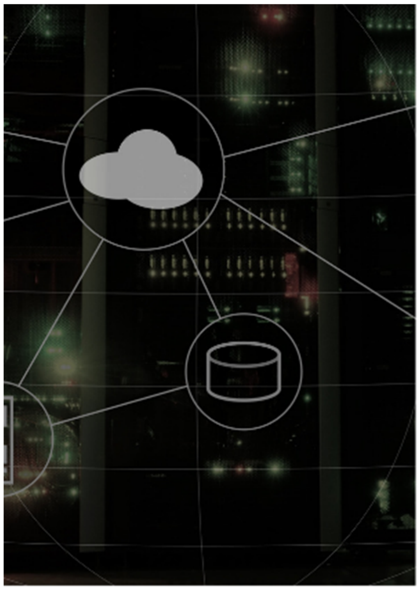

The Digital Economy, Global Value Chains and Asia

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Contents

Executive Summary 1
1. Introduction 3
2. Definitions and Methodology 4
3. The Digital Economy and Global Value Chains 6
 3.1. Mapping the Digital Economy Global Value Chain 8
  3.1.1. Software (Traditional; Transition Firms) 11
  3.1.2. IT Services (Traditional to Digital) 12
  3.1.3. Platforms; Internet Software & Services (New) 14
 3.2. Digital Transformation in the Industrial Equipment Market 16
  3.2.1. Key Players 17
  3.2.2. Emergence of New Digital Services for Industrial Equipment 19
4. Lead Firms and Company Case Studies 25
 4.1. Internal Workforce Development and R&D Spending 25
 4.2. Mergers and Acquisitions 30
 4.3. Start-ups, Venture Capital and Investments 31
 4.4. Collaborations 35
 4.5. Collaboration for Interoperability and Conflicts of Interest 38
 4.6. Entry and Upgrading in the Digital Economy 40
5. Human Capital and Workforce Development 42
 5.1. Workforce Gap 46
 5.2. Certifications 46
6. Geographic Analysis: Country Findings 47
 6.1. National Policies 47
 6.2. Singapore 54
 6.3. India 55
 6.4. China 56
 6.5. Korea: Key Takeaways 57
7. Recommendations 63
8. Appendix 68
References 78

Tables

Table 3-1. Digital Economy Market Segments/Final Products, Values, 2017-18 8
Table 3-2. Digital Economy Infrastructure (Telecommunications, ISPs) 10
Table 3-3. Software Segment Definitions and Market Estimates 11
Table 3-4. IT Services Segments, Companies and Market Values 13
Table 3-5. Internet Software & Services (Platform, Search Engines, Cloud, e-Commerce) 14
Table 3-6. Select Analytics Start-Ups 19
Table 3-7. Technology Layers in the Industrial Internet of Things 21
Table 3-8. Capital Equipment GVCs Enhanced by Digital Business Models 23
Table 4-1. Characteristics of Lead Firms in the Digital Economy 25
Table 4-2. Digital Firms and Industrials, R&D Expenses and Locations, 2017 26
Table 4-3. Total, Digital Economy and Industrial Revenue and R&D, 2012 and 2017 29
Table 4-4. Digital Firm & Industrials Acquisitions, Count and Value 30
Table 4-5. Digital and Industrial Firm Investments, Count and Value 32

Table 4-6. IIoT Start-Up Investment Activity, by Country, 2009-2018 35
Table 4-7. Digital Firm and Industrials Collaborations and Events 36
Table 4-8. Digital Economy Strategies, Company Case Studies 41
Table 5-1. Skills/Technical Focus Areas 43
Table 5-2. Employee Profile, Digital Economy GVC, 2017 44
Table 5-3. Non-Computer Occupations in the Digital Economy Industries, 2017 45
Table 6-1. Select Policies in Countries Leading Industry 4.0 49
Table 6-2. Company Cases: Digital Activities, by Geography 51
Table 6-4. Key Findings for Korea 57
Table 6-3. Leading Industrial Robot Suppliers 58
Table 6-5. Top 25 Digital Companies in Korea (based on 5-year average sales) 59

Table A-8-1. Digital MNE GVC Companies 68
Table A-8-2. Industrial Equipment GVC Companies 70
Table A-8-3. WIR: Digital MNEs and ICT MNEs (other classifications, SIC, PwC, CBI, S&P) 71
Table A-8-4. Industry Segments by Industrial Classifications: ISIC4, KSIC-07, NAICS 73
Table A-8-5. Types of Software (IBIS, CFRA, CBI) 75
Table A-8-6. Key Institutional Stakeholders in the Digital Economy GVC 77

Figures

Figure 3-1. Digital Economy Segments, Products and Firms 9
Figure 3-2. Digital Transformation of the Capital Equipment GVC 24
Figure 4-1. R&D Intensity (R&D Spending/Total Revenue), Select Firms, 2011-17 28
Figure 4-4. Key Actors & Relationships in the IIoT Space 39

Boxes

Box 3-1. Infrastructure Services (Telecommunications, ISPs) 10
Box 3-2. Industrial Internet of Things Creates Opportunities for Analytics Start-Ups 19
Box 3-3. Technology Layers in IIoT 21
Box 4-1. GE's Digital Transformation: A New Approach to Human Capital Recruitment 27
Box 6-1. Smart Factory: Automation and Robotics 58
Box 7-1. Profile Google Campus Program 63
Box 7-2. Government Support for Software & Service Development in India and Mexico 65
Box 7-3. IIoT Opportunities Exist for Latecomers, but Challenges Remain 66

Executive Summary

Advances in technology and associated services have created opportunities for a wide range of new services in a variety of global value chains (GVCs), which has implications for economic development across the world. This report examines the digital economy and how the adoption of new technology is changing manufacturing industries, particularly for industrial capital equipment. In doing so, it identifies key elements of digital firm strategies and the role different geographic locations are playing in this digital transformation with a focus on how one country—Korea—can enter the growing digital ecosystem.

The first contribution of the report is to provide a framework and definition for evaluating the digital economy and how it influences industrial equipment. It identifies several key trends, including the following:

- **The rise of services creates new industries and stages in the GVC, altering the distribution of value within existing GVCs.** Manufacturing-related services, particularly those previously considered "after-sales" are becoming equally important sources of revenue, if not more so, than the manufacturing operations themselves. Firms earn a larger share of revenue by performing services than by selling physical goods.

- **The digital economy has significantly different skills requirements, with changes to traditional job roles and a greater emphasis on digital skills.** Such skills will increasingly be applied in agile business organizations that are constantly seeking to innovate and adapt for competitive advantage.

- **In the data-driven global economy, companies are expanding their value creation through collaborative ecosystems.** Collaboration is a key driver of success in a connected, Industry 4.0 world. It is the convergence of multiple technologies rather than a single technology that, in combination, enables firms to adopt new ways of doing business.

The report then shifts its analysis to how Korea aligns with global trends. It uses detailed, data-driven evidence from market reports and company cases to show how activity in the country is different from other countries and firms. Among the key findings are the following:

- **Korea has limited participation in the global digital economy.** There is one Korean firm on the UNCTAD top 100 digital MNEs list and only one of the 21 IT software and service companies on the ICT list. Existing firms tend to be small (based on sales and employment) and domestically focused. Korea has an immediate opportunity to leverage its existing industrial base in several key areas to develop new digital services.

- **Korean firms are often captive or closely tied to Korean MNEs, with few independent companies.** Many of the sizeable digital firms in Korea have software and IT-related subsidiaries, but these are focused on development for the domestic market or their foreign locations and sales mimic the parent company's global footprint. Even if the firm is independent from an ownership perspective, they are still highly dependent on their parent company for sales.

- **Korean firms' strategy is focused on internal development; however, R&D spending may still be insufficient and misaligned to achieve global growth**. Korea has been deemed the world's most R&D-intensive country, investing 4.3% of GDP in R&D in 2014 and it ranked first in business R&D in the OECD economy survey. Services, however, accounted for only 8% of Korea's business R&D in 2013, well below the OECD average of 38%. While all companies profiled in this report have a department or subsidiary focused on R&D, the Korean companies' locations are all in Korea. Global digital firms, by comparison, have innovation centers at home and abroad; however, none of the firms examined have significant activities in Korea. The lack of global interaction and exposure undermines the country's potential to tap into global trends.

- **Acquisitions and Venture Capital (VC) investments are uncommon in Korea.** In the United States (US), a global leader, acquisition activity in the digital sectors is significant, allowing them to tap into simple, nimble innovative firms. IBM, Microsoft and Google have acquired at least 165 companies each over the course of the last 15 years. The Korean firms, on the other hand, have acquired at most 15 firms each, with most activity occurring in the last five years. Startups have advantages over larger industrial peers; they can be very specific, focusing on single industries with direct and tangible applications. They can also respond more quickly to changing technology as they do not have decades of legacy equipment or organizational norms to confirm to.

- **Korean firms have few partnerships and collaborations.** Strategic partnerships between digital firms, manufacturers and retailers in different sectors and regions are key tools driving digital transformation and expansion into new areas. Korean firms' partnerships are more limited and are primarily with other domestic firms.

The report also uses detailed company and country case studies to highlight how other actors have successfully entered and upgraded in the digital economy. Aggregated, these individual factors inform recommendations for Korea's path forward in the industry. The most appropriate strategy is for Korea to pursue a proactive, *international* approach to grow its digital economy. Collaboration with, investment in, and recruitment of foreign firms can all be important components.

While this approach is different from Korea's historical domestic driven development path, there are no successful examples of firms in the global digital economy that have not done these things. Although Korea's development strategy of leveraging domestic firms rather than FDI-led globalization has been successful, in the absence of a large domestic economy, this strategy has a low likelihood of success in the digital world. The new digital economy relies on interoperability and increasingly connecting previously unrelated people, places and things.

1. Introduction

Established industry leaders across all sectors face competition from new digital companies that have successfully created technology platforms that change the way buyers and suppliers interact. This creates a new layer in GVCs, alters competitive dynamics and challenges the power of traditional lead firms. Korea will need to understand these changes and respond to them to remain competitive in the long term.

The digital economy represents economic activity that results from billions of digital connections among people, firms and devices. It changes conventional notions about how businesses operate and interact and how consumers find information, purchase goods and obtain services. Due to its catalytic changes, the opportunities associated with the digital economy have been analyzed from a variety of perspectives in recent years. The digital economy includes the software and services that make up the information technology (IT) global value chain and the increasing incorporation of these activities in industry-specific GVCs (or digital transformation). While there are numerous estimates associated with the size of the global market,[1] the overall growth trajectory is relatively unambiguous. Patents for Artificial Intelligence (AI) in the leading five IP offices around the world increased 6% per year in the period from 2010 to 2015, which was more than twice the growth rate observed for all patents (OECD, 2017). Looking ahead, the annual growth rate for individual sectors related to the digital economy are expected to be close to 50% (AI), 34% (Internet of Things) and 15% (industrial robotics) from 2018 to 2023 (BCC, 2018).

Globally, there is a race between governments to ensure their country develops the digital technologies and platforms that allow each to remain competitive. Germany launched the Industry 4.0 initiative as part of their overall development strategy in 2011; the same year, the United States (US) launched the Advanced Manufacturing Partnership, and China launched the "Made in China 2025" program. Japan unveiled specific programs in key areas (IoT Acceleration Consortium (IOTAC) and Robotics Revolution). Other countries around the world are also vying for their position, including France (Nouvelle France Industrielle); Sweden (Produktion 2030); Spain (Industria Conectada); and, Italy (Fabbrica Intelligente) (Forrester, 2017b; Kagermann et al., 2016). In 2016, Singapore allocated its largest ever research and development (R&D) budget to drive Industry 4.0 technologies adoption in the city-state.

This report seeks to understand how Korea is responding to these changing competitive dynamics by identifying its position in the digital economy GVC. Historically, Korea's economic development has been rooted in its prowess in manufacturing industries; however, this is being reshaped by new digital technologies. For Korea to maintain its competitive advantages, it needs to understand exactly how these new technologies will shape the future of these industries and how it can position itself to do so.

[1] The estimates for the size of the IIoT market vary widely, with optimistic measures reaching as high as US$800B by 2020 (Columbus, 2018); even conservative estimates of around US$85B suggest significant market potential. Establishing better measures at this early stage is clearly difficult due to the incipient and intangible nature of the business. Industrials and manufacturing, in general, are highlighted in these estimates as having amongst the highest market growth potential amongst different sectors (Columbus, 2018).

This research looks at the increasing importance of digital services in GVCs. It builds on the outcomes from the previous study in which a key takeaway was a relative weakness in services in Korea.[2] At present, service-focused economic development efforts are tied to traditional service industries (finance, insurance, retail) rather than to manufacturing-related or services that support industries. Specifically, IT and computational science-based services, which underpin Industry 4.0 trends in automation, the Internet of Things (IoT), and data analytics, is a potential strategic area for Korea. Engaging in these advanced activities have relatively high barriers to entry and requires general, technical, and industry-specific knowledge, which align with Korea's strengths in electronics, gaming, manufacturing, and Science, Technology, Engineering and Mathematics (STEM) education. These firms also often start as small and medium-sized enterprises (SMEs) that collaborate with or are absorbed by larger companies, so it aligns with the Korean government's interest in SME development.

This research builds on the recommendations in Duke-KIET (2017) to pursue service-related opportunities in higher-value manufacturing-related services, emerging (data-driven) post-production segments of GVCs and IT and software services. It describes the three main areas of digital services (software, IT services, and internet software and services) and servicification opportunities and uptake in a key end market, the capital equipment GVCs from the perspective of manufacturers, referred to as the Industrial Internet of Things (IIoT).

This paper draws on primary and secondary research including market research reports, news and journal articles on the subject matter with case studies of 28 global leading firms in the digital economy. The primary audience for this research is researchers and policymakers interested in Asian economic development and policy.

2. Definitions and Methodology

This section clarifies how select terms are used in the report and outlines the methodology used for reaching the report's conclusions.

There is ambiguity about what terms such as "digital transformation" encompasses, how it will be applied in industry and the implications for development. This is partly due to the overall complexity—the technologies continue to evolve and the scope for further innovation appears seemingly endless. In this report, we refer to digital transformation generally as the significant incorporation of digital technologies into products, operations and business models.

In the context of manufacturing, two key categories of these new digital technologies are relevant: production technologies and services. The major digital impact on production technologies is in the areas of automation and additive manufacturing. This includes the significant incorporation of robotics into operations with progress driven by machine learning and AI. This group of technologies is increasingly referred to under the banner of 'Smart Factory.' The overall vision of these systems is to automate and integrate production lines, design and produce collaboratively and virtually, and improve the efficiency with which these are delivered to the client. Services, on the other hand, encompass the process of data collection, analysis and new business models enabled by the increased connectivity of equipment, products,

[2] Labeled as 'servicification' in the report.

and users and the digital mapping of the environments in which these interact. This includes 'big data,' and IoT. These can collectively be referred to as 'Product and System Smart Data.' While there is undoubtedly overlap between these two categories, the analysis of how firms and countries are approaching digital technologies suggests this distinction is useful.

This report focuses on the latter in the context of industrial manufacturing sectors. Specifically, it seeks to unpack how digital technologies are creating opportunities for upgrading in a range of new services in capital equipment subsectors and the role different countries are playing. Manufacturing GVCs of this equipment, often referred to as "heavy" or "industrial" equipment, is distinct from that of other manufacturing markets. This equipment is characterized by its mission-critical nature, that is, its performance is fundamental to the operations of its buyers; it is typically expensive, technologically complex, and increasingly durable both to withstand the extreme conditions under which it operates but also to improve its performance. These features distinguish it from consumer-oriented manufacturing and create distinct opportunities for digital service value creation.

The following methodological approach was used to build an understanding of how incumbent IT software and service technology firms, new platform providers, and new digital services are being deployed in the capital equipment sectors. First, a review of the existing academic and trade literature was undertaken to understand key crosscutting concepts and technologies that apply to the broad field of industrial digital technology. These included publications developed by international development organizations and consulting firms that have written prolifically about these emerging trends in recent years.

Next, profiles of leading companies in each segment were created to determine critical factors in start-up and growth. Eight software companies, five IT service companies and six internet platform companies were profiled (Table A-8-1). Digital companies were selected from the UNCTAD World Investment Report (WIR) Top 100 Digital MNEs and IT software and services (top 100 ICT firms). Next, nine leading equipment manufacturers with diverse geographic bases, including the US, Europe and Asia were selected to profile (
Table A-8-2). These original equipment manufacturers (OEM) have been at the forefront of the development and incorporation of digital technologies in their manufacturing sectors. These include six IIoT platform integrators (ABB, Bosch, GE, Hitachi, Honeywell, Siemens) and three discrete equipment manufacturers (Caterpillar, Komatsu, Rolls Royce).

Each profile included the following key themes:

1. Evolution of products, services and sales destinations; how the company earns revenue;
2. R&D expenses and R&D as a share of revenue;
3. Collaboration and technology acquisition from other firms or universities (is development in-house, via mergers and acquisitions (M&A) or outsourced). Importance and interest in national and international collaboration with competitors and development partners;
4. Venture Capital (VC) activity; SMEs as a source of innovation and technology;
5. Profile of human capital and workforce skills and availability.

Firm profiles were developed using annual reports, interviews, press releases, human resources information, organizational memberships, and news media articles, amongst other sources. Any examples used in this report are based on publicly available information.

For the capital equipment analysis, key themes were examined in both the literature review and firm profiles. These included new digital-based services (products-as-a-service, platforms-as-a-service), historical context for the emergence of new digital services, industrial organization, capability development within and across organizations and the global footprint of operations. The research questions covered both enabling technologies; that is, those related to creating data flows to and from equipment as well as value-enhancing technologies, those related to analyzing and monetizing the data and connecting it with other segments of the value chain. This analysis allowed us to develop a framework for understanding the role and potential impact of digital services on the GVCs of capital equipment industries as well as the key challenges that have inhibited its full-scale deployment to date.

3. The Digital Economy and Global Value Chains

The digital economy is characterized by new types of firms, new relationships, new sources of power and an increasing number of partnerships between traditional partners and seemingly unrelated sectors. While the ability to collect and use data in industrial and consumer markets has always existed, the ability to collect, store, and analyze data at the current scale has only emerged recently and will continue to increase in importance.

Established industry leaders across all sectors are facing competition from the likes of new digital companies that have successfully created new technology platforms that change the way buyers and suppliers interact. Looking into the future, the impact is expected to become more pronounced, with implications for both manufacturing and services activities. The emerging data-driven global economy may cause significant further shocks to GVCs and the participation of different locations and geographic regions. Some of the key findings related to the digital economy and GVCs are highlighted below.

1. **The rise of services creates new industries and stages in specific GVCs and alters the distribution of value within these chains.** Manufacturing-related services, particularly those previously considered “after-sales” are becoming just as important as sources of revenue, if not more so, than the manufacturing operations themselves. In some capital equipment sectors, after-sales services already account for more than half of manufacturing firms’ revenues. Across sectors, there is a shift to more of a pay-per-use model as opposed to outright ownership or a fixed-price contract.

   More firms earn a **larger share of revenue by performing services** than by selling physical goods. For example, IBM’s revenue in 1997 and 2017 was nearly the same (US$79 billion). However, the composition of that revenue is quite different. In 1997, hardware sales accounted for 46% of earnings, compared to just 8% of revenue in 2017. Microsoft is another example of shifting from traditional software to platform services. In 1997, the company’s revenue was primarily from operating system software, however in 2017, 36% was from services, driven by strong growth in the commercial cloud sector.

2. **Additional data enables equipment manufacturers to functionally upgrade and provide analytical consulting services to clients.** This has the potential to *shift the governance structure* in end markets. Armed with data from global fleets operating in a variety of conditions, equipment manufacturers are positioned to provide their clients with consulting advice on how to maximize performance. The relationship between these manufacturers and their clients has generally been transactional in nature with manufacturers providing equipment according to specifications required by the clients. However, the advent of digital connectivity and analytics provides these equipment developers with increased insights into the processes of how their clients operate. Increased data generation and analysis now provides the equipment maker with an understanding of how to undertake the business (Kasper, 2018); in doing so, equipment providers can become solution providers—and charge more for this service.

3. **There is a dichotomy between the products and services offered and revenue sources in consumer segments due to advertising.** Many companies engaged in the platform segment earn most of their revenue from digital advertising, with firms such as Google and Facebook offering end-users free accounts on their platforms and earning revenue from businesses that advertise on these websites using data provided by the users in the creation of their accounts. The rise of digital ads is also seen in the share of digital as a proportion of total media ad spending (2016). Globally, 34% of advertising outlays were for digital ads. In Korea, it was 37%, in the US, 36%, and in mainland China, 52% of all ad spending was for digital. Regionally, digital ad spending is highest (39%) in the Asia-Pacific region (eMarketer, 2016).

4. **The digital economy has significantly different skills requirements, with changes to traditional job roles and greater emphasis on digital skills.** Talent is needed that understands both technologies and business applications. Competing in the digital economy requires workers with skills in programming *and* data analytics. Demand for workers with these skills has increased significantly, with workers earning wages significantly above the national average in related occupations in the US. Computer systems design and services and software publishers are among the industries with fast-growing employment and wages, with compound annual rates of change (2016-26) of 2% and 1.8% respectively compared to 0.7% (US BLS 2018). Average or above average growth is predicted for the next decade for nearly all occupations.

5. **The digital economy has led to a rise in new forms of education: certifications.** All major software and service providers offer education and training for their products to enable workers to attain various levels of certification. This acts as revenue for the company and provides an alternative to more formal education. Google, IBM, Oracle, Microsoft, Red Hat, Citrix and Salesforce all offer training and certifications for their products. This is driven, in part, by the lack of supply compared to demand for programmers, developers and analysts. One article suggests that in 2017, all US computer science graduates would fill less than 9% of open developer positions (Salesforce, 2018).

6. **In the data-driven global economy, companies are expanding their value creation through collaborative ecosystems rather than a simple focus on linear supply chains.** Creating a culture of collaboration is needed for success in an Industry 4.0 world, whether in-house, within the supply chain or across industries (Siemens, 2018b). Rather than a single technology, it is the convergence of multiple technologies that, in combination, enable firms to adopt new ways of doing business (UNCTAD, 2017a).

