with a commitment in its 2017 Industrial Strategy to raise total R&D investment to 2.4 percent of GDP by 2027. This would leave the UK

137 Breitschwerdt, Cornet, et al., *The Changing Aftermarket Game.*

138 Benjamin Hyman, "Can Displaced Labor Be Retrained? Evidence from Quasi-Random Assignment to Trade Adjustment Assistance," *SSRN*, April 20, 2018, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3155386.

139 Abhijit Banerjee and Esther Duflo, *Good Economics for Hard Times* (New York: Public Affairs, 2019), Chapter 3.

140 UK Office of National Statistics, "International Trade in Services, UK: 2017," January 31, 2019, https://www.ons.gov.uk/businessindustryandtrade/internationaltrade/bulletins/internationaltradeinservices/2017#toc.

141 Automotive Council UK, *The International Competitiveness of the UK Automotive Industry: 2018 Report.*

above the current OECD average. In contrast, US federal R&D spending as a share of economic output has been in decline since the 1970s.[142]

More can be done to ensure that the UK is a leader in this area, however. In particular, the government should revisit its incentive structure for corporate R&D. While it has been a global leader in its introduction of above-the-line R&D credits and schemes such as the Patent Box (which provides tax relief for profits earned from patented inventions), the generosity of tax credits has fallen behind that of many countries, such as France and Spain.[143] Post Brexit, the government must also ensure that any research that is benefitting from EU funding or collaboration is adequately supported. At a minimum, it should commit to safeguarding or replacing this funding through its own investment.

State spending on digital-enabling infrastructure such as high-speed internet and mobile connectivity will be more important than ever. The UK is globally competitive, but crucial bottlenecks do exist: Only 54 percent of major roads in the UK currently have sufficient 4G coverage to support connected vehicles, for example.[144] Looking forward, finalizing the UK's procurement and rollout of its 5G network must be a high government priority.

4.1.4. Public-Private Cooperation

UK regulators and government departments must continue their collaboration with industry as these transformative technologies arrive. In the three industries analyzed in this report, public-private cooperation is commendable, such as the Automotive Council UK and the Association of the British Pharmaceutical Industry's work with the National Health Service. Co-authored reports such as the *Life Sciences 2030 Skills Strategy* provide clear roadmaps and highlight areas of industry need. The UK's regulatory environment for autonomous vehicle development is considered world leading, to give just one example.[145]

Financial services, and the work of the Financial Conduct Authority (FCA) in particular, are the gold standard in this respect. The FCA has consulted openly with businesses on technologies such as distributed ledgers and cryptocurrencies, providing clear guidelines and expectations. The FCA's pioneering Project Innovate has led to tangible success: Its regulatory sandbox has helped firms achieve authorization for new technologies 40 percent faster.[146] The Open Banking regulation has complemented these efforts since 2018. Following the FCA's lead, thirty jurisdictions around the world now implement a form of regulatory sandbox.[147] The sandbox, and the FCA's work more generally, should be an example to follow in other sectors.

4.2. Multilateral Recommendations

4.2.1. Reducing Barriers to Trade in Services through Shared Standards

Costs of trade in services are roughly double that of trade in goods—despite a 9 percent decline between 2000 and 2017.[148] Barriers to services trade are primarily regulatory in nature, rather than the tariff-related hurdles most commonly found in goods trade. Liberalization has thus proven more difficult in this area in part because it touches on thorny behind-the-border matters—such as labor mobility, professional standards, and consumer protections—to a degree that goods trade policy does not. Often, these barriers are not intended to restrict trade, but instead aim at some other domestic public policy objective. As such, encouraging countries to harmonize these policies and make them interoperable, particularly in the digital realm, is challenging.

The problem of incompatibility between jurisdictions and systems was highlighted in the financial services case study with regards to blockchain. Similarly, the pharmaceuticals section (3.2.) described the nonuniform regulatory frameworks across markets for collecting electronic medical records data. This lack of interoperability severely constrains the potential of AI applications for international clinical drug trials.

Data privacy is a classic illustration of the difficulty of achieving harmonization. The EU, which treats privacy as a fundamental right, has developed the General Data Protection Regulation (GDPR), which provides users with strong controls on their personal data. Others, like the United States, currently take a more lenient view. Indeed, the United States–Mexico–Canada Agreement's (USMCA's) digital chapter diverges significantly from the GDPR, such as with its prohibition on restrictions on

142 American Association for the Advancement of Science, "Federal R&D Budget Trends: A Short Summary," January 2019, https://www.aaas.org/sites/default/files/2019-01/AAAS%20RD%20Primer%202019_2.pdf.

143 Automotive Council UK, *The International Competitiveness of the UK Automotive Industry: 2018 Report*.

144 SMMT, "SMMT Motor Industry Facts 2019."

145 Ibid.

146 Financial Conduct Authority, *Regulatory Sandbox Lessons Learned Report*, October 2017, https://www.fca.org.uk/publication/research-and-data/regulatory-sandbox-lessons-learned-report.pdf.