7. **The US is the dominant player.** A large share of digital MNEs are based in the US, and more subsidiaries are domestic (and in the US) than the overall group of MNEs (UNCTAD, 2017a). Of the top 100 digital MNEs by sales or operating revenues (2015), 67% are US firms; 23% are European, four are Japanese, two Chinese and one each from Korea, Canada, Mexico and South Africa (UNCTAD, 2017a). This is also supported in the PwC Global Innovation 1000 study, where 57% of firms in digital economy-relevant industries are from the US. In comparison, only 24% of industrial (38/157) MNEs are from the US (PwC, 2018). For all industries, the US is the top country, and is generally followed by Japan and China; Korea is 6th (based on firm count, R&D spending and revenue). For digital companies, the US is the clear leader, followed by China. After China, ranks differ based on firm count, R&D and revenue (PwC, 2018).

3.1. Mapping the Digital Economy Global Value Chain

The digital economy is composed of **three primary segments**: 1) software; 2) IT services; 3) Internet software and services (ISS) platforms. These are supported by, telecommunications and Internet service providers (Box 3-1), that provide the infrastructure that enables digital firms to operate.[3] Table 3-1 provides a summary of the key elements for each segment; each is explained in more detail and defined qualitatively and quantitatively in the subsections that follow. Figure 3-1 shows the key products, firms and activities that make up the digital economy.

Table 3-1. Digital Economy Market Segments/Final Products, Values, 2017-18

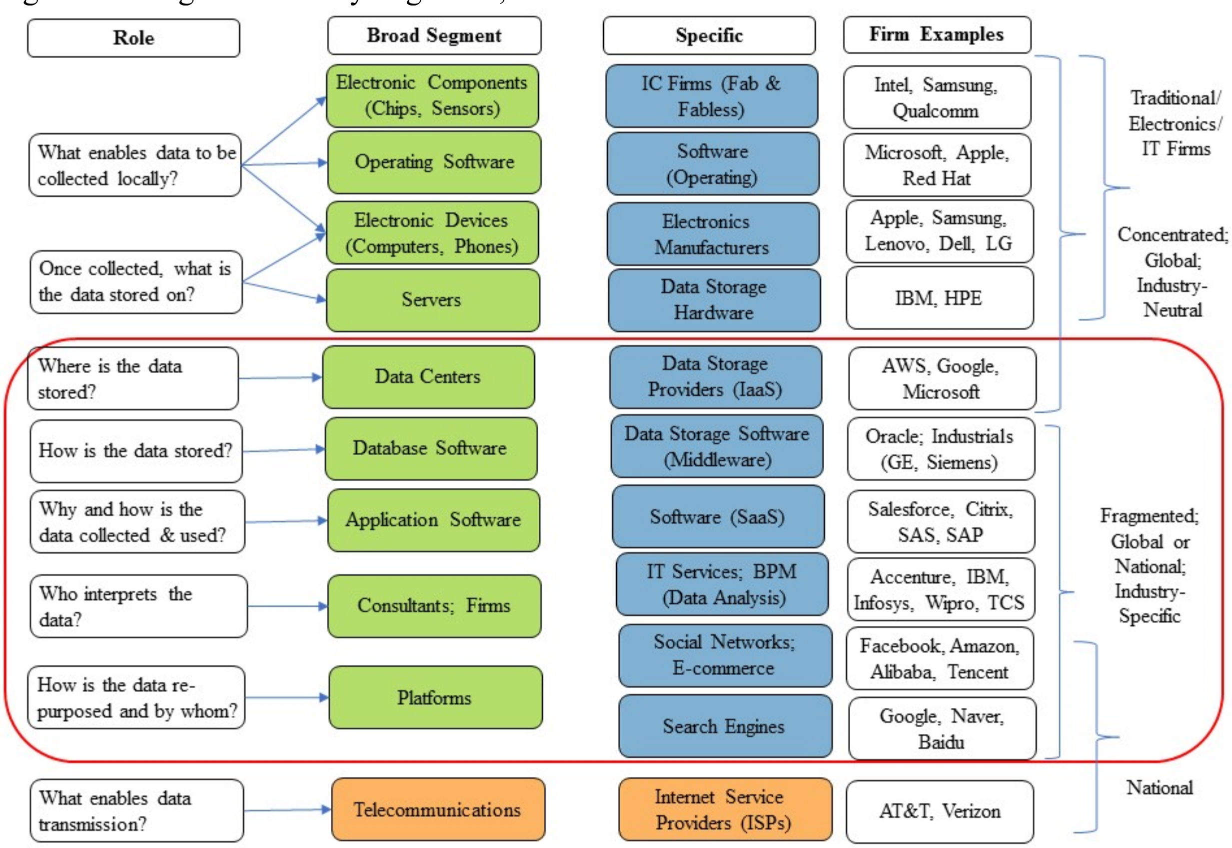
Segment	**Types**	**Revenue Source**	**Industry Codes**	**Global Market Revenue**	**Firms**	**Key Themes**	**Workforce**
Software	Application (incl. SaaS) Operating	One-time sale, license for specified number of users and/or time; tech support and updates	5112 (NAICS) 5820 (ISIC)	$335 B, 2016	Microsoft, Oracle, SAP, SAS, Salesforce, Citrix, Red Hat, Kakao	Collaboration Acquisition	Software App Developers, Computer User Support Specialists,

[3] Related are the tangential fields of IT hardware and infrastructure. IT hardware includes the physical electronic devices that are used to create and store data. Infrastructure involves the physical components required to transmit data electronically and service activities related to storing data. This analysis does not include hardware or physical IT infrastructure. Infrastructure services are included as a means of providing a full picture, but these services are often regulated at the national level by a small number of companies. It is important to be aware of these companies because they play a role in the context of institutions and standards. In this report, data center services (IaaS) are included in the Internet platform section, however these are also related to the infrastructure services environment.

IT Services	IT consulting, business process services, data analysis (software users)	Service fees	5415 (NAICS) 62 (ISIC)	$668 B, 2016	IBM, Accenture, Infosys, Wipro, Samsung SDS	India; most offshored; lowest M&A	Programmers, Computer Systems Analysts; Data Analysts
Internet Software & Services (ISS) Platforms	Search engines Social networks Cloud (IaaS, PaaS) E-commerce	Advertising, Commission, Service fees	51821 51913 (NAICS) 63 (ISIC)	$191 B $83, '15 $27, '15 $9, '16 $72 B	Google, Naver, Baidu, Amazon, Alibaba, Facebook	VC Investment; Acquisitions	Software developers; architects, Programmers, Customer Service Reps; Sales Reps
Infrastructure services (Telecom, ISPs)	Internet service (home & wireless), mobile	Service fees	517 (NAICS) 61 (ISIC)	$2.1 T $1.3 T, '17 $720 B	Verizon, AT&T		

Sources: see specific sections and Appendix tables.

Figure 3-1. Digital Economy Segments, Products and Firms



Source: Authors

Box 3-1. Infrastructure Services (Telecommunications, ISPs)

This segment provides the infrastructure services needed to access and transmit digital content. The main groups are Internet Service Providers (ISPs) and wireless telecommunications carriers. These companies provide fixed and mobile/wireless internet access and mobile phone (voice and text) services. Many companies are in both segments. The global market for internet access via fixed and wireless connections is approximately $1.3 trillion and mobile service is $720 billion for a combined value of $2.05 trillion in 2017 (does not include wired telecommunications or equipment sales).

Table 3-2. Digital Economy Infrastructure (Telecommunications, ISPs)

Focus & Geography	Products & Services	Companies (Specific)	Revenue (US$)	Source
ISPs (Home Internet; fixed) (GL)	DSL, Cable, Fiber; Dial-up	NTT (5%), China Telecom (4%), Verizon (4%), AT&T (3%)	**$620B 2017***	(IBISWorld, 2017j)
Internet Access (GL)	ISP revenue: fixed & wireless	N/A	$981B 2016	(MarketLine, 2017b)
ISPs (US)		Verizon (15%), AT&T (14%)	$118B 2018	(IBISWorld, 2018c) NAICS 51711d
Wireless Telecommunications (GL)		Verizon (7%), SoftBank (7%), China Mobile (6%), AT&T	$1,625B 2017	(IBISWorld, 2017k)
	Wireless internet		**$712B 2017***	
	Mobile phone service		**$720B, 2017***	
	Equipment/hardware		$193B, 2017	
Wireless Telecommunications (US)		Verizon (24%), AT&T (24%), T-Mobile (12%), Sprint (9%)	$255B	(IBISWorld, 2017ab) NAICS 51721
Wired Telecom (US)	Home phone; cable	AT&T, Verizon, Century Link	$75B 2018	(IBISWorld, 2018j) NAICS 51711c
VoIP (US)		No major Skype (Microsoft)	$23B	(IBISWorld, 2017z) NAICS 51711e
Satellite Telecom (US)		EchoStar, Intelsat, SES	$7B	(IBISWorld, 2018e) NAICS 51741
Telecommunications (US)	Integrated (95%), Alt. Carriers (5%)	AT&T (49%), Verizon (45%), Century Link (3%)		(CFRA, 2018b)
Mobile/Telecom (GL)	Telecom services			CBI Industry

Note (*): indicates value is used in the main table estimates. Global (GL).

ISPs (i.e., home internet): provide internet access via wired networks using wireline infrastructure, which is also used by wired telecommunications providers, but to supply voice and data. Types: DSL internet (46%); Cable internet (31%): increasing; Fiber to the premises (FTTP) (22%); Dial-up (narrowband), satellite and other (1.7%) (2017)(IBISWorld, 2017j). ISPs' revenue is from the provision of narrow and broadband internet connections and wireless through consumer and corporate channels (MarketLine, 2017b).

Wireless Telecommunications Carriers (i.e., mobile phone voice & messaging and wireless data): operate and maintain switching and transmission facilities to provide direct communications via wireless transmission. Services include cellular voice phone, messaging, broadband data and mobile backhaul services (i.e. transferring data from small subnetworks to a network core). Carriers also retail mobile handsets and equipment to consumers, but this revenue is not included (IBISWorld, 2017k).

Wired Telecommunications (i.e., home phone and cable providers): phone and data over wired networks (IBISWorld, 2018j). Firms provide local and long-distance voice communication services using the public switched telephone network. These tend to be the same firms offering other telecom services, but this segment is not included in digital market estimates.

3.1.1. Software (Traditional; Transition Firms)

The main software divisions are systems and application specific. Application software is fragmented and diverse; there are over 35 different types of application software compared to systems, which is primarily composed of two segments (operating and database) and is driven by a smaller number of incumbent IT firms. Distribution has become easier in recent years due to the development and uptake of broadband internet access. This enables software to be purchased, delivered, and updated without the need for physical media or distribution, allowing software to spread rapidly (MarketLine, 2017d).

The global market for software is estimated at $335 billion (MarketLine, 2017e). As with other segments, numerous market reports related to software were reviewed to identify common segments, companies and market estimates (Table 3-3). Companies with the largest software businesses (Microsoft, Oracle, IBM and SAP) accounted for 37% of worldwide commercial software revenue in 2014 according to IDC (CFRA, 2017c). The largest global software companies were established prior to 2000. These firms have been able to remain relevant and expand into new applications often via acquisitions of tech firms in specific areas, and more recently through startup investments.

Table 3-3. Software Segment Definitions and Market Estimates

Report Focus and Geography	Specific Segments	Companies (Specific)	Market Rev. ($US, B), Year	Data Source
Software (GL)	Five: Software infrastructure 49%; Enterprise apps 29%; Info Mgmt. 13%; Security 6%; Enterprise mobility mgmt. 3%	IBM, Microsoft, Oracle, SAP (MarketLine, 2017d)	**$335B 2016**	(MarketLine, 2017e)[4]
Software (US)	Three: 39 companies[5]: Systems: 68%: 13; Application: 24%: 23; Home Entertainment: 8%: 3	Microsoft (45%), Oracle (17%), Adobe (6%), Salesforce (6%)	--	(CFRA, 2017c)
Software (GL)			$217B 2018	(Mind Commerce, 2018)
Software (US)	Application (38%), Systems (31%)	Microsoft (20%), IBM (9%), Oracle (5%)	$218B 2017	(IBISWorld, 2012e, 2015e, 2017v)
Software (China)			$837B 2017	(IBISWorld, 2018h)
Software, non-Internet/mobile (GL)	35 industries	Financings: 13,608 Exits: 5,349		CBI Sector; Data: 1998-2018 (June 1)
Cloud Computing (GL)	SaaS	Salesforce, Microsoft, SAP	$10B 2016[6]	(MarketLine, 2017a)
Mobile Apps (GL)			$4B 2015	IDC Global (CFRA, 2018a)

[4] Market values assessed at manufacturer selling price (MSP), based on revenues from software sales and licenses. Currency conversions calculated using constant 2016 annual average exchange rates. ML does not include estimates for missing countries and global figures are a summation of country data.
[5] Three companies established between 2000-04 (Barracuda Networks, Gigamon and Agilysys (just changed names in 2003) (CFRA, 2017c). IBM and SAP are not in software in CFRA.
[6] Values are calculated based on revenues accrued from these services. Total cloud market: $13.6B, 2016.

Report Focus and Geography	Specific Segments	Companies (Specific)	Market Rev. ($US, B), Year	Data Source
Smartphone App Developers (US)		No major; all < 1%	$2.4B 2018	(IBISWorld, 2018g)

Within systems software, operating systems include:

- PCs: Microsoft, Apple
- Unix, Linux
- Mainframe (IBM): z/OS and DOS/VSE (CFRA, 2017c).

Database software can be relational or non-relational. Relational is the largest (86% of market) and Oracle and IBM are the largest players. IBM's relational DBMS, named DB2, is used widely, particularly in the mainframe-computing environment. DB2 was the first product to incorporate Structured Query Language (SQL). Following IBM's lead, other computer vendors have integrated SQL into their database products (CFRA, 2017c). Microsoft is the dominant player in non-relational software.

Application-specific software is the most relevant and growing segment. A detailed table of many different types is provided in the Appendix (A-3). This can also be extended to software programs specifically for mobile devices, or 'mobile apps.' Smartphone app developers create and publish applications (apps) for smartphones. These are sold in a special "app store" that can be accessed through the device (IBISWorld, 2018g). These companies primarily generate revenue through in-app purchases and advertisements, not through the actual process of developing the application. There are also application developers contracted by companies to build and perhaps maintain a mobile app for their business. Large companies with significant online business often employ application developers in-house, however many companies choose to outsource the development and maintenance to third-party IT companies.

The software segment also includes the growing Software as a Service (SaaS) market, which was valued at $10 billion globally in 2016 (MarketLine, 2017a). In SaaS, software is hosted in the cloud (offsite servers), so it doesn't take up hard drive from the computer of the user or servers of a company. Salesforce, Microsoft and SAP are the three largest cloud software revenue earners (CFRA, 2017c)

3.1.2. IT Services (Traditional to Digital)

These companies deliver business, operational, strategic and technology consultancy and services to reshape customer business models for digital workloads (CFRA, 2018a). IT services is not a new industry, but one that is impacted by the advent of new digital technologies. Information technology and business service companies are users of software, particularly application-specific software, listed in the previous section. The line between software and IT services is blurry as many companies often provide some application-specific software development in addition to managing data, providing data analytics and other business services. There is also overlap with IT platforms as firms in this category may also provide infrastructure and platform services (application hosting and data centers, desktop support and management, security and storage).

Like software, large global IT service firms have been in business since before the year 2000 (CFRA, 2018a).[7] The most notable global firms in this segment include IBM, Accenture, CTS, DXC, SAP, Capgemini, Fujitsu, TCS, Atos and Oracle. Many of the leading IT service companies started as hardware providers. IBM, TCS, Wipro, Samsung SDS (through Samsung Electronics) all started in electronics hardware before moving into their current business models driven by services. M&A activity is increasing in this sector; announced M&A transactions in the IT services industry totaled $32 billion in 2015, up from $15 billion in 2014 (S&P, 2016)., but the total value is small compared to the other sectors. Like other sectors, contracts are shifting from fixed-price to variable, consumption-based contracts; between 2014 and 2016, the share increased from 5% to 14% (CFRA, 2018a).

Table 3-4. IT Services Segments, Companies and Market Values

Report Focus & Geography	Specific Segments	Companies (Specific)	Market Rev. ($US, B), Year	Data Source
IT Services: Consulting & Other (GL)		Total: 14 (2017) IBM, Accenture, Cognizant Technology Solutions (80%)[8]	$933.1B 2016	(CFRA, 2018a)[9]
	Business Consulting $29B (operations)		$104.5B	
	Key Horizontal BPO		$180.4B	
	Support & Training		$148.3B	
	IT Outsourcing		$261.6B	
	IT Project Oriented		$238.4B	
IT Services (GL)	Infrastructure, Application & BPO	Accenture, Fujitsu, HPE, IBM	**$668.3B 2016**	(MarketLine, 2018c, 2018d)
	BPO	Capgemini, CBRE, Genpact, Infosys. 2017: Accenture, CGI Group, Synnex, Telus	$140.5B 2016	(MarketLine, 2018a, 2018b)
Digital Transformation (GL)	Big Data $21.3B Analytics $5.2B	--	$26.5B, 2015	IDC Global (CFRA, 2018a)
IT Consulting (US)		Accenture, IBM, HPE, Dell (no major player)	$408.2B 2017	(IBISWorld, 2015d, 2017n)
BPO (US)			$135.9B 2015	(IBISWorld, 2015a)
IT Services (US)		Total 41 (2016, July)		(S&P, 2016)

Note: payment processing companies (Visa, Mastercard, PayPal) are categorized as IT services by some market reports but are not included here. GL=Global.

IT services includes managing data related to clients, finance and accounting, human resources, procurement, and other industry-specific areas (MarketLine, 2017c). These services are also referred to as business process services (BPS) and business process outsourcing (BPO). Some also use the term BPS to mean “technology infused outsourcing services” representing the shift to digital or automated services rather than just offshoring to lower-cost locations (CFRA, 2018a). According to HfS Research, revenues from digital services accounted for 19% of all IT professional services in 2016, and is expected to be 38% by 2021 (CFRA, 2018a).

[7] Except CSRA (Computer Sciences Corp. (CSC) spin-off in 2015), all founded before 2000. IBM is the oldest, followed by CSC (est. 1959). CSC acquired HPE’s Enterprise Services business in March 2017, creating DXC.

[8] Others: DXC, Gartner, Leidos Holdings, CSRA, Teradata, Science Applications, CACI International (est.1962), Acxiom, ManTech International, Virtusa and Perficient.

[9] Source’s market size source: IDC.

IT services includes consulting, which may pertain to the company's management, operations or finances. Consultants analyze a company's data and performance metrics and provide strategic advice. For some companies, fees are tied to operational efficiencies achieved by the suggested improvements. Key players are large firms from the US and Europe, including IBM and Accenture (CFRA, 2018a).

3.1.3. Platforms; Internet Software & Services (New)

This sector includes search engines (largely Google), social networking, cloud providers (IaaS and PaaS) and e-commerce. These are newer companies with two-thirds established between 1994 and 1999 (CFRA, 2017b).

Table 3-5. Internet Software & Services (Platform, Search Engines, Cloud, e-Commerce)

Report Focus & Geography	Specific Segments	Companies (Specific)	Market Revenue	Data Source
Total (Global)			**$191B, 15-17**	Estimate based on below
Global	Search engines	3-Alphabet, Yahoo, Naver	**$83B, 2015**	(UNCTAD, 2017a)
Global	Social networks	5-Facebook, IAC/Match, LinkedIn, Twitter	**$27B, 2015**	(UNCTAD, 2017a)
Global	E-commerce	3-Amazon, Alibaba, eBay	**$72B, 15-17**	(UNCTAD, 2017a)
Cloud Computing (GL)	Cloud: IaaS, PaaS IaaS $4.5B PaaS $4.2B[10]	AWS, Google, Microsoft; IBM, Red Hat	**$9B, 2016**	(MarketLine, 2017a)
Internet Software & Services (US)		Total 18 (2017) Alphabet (67%), Facebook (20%)[11]	$135B, 2016	(CFRA, 2017b)
Digital Transformation (GL)	Social networks Cloud platforms		$33B, 2015 $28B, 2015	IDC (CFRA, 2018a)
Internet (Global)	ISS, eCommerce, Stealth Mode	Financings (#): 74,252 1998-2018 (June 1)		CBI Sector: 3 Industries
IIoT Cloud Computing (GL)			$92B 2017	(Mind Commerce, 2017)
Search Engines (US)		Alphabet 91%, Microsoft 6% (Bing, Internet Explorer)	$60B 2017	(IBISWorld, 2017t); NAICS 51913a
Internet Publishing & Broadcasting (US)		Facebook (15%), Alphabet (12%), Apple (9%), Netflix (5%); Oath (Verizon), Hulu (Comcast, Fox, Disney & Time Warner), Twitter	$119B 2017	(IBISWorld, 2017m) NAICS 51913b
Data Processing & Hosting (US)		IBM[12] (8%); Salesforce, Amazon, HPE, Google, Apple, Dropbox	$175.2B 2018	(IBISWorld, 2018a) NAICS 51821
Social Networking Sites (US)		Facebook (72%), LinkedIn (11%), Twitter (6%); Snap	$26B 2017	(IBISWorld, 2017u)

[10] Values are calculated based on revenues accrued from these services. Total cloud market: $13.6B, 2016.
[11] Others: eBay, Akamai Technologies, Blucora, Cars.com, DHI Group, J2 Global, Liquidity Services, Liveperson, LogMeIn (2003), NIC, Quinstreet, Shutterstock (est. 2003), SPS Commerce, Stamps.com, Verisign and XO Group. Top Internet Software Companies' Revenue, 2016, p.14. Total revenue is sum of revenue of the 18 companies listed.
[12] Relevant IBM divisions in IBIS for estimate: cognitive solutions and cloud platforms divisions.

Report Focus & Geography	Specific Segments	Companies (Specific)	Market Revenue	Data Source
Social Networking (China)		Tencent, SINA, Baidu, China InterActive	$6B, 2018	
Internet Services (China)		Alibaba, Tencent, Baidu, Netease, Qihoo360, Sohu, SINA	$369B, 2017[13]	(IBISWorld, 2018d)
E-Commerce & Online Auctions (US)		Amazon (21%)	NR b/c valuing sales	(IBISWorld, 2017e) NAICS 45411a

This sector is the most diverse; the central theme is that businesses are dependent on the Internet and are entirely digital companies. Many of these are newer companies (est. after 1995). In the WIR, these are the platform companies, digital content, e-commerce and some of the digital solutions companies (these are also in software). This segment is primarily a **consumer market** (B2C), except cloud companies, rather than industrial (B2B). Companies in this segment earn revenue from advertising or from fees paid by other companies to access the platform.

These companies have been investing significantly in new offerings, international expansion, and large-scale data centers. There has been considerable M&A activity (CFRA, 2017b).

Accessing information on the Internet involves Internet browsers, search engines and hosts. The following global shares are based on annual 2017 data from (StatCounter, 2009-2018).

- **Internet Browsers:** for desktop or mobile; one is preinstalled on devices (OEM), however, most can be installed on any device/operating system. Shares[14]: Chrome (Google) 54%, Edge 2%/Internet Explorer 4% (Microsoft) 6%, Safari (Apple) 14.5%, Firefox (Mozilla) 6%, UC Browser 8%, and Opera 4%.
- **Search Engines:** method of searching content on the Internet. Shares: Google (92%), Bing (2.8%), Yahoo (2.1%), Baidu (1.3%), Yandex (0.4%).
- **Search Engine Host:** to show content to a specific geographic area or device (optimized for mobile vs. desktop). Assume this in part to help with language issues. In 2017, Google.com accounted for 19%; however, in 2012 it was 25% and for 2018 (as of June), it was 29%. Other top hosts are also Google-operated.

Cloud computing has three segments, of which two are considered part of the ISS platform sector in this report. Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) account for half of the cloud computing global market with global revenue of approximately $8.7 billion in 2016 (MarketLine, 2017a).

In the PaaS market, valued at $4.2 billion, the provider manages the server and develops the software program. The provider may or may not provide the infrastructure as well. IBM Bluemix and RedHat OpenShift are examples. In the IIoT segment, the platforms provided by integrators such as GE, Bosch and Hitachi are also PaaS. These companies do not host the data, but they provide the platform.

[13] $194B, value not including basic Internet Access Services.
[14] Data for Internet Browsers and Search Engines includes desktop, mobile, tablet and console.

In IaaS, the user manages the server and the cloud company provides the location (data center). The market is valued at $4.5 billion and AWS is the main provider, followed by Microsoft Azure and Google Cloud. Of the three, Google was the last to enter (2013) and focuses more on consumer markets. Azure began in 2010 and caters more to the industrial market. AWS was the first (2006) and accounts for the largest share of the market (44%) (MarketLine, 2017a). Given AWS' affiliation with Amazon's e-commerce segment, some companies, such as Walmart and Target, do not use their cloud services. Target initially partnered with AWS before recently switching to Google (CB Insights, 2018b).

Company	**Entry Year**	**Data Center Regions**	**Cloud Acquisitions (2013-Aug. 2018)**	**IaaS**	**PaaS**	**IaaS/PaaS Share**
AWS	2006	19	12	44% of IaaS		33%
Microsoft Azure	2010	44	24	Industrial Walmart	X	13%
Google Cloud	2013	17	24	Consumer Spotify, Snap, Target		6%

Sources: CB Insights (2018b)

Cloud computing is related to the move of keeping data internally at a facility versus storing it in a data center at another location. Within offsite data storage, there are different types, such as Cloud, Edge and Fog computing (CB Insights, 2018e). The cloud is storing data remotely, often at a distance. Edge occurs closer to the device with sensors and fog is between the edge and the cloud; edge computing is more secure and faster. Multi-cloud creates the need for tools that enable operating across clouds. Enabled by microservices and containers; containers communicate using APIs. Cloud providers must support the container programs (containerization tools). Third party containerization tools are the most popular (Docker is the most popular). Patents are a key strategy for the three companies too (CB Insights, 2018b).

There are public and private clouds, but public clouds are becoming more popular. Mergers and acquisitions demonstrate how industry leaders are utilizing their economic strength to acquire smaller players who hold valuable technological knowledge, a trend which is expected to become increasingly prevalent within the industry. However, because large players can attract highly-skilled individuals they may instead choose to use their own in-house talent to create innovative solutions. Buyers in industries **with a strong regulatory environment** may not wish to use cloud services if private data is not stored in local data centers (MarketLine, 2017a).

3.2. Digital Transformation in the Industrial Equipment Market

The services offered by firms in the digital economy GVC are used in all end markets across virtually all industries in the economy, including automotive/transportation, retail, healthcare, smart utilities and energy and others. This section focuses on the impact and adoption of digital technologies in the industrial market, paying close attention to industrial equipment manufacturing firms. The industrial equipment market was chosen over others due to its relevance to Korea.[15] Among the many sectors using industrial equipment, the focus was primarily on non-consumer products, including aerospace, marine, mining, oil and gas (O&G), power and rail. These firms include industrial integrators and equipment manufacturers.

The following subsection explores the digital transformation associated with industrial equipment in further detail, first assessing key players before detailing the emergence of new digital services.

3.2.1. Key Players

The major actors in this space include industrial integrators, software developers, cloud infrastructure providers, discrete equipment manufacturers and others. These actors are supported by a range of hardware and middleware suppliers, such as gateway manufacturers and software firms that help connect databases to software platforms.

Industrial "Integrators"

These firms include industrial power and automation manufacturers such as GE, Hitachi, Honeywell, Siemens, Schneider Electric and Yogokawa. These firms generally have over 100 years of experience dominating industrial manufacturing and control systems integration. They have established open, industrial cloud platforms including Predix, Lumada, Mindsphere and Ecostruxxure, which allow third-party developers and equipment providers to use their platforms to collect, transmit, enrich and analyze data (GE Digital, 2013). These firms lead the IIoT market for two reasons: First, IIoT and its associated analytics directly builds on industrial automation capabilities (Stackpole, 2017; Woods, 2016). These capabilities are on-board, or on-site control systems. IIoT allows information from these systems to be enriched with data coming from multiple other pieces of equipment and environmental data to enhance overall decision making. Second, they have leveraged their strong presence as manufacturers and systems integrators in a range of industries, from manufacturing to oil and gas and mining to develop and test solutions for a variety of vertical markets in their own factories and equipment (Lohr, 2016).

The digital transformation initiatives launched by these firms mark definitive shifts in the strategies of these firms to become service companies. Siemens, the epitome of German manufacturing strength, has declared it fully intends to become a software company. While relatively incipient, this shift is beginning to impact the bottom line on some of these firms. By the end of 2017, digital revenue at Siemens (listed as Digital Factory) accounted for 13.7% of the company's income. It was also the most profitable segment of the company, despite significant expenses in R&D investments; profits increased 26% year-on-year and margins were amongst the highest in the group (14-20%) together with financial services (Siemens, 2018a).[16]

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[15] For example, Korean shipbuilders dominate the marine and offshore segments (Brun & Frederick, 2017); Doosan, Korea's mining and construction equipment manufacturer is ranked as the 6th largest globally, with a 4% market share (Hayes, 2018); and Hyundai Rotem is considered a top 10 global supplier of rolling stock, including locomotives, high speed trains, and light passengers trains (McKinsey & Co., 2017a).

[16] GE has been a major contributor to the establishment of the industrial internet of things market since 2012. However, during 2017-18, GE saw a major decline in its stock price and the company began a major restructuring. This may include the eventual sale of GE Digital. This may undermine the company's continued ability to shape the digital economy in the future.

Software Developers
These firms include large established IT firms that provide enterprise software and services to clients, as well as new start-up firms that have emerged in recent years. From Microsoft and Oracle to SAP, SAS and Salesforce, these firms have traditionally been key partners to equipment manufacturers (OEM) by providing IT support in enterprise resource planning (ERP) and human resources management (HRM) and customer relationship management (CRM). With significant IT capabilities, including their own IoT clouds for enterprise data, these firms are serving primarily as systems integrators, including data from operational technology (OT) into enterprise software systems for processing and harnessing the value across OEMs. While these firms still have limited engagement in the operational technology space itself, they are increasingly working with buyers in these global markets. For example, Cisco and IBM both partnered with major mines to help them launch system wide digital programs for operations ("Investment in Mining Technologies," 2017). SAP has also begun to provide OT information, working directly with TrenItalia (Buntz, 2018; Forrester, 2018a) and upstream companies in the oil and gas sector (Fedem Technology, 2018). Smaller software firms focused specifically on big data analytics for operational technology are also emerging (Box 3-2).

IT Service Providers
These firms are traditionally IT service firms however, they are also beginning to provide services related to machine and equipment connectivity. Indian IT firms that emerged in the 1990s and 2000s as key IT and business process (BP) outsourcing partners, including Infosys, TCS and Wipro, are the primary actors in this segment. Like enterprise software developers, they have been focused on OT-IT systems integration, experimenting with providing services on existing IIoT platforms, including GE's Predix and Siemens' Mindsphere. However, their historical role as back office IT providers has also positioned them as providers of data systems management for discrete equipment manufacturers and they are beginning to close deals in the space. For example, Wipro provided mining and construction equipment manufacturer, JCB, with a turnkey IoT solution to connect their global fleet – from the sensors to the cloud (Wipro, 2018a). TCS has provided data processing and engineering support for Rolls Royce since the 2000s, a role that has expanded as the OEM has sought to leverage big data across its supply chain and broaden its asset management services.

Cloud Infrastructure Providers
Cloud infrastructure service provision is dominated by three key firms: AWS, Microsoft Azure and Google Cloud. Several factors have contributed to the consolidation of this market segment; (1) *growing volume*: full, real-time, remote monitoring of industrial equipment requires multiple data points to be gathered across thousands of machines on a highly regular basis. Be it multiple times per second, or once a minute, this generates extremely high quantities of data; (2) *varied regulatory requirements*: security (and privacy) concerns have contributed to the emergence of regulations regarding where this data can be transmitted and stored to ensure its veracity; (3) *global coverage*: providing coverage for IIoT equipment in fields such as aerospace, mining and oil and gas requires truly global coverage. To provide comprehensive support for equipment providers or IIoT platforms, infrastructure providers must allow for high speed access to many locations. The scale of investment required is in the range of tens of billions of dollars. As a result, the segment is concentrating. GE previously planned to launch its own data storage operations to support Predix, however, they changed course following Amazon's investment

announcements (Darrow, 2017). Others such as Wipro have divested from this segment (Wipro, 2018b). Most platforms analyzed for this report use Microsoft Azure or AWS, however, there is a trend towards enabling platforms to be cloud agnostic; that is, to operate on any cloud infrastructure. This shift is significant, as it moves towards the commoditization of data storage in IIoT (Darrow, 2017).

Discrete Equipment Manufacturers

Companies such as Caterpillar, Komatsu and Rolls Royce are taking a distinct approach to digital by tapping into its transformative power to drive their own manufacturing businesses, but, they have not sought to provide of these services to other manufacturers. While some of these firms have been at the cutting edge of telemetry and connectivity of their own machines for decades, today, they are focused on developing strong internal analytical expertise, and combining it with strengths in manufacturing to drive automation and machine learning, more than developing IIoT technology itself. Rolls Royce launched its own analytics division R^2 Data Labs in 2018 but relies on TCS to provide data processing operations (Rossi, 2016).

Box 3-2. Industrial Internet of Things Creates Opportunities for Analytics Start-Ups

With the very large industrials and IT firms competing and collaborating on developing the infrastructure (hard and soft) for IIoT, an important space has emerged for start-ups focused on analytics. With platforms such as Predix and Mindsphere in place, these firms are focused specifically on developing analytical algorithms to help firms make sense of and monetize the stream of data available to them. This segment accounted for the third largest share of start-up investing over the last twenty years. Table 3-6 lists some of the leading start-ups.

Table 3-6. Select Analytics Start-Ups

Industry/Vertical	Select Analytics Start-Ups
Aerospace	Bit Stew (GE); C3IoT; Spark Cognition
Manufacturing	Alluvium; Augery; Enlighted; Foghorn; Maana; Machine Metrics; mnubo; Sight Machine; Striim; Tulip Interfaces
Marine	Arundo; Nisomar; SpaceTime;
Mining	Airware; Element Analytics; Falkonry; Foghorn; Kesprey; Uptake; Seeq; TrendMiner
Oil & Gas	Ambyint; Arundo; C3IoT; Element Analytics; Fedem Technology; Foghorn; Maana; Presenso; Seeq; Spark Cognition; TrendMiner
Power/Utilities	Bit Stew; Boraydata; C3IoT; Element Analytics; Foghorn; Presenso; Seeq; SpaceTime; TrendMiner
Pulp & Paper	Element Analytics; Seeq
Rail	Foghorn; SpaceTime; Uptake

The size of these start-ups affords several advantages over their larger industrial peers; first, they can be very specific, focusing on use cases in single verticals with direct and tangible applications. Second, they can respond more quickly to changing technology. These companies offer benefits to both discrete manufacturers and their buyers who are not looking to develop in-house capabilities but are rather looking to harness the information to develop services or reduce costs. They bring together experts from the tech sector and industrials. This allows them to combine new information technologies with deep domain expertise.

Sources: CB Insights (2018c); Crunchbase (2018); Nanalyze (2017); Stackpole (2017); Tweed (2016)

3.2.2. Emergence of New Digital Services for Industrial Equipment

Digital services in industrial equipment GVCs builds on developments in digital controls and after-sales services. This subsection discusses how these digitally driven services have emerged within capital equipment GVCs and the potential impact of their growing importance on the GVCs served by these equipment providers.

The advance of digital services in capital equipment is built upon an earlier trend in 'servitization' of manufacturing industries.[17] In capital equipment sectors, spare parts typically sell at seven to eight times their original value, creating long-term income after the initial sale of equipment (Bamber & Gereffi, 2013; BCG, 2014; Smith, 2013). Increased durability of equipment and parts, however, has resulted in less demand for physical replacements and subsequently less revenue to OEMs, thus requiring firms to develop new revenue generating strategies from their client base. In response, many firms have or are shifting towards new service offerings (BCG, 2014); one of the most significant areas has been after-sales maintenance, repair and overhaul (MRO) services. The services offerings that have emerged cover spare parts provision, maintenance, product lifecycle management (PLM) and asset monitoring amongst others. MRO services offer a lucrative additional stream of income for OEMs. Commercial aerospace MRO in 2017 was worth US$77.5B (Oliver Wyman, 2018), while in 2017, mining giant BHP Billiton alone spent US$3.5 billion on maintaining its machinery and equipment (BHP Billiton, 2018). These services have both helped firms to differentiate themselves from competition, while at the same time driving margins; one survey found that gross margins on services were 12% higher than those from new equipment sales (Bain & Company, 2015).

This services space had previously been dominated by client in-house departments or by third party licensees; however, OEMs have increasingly leveraged their technology leadership position to increase their participation, using strategies such as limiting access to technical manuals, parts and tooling, making services certifications more difficult to obtain and using economies of scale that makes it difficult for others to compete (Bamber & Gereffi, 2013; Kasper, 2018; McKinsey & Co., 2017a). The financialization[18] of sectors such as aerospace and mining and the rise of leasing companies in many of these sectors has also supported the entry of OEMs, as these leasing companies tend to lack capabilities for maintenance (McKinsey & Co., 2017b). The entry of OEMs into the MRO segment can offer benefits for equipment owners, particularly smaller ones, where OEMs can provide a single source for maintenance and expertise that owners and/or third-party operators cannot easily maintain on their own. Furthermore, operators no longer have to hold on to large inventories of spare parts; freeing up significant cash flow (Kim et al., 2007).

Digital monitoring of equipment was introduced, at site or remotely, giving rise to preventative maintenance contracts, a precursor to today's predictive maintenance, and PLM services (Grubic & Peppard, 2016). First, this data was manually downloaded from equipment periodically to help

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[17] Servitization is the term given to a transformation where manufacturers increasingly offer services that are tightly coupled to their products (Baines & Lightfoot, 2013) and its use is growing in the international business operations management literature. This differs from the term "servicification" used by GVC scholars, which refers to the increased use of services in the manufacturing or production process.
[18] Refers to the entry and ownership of firms in these sectors by private equity investors with limited industry specific knowledge.

identify when equipment might fail, or parts need to be replaced. Overtime, more frequent measures were recorded, and their transmission increased as telematics improved. Today, sensors capture input on variables from location, temperature, speed, and volume to vibration and even levels of operator awareness. This is transmitted and processed in real-time allowing for both immediate reaction as well as analysis of historic data or 'data at rest' to improve analytical functions. Asset monitoring and PLM account for the majority of industrial digital services applications in operation to date (Lohr, 2016; PTC, 2017). At the same time, access to this operational data provides companies with more precise insights into client operations and behaviors (Jonsson et al., 2008).

Central to increasing the efficacy of monitoring has been the declining cost of sensors (CB Insights, 2018c), data transmission, storage and processing on a global basis (Accenture, 2015), as well as the development of new, more powerful and cost-effective gateway devices. Industrial equipment generates extremely large quantities of data; it is estimated the average oil platform generates 1.2TB of data per day; likewise, in the mining sector, Komatsu's mining equipment fleet generates around 30TB per month (Cloudera, 2018b). The new technologies for data transmission, storage and computing, have enabled more data to be collected and monitored remotely, providing a much more complete picture than just five years ago. Box 3-3 details the technology layers engaged in the deployment of these systems.

Box 3-3. Technology Layers in IIoT

Achieving the IIoT goal of connecting industrial machines to enterprises' information systems and other business processes requires several technology layers. Adding to the complexity, advanced analytics, the key to driving value creation from IIoT, demands even more technology to be incorporated. Definitions of these layers are provided below.

Table 3-7. Technology Layers in the Industrial Internet of Things

	Layer	Description	Select Firms
Predominantly Hardware	**Sensors and Actuators**	Sensors are installed on devices to measure and digitize desired analog variables, such as temperature, speed, location, vibration, awareness, etc. These transmit 'tags' or raw data points including name, value, time, data quality, data type to localized control systems or gateway devices. Actuators receive and implement control signals allowing for remote operations.	Intel, ARM, Cavarium
	Centralized and Distributed Control Systems and Supervisory Control and Data Acquisition (SCADA)	These systems allow for automated machinery and equipment functions onsite. Controls systems can be centralized or distributed and operate onsite, while SCADA enables remote control and connectivity across multiple sites. These technologies are important precursors to IIoT remote control, monitoring and automation.	Siemens, ABB, Honeywell, Rockwell Automation, Yokogawa
	Gateway Devices	These are located between the control systems and the cloud; collect, transmit and receive data. Also provide processing capacity, allowing data analytics to run onsite. Devices must have data center level storage, processing and analytical capacity and thus powerful computing capabilities and must be designed for the remote and rugged conditions in which it operates.	Dell, HPE, Cisco
	Cloud Infrastructure & Data Centers	These provide storage for data at rest. These must allow for significant volumes of data storage and retrieval and must be geographically located to ensure data transmission and storage complies with regulatory requirements.	Amazon Web Services, Microsoft Azure,

			Cloudera, SAP HANA
Predominantly Software	**Cloud Platforms**	Receive data generated from connected devices, sensors, applications, clients, and collaborators, and host applications to process and/or analyze this data to generate responses. Facilitates real-time responses to events identified in data streams.	GE (Predix), Hitachi (Lumada), Siemens (Mindsphere), Bosch IoT, Schneider Electronics (Ecostruxxure)
	Advanced Analytics Applications	Provides new insights and intelligence to optimize decision making significantly and enable intelligent operations leading to transformational business outcomes and social value.	
	Edge Computing Applications	Allows for processing data at its source; users near the equipment receive notifications and performance data without relying on the cloud. With equipment operating in remote locations around the world, this helps improve responsiveness and reduce cost. These analytics, however, do not (yet) directly interact with DCS/SCADA systems and are strictly informative.	Bit Stew Systems (GE), FogHorn, Sight Machine
	Intercloud Processing/ Systems Integration	Connectivity between multiple clouds that allows numerous data streams to be integrated and analyzed. Key for connecting equipment from multiple providers, as well as connecting OT systems with enterprise systems to drive improved analytics for upstream design, production and sales stages of the value chain.	TCS, Infosys, Tech Mahindra, SAP, Siemens, Cisco, Salesforce

Source: Authors; based on Industrial Internet Consortium (2017)

The expansion of remote asset monitoring service agreements in equipment chains, along with IIoT connectivity and analytics has further increased the value that can be derived from these services. Where OEMs were previously able to support customer needs on individual equipment, today, enhanced connectivity, data enrichment and real-time fleet-wide or systemwide analytics, allow OEMs to not only provide preventative or predictive maintenance, but also solutions for optimizing client productivity across their business. This moves OEMs from simply being able to determine when an event might occur, to consider why it occurs and therefore, how to avoid it. This, of course, is of tremendous value to clients. For example, GE Engines observed increased frequency in unscheduled services for its jets; using fleet analytics on multiple airlines, the company was able to determine this was the result of climatic conditions on routes in Asia and the Middle East. This allowed it to advise airlines to introduce specific, low-cost washing operations between flights, which vastly extended the periods between services. Annual airline savings were estimated at US$7 million (Wining, 2016).

While increasing pace, the uptake of digital services and PaaS models in the capital equipment field, nonetheless, is still slow and uneven across industry, region and firm size (Forrester, 2018b; UNCTAD, 2017b), and in practice, digital is used as a means to reduce costs, rather than drive revenue (BCG, 2016). Industrial products lead in terms of adoption; other sectors such as aerospace, medical devices, and utilities/oil & gas continue to have significant market potential (Buntz, 2018; McKinsey & Co., 2017b; PTC, 2017). Larger firms have led IIoT adoption (McKinsey Global Institute, 2017). These firms have greater flexibility to pilot new technologies and the greatest potential for impact due to their economies of scale (PTC, 2017).

Analysis of longitudinal data allows equipment manufacturers to manage risk in their service contracts; allowing them to offer more performance-based contracts (Bakshi et al., 2015; Kim et al., 2007; Porter et al., 2014), products/availability-as-a-service (XaaS), and benchmarking and consulting services. These new service models are detailed in Table 3-8.

Table 3-8. Capital Equipment GVCs Enhanced by Digital Business Models

Model	Description	Role of Digital	Reason for Customer to Contract with OEM
Spare Part Supply & Warranty	Equipment is purchased by customer. Customer purchases spare parts according to their internal schedules.	Analysis of sourcing patterns improves spare part availability and management.	OEM designed and built equipment; expertise & product quality.
After-Sales MRO Services	Equipment is purchased by customer, accompanied with a SLA to provide scheduled maintenance and spare parts for a set period of time.	Analytics of equipment performance indicators increases precision of when maintenance is required, optimized negotiations.	OEM's design and construction competencies provide strong basis for repair knowledge.
Products as a Service (Performance-based contracts)	Equipment use is paid for based on performance; contracts include incentives and fines for availability, revenue payments around product usage and are typically long term in nature.	Analytics of equipment & systemwide performance indicators increase precision of optimal operating parameters, allowing for timely maintenance, operator training, etc.	OEM designed and built equipment, assumed knowledge they are best positioned to optimize operations.
Benchmarking and Performance Consulting	OEM provides advice on how to maximize performance of equipment.	Industry-wide analytics on data gathered across clients.	OEM has insights into equipment operations in a wide range of conditions.