147 WTO, *World Trade Report 2019*, 156.

148 WTO, *World Trade Report 2019*, 6.

The exchange rates and logos of Bitcoin (BTH), Ether (ETH), Litecoin (LTC) and Bitcoin Cash (BCH) are seen on the display of a cryptocurrency ATM of blockchain payment service provider Vaerdex at the headquarters of Swiss Falcon Private Bank in Zurich, Switzerland May 29, 2019. REUTERS/Arnd Wiegmann

cross-border information transfers.[149] Exemptions and differing legal interpretations throw up further hurdles even between countries with similar principles around data privacy. This divergence is a large barrier to trade in data-intensive services, as firms are forced to adapt to different regimes across borders.

More broadly, variation across countries regarding the trade-off between regulation and innovation is a hurdle to the development of global governance for emerging technologies. Recent years have seen an abundance of conflicting proposals for international governance of artificial intelligence, for instance. The EU and the World Economic Forum have both released statements of principles in the past year alone. Standards bodies IEEE (Institute of Electrical and Electronics Engineers) and ISO (International Organization for Standardization) each have their own ongoing initiatives.[150] The G20 endorsed the OECD's AI Principles last year, but stressed that they were nonbinding. The intensity of competition for AI dominance risks triggering a global race to the bottom in standards and safety precautions. There is a clear need for a unified multilateral effort to create international norms. Some have argued that the most logical forum for this to occur is at the United Nations, modelled on the Intergovernmental Panel on Climate Change.[151]

Given these issues, it is perhaps unsurprising that there has been no major reform to services trade policy through the WTO since the late 1990s, with the entry into force of the General Agreement on Trade in Services (GATS) and agreements on telecommunications and financial services. Instead, progress has predominantly occurred through regional and bilateral trade agreements: Since

149 Barbara Matthews, "How the USMCA Impacts Transatlantic Trade Policy," *New Atlanticist*, Atlantic Council, December 13, 2019, https://www.atlanticcouncil.org/blogs/new-atlanticist/how-the-usmca-impacts-transatlantic-trade-policy/.

150 Peter Cihon, *Standards for AI Governance: International Standards to Enable Global Coordination in AI Research and Development*, University of Oxford, April 2019, https://www.fhi.ox.ac.uk/wp-content/uploads/Standards_-FHI-Technical-Report.pdf.

151 United Nations University Centre for Policy Research, "AI & Global Governance: Why We Need an Intergovernmental Panel for Artificial Intelligence," December 20, 2018, https://cpr.unu.edu/ai-global-governance-why-we-need-an-intergovernmental-panel-for-artificial-intelligence.html.

2015, nearly 70 percent of regional pacts have covered trade in services.[152]

The potential gains of further liberalization at the global level are significant, however. Those services sectors facing lower barriers are characterized by higher productivity growth than those with more impediments.[153] There is also a strong correlation between a country's barriers to entry in services sectors and its investment in digital technologies.[154] As services become ever more important to GVCs, these costs will become more prohibitive.

4.2.2. Reviving the Global Trading System

It is therefore not the time to give up on multilateral agreements. The WTO, for all its issues highlighted in Section 1, remains the only institution with the capacity and credibility to craft a global pact that harnesses these new technologies in services trade. The institution will require significant reform to assuage the concerns of members, but recent proposals by the EU and others provide grounds for optimism.

However, the proliferation of regional trade agreements, such as the USMCA, risk undermining the WTO further. Many of these pacts have embedded rigid dispute settlement mechanisms (DSMs) that eschew independent arbitrators such as the WTO. The concern is that these DSMs will increasingly replace the WTO's role—not least in emerging areas such as digital trade. The result would be a global patchwork of regulations of digital services.

Any tentative agreement should therefore be built upon the provisions of GATS, so that it can be adopted more broadly by WTO members as and when the political will exists. Indeed, this was the rationale of the stalled Trade in Services Agreement (TiSA), negotiations for which began in 2013 among twenty-three members of the WTO that collectively account for 70 percent of world trade in services and include some of the largest net exporters of services. TiSA seeks to liberalize services trade by tackling barriers such as technical standards, licensing, permits, and qualification requirements. If these services leaders can agree on solid standards, they can create a foundation for reliable best practices as other countries, such as China, continue to grow their services exports.[155]

By emulating GATS in structure, TiSA could easily become a wider WTO agreement. The UK should seek to reenergize the TiSA discussions given its significant interest in the agreement, with financial services and other areas of competitive advantage central to the negotiations. Progress on TiSA could help alleviate transatlantic trade tensions in goods, by spotlighting an area of shared interest.

A valid concern with this approach is the potential for opposition from developing economies, given this paper's assertion that the gains from services trade liberalization will disproportionately accrue to advanced economies. A swell of resistance, spearheaded by the Africa Group and India, to a US-led push for a new digital trade agenda at the 2017 WTO ministerial in Buenos Aires demonstrates the deep skepticism of many emerging economies.[156] Any successful multilateral approach will therefore have to address these well-founded fears.