Source: Authors, adapted from Baines and Lightfoot (2013).

The vast amounts of equipment data gathered and enriched is now being used to improve entire value chain operations, creating a 'digital thread' through the GVC. This data is increasingly used to create new services in the design (Baines & Lightfoot, 2013), production and sale segments of the value chains of equipment in addition to post-sales service support. 'Digital twins', that is, digital replicas of the equipment, are created in design, production and performance operations to improve functionality, customize design and enhance existing computer-aided design (CAD) modeling, optimize production cycles and increase sales. Use cases are still relatively limited; one example is One Aviation's design and modeling of aerospace components for the business aviation segment (MIT Sloan Management Review & Deloitte Insights, 2018). In MRO operations, another use case includes field technicians using augmented reality glasses, leveraging these twins, to help them identify problems and solutions faster (Caterpillar, 2015). This also allows OEMs to centralize their scarce, and highly trained personnel in control centers, covering larger geographic areas and more clients. There is a consensus that these and other technologies, particularly increased machine learning and AI will take some time to reach the market.[19]

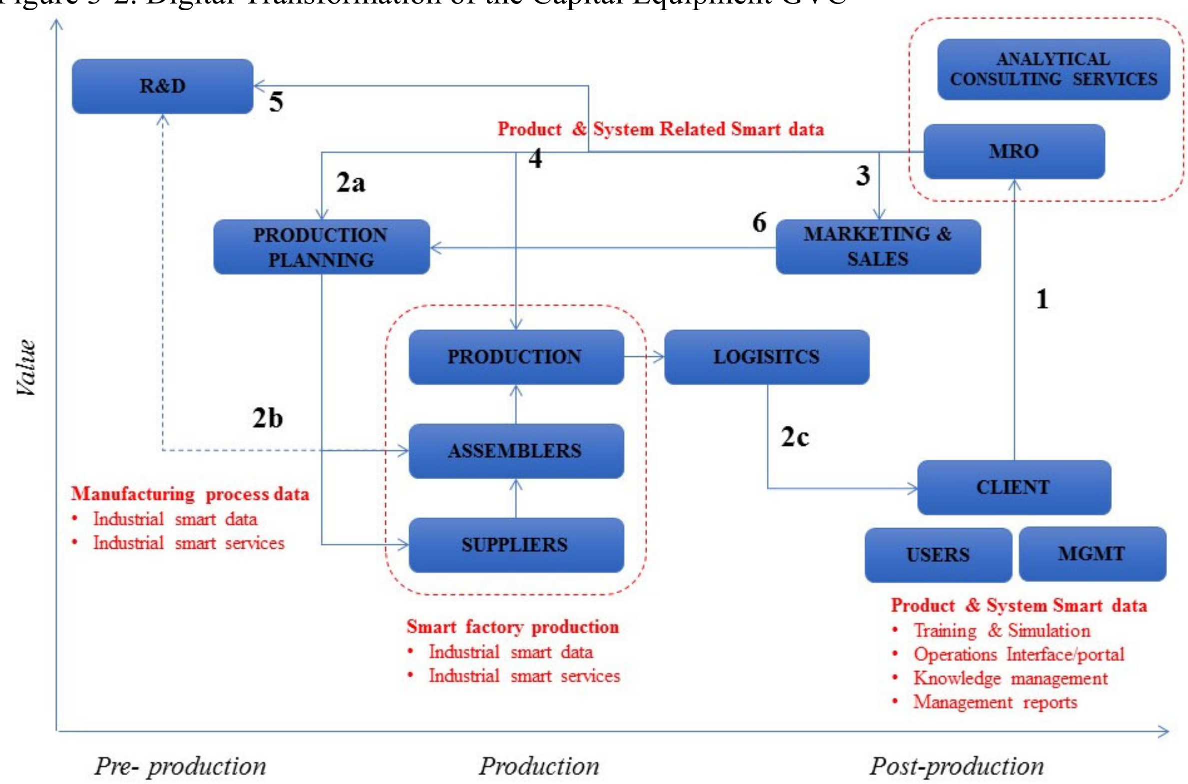
At the same time, this data is integrated across organizations, as operational technologies are connected to enterprise technologies to **drive process and product upgrading**. This 'closes the loop', allowing key performance indicators (KPI) from machines and equipment and sales data

[19] For example, a 2017 interview with Singapore-based Bosch Software Innovations Asia Pacific Regional President gave estimates that some of their projects will take at least two more years to reach market, and up to 1.5-2 years to transfer that knowledge to their clients (EDB Singapore, 2018).

to drive design and production planning, supply chain operations, and HR deployment (Industrial Internet Consortium, 2017; MIT Sloan Management Review & Deloitte Insights, 2018).

In R&D and design stages, increased data availability and the ability to fully leverage CAD (and 3D Printing) to build and test prototypes is contributing to a reduction in R&D spending and its costs vis-à-vis other stages of the chain (CB Insights, 2018d). In production planning, Tier 1 suppliers have visibility into OEM's procurement systems; as these are enhanced automatically by data flowing from operations and sales, these suppliers can refine their response, creating efficiencies through the supply chain (Baines & Lightfoot, 2013). This has created additional digital services, provided either in-house or by external suppliers. SAP HANA cloud platform and software, for example, already has a broad base of capabilities linking enterprise data with operational data from equipment; combined these closed loop systems can be automated to maximize potential sources of value within organizations. This process upgrading means companies can spend more time innovating new products (*product upgrading*) and focusing on customer needs than coordinating firm resources. Figure 3-2 illustrates where digital services are being integrated into the value chains of capital equipment OEMs.

Figure 3-2. Digital Transformation of the Capital Equipment GVC



Source: Authors
Notes: Digital Feedback Loops
1 Asset management, predictive maintenance, standard and advanced SLA
2 Inventory management and spare parts supply; (a,b,c) transparency of demand across supply chain
3 KPI & customer value drivers inform sales
4 Quality management
5 Improved design and engineering based on KPI across fleet (compare real and digital twin outcomes)
6 Sales order drives production planning.

4. Lead Firms and Company Case Studies

This section analyzes the key factors for creation, development and growth in the digital economy using examples from company cases. It looks at key factors for starting the business and growing into new products and end markets, including collaboration (inter-industry, supply chain, national/international), SMEs as a source of innovation and technology (acquisitions and investments), R&D investment and workforce skills/availability, and innovation environment (location). Key characteristics of firms leading the way in the digital economy are in Table 4-1.

Table 4-1. Characteristics of Lead Firms in the Digital Economy

1	**R&D spending** as a share of revenue is higher; for industrials, there has been a general upward trend in R&D intensity since 2011. Firms are investing in **workforce development** to expand digital skills. Workforce largely in computer science, engineering, and analytics; makes up significant share of positions on career websites.
2	M&A activity to achieve greater diversity (products and markets); M&A still mostly in the US and most popular in the software and Internet software and services segments. Industrials, both integrators and discrete manufacturers have also relied on **major acquisitions to drive capability development** in digital from connectivity, visualization and planning to analytics and cybersecurity.
3	Firms have **Corporate Venture Capital** arms or have created start-up funds. Global MNEs **create incubators and start-up programs** for entrepreneurs globally
4a	**Collaboration** with firms from different industries is common and important Significant VC from non-tech companies IT occupation data shows that workers in the digital economy are in many different types of companies and industries. For example, there are approximately 4 million digital workers in the United States (based on ONET data, 2017), however only 37% are employed in digital companies.
4b	Collaboration with firms in different digital sectors is common and important (particularly due to the need for interoperability)
4c	Evidence for both: Digital MNEs are the glue; convene stakeholders, with many holding annual conferences organized by geography and topical area. Many digital economy companies were started by former employees of existing technology firms.

Source: Authors

The agents of change are not the incumbent firms but a combination of new start-ups providing new digital technologies, suppliers who embrace digital opportunities to move up the value chain, and customers who are not just on the receiving end of a product or service but are actively co-creating it (UNCTAD, 2017a). Many of the large incumbent firms were established decades ago as electronics hardware or operating software firms. These companies build their digital portfolio of IP and domain expertise (1) organically (i.e., through **human capital**) and represented in part by **R&D expenses**, (2) through **M&A activity** and (3) investments in start-ups or (4) via **joint innovation with partners** to help expand reach. Other forms of **collaboration** among firms in different industries and segments of the digital economy is also a critical element. These are key factors to compare among firms in terms of entry and upgrading in the digital economy.

4.1. Internal Workforce Development and R&D Spending

In markets where new products are frequently launched, R&D investment is important. For example, a large software company can obtain intellectual property by acquiring the company that originally generated it (such as Google's purchase of Android Inc. or Oracle's acquisition of Java technology in its takeover of Sun Microsystems). This strategy often requires significant funds (MarketLine, 2017d).

Table 4-2. Digital Firms and Industrials, R&D Expenses and Locations, 2017

Segment	Company	R&D Value (US$B)	Share of Revenue	R&D Arm, Labs, Locations
Software	Citrix	$0.42	15%	R&D: India (Bangalore)
	Red Hat	$0.48	20%	Open Innovation Labs (Singapore, UK, Boston)
	Salesforce	$1.6, FY18	15%	US, Europe (>80% of employment)
	Oracle	$6.2	16%	Oracle Labs, 2010 (prior Sun Microsystems Labs)
	SAP	$3.8	14%	Global Labs: 20 (**India**, 2)
	Microsoft	$13	14%	Microsoft Research Lab, 1991
	SAS	$0.8	26%	--
	Kakao Corporation	$0.2	12%	R&D Center, 2010; Media Research Institute, 1995
IT Services	IBM	$5.8	7%	THINKLab, 2014, 12 Research Labs (China, India, Japan, Israel)
	Samsung SDS	$0.12	1.4%	Three: IT Research Institute, 1985, Pangyo Campus, Seoul R&D Campus
	Infosys	$0.03	0.3%	--
	TCS	--	--	Academic COIN, 2010 Digital Re-Imagination Studio, CA, US, 2016
	Wipro	--	--	Wipro Digital, UK, digital business unit, collaborates with clients to deliver customer-centered digital transformation.
ISS Platforms	Alphabet/Google	$16.6	15%	X, 2010 The Garage, 2008 AI Center, 2017, China
	Baidu	$2.0	15%	Baidu Research, 5 labs (US)
	Naver Corporation	$1.0	24%	Naver Labs, 2013
	Amazon	≤ $22.6	13%	Lab 126, 2004, CA, USA
	Alibaba Group	$2.5	11%	--
	Tencent Holdings	$2.8	8%	Tencent AI Lab, 2016
Industrials: Integrators	ABB		4%	ABB Ability Innovation Center, Bangalore, India; Collaborative Operational Center (Shanghai, China), IIoT Center, Singapore
	Bosch		9%	IIoT Center, Singapore; Bosch Software Innovations R&D Center, Germany
	General Electric		5%	Predix app developers, digital foundry, China
	Honeywell		5%	Software development center, Atlanta, GA US (2016)
	Hitachi		3%	--
	Siemens		6%	Asia Pacific Digital Experience Center R&D (China)
Industrials: Discrete	Caterpillar		4%	India Engineering Design Center (900 engineers); R&D Center (China)
	Komatsu		3%	Smart Services Centers (near customers): Australia, Chile, South Africa
	Rolls Royce		9%	R2 Data Labs, 2018: Analytics Division Innovation & Service Centers (UK, US, Singapore, India, New Zealand)

Source: Authors; data from annual reports, websites, market reports; R&D values are FY17 unless otherwise noted.

Directly Hiring New Talent: Consistent with their stated goals to become software-driven companies, many of the industrial integrators have committed to significant in-house development of digital services capabilities. While it is generally common for innovation to remain in-house, this also reflects a commitment for digital services to become core competencies of these firms. GE and Siemens, for example, launched aggressive recruitment campaigns to hire thousands of software developers each; by December 2017, Siemens employed 24,500 software engineers (Busch, 2017), while Bosch employed 15,000, with 3,000 focused on IoT issues alone.

Box 4-1. GE's Digital Transformation: A New Approach to Human Capital Recruitment

As part of General Electric's efforts to transform to a digital company, the firm made several key changes to its human resources practices. First, it attracted experienced tech managers and tasked them with recruiting human capital from the tech field, arguing, "you have to speak the same language". Second, it geographically located its software division charged with developing Predix to San Ramon, just outside of Silicon Valley to tap into their labor pool. Similarly, it relocated its GE headquarters to Boston to tap into the city's emerging engineering talent. The San Ramon center employed 1,700 developers by 2016. Third, they adjusted their compensation packages including bonuses and equity to be more aligned with the benefits offered by other firms in the area; these benefits are not typically seen in the industrials segment. According to a Glassdoor survey in 2016, senior software engineers at GE were making the same as those at IBM – and more than SAP and Oracle. Fourth, it launched a marketing campaign to illustrate the company's shift into industrial analytics, spotlighting the role for young, motivated software developers and engineers. Finally, it began hosting conferences for software developers in Las Vegas and launched the Digital Foundry to help app developers get started on Predix. These are considered standard for IT service firms, but not for industrials.

Sources: Boulton (2017); Lohr (2016); Lyons (2017); Mann (2016)

These firms generally followed similar strategies of establishing separate subsidiaries to grow their software and digital operations. Siemens Software, Bosch Software Innovations and Honeywell Technology Solutions are all examples of this. Siemens hired an external American company to run next47, an internal incubator supporting its IIoT efforts (The Economist, 2016). While there are multiple reasons for doing so, one stands out: organizational culture. By separating these functions from the broader organization, sometimes even geographically, industrial firms shielded these units from being stifled by their predominant corporate culture (The Economist, 2016).

Discrete manufacturers have also hired new talent for analytics roles, although the importance placed on these divisions differs across firms and sectors. Some, including all leading aerospace firms as well as a host of mining equipment manufacturers,[20] have recently created specific divisions dedicated to data analysis, hired Chief Analytics, Digital or Data Officers or enhanced

[20] These include GE Aviation, Pratt & Whitney and Rolls-Royce as the world's leading jet engine suppliers, as well as the four major integrators, Airbus, Boeing, Bombardier and Embraer. Mining equipment companies advancing in this area include Caterpillar, FLSmith, Metso and Atlas Copco. Oil and gas equipment manufacturers have been less proactive in establishing these roles. Hitachi supports its rolling stock programs through the Lumada platform and services from Hitachi Vantara.

their Chief Information Officer role to drive their analytics initiatives (Gartner, 2018). These roles have drawn on talent from both consulting and IT services, such as Accenture and Cisco.[21]

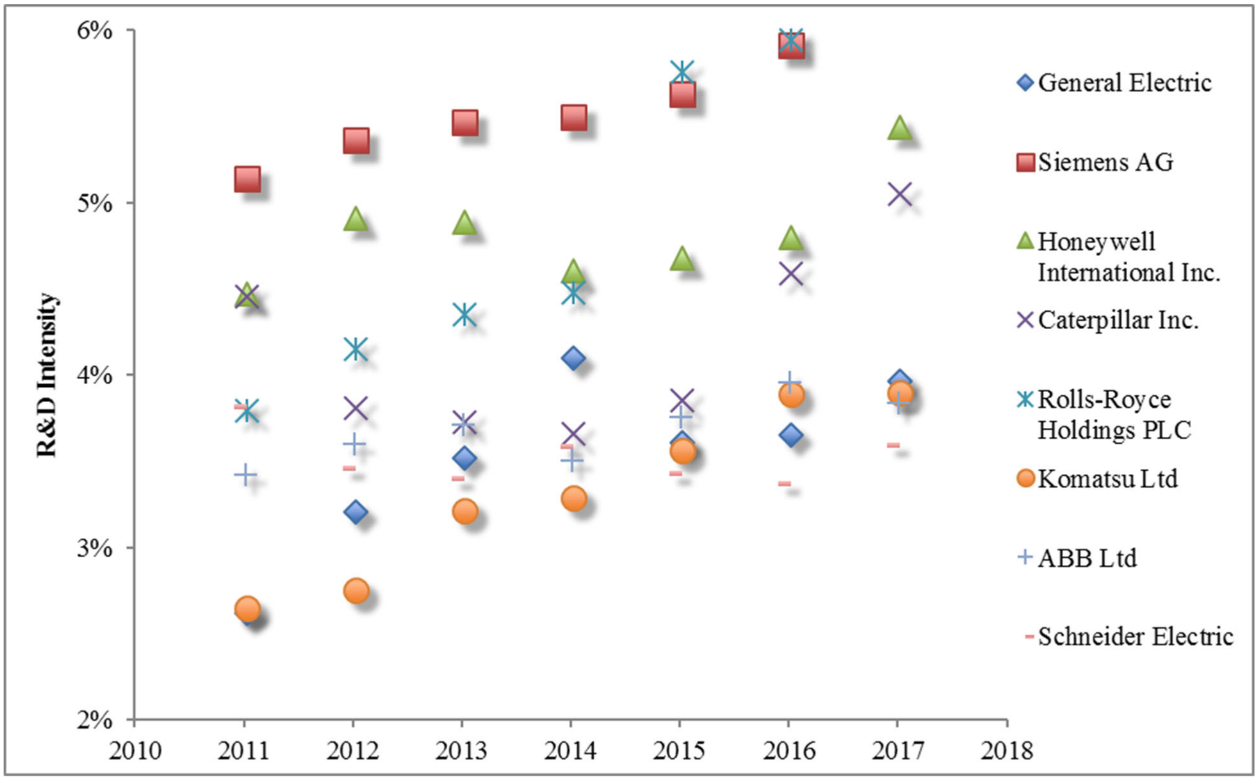
Outsourcing is primarily seen amongst discrete manufacturers in connectivity and the development of their software stack, while analytics skills are being grown internally, reflecting the firm's priorities as core competencies. Firms that are relatively new to smart, connected equipment have outsourced the development of these capabilities to catch-up with peers.[22]

Another driver of outsourcing and offshoring are skill shortages, particularly for complex data analytics, where respondents anticipated extreme difficulty in attracting, retaining and affording the relevant in-house talent (Siemens, 2018b). In software and IT services, **Asia Pacific employment** accounts for at least 15% of employment across firms. **India** accounts for the largest share (except Kakao and Samsung SDS), ranging from at least 5% of employment up to 30% for non-Indian firms. For the industrials, Asia accounts for 13% to 32% for non-Asian based firms. India is also the primary offshore location for these firms, followed by China.

There has also been a strong drive towards **internal innovation and R&D**. Since 2011, there has been a general upward trend in R&D intensity amongst the industrial firms analyzed (Figure 4-1), which coincides with their increasing focus on digital transformation. While specific figures are not available for industrials, recent estimates suggest that one in every two new innovation centers (since October 2016) are focused on some aspect of digital transformation (Capgemini Digital Transformation Institute, 2017).[23]

Figure 4-1. R&D Intensity (R&D Spending/Total Revenue), Select Firms, 2011-17

[21] Caterpillar's first Chief Analytics Officer, Morgan Vawter was the Lead at Accenture's Digital Data Management and Analytics Practice, while Neil Crockett had approximately 15 years in management roles at Cisco prior to joining Rolls Royce to launch R2 Data Labs.
[22] JCB, a leading competitor of Caterpillar and Komatsu, contracted Wipro to provide turnkey IoT operations, initially connecting its Indian fleet, and then expanding to its global fleet (Wipro, 2018a). Several manufacturers such as Rolls Royce and Komatsu that carried out activities in-house in the past, have leveraged the capabilities of Cloudera, TCS and cloud providers such as Microsoft Azure to centralize previously isolated data sources (Cloudera, 2018b; Rolls-Royce, 2017), increasing their potential to drive analytics.
[23] In 2017, Siemens spent US$1.4 billion on R&D in digital business (Busch, 2017). In January 2018, Bosch opened an R&D center in Berlin as home to its global Bosch Software Innovation headquarters; IIoT connectivity is central to the US$380 million research campus goals. GE spent over US$1 billion setting up its San Ramon development center. Digital innovation and analytics has been a core focus of Caterpillar's US$2B R&D budget over the past five years (Caterpillar, 2018).



Source: Authors, based on PwC (2018).

Digital firms **spend a significant amount on R&D** in terms of overall R&D dollars spent and based on the ratio of R&D spending to revenue. The PwC [2018 Global Innovation 1000] looks at R&D spending of public companies. The Global Innovation 1000 companies collectively account for 40% of the world's R&D spending, from all sources, including corporate and government sources. In 2017, there were 125 companies in the digital economy, representing 13% of firms in the study (1,000 total).[24] These firms accounted for 16% of overall R&D spending and only 6% of revenue. In comparison, industrials accounted for 16% of firms and revenue, but only 12% of the R&D total. **Digital firms spend more on R&D as a share of revenue** than industrials and the average of all firms (12% compared to 3% and 4% respectively) (PwC, 2018). Industrials (except Germany) spend less on R&D as a share of revenue than the average of all firms.

Table 4-3. Total, Digital Economy and Industrial Revenue and R&D, 2012 and 2017

Variable	2012	2017	Change
Total Firms	965	1,000	4%
R&D Total	$513	$702	37%
Revenue Total	$14,863	$15,640	5%
R&D as a Share of Revenue Total	3%	4%	--
Average R&D/Firm	$0.53	$0.70	32%
Average Revenue/Firm	$15.40	$15.64	2%
Digital Firms	115	125	9%

[24] Relevant industries in the PwC Global Innovation 1000 representing the digital economy include (1) Web Portals/ISP, (2) Internet and Direct Marketing Retail, (3) ISS, (4) IT Services and (5) Software. This covers all the ISS industry groups and all but one company in Retailing.

Variable	2012	2017	Change
R&D Digital	$60	$111	84%
Revenue Digital	$552	$920	67%
R&D as a Share of Revenue Digital	11%	12%	--
Digital's Share of R&D	12%	16%	35%
Digital's Share of Revenue	4%	6%	58%
Average R&D/Firm Digital	$0.5	$0.9	70%
Average Revenue/Firm Digital	$4.8	$7.4	53%
Industrial Firms	153	156	2%
R&D Industrial	$67	$82	23%
Revenue Industrial	$2,132	$2,529	19%
R&D as a Share of Revenue Industrial	3%	3%	--
Industrial's Share of R&D	13%	12%	-10%
Industrial's Share of Revenue	14%	16%	13%
Average R&D/Firm Industrial	$0.4	$0.5	20%
Average Revenue/Firm Industrial	$13.9	$16.1	16%

Source: PwC (2018). Values in US$, billions. Note: Firm count in 2012 based on firms with data available in 2012 that were also included in 2017. Industrials: Industry sector (industrials)/industry group (capital goods); 156 companies; includes all companies in capital goods and 156/163 in the industrials industry sector.

4.2. Mergers and Acquisitions

M&A activity is significant and acquisition deals in tech are some of the largest, with many valued over US$1 billion every year. Acquisitions are most common among software companies. The value of acquisitions is difficult to obtain, and the values below generally only represent 25-30% of the values of firms acquired for each company. Nevertheless, there are four companies that clearly have more acquisition activity than others: Oracle, Microsoft, IBM and Google. These four firms have acquired over 700 companies alone in the last two decades. In comparison, four large industrials (ABB, GE, Honeywell and Siemens) have only acquired around 200 companies. This shows that even if all digital companies are actively acquiring firms, the importance of acquiring companies to enhance capabilities is more common in digital than non-digital firms. Furthermore, acquisition activity by industrials has increased in the last five years as these firms seek to gain digital capabilities.

Table 4-4. Digital Firm & Industrials Acquisitions, Count and Value

Segment	Company	Acquisition Avg. Count	Acquisition Count	Value (US$)	Years & Notes
Software	Citrix	43	42-45	$2B	
	Red Hat	25	19-30	$5B	
	Salesforce	53	53	$17B	
	Oracle	**135**	**133-137**	**>$71B**	41/133 have value
	SAP	37	37	$33B	
	Microsoft	**212**	**177-248**	**>$79B**	**Seven >$1B 70/248 have value**
	SAS	12	9-15	--	2000-2012
	Kakao Corporation	7	7		
IT Services	**IBM**	**166**	**166**	**>$41B**	44/166 values (S&P)
	Samsung SDS	6	6		--
	Infosys	9	9	$1B	2011-2018
	TCS	7	7	$11M	2012-18 5 Asia; 2 Europe
	Wipro	14	14	$2B	2003-18

Segment	Company	Acquisition Avg. Count	Acquisition Count	Value (US$)	Years & Notes
					6 N. America; 2 Asia
ISS	**Alphabet/Google**	**200+**	**200+**	**>$34B**	**43/200 have value**
	Naver Corporation	15	15		
	Baidu	13	10-17	$4B	2004-2017; 6/16 value
	Amazon	60	59-78	$22B	27/78 value
	Alibaba Group	27	21-34	$12B	
	Tencent Holdings	6	5-7	$9-14B	
Industrials: Integrators	ABB		19	--	4 of 19 digital
	Bosch				
	GE		55	$31B	
	Hitachi		18	$2B	6 Asia; at least 2 digital
	Honeywell		28	$13B	1 Asia, $338M, 2011, not digital
	Siemens		82	$17B	1998-2018 6 Asia (≤ 2009)
Discrete Manufacturers	Caterpillar		2	--	2010 & 2017
	Komatsu		2	$4B	N. America
	Rolls Royce		2	--	2013 & 2017

Source: Authors; data from CBI and S&P.

Both integrators and discrete manufacturers have relied on **major acquisitions to drive capability development** in digital from connectivity, visualization and planning to analytics and cybersecurity. Siemens and GE again feature as the largest spenders, alongside Honeywell. Siemens has reportedly spent some US$10 billion on software acquisitions (Buntz, 2017), with two significant purchases to help develop the Mindsphere digital thread services: Mentor Graphics and CD-adapco for US$4.5B and US$0.97B respectively. Mentor Graphics was the second largest acquisition the firm has made in the last two decades, trailing only the US$7.7B acquisition of Dresser-Rand equipment manufacturer.

Acquisitions are not common for discrete manufacturers—each only had two. Caterpillar, while not betting as big as its larger peers, also made a major acquisition with the 2015 purchase of ESRG Technologies. A remote asset monitoring and analytics firm in the marine sector, this acquisition boosted capabilities in remote telematics and analysis (Grayson, 2015).

4.3. Start-ups, Venture Capital and Investments

In addition to acquiring firms, it is common for digital companies to invest in start-ups and many have entire Corporate Venture Capital (CVC) divisions or subsidiaries. CVC is a growing share of the overall VC market.[25] CVC represented 20% of all VC activity in 2017. Globally, 546 CVCs around the world participated in 1,791 global deals worth $31.2B in funding throughout 2017 (CB Insights, 2018a). In 2013, by comparison, there were 989 deals for $9.9B.

An increasing share of "non-tech" companies are investing in tech start-ups. Even though tech or telecom companies only account for 12% of the Fortune 500 companies, they have historically

[25] Overall VC deals include venture capital, corporate venture, growth equity, and super angel investments, whereas CVC deals only include corporate venture.

been responsible for most investment activity in tech companies (CB Insights, 2017b). However, tech investments by non-tech corporations are on pace to surpass that of tech corporations for the first time. In 2017, 51% of Fortune 500 investments into private tech companies have come from non-tech corporations, up from 29% in 2014.

While investment activity is growing in Asia, it is still nascent in Korea. Since 2012, VC-backed Asia tech startups have raised $106 billion across more than 5,000 deals (CB Insights, 2017a). Overall, activity in Korea has been less active, although it is growing. Based on a deal search in CBI for June 1, 1998-June 1, 2018, there were $6.8 billion and 860 deals in Internet, Mobile or Software. This represented 60% of overall deal value and 70% of deals. All occurred since 2008, while most were in the last three years. The top investor was Kakao.

Based on the CBI data, the digital economy had over 100,000 financings and a total value of US$931.6 billion (not including IT services) and 27,000 exits. There are three main sectors related to the digital economy in data provided by CB Insights. Internet is by far the largest sector for deals across all categories (number of financings, value and exits). Over the last 20 years, the total finance value was US$541 billion with 16,426 exits.

Internet platform companies are the most significant VC investors, however Naver and Kakao is in the bottom group of investors with less than $1 billion. Whereas Kakao is considered a software company based on its industrial classification, its activities are more aligned with Internet platform companies. In 2017, Kakao Ventures was the ninth-most active CVC globally and appears to be focused on artificial intelligence.

There are various types of **incubator models**. Some firms set up their own programs, others partner with local start-up programs, and others partner directly with local start-ups. AWS is an example of local start-up partnerships. It entered China through a partnership with DreamT incubator, a newly established organization that works closely with local governments in Shanghai, Beijing, and Chongqing. DreamT is run and managed by an independent entrepreneurial team, with some government support and incentives. As such, the effort is aligned with the Chinese government's priority to support entrepreneurship and it does not require the MNE to build the support infrastructure from scratch (Prashantham & Yip, 2017). In other locations Amazon works with a group called TechStars.

Company cases: VC Investment Groups

The values represent the total value of the investment rounds the companies participated in (not just the value invested by the company profiled).
Group 1: >$10B: Tencent, Alibaba, Google, Baidu
Group 2: >$4-10B: Salesforce, SAP, Microsoft (GE and Siemens, but not just digital)
Group 3: $1-4B: Oracle, IBM, Amazon
Group 4: < $1B: Kakao, Citrix, Red Hat, Naver, SAS (Industrials, except GE & Siemens)

Table 4-5 lists investments made by each of the profiled firms. It includes activity by the firm itself as well as any VC subsidiaries or incubator/start-up programs (marked with **).
Table 4-5. Digital and Industrial Firm Investments, Count and Value

Segment	Investor, Year Established, Fund Size (US$)	Financings			Global CVC [a]	Asia Tech [b]
		Count, Years	Round Value	Total Value	Rank	Rank
Software	Citrix Systems Citrix Start-up Accelerator, 2011**	34, 2000-2018 52, 2011-2017	$320.4M $17.9M	< $400M		
Software	Red Hat Red Hat Ventures, 2000-not operational	20, 1999-2018 --	$458.1M --	< $500M		
Software	Salesforce Salesforce Ventures, 2009 Salesforce Accelerate, (called Incubator in 2016-17), 2016**	4, 2010-2016 339, 2007-2018 4, 2018 29, 2016-2017	$2.9M $6B $0 $0	$6B	3	13
Software	Oracle Oracle Scaleup Oracle Startup Cloud Accelerator, 2016, 9 locations (India, 3; Singapore, Israel, Brazil)** Past: Oracle Ventures, 1999	57, 1998-2018 2, 2018 81, 2016-2018 --	$1.8B $0 $0 --	$2B		
Software	SAP Sapphire Ventures, 1996[26]	5, 2008-2016 230, 1998-2018	$68M $6.7B	$7B		
Software	Microsoft Microsoft Scaleup (Accelerator)** M12, 2016/18, former Microsoft Ventures Microsoft for Start-ups, 7 Reactors**	114, 1995-2018 449, 2012-2018 77, 2016-2018 --	$7.1B $14.5M $1.4B --	$9B	MV, 7	
Software	SAS	1, 2000	$45M	$45M		
IT Services	IBM IBM VC Group (IBM Ventures, 2000) IBM Alpha Zone, 2014**	7, 1997-2017 23, 1998-2018 --	$165M $893.5M --	$1B		
IT Services	Samsung Ventures, 1999 [27] Samsung SDS	219, 1998-2018 1, 2018	$5.2B $0	$5B	SV, 10	
IT Services	Infosys Infosys Innovation Fund, 2015, ($500M)	8, 2000-2018 11, 2015-2018	$158M $51M	$210M		
IT Services	Tata Consultancy Services COIN EmTech Program, 2010** No VC arm	2, 1999 & 2015 -- --	$42M	$42M		
IT Services	Wipro Wipro Ventures, 2015, ($100M)	8, 2013-2018 21, 2015-2018	$67M $307M	$375M		
ISS	CapitalG, Google Capital, 2013 Google Ventures (GV), 2009 Alphabet Google Google Campus, 2012**	51, 2013-2018 647, 2009-2018 4, 2017-2018 71, 2001-2018 --	$9.3B $16.1B $965M $6.4B --	**$33B+**	GV, 1	
ISS	Amazon Amazon Alexa Fund, 2015 Alexa Accelerator, 2017 (Seattle)**	67, 1998-2018 54, 2015-2018 20, 2017-2018, Seed	$3.1B $945.9M $2.4M	$4B+		
ISS	Alibaba Group Alibaba Entrepreneurs Fund, 2015**	151, 2010-2018 29, 2016-2018 59, 2013-2018	$33.1B $442M $8.28B	**$42B+**		13

26 SAP Ventures, 1996-2011, spun-off; rebranded as Sapphire in 2014. Sapphire Ventures is no longer entirely owned by SAP but is closely connected and is included with SAP's total.

27 SVIC 31st New Technology Investment Cooperative is an investment cooperative that SDS holds 99% ownership; value 6.9B won in 2017. Is under a company called Samsung Venture Investment Corporation (SVIC). Issue funds each year. SVIC 31: August 2015, 10B won, 5-year.

Segment	Investor, Year Established, Fund Size (US$)	Financings			Global CVC [a]	Asia Tech [b]
		Count, Years	**Round Value**	**Total Value**	**Rank**	**Rank**
	Ant Financial Services Group[28] Create@Alibaba, 2016 (China)**	3, 2017, Biz Plan	$0			
	Tencent Holdings Tencent AI Accelerator, 2017**	398, 2008-2018 25, 2017	$61.5B $0	**$62B+**		1
	Baidu Ventures, 2016 (early) Baidu Capital, 2017 Baidu (late stage)	73, 2016-2018 4, 2017-2018 50, 2010-2018	$1.5B $1.6B $7.6B	**$10B+**		10
	Kakao Ventures, 2012[29] Kakao Investment, 2014[30] Kakao Corporation Kakao Mobility	81, 2012-2018 2, 2018 11, 2015-2018 3, 2017-2018	$133.5M $1.8M $61.6M $14.5M	< $300M	KV, 9	
	Naver Corporation Naver Ventures, 2013 Naver D2 Startup Factory, 2015** Springcamp Space Green, 2017 (France)**	24, 2013-2018 9, 2016-2018 24, 2015-18, Seed 22, 2017-18, Seed --	$375.4M $111.8M $0 $3.21M --	$500M		
Industrials: Integrators	ABB ABB Technologies Ventures, 2009	3, 2000-2011 34, 2008-2018	$98M $483M	$581M		
	Bosch Robert Bosch VC, 2007, US$150M	-- 81, 2008-2018	-- $939M	$1B		
	General Electric GE Ventures, 2013, $150-$200 (Annual) GE Digital	135, 1998-2018 202, 2008-2018 1, 2017	$5B $4B $2M	$9B	GEV, 5	13
	Hitachi Hitachi Ventures Catalyst Fund, 2000 Hitachi High-Technologies Corp.	19, 2000-2018 -- 2, 2017-2018	$1.4B -- $11.2M	$1.4B		
	Honeywell Honeywell Ventures, 2017, US$100M	7, 2000-2015 4, 2017-2018	$134M $83M	$217M		
	Siemens next47[31] Siemens Ventures, 1999, US$100M Industry of the Future Fund, 2014, US$1.1B, 2018 (not in CBI)	31, 1996-2018 243, 1998-2018 12, 2001-2018 --	$702M $3.9B $9M --	$5B		
Industrial: Discrete	Caterpillar Caterpillar Ventures, 2015 Caterpillar Financial	9, 2000-2017 13, 2015-2018 2, 2010-2011	$133M $193M $200M	$525M		
	Komatsu only (No VC arm)	1, 2015	$0	$0		
	Rolls Royce only (No VC arm)	2, 2018	$37M	$37M		

Source: CB Insights, Deal Search, Investment Stage (all included, but above table does not include exits or other), all dates. Search dates: October 10, 12, 2018. Stages: Convertible Note, Seed/Angel, Series A, Series B, Series C, Series D, Series E+, Private Equity, Growth Equity, Debt, Grant, Other Venture Capital, Other, M&A, IPO, Dead. (a) Global CVC 2017 Rank (CB Insights, 2018a); (b) CVC-Backed Asia Tech Investments, 2017 Rank (CB Insights, 2017a). Final column with companies: Select Investments in IIoT Start-Ups; based on CB Insights Deal Search.

[28] Alibaba Capital Partners, 2008 (not in CB Insights, but have listed as a VC)
[29] K Cube Ventures: 2012-18 (Feb.); Kakao Ventures since March 2018.
[30] K Venture Group: 2014 (Dec)-2017 (March); Kakao Investment: 2017 (April)-present.
[31] Siemens Ventures was renamed next47.

Software and IT Services: Infosys, Wipro and TCS are all also investing in analytics firms to support their IIoT ambitions. Infosys launched a US$500 million fund (2013), while Wipro had a US$100M fund in 2014 (Agarwal, 2017).

Industrial firms have also tapped into the start-up world to gain access to new digital and software technologies by launching targeted VC funds. Industrial IoT funding of start-ups grew from US$208 million in 2011 to US$1.2 billion in 2015, accounting for one-third of all IoT spending (CB Insights, 2018c). Industrial firms are key players. In 2014, Siemens launched a US$100 million Industry of the Future Fund specifically focused on young start-ups in the digitization field (Siemens, 2014). GE Ventures has been the most active investor in IIoT in the past five years, with 51 IIoT deals and investments in companies such as Sight Machine (data analysis for heavy industry) and Rethink Robotics (warehouse automatization). Nonetheless, start-up activity is in its early stages, most funding is in early round investments (39% seed; 24% Series A) and there have been comparatively few exits or acquisitions (16%, 124/776).

The start-up activity fostering much of the innovative systems development in IIoT, however, is distributed quite differently around the world. Using CB Insights database on VC investments in IIoT start-ups, the US exceeds all other locations, accounting for approximately two-thirds of all firms. This is followed by India (5%); Canada (4%); Israel, UK, France and Germany (3%); China, Japan, Australia and the Netherlands with 2%. **Korea registered just one firm.**

US dominance in start-ups is even more pronounced when deal activity is considered, accounting for 70% of all IIoT start-up deals. China leads in terms of average deal size of investment in its start-ups with US$27M, more than double all other countries except France (Table 4-6) (CB Insights, 2018c). Chinese deal size is consistent with the broader trend of large venture investments; however, their participation in terms of numbers of deals in IIoT is much smaller compared to the broader digital services category (Fannin, 2018).

Table 4-6. IIoT Start-Up Investment Activity, by Country, 2009-2018

Country	Share of Deals	Avg. Deal Size (US$, M)	Median (US$, M)
United States	69%	9.87	5
India	3%	8.08	4
Canada	3%	5.79	3
Israel	3%	11.2	8
Germany	3%	8.89	6.7
United Kingdom	3%	9.05	4
China	3%	26.6	12.1
France	2%	17.2	3.56
Australia	1%	2.34	0.6
Japan	1%	7.18	6.72
Total	**91%**		

Source: CB Insights (2018c), IIoT Landscape, downloaded June 6, 2018. Investment rounds included: Seed, Series A-E+, Private Equity, and Convertible Note.

4.4. Collaborations

Inter-industry collaboration: An increasing share of non-tech companies are investing in tech start-ups. Tech investments by non-tech corporations are on pace to surpass those of tech corporations for the first time in 2018 (51% of Fortune 500 investments into private tech companies have come from non-tech corporations in 2017 YTD, up from 29% in 2014) (CB Insights, 2017b).

Collaborating with companies in different industries is common and important to digital MNE development. Digital MNEs are often **conveners of key stakeholders**; several hold an annual conference and organize other events for specific geographic and/or topical areas. This increases awareness of the company and provides opportunities for collaboration. Google, Amazon, IBM, Red Hat and Salesforce among others all hold an annual event. Among Korean firms, Naver also holds such an event. IT service firms are not conveners.

Table 4-7. Digital Firm and Industrials Collaborations and Events

Segment	Firm	Software & IT	ISS/Platform/Cloud	Hardware	Buyers/ Industrials	Event
Software	Citrix	Microsoft, TCS (2003)	AWS, Google Cloud	Cisco	Samsung	Citrix Synergy, < 2017
	Salesforce	IBM	Google	Cisco		Dreamforce, 2003
	Microsoft	SAP, IBM, Capgemini	Sigfox, Flipkart, NetApp, China Standard Software		GE, Samsung, BMW,	Microsoft Ignite, 1993
	SAS	Accenture, IBM, Oracle, CapGemini	Cloudera, EMC, Hortonworks, GoPivotal, Teradata	Cisco, Intel, HP	Deloitte, E&Y	SAS Global Forum
	Oracle	Accenture	Tencent,		GE	Oracle OpenWorld, 1998
	SAP	SAS, Microsoft, IBM, Accenture	IIC, 2015		IIoT: Siemens, Bosch	Sapphire Now & ASUG May
	Red Hat	Accenture, IBM, TCS, Wipro	Amazon (2017), IBM	Intel, Cisco	Lotte Data Comm (Korea), Lenovo	Red Hat Summit
	Kakao		Tencent			
IT Services	IBM	Salesforce, Microsoft, TCS JV (1993)	Cisco,		Lotte Group, Whirlpool, Pfizer	Think, 2018 (at least)
	Samsung SDS	Microsoft				
	Infosys		IIC, 2015		GE Digital, 2015; Siemens, 2018; Hitachi	
	TCS	IBM, 1993 (JV)	Cloudera, 2014 IIC, 2014		Rolls Royce, 2017; Siemens, 2017; GE, 2016 Bosch, Hitachi	
	Wipro	SAP	IIC, 2017		Bosch, Hitachi, GE Digital, JCB	
ISS/platform	Alphabet/ Google	Salesforce				Google I/O, 2008
	Naver		Gohere (hotel reservations), Fusiondata (cloud)			Deview, 2006

Segment	Firm	Software & IT	ISS/Platform/Cloud	Hardware	Buyers/ Industrials	Event
	Baidu	Microsoft, Nvidia	Alibaba (via AutoNavi), Tencent, JD.com, Rakuten (Japan, e-commerce)	Google invested ($5M)	Autonomous Vehicles Bosch, Hyundai, Samsung (via Harman), TomTom, Xiaomi	
	Alibaba	SAP, Accenture, Nvidia (2016)	SK Holdings, SoftBank			Alibaba Cloud Summit Infinity: Singapore Computing Conference: China
	Amazon	RedHat (2017)			Ford,	Re:Invent, 2012
	Tencent					
Industrials: Integrators & Discrete Manufacturers	ABB	IBM, Salesforce				
	Bosch	IBM	Alibaba IIC member	Cisco	GE Digital, ABB & LG (smart homes)	Bosch Connected World, Feb.
	General Electric					Minds + Machines, Oct.
	Honeywell	TCS, Oracle, SAP	IIC member		IRootech (China)	Honeywell Connect Nov.
	Hitachi		IIC member			Hitachi NEXT Sept. (2017)
	Siemens	SAP, Salesforce	IIC member		Bosch	
	Caterpillar	SAP	University partners			
	Komatsu		Cloudera			
	Rolls Royce	TCS, 2017				

Sources: Authors; market reports, news articles, websites.

Collaboration in Capital Equipment GVCs

As these systems are making use of cutting-edge technology, with significant innovation and change still underway, firms are pursuing a **highly collaborative approach to development** and no single industrial platform has emerged as a dominant model. Collaboration is taking place on multiple levels, including multilateral initiatives such as oneM2M and the Industrial Internet Consortium (IIC). One of the most important of these to emerge thus far is the Industrial Internet Consortium (Kagermann et al., 2016). All the firms mentioned thus far are members of this public-private community focused on advancing innovation in the area of big data in the connected industrial world (Industrial Internet Consortium, 2018).[32] At the core of their work is standardization, innovation and security. The organization is focused on establishing international standard protocols, providing "test beds" for innovation and collaboration amongst different actors, particularly in the areas of AI and machine learning.

[32] Korean members: Samsung Electronics, Korea Industry 4.0 Association. Korea Electronic Technology Institute.

While industrials have invested heavily in developing and/or acquiring capabilities in operational technologies for the implementation of IIoT, closing the loop and connecting data flows back into enterprise systems is being driven through **partnerships and networks with large and medium-sized IT software and service firms**. SAP has particularly extended its dominant position in real-time transaction data to support manufacturers. The company has partnerships with Siemens Mindsphere, Bosch IoT, GE Predix amongst others. Salesforce has also played an important role in connecting marketing and sales reps with real-time and historical performance data obtained from PLM operations across OEM fleets to help directly drive sales. For example, Salesforce's cloud system, together with streamed data from ABB Ability provides sales representatives with client-specific information on performance, how that performance compares with others operating the equipment, a pipeline of potential products based on past customer purchase and performance history, as well as real-time scheduling for installation and field services operations (Dean, 2016).