The UK, the United States, and other advanced economies must engage with emerging market economies, emphasizing how digitalization will inevitably affect them—as this report has illustrated. As such, emerging economies should embrace a clear framework on services sector promotion, intellectual property–based innovation, and technology transfer and know-how to reduce their vulnerabilities to services disruption in global trade.[157] Moreover, many emerging economies are welcoming new digital rules in the hope they will help them attract investment in their fledging digital industries. Digitally enabled services rely less on physical infrastructure and geography, which should be to the benefit of developing economies, which typically lag behind in these areas.[158] Indeed, the WTO predicts that developing economies could see their share in global services trade increase by as much as 15 percent by 2040 if they successfully adopt new digital technologies. Advanced economies should make this case and partner with receptive governments in developing economies to build a strong coalition behind a multilateral services agreement.

Alongside this push, the UK and the United States can begin bilateral discussions more immediately in mutually beneficial areas, such as norms around data privacy, cybersecurity, and intellectual property protection, as standard-setters for others to follow. The failure of liberalization efforts through

152 WTO, *World Trade Report 2019*, 154.

153 Sebastien Miroudot, Jehan Sauvage, and Ben Shepherd, "Measuring the Cost of International Trade in Services," Developing Trade, January 22, 2013, https://developing-trade.com/wp-content/uploads/2014/11/DTC-Article-Chapter-2013-5.pdf.

154 World Bank, "*World Development Report 2016: Digital Dividends*," 2016, https://www.worldbank.org/en/publication/wdr2016.

155 Barbara Matthews, Earl Anthony Wayne, and Cecilia Pan, "Trade in Services Agreement: A Way Out of the Trade War?" *New Atlanticist*, Atlantic Council, July 23, 2018, https://www.atlanticcouncil.org/blogs/new-atlanticist/trade-in-services-agreement-a-way-out-of-the-trade-war/.

156 Shamel Azmeh, Christopher Foster, and Jaime Echavarri, "The International Trade Regime and the Quest for Free Digital Trade," *International Studies Review* (2019), https://doi.org/10.1093/isr/viz033.

157 Natallie Rochester, "The Potential of Trade in Services for Developing Countries," in WTO, *World Trade Report 2019*, 166-187.

158 WTO, *World Trade Report 2019*, 7.

the Transatlantic Trade and Investment Partnership and Transatlantic Economic Council can provide some lessons here. The United States and the UK should start small, focusing on regulatory areas in which there is already close policy convergence to build confidence before tackling the more contentious issues. They should also target regulating new technologies first, such as by setting safety standards for autonomous vehicles, where domestic rules and political priorities have not yet become entrenched. In this sense, emerging technologies can serve as the focal point for a modern agreement on digital services trade.[159]

After it leaves the European single market, the UK has the opportunity to be a leader in driving greater global regulatory cooperation by developing common standards and improving information exchanges. Again, the UK's FCA is a pioneer in this respect: Through its Project Innovate scheme, it has signed cooperation agreements with counterparts around the world, including Canada, China, and Japan, to promote information-sharing on emerging trends in financial innovation. Its Global Financial Innovation Network seeks to promote multi-jurisdictional regulatory sandboxes to reduce policy divergence between countries.[160] The UK should also leverage its expertise in other sectors by providing technical assistance and capacity-building to other jurisdictions as they establish their regulatory regimes for these new technologies and changing services trade patterns.

4.3. Conclusion

These reforms are urgently needed. As the case studies elucidated, these emerging technologies are already disrupting GVCs in major industries. Domestically, the UK must act to ensure it is ready to embrace the potential for growth in services trade. Policy should focus on the following: addressing digital skills shortages and providing an architecture for lifelong learning by implementing a skills wallet initiative; reinvigorating spending on R&D in knowledge-intensive sectors and digital-enabling infrastructure across the country; deepening regulatory collaboration with industry, leveraging the success of the FCA in financial services; and, finally, ensuring sufficient financial support exists for those workers left behind by the forthcoming disruption.

This report's core argument is that for the potential of these technologies to be fully realized within GVCs, multilateral cooperation is required. A fragmentation of regulations in these areas will inhibit the exchange of digital services across borders. The UK and other advanced economies must therefore prioritize global agreements on digital trade. TiSA provides a promising starting point to establish shared standards and interoperability within the WTO framework. The United States and the UK, after Brexit, can begin immediately to leverage their expertise to propagate best practices alongside this effort.

159 Matthews, "How the USMCA Impacts Transatlantic Trade Policy."

160 WTO, *World Trade Report 2019*, 156.

About the Authors

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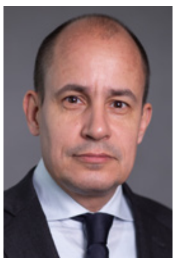

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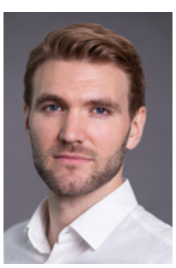

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