Industrial IIoT and universities: Surprisingly, individual firm collaborations with university research centers are relatively small-scale and limited. Examples include CAT Data Lab at the University of Illinois, where students work on potential businesses leveraging new data analytics for CAT's supply chain, and Rolls Royce's agreement with Hasso Plattner and Alan Turing Institutes. Collaborations have been broader in their base, with larger scale public-private consortiums, such as IIC[33] and the 5G Initiative which focuses on connectivity and edge for IIoT, bringing together University of California Berkley with Honeywell, GE, Ericsson and Intel (Ericsson, 2017). Firms, research institutes, universities and associations use these collaborative platforms as a means of enhancing know-how, reducing development time, and avoiding redundancy (Kagermann et al., 2016).

4.5. Collaboration for Interoperability and Conflicts of Interest

The systems-wide approach proposed by promoters of IIoT depends on the ability of an array of people, equipment and processes to connect seamlessly. Elements are developed by a range of different suppliers, creating a strong need for common languages, connectors and interfaces to ensure interoperability across devices. Achieving these **high levels of collaboration** is challenging, and the relationships between these actors is complex due to the sensitive and diverse nature of the data exchanging hands and overlapping business interests of the integrators. Figure 4-4 below illustrates the relationships between the different actors, the value drivers and key challenges they face in achieving interoperability.

[33] IIC has over twenty university members from around the world, including Johns Hopkins University (US), University of Pennsylvania (US), University of Stuttgart (Germany), Cork Institute of Technology (UK), Shenyang Institute of Automation (China), Korea Electronics Technology Institute, Beijing University of Technology (China), and A*Star institutes (Singapore) amongst others (Industrial Internet Consortium, 2018).

Figure 4-2. Key Actors & Relationships in the IIoT Space

Relationship Value Drivers →

Key Challenges ↓

IIoT Key Actors & Roles	**Operators:** Use equipment in their operation, may buy or use as-a-service.	**Discrete Manufacturers**: Develop equipment, provide PLM & MRO services.	**Integrators:** Provide IIoT platform to connect and analyze data for multiple machines/equipment.	**IT Services Providers**: Connect OT with enterprise level data to drive design, production, sales decisions.
Operators		Fleet-wide data availability & enrichment can optimize equipment performance for any operator. Enhanced MRO service provision ensures increased reliability & availability for operators.	Systems-wide data availability & enrichment on platforms provided by integrators helps maximize knowledge on improving processing; results in cost savings and increased output.	Systems-wide data enabled by IT services providers connecting OT and IT data can streamline operations, optimize human capital deployment, retail operations, amongst others generating cost savings and increasing output.
Discrete Mfg.	Technical and data ownership considerations		Discrete manufacturers can use digital thread enabled by integrators to enhance their own design, production and sales operations for specific equipment.	Discrete manufacturers use OT-IT data connections enabled by IT services providers to improve ERP, HRM and CRM; improves deployment of firm resources; optimizes sales operations.
Integrators	Not all equipment is smart/connected or is from multiple OEMs; Integrators owning operations in sector create data ownership & access concerns e.g. GE Oil & Gas.	Data ownership & access constraints as integrators also sell equipment in same segments. e.g. Siemens PLM CAD systems manage more of their competitors data than their own.		Maximum value can be derived for operators in all stages by integrators connecting services with IT enterprise data.
IT Services Providers	Technical interoperability constraints; data protocols, etc.	Potential technical considerations & data volume constraints.	Potential competition in IIoT offering; IT service providers building increasingly sophisticated platforms with more focus on machine learning. e.g. SAP Leonardo.	

Source: Authors

Technical constraints to interoperability arise from a combination of unconnected, legacy equipment and equipment supplied by multiple OEMs. Newer and large equipment tends to be smart and connected; however, these often must operate with older or less sophisticated equipment. This occurs particularly when equipment is inserted into brownfield operations, such as existing mines or oil refineries (Grubic & Peppard, 2016). Due to the high original technology costs, it is not immediately cost-effective to install and monitor sensors on all machines and equipment within an operation. This is slowly being resolved as lower-cost "plug and play" sensors are entering the market however overall cost-effectiveness will continue to determine how quickly all equipment is connected. As additional sensors are added, it amplifies the existing challenge of multiple OEMs and vendors within an operation. Each OEM has developed their own approach to smart machines, combining different sensor types, data languages and security protocols. To ensure systemwide benefits are obtained, these need to be standardized. The IIC provides a strong forum for undertaking this role and has already begun to produce frameworks to help govern these technical interoperability concerns (e.g. The IIoT Analytical Framework Industrial Internet Consortium (2017)).

Resolving the challenges of business dynamics is somewhat more complex. Central to this is the ownership and access to the data streams being generated by this equipment. The integrators have emerged as the leaders in IIoT due to their strengths in industrial automation and controls as well as their status as discrete manufacturing operations, which has provided them with a testing ground for this technology. This generates strong potential conflict of interest with their clients, be it operators or discrete manufacturers using their platform. Operators fear that the platforms will sell consulting services to their competitors as a result of analyzing their data systems. Discrete equipment manufacturers such as Komatsu, Caterpillar and Rolls Royce—all of which compete directly with divisions of these integrators—have thus far preferred to either build their systems in-house or with the help of IT services providers, such as IBM, TCS or Wipro, rather than provide their direct competition with full access to their equipment operations.

In some industries, such as aerospace, the model of collaboration is already relatively mature; jet manufacturers compete directly based on the services and overall cost of ownership and collaborate directly with airlines to design products to understand their needs. In the mining industry, miners have proactively been developing their own systems-wide solutions, attempting to avoid being overly dependent on any one equipment supplier ("Investment in Mining Technologies," 2017). Rio Tinto, for example, launched the Mine of the Future in 2007 and began to drive automation and increased digital solutions internally rather than forfeit systems-wide knowledge to their providers.

4.6. Entry and Upgrading in the Digital Economy

Each of the strategies (R&D, acquisitions, VC, collaborations) discussed above can be viewed as the way companies enter the digital economy and ways in which companies upgrade or expand their capabilities. For example, joint ventures and acquisitions are ways to enter new geographic end markets. Collaborations with companies in different sectors of the same value chain or completely different industries lead to intersectoral upgrading. Investing and acquiring start-ups is a way to expand or improve products or process.

As firms seek to upgrade into these new digital services, they are tapping into several areas to develop capabilities. Operational technology capabilities are being developed with in-house capability development in mind, either through direct recruitment of new **human capital** with completely new skillsets, **acquiring** emerging companies with existing capabilities or **investing** in new start-up firms for later acquisition. Outsourcing has been concentrated more amongst discrete manufacturers in the key digital technologies, with firms focusing on data analytics. For the integration of operational data with enterprise systems, firms have thus far sought out

partnerships with leaders in each key area, leveraging existing strengths and extending their market potential rather than attempting to compete.

Table 4-8 lists the most prevalent strategies used by each of the firms examined in this report. While all firms engaged in each strategy to some extent, this seeks to identify the primary drivers of capability development. In software, collaborations are a critical element across all firms. These are most often with other firms in the digital economy sectors, but also extend to customers and solutions development. Large companies are more active in acquiring and investing in start-ups.

Table 4-8. Digital Economy Strategies, Company Case Studies

Segment	Company	Strategy
Software	Citrix	Collaborations
	Red Hat	Collaborations
	Salesforce	Acquisitions VC investments Collaborations
	Oracle	Acquisitions Collaborations
	SAP	Collaborations
	Microsoft	Collaborations
	SAS	Internal (R&D & workforce) Collaborations
	Kakao Corporation	Mergers VC investments (but small from global perspective)
IT Services	IBM	Acquisitions
	Samsung SDS	--
	Infosys	VC investments new key strategy for capability development
	TCS	Workforce: investing in digital training
	Wipro	VC investments (20+ since 2016) Acquisitions Workforce: investing in digital training
ISS Platforms	Alphabet/Google	Collaborations Acquisitions VC investments
	Baidu	Collaborations VC investments
	Naver Corporation	VC (more than acquisitions) Mergers
	Amazon	Acquisitions
	Alibaba Group	VC investments
	Tencent Holdings	VC investments
Industrials: Integrators	ABB	Acquisition strong contributor to development strategy combined with in-house development (not evident in data)
	Bosch	Acquisition strong contributor to development strategy combined with in-house capability development (do not have data)
	General Electric	Investments Acquisitions M&A strong contributor to capability development
	Honeywell	Acquisitions M&A strong contributor to capability development strategy
	Hitachi	Strategic acquisition; Pentaho, US, 2015, US$600M to launch Vantara Lumada

Segment	Company	Strategy
	Siemens	Investments Acquisitions M&A strong contributor to capability development strategy
Industrials : Discrete	Caterpillar	In-house primary Industry-specific investments (to access new digital technologies)
	Komatsu	One strategic acquisition; acquired Joy Global rather than digital start-up
	Rolls Royce	In-house & partnership (TCS) Industry-specific acquisitions

Source: Authors

5. Human Capital and Workforce Development

Human capital is often cited as a constraint to moving into a more digitalized economy. These positions are often medium to high skill, require access to computers and software and typically require at least the equivalent of an Associate two-year degree. There are two *primary groups:* software engineers/programmers and research/data analysts. In addition, there are new positions in customer-facing positions such as user experience (design) and technical/marketing (sales) and a greater need for workers with complex problem-solving skills that can integrate applications and systems (solution architect).

Digital industries are labor-intensive. For example, mobile application development relies on programmers to create and maintain app infrastructure; labor accounts for the largest percentage of industry revenue and workers earn high wages. Industry employees often have undergraduate and advanced degrees in computer science and are often trained in several programming languages, such as Java, C, C++, Python and Ruby, among many others (IBISWorld, 2018h).

The main programming activities include:

- R&D: developing new applications and uses of software; may or may not be client-driven
- Development: programming; in most cases the output is client-specific, but standard software packages also exist.
- Integration/Adaptation: modifying or updating an existing program to fit specific needs.
- Maintenance: support and updates for existing programs.

Service activities that focus on design and marketing come into play when the focus is on marketing or a web-presence is involved. These activities include graphic design[34], animation, user experience (UX), and digital marketing/search engine optimization (SEO). Employees engaged in UX analyze how users feel about a system, looking at such things as ease of use and how a user navigates through a website.

The table provides the main areas or departments of a company as well as the programming languages, frameworks, systems, tools and education requirements of workers in this field in these various subsectors.

[34] Graphic design can be for the web or print media (catalogs, brochures, packaging); if for print, this could arguably be more aligned with the BP segment, however we believe that graphic design related to web capabilities is more likely to be performed offshore as part of an overall digital marketing program.

Table 5-1. Skills/Technical Focus Areas

Main	Subsectors	Languages/ Frameworks	Software/Tools	Education/ Experience
Programming (Computer (web/desktop), Mobile, Video Gaming, Embedded)	Development	PHP, .NET (C#, F#), Java, C++ Operating Systems: Mobile: Android, Windows iOS/Apple	Databases: MySQL, MS SQL, Oracle; E-commerce: Magento	4-year degree: Computer Science/ Engineering; experience
	Integration/ Adaptation		Content Management Systems: Drupal, SharePoint, Joomla	
	Front-End Development	HTML5, CSS3, JavaScript	XML, XSL, jQuery	
Design	Graphic Design	--	Photoshop, Illustrator, InDesign, Dreamweaver	
	User Experience (UX)	--	Generating wireframes (Balsamiq, OmniGraffle) and wireflows; Google Analytics	
Marketing	SEO	--	Google Analytics & Adwords	4-year degree: Marketing, Communications
Project Management	--	--	--	

Software can fall within several focus areas that can be considered 'internal' to the company or web-based. Internal areas pertain to systems that manage data related to people (workers), companies (buyers/suppliers), products, and/or processes and include:

- Enterprise Resource Planning/Management (ERP/ERM)
- Customer Relationship Management (CRM)
- Human Resource Management (HRM)
- Data Management & Analytics.

Software for internal-use does not necessarily require as much design or marketing because the purpose is to store, manage and analyze data to optimize a company's performance; not to market or sell to customers.

There is also increasing demand for integrated internal systems that can "talk" to one another and combine the data and functionality of individual ERM and CRM systems. For example, it is advantageous for a company to have a program that analyzes and maintains data on suppliers and distribution/inventory (ERP/ERM), customers and sales (CRM), and real-time information on purchases (e-commerce) (Frederick et al., 2016). This requires workers in systems integration of solution architects.

Services that are web-based do require these things as they primarily focus on marketing (website development) and e-Commerce (selling online). Online retail/e-commerce is a rapidly growing segment that will continue to create opportunities for programmers and front-end positions.

Standard Occupational Classification (SOC) system codes in the computer and mathematical family (15) related to computer occupations (15-1) are most relevant for identifying jobs in the digital economy. The following table presents these 13 detailed computer occupations, US employment in 2017, the share of computer occupation employment each one accounts for and the relative importance of each occupation to the four main North American Industrial Classification System (NAICS) codes for digital economy industries: 5415, 5112, 5182 and 5191.[35] These four codes will be referred to as the digital industries.

Table 5-2. Employee Profile, Digital Economy GVC, 2017

SOC Code	SOC Title	% of SOC 15-1 Emp.	Total Emp in SOC, 2017	Emp in Digital*	% SOC Emp. in Digital *	SOC Occupation Rank for NAICS			
						Services (5415)	Software (5112)	Data Process & Host (5182)	Other Info Services (5191)
15-1132	Software Developers, Applications	21%	849,230	453,500	53%	1	1	1	1
15-1151	Computer User Support Specialists	15%	613,780	184,040	30%	3	2	3	10
15-1121	Computer Systems Analysts	14%	581,960	211,890	36%	2	9	4	14
15-1133	Software Developers, Systems	10%	394,590	164,760	42%	4	3	6	15
15-1142	Network & Computer Systems Admin.	9%	375,040	88,560	24%	7	16	9	24
15-1199	Computer Occupations, All Other	8%	315,830	81,000	26%	9	10	10	20
15-1131	Computer Programmers	6%	247,690	125,130	51%	5	5	13	30
15-1152	Computer Network Support Specialists	5%	186,230	45,250	24%	14	22	11	47
15-1143	Computer Network Architects	4%	157,830	53,290	34%	13	28	18	39
15-1134	Web Developers	3%	125,890	42,280	34%	20	19	22	7
15-1141	Database Administrators	3%	113,690	26,570	23%	25	32	23	42
15-1122	Information Security Analysts	3%	105,250	33,690	32%	17	43	25	63
15-1111	Computer & Info. Research Scientists	1%	27,920	8,260	30%	47	41	83	75
15-1	**Total: Computer Occupations**		**4,094,930**	**1,518,220**	**37%**	1,125,750	189,160	124,780	78,530
15-1	**Share of emp. in NAICS in SOC 15-1**	**51%**				**56%**	**52%**	**41%**	**29%**
	Total employment in NAICS 4D based on sum of detailed occupation data**		2,950,300			2,008,310	361,990	305,070	274,930

Sources: O*NET/BLS; NAICS: 5415, 5112, 5182 and 5191. Note (*): digital means the four NAICS codes in the table. (**): total employment varies based on data source. Not off by significant amount, but there are differences.

In the US, the digital economy employs between 3 and 4 million workers. Total employment in the four main NAICS codes was approximately 3 million in 2017 while employees in computer occupations was approximately 4 million. The number of workers in the digital industries has **increased from approximately 2 to 3 million in just a decade (2007 to 2017).**

Approximately half (51%) of the workers in digital industries are in computer occupations, but only 37% of workers in computer occupations are employed in digital-specific companies, the four main, four-digit NAICS codes. This indicates that workers with digital skills span across many industries beyond purely digital companies (nearly two-thirds). Similarly, not all workers in digital companies are in computer occupations, but it is a sizeable share (over half).

[35] Other Information Services: should only be 51913 for digital, but data at 5-digits is not available for occupations. 5-digit NAICS codes can be uniformly applied across the three main categories. For software and computer systems, 4-digit data is the same as five.

The top computer occupation is Software Developers, Applications (15-1132). It is also the primary occupation for all four digital industries; 53% of application software developers are in one of these four industries. The other occupation with over half of employment in digital industries is Computer Programmers (15-1131) at 51%.

Of the four NAICS codes, IT services has the highest share of workers in computer occupations (56%), followed by software with 52%. The Internet software and service industries (NAICS 5182 and 5191), have the lowest shares of computer occupation employment at 41% and 29% respectively.

Most computer occupations require a bachelor's degree or higher. Only one occupation, Computer Programmers, is predicted to decline for projected growth (2016-2026). All other occupations are predicted to have average or much faster than average growth rates. Between 2016 and 2026 there are expected to be more than **436,000 US job openings** in computer computers (O*Net).

Workers in digital occupations earn high salaries well above the US average. The median salary for computer occupation in 2016 was approximately $87,000/year and $42/hour. In 2016, the digital sectors had average annual wages two to three times greater than the US average for the private sector ($53K compared to $106-$205K). This has been the case since at least 2007.

The top occupations for digital industries that are not considered computer occupations are in Table 5-3. The main occupation are computer and information system managers, of which 31% of workers are employed in digital industries. Other occupations are primarily in sales and customer service representatives.

Table 5-3. Non-Computer Occupations in the Digital Economy Industries, 2017

SOC Code	SOC Title	% SOC Emp. Digital*	Total US Emp. in SOC	Digital Industries Total	Number of Employees from SOC in NAICS				SOC Occupation Rank & Share of Emp. for NAICS			
					5415	5112	5182	5191	5415	5112	5182	5191
11-3021	Computer & Info. Systems Managers	31%	365,690	112,970	81,090	13,430	9,370	9,080	6, 22%	7, 4%	8, 33%	6, 2%
41-3099	Sales Reps, Services, All Other	11%	1,004,020	112,340	65,610	8,600	15,150	22,980	8, 7%	12, 1%	5, 2%	2, 2%
43-4051	Customer Service Reps	3%	2,767,790	95,080	45,190	10,950	24,900	14,040	11, 2%	8, 0%	2, 1%	3, 1%
41-4011	Sales Rep., Wholesale & Mfg., Tech & Scientific Products	15%	327,190	49,360	28,030	17,780	2,780	770	18, 9%	4, 5%	28, 1%	54, 0%
13-1161	Market Research Analysts & Marketing Specialists	10%	596,450	61,450	31,320	13,690	5,810	10,630	16, 5%	6, 2%	15, 1%	4, 2%
43-9021	Data Entry Keyers	10%	180,100	18,020	43	51	7	43				

Sources: Authors; data from O*NET and US BLS.

5.1. Workforce Gap

Developing digital skills is required for a successful transition to Industry 4.0. Three main areas emerged as areas with skill shortages in a recent survey (Siemens, 2018b). The first area is digital production expertise, which enables operational staff to **interpret machine and performance data** on their handheld dashboards and take appropriate action. The second is **digital maintenance capabilities**, where engineers have the knowhow to maintain complex digitalized operating systems and equipment. The third digital skill shortage area was **operating and strategic analytics**, where analysts can interpret the reams of "big data" generated by the completely digitalized environment—including production data, supply chain data, market data and financial data—to create and interpret valuable insights to improve competitiveness. Digital skills are also needed at the management level to create a clear, phased plan to achieve a more data-driven business model (Siemens, 2018b).

Skilled programmers are the key to success in software, forcing players to rely on the continued service of highly qualified and usually well-paid employees. Software development is labor intensive, since ultimately it depends on highly skilled programmers, literate in mathematics and the constantly evolving area of computer science (MarketLine, 2017d).[36]

Next-Generation Talent Key to Lead Digital Transformations (CFRA, 2018a)**:** the success of implementing digital offerings will hinge on the ability of IT consulting and other services sub-industry constituents to acquire the necessary talent, as these roles become a substantial portion of the overall workforce mix. Examples of digital roles include **solution architects**, project managers, and network engineers. Companies such as DXC continue to **recognize the talent gap** by delicately balancing company goals without cannibalizing human capital (12,000 new hires slated for 2018).

Computer and IT occupations are projected to grow 13% from 2016 to 2026, faster than the average for all occupations, according to the US BLS. These occupations are expected to boost the number of new jobs considerably, which continue to be driven by cloud computing, big data and analytics, and the increasing number of mobile devices connected via the IoT.

In addition, organizations are focusing on innovation, and diverting away from mundane everyday operations and with it, increasing the need for different skills. A survey conducted by HfS Research (on the skills that businesses find the most challenging to recruit) revealed the top three hardest skills to recruit are complex problem solving, critical thinking, and creativity which, are all key pillars of innovation and consultancy. An applied example of the workforce gap, there has been a shift to '**crowdsourc**e' platforms for talent acquisition where recruiters seek talent (CFRA, 2018a).

5.2. Certifications

Software and IaaS/PaaS firms offer certifications to individuals to demonstrate proficiency in using programs developed by the company. This provides a revenue stream for the company and

[36] Amazon alone has 6,300 open positions for software development and solutions architects (as of September 2018)

provides a way to fill the workforce gap by enabling individuals to learn the necessary skills in less time and for less money. Offering training programs is also a strategy for lead firms to increase market share by providing an alternative path to train workers.

Firms offering certifications are included in the Appendix table. These include Microsoft, Oracle, SAP, Salesforce, Citrix, SAS, IBM, Cisco, Apple, Java and Google.

6. Geographic Analysis: Country Findings

The supporting environment for the digital economy includes industry associations, government agencies, standard and certification bodies and educational institutions, among others. These are the groups that regulate and provide support for firms in the global digital ecosystem (Table A-8-6 provides details).

6.1. National Policies

There are several areas in which national policies impact business in the digital economy, including the following:[37]

Privacy regrading data collection: The regulatory environment surrounding data varies by market and type. For example, consumer privacy pertains to data on people, from personal information provided by the subscriber to data collected on how someone uses a digital service, is primarily regulated at the national level. Each country has a policy on the type of personal data and information that can be collected by Internet service providers and platforms. The purpose of this legislation is to protect the privacy of Internet users.

Industrial data (such as that collected by capital equipment) related to process and product metrics that do not involve human subjects or government contracts is collected and regulated by the private sector. Whereas this is less of a national policy issue in the industrial sectors, data and cybersecurity are still concerns due to the high volumes of sensitive data moving over the internet (Siemens, 2018b).

Mobile applications have provided a gateway to consumer data. Since the introduction of the mobile app platform, developers have accessed unique device identifiers (UDIDs) present in every phone. By accessing UDIDs, developers have been able to gain access to user information, enabling them to raise revenue by selling user data for marketing purposes. However, with growing privacy concerns among the public, app marketplaces like Apple have begun to phase out UDIDs. As a result, policies that eliminate developers' access to private information have the potential to negatively affect industry revenue growth moving forward (IBISWorld, 2018g).

Internet content access: countries also have policies regulating access to Internet, and whether companies can block (or impact access to) content. Those in favor of equal access to all users support the concept of net neutrality. This legislation primarily pertains to ISPs. Equal access is common for telecommunications, however, even though ISPs are often owned and operated by

[37] (UNCTAD, 2017a), p. 207-210 provides a good overview of key policy areas.

telecommunications companies, they are classified as providers of unregulated information services, placing them outside the scope of telecommunications regulators.

Data centers and storage: some countries, or at least government agencies, have policies on where and how data can be stored, stipulating that it must remain within national boundaries.

Corporate taxes and incentives: taxes, and tax-reducing incentives, have an impact on where and how companies choose to invest and do business. While digital companies tend to generate less revenue than industrials of manufacturing firms, they often have a corporate value structure with comparatively more intangible assets and current assets (cash) and are generally more profitable (UNCTAD, 2017a). They also need to maintain large cash reserves for investments, as evidenced by the importance of acquisitions and VC investments. These profits are subject to corporate taxes, and therefore corporate tax rates impact where companies maintain cash reserves. For example, US tech MNEs kept 62% of their foreign earnings unremitted in 2015; this was three times higher than non-tech companies (UNCTAD, 2017a). To encourage firms to repatriate this cash and increase investment, a US tax overhaul bill was introduced to reduce overseas cash repatriation taxes from 35% to 15.5% on income held as cash and cash equivalents and to 8% for illiquid assets (CFRA, 2018a), to reduce the overall effective tax rate. The impact of corporate taxes is also evident in Chinese firms, with two of the three profiled setting up a primary operation in the Cayman Islands.

More specific to the digital economy, countries also establish special tax rates for companies participating in certain sectors chosen as economic development priorities. For example, China has had favorable polices for the software industry since at least 2000 when *Document 18: Policies on Further Encouraging Development of Software and IC Industry* was released. This was expanded and continued in 2011 with *Document 4: A Basket of Measures to Further Boost the Software and IC Industry*. This provided preferential conditions covering finance and tax, investment and finance, R&D, imports and exports, talent, IP rights and market aspects, to benefit firms along the supply chain. The policy was applicable to all qualified software and IC firms licensed in China; any ownership.

In China, the corporate income tax (CIT) rate is 25%, but there are two schemes for digital companies:[38]

(1) Preferential tax rate of 10% under the EIT law if it qualifies as a "Key Software Enterprise." Subject to relevant governmental authorities' assessment each year. Prior to this in 2011, qualified firms benefited from 'the 2+3 year tax holiday', which was effective from first profit-making year or 2017 whichever is earlier. This provided two years free of tax and three years at 50% of the standard rate.

(2) Preferential tax rate of 15% for three years under the EIT Law if it qualifies as a "High and New Technology Enterprise" (January 2016). Government agencies consider: ownership of core technology, whether the key technology supporting the core products or services fall within the scope of high and new technology strongly supported by the state as specified in the measures, the ratios of R&D personnel to total personnel, the

[38] The software benefit appears to be national, but the high-tech enterprise was limited to specific geographic areas. Prior to January 1, 2008, the CIT was known at the enterprise income tax (EIT) which had different rates for domestic and foreign-owned firms.

ratio of R&D expenditures to annual sales revenues, the ratio of revenues attributed to high and new technology products or services to total revenues, and other measures set forth in relevant guidance. Prior to this, qualified new/high tech enterprises established in Shenzhen, Zhuhai, Shantou, Xiamen, Hainan and Pudong New Area of Shanghai established after January 1, 2008 were also eligible for the 2+3 year tax holiday.

E-commerce specific policies were first mentioned in the 10th FYP as the Information Industry (2001-2005), and the 12th FYP (2011), and significantly in the 13th FYP (2016). In 2015, China also released the **Internet Plus Plan** designed to capitalize on China's huge online consumer market and optimize manufacturing, finance, healthcare, and government; aimed at building up the country's domestic mobile Internet, cloud computing, big data, and IoT sector firms and creating global competitors by assisting domestic firms' expansion abroad.

Digital Economy Policies and Programs

Globally, there is a race between governments to ensure their country develops technologies and platforms that allow each to remain competitive. Germany launched the Industry 4.0 initiative as part of their overall development strategy in 2011; the same year, the United States (US) launched the Advanced Manufacturing Partnership and China launched the "Made in China 2025" program. Japan unveiled specific programs in key areas (IoT Acceleration Consortium (IOTAC) and Robotics Revolution). Other countries around the world are also vying for their position, including France (Nouvelle France Industrielle); Sweden (Produktion 2030); Spain (Industria Conectada); and, Italy (Fabbrica Intelligente) (Forrester, 2017b; Kagermann et al., 2016). In 2016, Singapore allocated its largest ever R&D budget to drive Industry 4.0 technologies adoption in the city-state.

Under the Creative Economy strategic plan, Korea aims to become a regional tech startup hub. The government is investing US$3 billion in the program, which will boost spending on emerging technologies and related tech services. The public and private sectors will also work closer on technology initiatives: Samsung and SK Telecom seek to transform the city of Daegu into an IoT test hub with infrastructure for connected cars and mobile health (Forrester, 2017a).[39]

Table 6-1. Select Policies in Countries Leading Industry 4.0

Year	Country	Initiative	Field/Goal	Promoted by
2014	Japan	e-F@ctory Initiative	Factory Automation	Business
2015	Japan	Industrial Value Chain Initiative (IVI)	Loose Standards	Academic institutions and businesses
2015	Japan	Industry 4.1 J	Cloud-based data processing	Business
2015	Japan	IoT Acceleration Consortium (IOTAC)	Linking IoT to Big data and artificial intelligence	Government and business
2015	Japan	Robot Revolution Initiative	Industrial and applied robots	Government and business
2010	China	Internet of Things Center Shanghai	ICT	Government
2015	China	Internet Plus	ICT	Government
2015	China	Made in China 2025	Manufacturing	Government

[39] Gedalyah Reback, "Following Cisco, Samsung aims to turn Daegu into South Korea's first major smart city," Geektime, March 28, 2016.

Year	Country	Initiative	Field/Goal	Promoted by
2013	China	Smart Factory 1.0 Initiative	Manufacturing	Business
2011	Germany	Platform Industrie 4.0	Manufacturing	Government
	Germany	BDEW	Energy	Industry Association
	Germany	BDI	Manufacturing/cross-sectoral	Industry Association
	Germany	Bitkom	ICT	Industry Association
	Germany	VDA	Automotive industry	Industry Association
	Germany	VDMA	Machinery and plant engineering	Industry Association
	Germany	ZVEI	Electrical and electrical engineering industry	Industry Association
	South Korea	Creative Economy Innovation Centers	ICT/Industry 4.0 Innovation	Government and business
2015	South Korea	Korean Smart Factory Foundation	Factory Automation	Government and business
2015	South Korea	Smart City Testbed Initiative	Smart cities	Government
2015	South Korea	Smart Factory Initiative	Factory Automation	Government and business
2014	USA	Industrial Internet Consortium	Overarching themes; standardization; testbeds; new business models	Business
	USA	Smart Manufacturing Leadership Coalition	Join pre-competitive research on an open platform	Business
2013	USA	AllSeen Alliance	Consumer Electronics	Business
2014	USA	Open Connectivity Foundation	Communication between different systems	Business
	UK	Catapult centers	Driving innovation; Industrie 4.0 subtheme	Government
2011	UK	High Value Manufacturing	Catapult center for digitalization of manufacturing	Government
	UK	Satellite Applications	Catapult center for digitalization of manufacturing, focus on ICT	Government
2011	UK	Manufacturing Technology Center	Part of HVM Catapult	Government
	UK	Advanced Manufacturing Research Center (AMRC)	Part of HVM Catapult	Government

Source: Adapted from Kagermann et al. (2016)

In IIoT, regionally, the Americas lead (45%), followed by Europe and the Middle East (33%) with Asia (22%) trailing (PTC, 2017). As a result, there is significant room for growth in the Asia-Pacific (AP) region, particularly driven by China which is predicted to drive approximately half of all regional IIoT demand, followed by Japan (27%) and Korea (11%) (Bosch Software Innovations & Frost & Sullivan, 2016).

Global Locations of IIoT Initiatives

Industrial leaders, Germany, Japan and the United States have played leading roles in introducing these new technologies to the market, however, they are not the only global locations to have emerged as important IIoT hubs. The race for talent, combined with new start-up hubs, distributed demand – from end clients and manufacturing plants, and forward-looking policy approaches have resulted in a globally distributed innovation network. Key locations include India, Singapore, China and Eastern Europe. The roles these countries play, however, differ due to their existing expertise and available labor force. India, for example, has leveraged its considerable strengths as an IT services provider, while Singapore has built on its advanced manufacturing capabilities in semiconductors, oil and gas, chemicals and aerospace.

The global race for talent is a major factor driving location decisions and hiring new talent is already considered to be the critical enabler of Industry 4.0 (BCG, 2016). Demand is peaking and driving up costs in primary locations; applications software developer demand in the US alone is projected to increase at four times the average occupation rate (7%) by 2026 (US Bureau of Labor Statistics, 2018); in Germany, the 800,000 software professionals fall short of the country's needs to drive its Industry 4.0 agenda (Holtkamp & Iyer, 2017).

Eastern Europe and Israel have become important centers for IIoT initiatives, drawing on two decades of IT experience as outsourcing initially shifted there in the late 1990s and 2000s. This, combined with a strong basis in engineering disciplines, has made these locations increasingly sophisticated and today they handle software development, and a growing share of analytical processing. Budapest is home to Cloudera's largest R&D operations (Cloudera, 2018a).

While global locations are possible thanks to widespread connectivity, analytical operations are also located near client operations to support localized service needs and to leverage deep, local knowledge (Baines & Lightfoot, 2013). Komatsu's Analytics Platform operations are in Queensland, Australia, in proximity to leading miners, such as Rio Tinto. The company also operates Smart Solutions centers in six locations, including Chile and South Africa. Similarly, ABB has Collaborative Operations Centers in key regions, which combine its DCS with ABB Ability cloud and IIoT capabilities. They have 16 sites around the world, including Houston, Miami, Sao Paolo, Genoa, Helsinki, and Oslo. These Centers serve clients in mining, oil and gas, pulp and paper, chemical manufacturing, marine and power generation. ABB knowledge and process experts work alongside software and analytics teams and operators (ABB, 2018a).

Table 6-2. Company Cases: Digital Activities, by Geography

Firm	Activity in Korea	Activity in Asia	Main Asian Countries	Digital Specific Division (Global)
Citrix	Sales office	R&D: India (Bangalore)	India	
Red Hat	Office, Seoul	Innovation Labs: 1/3 (Singapore)	Singapore	Open Innovation Labs: 3 locations
Microsoft	Microsoft Korea, Seoul, 1988, subsidiary, ISS; Invest in KT; CyberCrime lab	Accelerators: 4/8 locations (Israel, China (2), India)	China India Israel	Microsoft ScaleUp (Accelerator) 8 locations
Oracle	Oracle Korea, Seoul, 1989, subsidiary	Accelerators, 5/9 in Asia (India, 3; Singapore, Israel)	India Singapore Israel	Oracle Startup Cloud Accelerators, 2016, 9 locations
Salesforce	Sales office (subsidiary), SforceSystems Korea Ltd.	Employees in India and Israel		
SAP	2 Korean offices	Global Labs: 20 (India, 2) Strong growth in Asia (doubled since 2010). India: SAP Hana and SAP Leonardo	India (R&D; labs)	SAP (Leonardo): Bangalore, India; NYC, US; Paris,

Firm	Activity in Korea	Activity in Asia	Main Asian Countries	Digital Specific Division (Global)
		labs in Bangalore. Largest location outside Germany; 15% of R&D workforce.		France; Sao Leopaldo, Brazil
SAS	Office			
Kakao	HQ; R&D		Korea	
IBM	IBM Korea, Seoul, 1967, subsidiary	THINKLab, 2014, 4/12 Research Labs in Asia (China, India, Japan, Israel) IBM Alpha Zone, 2014 (**Israel**)		
Samsung SDS	HQ; R&D		Korea	
Infosys	Office (Korea)	Only campus outside India is in **China.** Stronger growth from Asia than other regions since 2010	India China	
TCS	Office (Korea)	Stronger growth from Asia than other regions since 2010	India	
Wipro			India	
Alphabet/Google	Google Korea, Seoul, 2007, ISS, subsidiary	AI Center, 2017, China Google Campus, 2012 (**Korea**, **Israel**, Poland, **Brazil**)	China	
Naver	HQ & R&D		Korea	--
Baidu	SmartStudy: 10% ownership (Korea) No office found		China	US (R&D)
Alibaba		Alibaba Entrepreneurs Fund, 2015 (HK, Taiwan); Create@Alibaba, 2016 (China)	China HK, Taiwan	
Amazon	Availability Zone; AWS Edge			
Tencent	Supercell (acquired) had an office		China	
ABB		Collaborative operational center in Shanghai to foster a close relationship with clients to build solutions. IIoT engineering team in Asia is in India. IIoT Center in Singapore.	China (client center) India (IIoT engineering) Singapore (IIoT Center)	ABB Ability: 16 locations: Houston, TX; Miami, FL, Sao Paolo, Brazil; Helsinki, Finland, Oslo, Norway; Singapore; Bangalore, India; Shanghai, China
Bosch		Rolling out Smart Factory pilot initiatives in Asian operations. One of the top IoT recruiters in India – its largest R&D hub outside Germany; established HQ in Singapore to enter SE Asian market and tap Singapore's policies supporting Industry 4.0.	China (Smart Factory pilot) India (R&D; IIoT) Singapore (HQ SE Asia, Industry 4.0) Japan	Bosch Software Innovations: Germany (HQ: 4 locations-Berlin, Cologne, Immenstaad, Waiblingen); Shanghai, China (Asia hub); Sofia, Bulgaria; Tokyo, Japan; Singapore.

Firm	Activity in Korea	Activity in Asia	Main Asian Countries	Digital Specific Division (Global)
General Electric		A little less active; but established a digital foundry in China for Predix developers. India has a software services location.	China (R&D) India (software)	Software services division (HQ San Ramon, CA), Atlanta, GA; India
Honeywell		Developed two campaigns East 2 East (E2E) and East 4 Rest (E4R) focus on building Asian centric solutions in Asia for Asia, and in Asia for the rest of the world. Shanghai and Bangalore key locations.	China India	Honeywell Technology Solutions: IIoT implementation (India 70%; China, Mexico, Czech Republic)
Hitachi		HQ (Japan). Diversified and global but 72% of revenue from Asia (50% Japan).	Japan (HQ) India	Software services division (HQ CA, US)
Siemens*		For Siemens PLM Software, India (Pune) a key location; Indian team is the largest outside Germany. China: one of the most important R&D sites. FY16: China: 4,500+ R&D workers, 20 R&D hubs; >11,000 active patents and applications.	China (R&D) India (software)	Siemens PLM Software division (HQ TX, US); Pune, India; Shanghai, China; Cincinnati, OH, US; Cypress, CA, US; Leuvan, Belgium
Caterpillar	--	BP services & manufacturing in China and India. Engineering/design also in India.	China India	Analytics at HQ (US)
Komatsu		--	Japan	
Rolls Royce		Increasing sales in Asia. Using India as a platform for R&D, IIoT and Analytics. Two R2 Data Labs in Asia.	India (R&D) Singapore (R&D)	

Source: Authors, based on company websites and annual reports. Note (*): Siemens is investing heavily in the future of China and partnering with the country and many customers on its way to digitalization. In addition to autonomous robotics, the company's core R&D areas in China include data analytics, cybersecurity, IIoT and digital twin, and connected city solutions (Siemens, 2017).

Activities in Asia

In the digital sectors, the US is the top location for software, services and Internet platform companies. In Europe, Germany is a key software location and France and Ireland have key IT service firms. India is a top destination for outsourced service and software. China is the only other country to have sizeable internet platform companies, however these cater to the Chinese market. Software and IT service operations in the country are largely for the domestic market. Israel is the only location that comes up in the Middle East, particularly for software and service operations. No locations are particularly important in Africa, and in South America, Brazil is the primary country for MNEs that have an office in the region.

The Asia Pacific region has relatively few native **software vendors** that sell to businesses and consumers, and most software vendors (apart from IBM, Oracle, and SAP) have been slow to adapt their products to Asian languages and currencies or set up sales and support operations.[40] As a result, custom-built software has had a big share of the Asia Pacific market, especially in India, Japan, and Korea, where large tech services firms have played this role. But the rise of companies like Kingdee and Yonyou in China and the expansion of US- and Australia-based SaaS vendors like Salesforce, NetSuite, and Xero are starting to reduce the need for custom software (Forrester, 2017a).

The large industrial companies are embracing a general shift towards Asia in terms of strategy; Asia accounts for an increasing share of their sales. Most leverage India, Singapore and China. None of the industrials mentioned Korea, as a specific market, or as an operational base. All industrials with IIoT platforms are collaborating with the major Indian IT firms to build apps for their platforms. Major acquisitions and investments are mainly in the US, indicating there is little support so far for the start-up environment in Asia.

Asia is still a follower in IIoT except Japan. Japanese firms have managed to get ahead by acquiring US technology (Hitachi bought Pentaho, allowing it to launch Lumada with analytical services; Komatsu bought Joy Global). They're becoming important bases for foreign firms to sell their technologies and services and even to undertake R&D, but they're not meeting Europe/US's development of new ideas or start-ups.

6.2. Singapore

Singapore is primarily a location for R&D and innovation centers. With 27, Singapore trails only Silicon Valley (75) in the total number of innovation centers, followed by London (22) and Bangalore, India (17) (Capgemini Digital Transformation Institute, 2017). As the emphasis on digital has increased, Singapore and India are moving ahead of other traditional innovation hubs, such as France and Israel (Capgemini Digital Transformation Institute, 2017).

ABB, Accenture, Bosch, Rolls Royce, Yokogawa, and Rio Tinto all have IIoT locations there. While Singapore has been a major player in the MRO segment of the aerospace, marine and oil and gas GVCs for some time (e.g. see Bamber and Gereffi (2013)), it is its advanced manufacturing capabilities and significant government incentives that have helped the city to attract IIoT centers. While these Centers are working on local solutions, they also include global teams (ABB, 2018b; EDB Singapore, 2018). Their proximity to manufacturing operations both locally and in Southeast Asia allows firms to test digital services for production operations. Singapore's government has launched several well-funded initiatives to support its goal to become the first fully Smart City and the global center for advanced manufacturing driven by digital technologies. The government announced a commitment of US$14 billion for R&D in the digital economy between 2016 and 2020 (Capgemini Digital Transformation Institute, 2017); this is the City-State's largest commitment to R&D to date. The city's strong intellectual property framework has helped attract firms looking to innovate for Asia.

[40] Leading Asia Pacific enterprise software companies include Kingdee and Yonyou in China; TrendMicro in Japan; Aconex, Altium, Atlassian, MYOB, and TechnologyOne in Australia; Hancom in Korea; and Xero in New Zealand.

6.3. India

Indian operations are largely in IT services and jobs of foreign companies with operations in India are often in software development. India has become an important center for IIoT initiatives, drawing on two decades of IT experience as outsourcing initially shifted there in the late 1990s and 2000s. This, combined with a strong basis in engineering disciplines, has made it increasingly sophisticated and today firms handle software development and a growing share of analytical processing.

Seven of the firms profiled are in the top ten IoT employers in India, including, GE, Bosch, SAP, Wipro, IBM, and Amazon (IOT India Magazine & Jigsaw Academy, 2017).[41] Several digital companies have significant share of workers in India, including IBM, Red Hat, Oracle, and Google.

Despite India's relatively poor performance in the host of "readiness" indices that are emerging for IIoT,[42] the country is home to the largest IIoT labs outside of home countries for several firms, including Bosch, SAP, and Siemens and policymakers from Germany to China are seeking to leverage Indian talent to support their IIoT ambitions (Bhattacharya, 2018; Holtkamp & Iyer, 2017). Bosch has 14,000 R&D associates in India, making it the company's largest R&D campus outside of Germany with 27% of its R&D employee count. The campus is focused on developing data mining and software solutions (Bosch, 2016).[43] GE, Bosch and SAP are ranked as five of the top ten IIoT employers in India (IOT India Magazine & Jigsaw Academy, 2017). ABB has established the ABB Ability Innovation Center in Bangalore rolling its past IT operations and development units into the new operation focused on digital technologies. Rolls Royce India engineering support services center established in 2005 as a small IT back office, employed 500 engineers by 2009; that year, these engineering support operations were connected to the firm's design network and PLM operations, facilitating "concurrent work on design models with colleagues around the world" (Rolls-Royce, 2010). Honeywell Technology Solutions employs approximately 7,000 people in India, together with another 3,000 in the Czech Republic, China and Mexico that provide the backbone to the company's IIoT strategy (Honeywell, 2018). These global operations are particularly well-suited for analyzing 'data at rest' or historical data to identify patterns and causation; these algorithms are then used to analyze real-time data onsite or at the edge.

Indian firms have minimal R&D spending but are investing in internal digital skill development. Employment has doubled (FY10-17) for Wipro and TCS, increased by 76% for Infosys. India's IT companies are upping their investment activity to absorb innovation and close the gap, so they are not left behind (CB Insights, 2017c). HCL and Wipro have the most private tech acquisitions with five each since 2012. Wipro focuses on IT service companies; by market cap, it is India's third largest IT company). Tata (TCS) is India's most valuable IT company, and has acquired one company, French IT services firm Alti in 2013. India tends to acquire rather than invest in

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[41] Others: Cisco, Qualcomm, and Accenture

[42] For example, both the WEF Future of Production Readiness and the Accenture National Absorptive Capacity (NAC) Index for IIoT rank India poorly, behind China and Brazil.

[43] This operation is technically not run under the Bosch Software Innovations division, however, many of the activities are focused on Industry 4.0 technologies.

companies. However, Wipro and Infosys have been relatively active investors and have even raised their own corporate venture capital arms for investing.

India continues to build strength in IT; at this stage, it's difficult for other countries to compete with this ability. Many countries are trying to recruit them – from Germany to China. However, India is still having trouble fostering its own, rather than being a cog in the global VCs of other firms. Analysis of Infosys, Wipro and TCS investments and acquisitions show a bias to foreign start-ups over Indian start-ups. Which is a positive trend that India is seeking investments in other companies to expand capabilities, however the lack of investment in domestic firms may indicate a comparatively weak start-up scene.

6.4. China

Chinese firms have R&D spending at similar levels to industry averages, engage in collaborations, and largely depend on VC investments (instead of M&A). All benefit from lower corporate tax rates in China from the digital and software tax schemes (which are often tied to R&D spending). Domestic firms have low sales outside China, and most are still focused on Chinese market. Even though Chinese firms are mostly for the domestic market, the large firms show initiative (and have the scale) to move into the regional and global market. The following provides key findings from the company case studies of Chinese firms.

Baidu

- **R&D:** Significant increase in share of workforce in R&D (2007-17): from 15% to 52%; R&D accounts for 15% of revenue (FY17; 8% in FY07). Have five R&D labs.
    - Note that Chinese preferential tax rates depend on R&D. Since 2013, have benefited from the Key Software Enterprise scheme and the High and New Technology Enterprise scheme since 2016.
- **Collaborations:** Several autonomous vehicle partnerships in 2017, including Bosch, Hyundai, Samsung (via Harman), Microsoft and Tencent and JD.com in 2016. Also have some partnerships in electronics area (Xiaomi).
- **Geography:** primarily in China but have R&D labs in the United States and a few US acquisitions in 2017. They also have a few investments in companies in Israel. For now, 99% of workers and 98% of revenue are from China.
- **M&A and VC:** more focused on VC than M&A activity but have one or two VC arms. Investments are primarily in ISS or application software.

Tencent

- Biggest increase in revenue is from the other segment (cloud and payment-related services; from less than 1% in 2010 to 18% in 2017); occurred between FY15 and FY17.
- **Collaborations** are important: among companies in China and internationally.
- **R&D** is lower than other companies (8%); more engaged in VC
- **Geography:** sales are primarily in China (97%), but investments and M&A and collaborations are more international than Baidu.

Alibaba

- **M&A and VC:** most active of the Chinese companies profiled. Have incubators as well.

- **Early mover into cloud computing;** have data centers outside China. Alibaba Cloud launched in 2009, yet still only 4% of revenue.
- Have a lot of employees in R&D (assume similar benefit as Baidu)

In IIoT, strong regional demand combined with country policies to encourage investment in IIoT activities have been key drivers in China. Activity in China by the **industrials**, such as GE's digital foundry, Siemen's Asia Pacific Digital Experience Center, Bosch Software's Shanghai hub and ABB Collaborative Ops Centers, primarily serve the vast Chinese market. Much of Chinese data cannot leave the country,[44] while other countries have restrictions of data flowing into China.

Chinese IIoT providers are also slowly emerging to compete on both the domestic and global markets, such as IRootech (RootCloud) and NeuCloud, a cloud platform with ambitions similar to Bosch and GE (Mu, 2018). IRootech just launched its first location outside China in Europe (April 2018) through an association with Honeywell. IRootech is a start-up and was funded by Sany Heavy, a Chinese firm like CAT and Komatsu. China is moving faster in the adoption of IIoT technologies at the factory level than the development of the technologies.

6.5. Korea: Key Takeaways

The following table and section provide the key findings on Korea's participation in the digital economy based on company case studies and literature review.[45]

Table 6-3. Key Findings for Korea

1	**Limited participation** in the global digital economy; Korea does not have a globally recognizable digital economy firm; existing firms tend to be **small** (based on sales and employment) and **domestically focused**.
2	Korean firms are often **captive or closely tied** to Korean MNEs, with few independent companies. Other large firms are a result of corporate mergers or branch plants of foreign MNEs.
3	Korean firms' strategy is focused on **internal development**, however **R&D spending** may still be insufficient and misaligned to achieve global growth. Foreign R&D activity in Korea is also low.
4	Korean firms do not actively acquire firms and **VC activity, while growing, is still very low.** Foreign digital firms have minimal investment activity in Korea (acquisitions or VC investment).
5	Korean firms have **few partnerships and collaborations** (with other digital economy firms or with firms in other markets).

Source: Authors

(1) Limited participation in the global digital economy

Korea is less focused on participating in the digital economy than other top countries such as the US and China. Of the 25 companies profiled outside Korea, none of them have a significant share of their workforce or operation in the country.

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[44] China's Network Security/Cybersecurity Law is gradually being implemented as a series of related regulations are drafted and published. This law, modelled on the General Data Protection Regulation (GDPR) in Europe, essentially prevents Chinese data from being transferred to foreign destinations. While principally focused on personal data, the law also extends to transportation, public utilities and other important sectors (Sacks, 2018; Zhang & Zhang, 2017).
[45] This section also draws on analysis in related project (Cho, et. al, 2018).

In the realm on Industry 4.0, Korea has been a primary adopter of automated production technology technologies as illustrated in Box 6-1 but has not been a significant player in the services side or development of robotics technology. The largest tech market segment in Korea is communications equipment (hardware rather than services) which is predicted to remain in the top spot. Korean providers Samsung Electronics and SK Hynix are leading vendors in that area (Forrester, 2017a).

Box 6-1. Smart Factory: Automation and Robotics

The increased availability of data has given way not only to the potential rise of services across manufacturing chains, but also to the enhancement of the production technologies within these operations. This has led to development and adoption of automated production systems and use of robotics. Korea, Singapore and Japan are three of the top five leading adopters of these technologies. In 2016, Korea had the highest number of robots per 10,000 workers in the world (631), compared to the global average of 74, and Singapore and Japan with 488 and 303 respectively. The **electronics sector** has been a leading adopter of these technologies (WEF, 2018).

While Korea and Singapore have embraced these technologies to drive their manufacturing sectors, they do not hold a significant presence in industrial robot production itself, which is dominated by Japan, Switzerland and the US (Demaitre, 2017; Francis, 2018). Hyundai Robots has launched an aggressive strategy to develop a presence in industrial robot production with the goal to become a top five producer, while Doosan and Hanwha Techwin have also launched initiatives. Several smaller Chinese suppliers, including Siasun and HRG also compete in the industrial robot sphere, but not at the scale of Japanese counterparts. The table below details the top 10 firms by number of installed industrial robots in 2017.

Table 6-4. Leading Industrial Robot Suppliers

	Firm	**Headquarters**	**No. Installed Robots Worldwide**
1	Fanuc	Japan	400,000
2	Yaskawa	Japan	360,000
3	ABB	Switzerland	300,000
4	Kawasaki	Japan	110,000
5	Nachi-Fujikoshi	Japan	100,000
6	Denso	US	95,000
7	Kuka	Germany/China	80,000
8	Mitsubishi Robotics	Japan	70,000
9	Epson Robotics	Japan	55,000
10	Staubli	Switzerland	45,000

There is one Korean firm on the UNCTAD (2017a) top 100 digital MNEs list (Naver, in the internet platforms category) and only one of the 21 IT software and service companies on the ICT list (Samsung SDS). Of the 125 digital economy firms in the PwC survey, only three are from Korea (Naver, NCSoft, Samsung SDS) (PwC, 2018). Based on the IIoT data, there is also only one company in Korea.

Korea is not the only East Asian country that has been slow to enter the digital economy at the global or regional scale; Japan and Taiwan also have limited participation. For example, while

Japan is the second country based on firm count, revenue and R&D spending overall in the PwC Global 1000, it has minimal participation in digital industries (only four of 171 firms).

Based on industrial statistics in Korea, software is the largest segment of its digital economy participation and within software, systems software is the largest (Cho et al., 2018). In Korea, the digital economy industries account for 1.5% of employment and 0.6% of establishments in 2016.There are 2.9 million people employed by digital companies in the US compared to **323,198 in Korea**. In terms of sales/output, Korea's sales were US$60 billion compared to US output of US$806 billion. This is also the case when compared to the relative size of the US economy to Korea's economy – the US is 13.5 times larger than Korea based on digital establishments (compared to 2.6 for the overall economy), 9.0 and 7.2 based on employment.

Korean digital firms are small (based on sales and employment) and domestically focused. Samsung SDS is reportedly the largest digital company in Korea (about US$8 billion and 23,000 employees), however it is a fraction of the size of any of the US digital firms included here. Similarly, sales for Naver and Kakao are both under US$5 billion, and both have fewer than 6,000 employees. U.S. digital firms are much larger with revenues of US$110 billion at Alphabet, US$79 billion at IBM and US$90 billion at Microsoft, and at least 80,000 employees per company.

Revenue per firm for digital companies in the (PwC, 2018) data was the lowest in Korea (when compared to China and the US) and below the world average for digital companies. In comparison however, revenue/firm across all firms and of the industrials was the highest in Korea and above the world average.

Those that do have foreign sales are limited to a few nearby Asian countries reported. For example, 29% of Naver's 2017 sales were international, but these were primarily from Japan, with only two percent of sales coming from other overseas locations. The US firms, on the other hand, all earn at least half of their sales from foreign sources: 53%, 62% and 50% for Google, IBM and Microsoft, respectively.

Table 6-5 identifies the largest digital companies in Korea based on five-year average sales using the definition drawn from KSIC codes provided in the table above.

Table 6-5. Top 25 Digital Companies in Korea (based on 5-year average sales)

Name	Industry	Year Established	Sales (billion ₩)
Samsung SDS	**Computer programming services**	**1985**	**8,055**
Naver	**Portals and other internet information media service activities**	**1999**	**3,395**
LG CNS	Computer system consultancy activities	1987	3,139
NEXON Korea	Online and mobile game software publishing	2005	1,344
Hyundai AutoEver	Computer system consultancy activities	2000	1,253
Netmarble Games	Online and mobile game software publishing	2011	1,099
NCsoft	Online and mobile game software publishing	1997	1,035
Daou Technology	Portals and other internet information media service activities	1986	1,024
Kakao	**Application software publishing**	**2006**	**1,016**

Name	Industry	Year Established	Sales (billion ₩)
IBM Korea	Application software publishing	1967	963
H Solution	Computer system consultancy activities	2001	912
Lotte IT Tech Co Ltd	Computer system consultancy activities	1997	767
NHN Entertainment	Online and mobile game software publishing	2013	646
KGInicis Co Ltd	Application software publishing	1998	579
KTDS	Computer system consultancy activities	2008	457
Com2uS	Online and mobile game software publishing	1998	354
Daewoo Information Systems Co., Ltd.	Computer system consultancy activities	1989	293
Pantech C&I	Other information technology and computer service activities	1995	289
Tisis	Application software publishing	2004	280
DB Inc.	Computer system consultancy activities	1977	261
Insung Information	Computer system consultancy activities	1992	256
Asiana IDT Inc.	Computer system consultancy activities	1991	249
Neowiz Games	Other game software publishing	2007	239
DoubleU Games Co Ltd	Online and mobile game software publishing	2012	237
Sangsangin Co Ltd	Computer system consultancy activities	1989	231

Source: Cho et al. (2018); based on KisValue.

(2) Korean firms are often captive or closely tied to Korean MNEs, with few independent companies.

Many of the sizeable digital firms in Korea have software and IT-related subsidiaries, but these are focused on development for the domestic market or their foreign locations and sales mimic the parent company's global footprint. Even if the firm is independent from an ownership perspective, they are still highly dependent on their parent company for sales.

For example, 53% of Samsung SDS' revenue in 2017 was in locations outside Korea, however an in-depth review of Samsung SDS' overseas subsidiaries compared to those of Samsung Electronics provides evidence of a dependent business model. First, all of Samsung SDS' overseas subsidiaries were established after those of Samsung Electronics. Secondly, of Samsung SDS' 56 overseas subsidiaries in 2017, 46 are in the same city as one of Samsung Electronics overseas companies, and of the remaining 10 locations, eight were in the same country, even if they were not in the same city. As such, only two of Samsung SDS' affiliates are in a location without a Samsung Electronics subsidiary nearby (Cho et al., 2018). This captive model is applicable for several of the top 25 technology companies in Korea including Samsung SDS, LG, Hyundai AutoEver, Lotte IT Tech, H Solution (previously Hanwha S&C Co.), and Daewoo Information Systems.

This is also evidenced in the PwC report; while there are 36 companies listed from Korea, several are related to the same corporate family leaving only 19 unique firms (PwC, 2018). Korean digital companies such as Samsung SDS, Hyundai Mobis and LG Display supply mainly to relatives in the parent firm's orbit. And the principal owners of those firms are other companies within the same conglomerate. Even if they are legally separate entities, they are still dependent in other ways.

Other large digital firms in Korea that are not part of the large chaebols in Korea are a result of **mergers**. Kako and Naver are both a result of different business units or firms becoming new companies. Both show a general tendency towards a more vertical, domestic and generally internalized business model.

(3) Korean firm strategy is focused on internal development

Korean firms' strategy is focused on internal development, however R&D spending may still be insufficient and misaligned to achieve global growth.

Korea has been deemed the world's most R&D-intensive country, investing 4.3% of GDP in R&D in 2014, and it ranked first in business R&D in the OECD economy survey (OECD, 2016; World Bank, 2017). Services, however, accounted for only 8% of Korea's business R&D in 2013, well below the OECD average of 38%. According to the 2014 Korea Company's Innovation Survey by the Science and Technology Policy Institute (STEPI) in Sejong, only 6.4% of Korea's service-sector firms were engaged in R&D activity over 2011-13 (cited in (OECD, 2016)).

Results from the PwC survey indicate similar lower R&D spending by service firms. R&D expenses as a share of revenue from the PwC (2018) survey indicate that digital firms spend more on R&D than the overall average (12% of revenue on R&D compared to 4%). Digital firms in Korea however spent less on R&D (approximately half) and earn 1/6th the revenue/firm. The nine Korean industrials in the survey also spent less on R&D than the world average as a share of revenue (1% compared to 3%) and based on average R&D spending per firm (US$165 million in Korea compared to US$528 million as a global average). Based on the overall sample of which 4% of the firms are Korean (36 of the 1,000 firms), Korea's R&D spending was comparable to the world averages. Korean firms accounted for 4% of the total revenue spent, and overall Korean firms spent an average of 3.3% on R&D as a share of revenue compared to the world average of 4.5%.

Evaluating Korea's R&D activity at the sector and industry level is likely misleading to the high degree of interconnectedness among parent firms and subsidiaries in multiple sectors. For example, while Samsung SDS only spent 1.4% of revenue on R&D in 2017, Samsung Electronics was close to 8%. It is likely that part of R&D spent by the parent firm is related to IT services, but this is masked by aggregate data.

The company case studies provide mixed results in terms of R&D expenses. Naver spent more than Alphabet (24% versus 15%) and Kakao and Microsoft spent similar shares (12% and 14%). IBM spent significantly more than Samsung SDS (1.4% and 7.3%), however R&D share of revenue is comparable to Samsung Electronics (7.6%).

All companies have a department or subsidiary focused on research and development, however the Korean companies' locations are all in Korea. Global digital firms have innovation centers at home and abroad, however none of the firms profiled appear to have any significant activities in Korea.

(4) Acquisitions and VC investments are uncommon in Korea

To enter new segments of the value chain or new product areas, it is common for firms to acquire companies that exhibit expertise in these areas. This provides a quick way for firms to gain access to key knowledge, intellectual property or access to new geographic markets.

In the US, acquisition activity in the digital sectors is significant. IBM, Microsoft and Google have acquired at least 165 companies each over the course of the last 15 years. The Korean firms, on the other hand, have acquired at most 15 firms each, with most activity occurring in the last five years.

As an alternative to acquisitions, it is also common for digital firms to set up venture capital arms to monitor and invest in promising start-ups. Korean firms appear to be slightly more active in this arena than in M&A. All three of the Korean companies have established one or more venture capital arms. Kakao and Naver are the most active in this area. Kakao is the most active investor in the digital economy in Korea, but its activity is still small from a global perspective.

In China, investments are the primary strategy pursued by digital firms. Individual investments by Tencent, Alibaba and Baidu are all larger than the *total* investment activity in Korea in digital sectors over the last 20 years ($6.8 billion and 860 deals in Internet, Mobile or Software). In India, acquisitions are more common, whereas acquisitions and investments are common in the US. There is a slight correlation between firm age and strategy with newer firms investing more in start-ups and more established firms more active in acquisitions.

Global digital firms also have few acquisitions or investments in Asia, especially Korea. Based on firm count, the number of acquisitions in Asia-Pacific of the firms profiled was generally less than 5% (CFRA & CB Insight databases).

(5) Korean firms have few partnerships and collaborations (with other digital economy firms or with firms in other markets)

Strategic partnerships between digital firms in different sectors and in different parts of the world are commonly formed to expand into new product and geographic markets. As the top search engine globally with over a 90% of the global market share, Google is the most international in terms of forming alliances and setting up offices in foreign countries. IBM and Microsoft have locations in over 100 countries and over 40% of Microsoft's workforce is outside the US.

Korean firms' partnerships are more limited and are primarily with other Korean firms. Two exceptions are Naver's new Space Green investment in the Station F incubator in France and Kakao's partnership with Tencent (China).

A few global software and IT service companies have announced partnerships with Korean firms. In the private sector, Lotte, the largest retailer in Korea, announced in late 2016 plans to partner with IBM to deliver cloud-based IBM Watson solutions across the group (Forrester, 2017a). Other companies, including Microsoft and Red Hat, also mentioned partnerships with Korean retail and finance companies.

7. Recommendations

Korea needs a more proactive, *international* approach to grow the digital economy in the country. Korea is a leader in electronics and automated equipment/robotics, however it is not on the map as a viable participant in the services side of the digital economy.

Facilitate the development of start-up incubator innovation centers and funds, particularly with foreign partners. Centers where developers gather to work and collaborate provide the ability to learn from each other, engage with venture capitalists (and foreign investors), and provide space and infrastructure. While government funded programs and spaces and domestic firms are a step in the right direction, Korea should encourage foreign digital MNEs to set up facilities and funds in Korea to increase networking and engagement opportunities and provide access to knowledge on foreign market trends that is not available in the country. Google's Campus Seoul program (Box 7-1) is an example of such a program. Incubators typically offer mentoring, marketing support, and introductions to venture capitalists and access to software and technologies from the MNE. Like incubators, partnerships with universities help align the skills learned in university programs with those of digital firms. University partnerships with foreign and domestic firms should also be targeted for promoting R&D. Financial assistance for smaller local firms to set-up foreign offices, innovation hubs or accelerators in Silicon Valley would help provide exposure. Asian companies including Baidu and Hitachi have set up key locations in this area to facilitate interaction with US firms.

A more open and international innovation environment would expand market opportunities and enable SMEs to develop new technologies that are adopted by foreign firms. At present, innovation is centered around development to support large domestic firms such as Samsung or LG. Korea would benefit from an innovation environment where SMEs can develop new products that are not tied to a lead firm or government funding. Acquisitions by tech firms provide evidence that relevant technologies can be developed independent of lead firms (Google, for example, has over 200 acquisitions).

A collaborative ecosystem also opens opportunities for employees from existing tech companies **to spin-off and establish new start-ups**.

Box 7-1. Profile Google Campus Program

History of Google in Korea

Google established a branch in Korea (Google Korea) in 2004. In 2006, Google began building relationships with the Korean government and in 2007, opened an R&D center with support from the Korean government. In 2012, Google launched a global K start-up with the Korean government and signed a partnership with K start-up and in 2013 President Park Geun-hye and CEO Larry Page met; Google was interested in Korea because of its start-up ecosystem and growth potential. In 2015, Google opened their first startup space in Asia in Seoul, which was their third campus location. The objective of the initiative is to help Korean start-ups enter the global market through and to allow start-ups in the US and Europe to utilize the Seoul campus as an entry point into Asia.

Campus Seoul, Start-up Training Center for Google

- Established in May 2015; provides physical space and start-up training programs.
- Google chooses start-up teams every six months through the campus program.

- **Selected teams stay six months** at Google Campus and receive free access to support programs.
- Provide benefits for entering global start-up business.
- Priority participation in global start-up support programs such as Google Demo Day.

Programs Supported by Google Campus Seoul

- **Campus Meetups:** developers and participants network and share technical and business issues.
- **Campus Mentoring:** assistance to help startups grow faster; Google experts provide advice directly in fields such as online marketing, UX, and Android app payment systems.
- **Campus Presents: s**uccessful entrepreneurs, industry leaders, venture capitalists, entrepreneurs, and artists who invite speakers to the campus to listen to their lectures.
- **Campus Startup School:** Campus for Moms: support program to help start-up mothers and fathers who had been postponing starting a business because of childcare.
- **Campus x Industry:** program connects start-ups with global or large companies to provide networking, partnerships and business expansion opportunities.
- **Campus Exchange:** Korean startups can visit other Campuses to meet local investors and experts, and provide global opportunities via networking events, lectures and training.

Achievements of Google Campus Seoul

- Since May 2015 (three years): startups created 1,132 jobs and attracted 113 billion ₩) (US$100M).
  - 2017: 232 new jobs created; 82 billion won (US$72.6M) (73% in 2017)
- Campus Seoul has hosted 336 programs, from training to friendship programs. The campus has hosted 14 Campus Recruiting Day events, with 140 start-ups and about 3,200 job seekers participating. In 2017, 335 startups raised funds in the Campus Seoul community.

Google Campus Global

- Locations: 6-7: London, UK (2012), Tel Aviv, Israel (2012), Madrid, Spain (2015), Seoul, Korea (2015), Warsaw, Poland (2015), São Paulo, Brazil (2016), Berlin, Germany (2018).
- 2017: US$255.2M raised by startups and 3,952 jobs created.

Sources: Google Campus Report

Foster **inter-industry collaboration**. The importance and opportunities for inter-industry collaboration are heightened in the digital economy. The data collected by one company or service has benefits to other non-competitive industries. Examples include Uber (data for city planning), Google (predictive healthcare), travel aggregators or Airbnb (economic developers), or utilities providers.

Collaboration is taking place on multiple levels, including multilateral initiatives. One of the most important of these to emerge thus far such as the Industrial Internet Consortium (IIC). All the firms mentioned thus far are members of this public-private community focused on advancing innovation in the area of big data in the connected industrial world (Industrial Internet Consortium, 2018). At the core of their work is standardization, innovation and security. The organization is focused on establishing international standard protocols, providing “test beds” for innovation and collaboration amongst different actors, particularly in the areas of AI and machine learning. There are only three Korean members: Samsung Electronics, Korea Industry 4.0 Association and Korea Electronic Technology Institute.

Baidu’s involvement with autonomous vehicle development is a good example of collaborations among different industries. These partnerships extend beyond China and even include Korean auto companies. Korea's ecosystem provides many opportunities to foster collaborations that would lead to new, innovation products for the international market. This is also an area in which the government can facilitate relationship building among firms.

Encourage foreign venture capitalists to invest in Korean firms and support independent, domestic VC funds. Israel helped launch the country's startups by supporting VC funds. More recently, other governments have tried to emulate the success of the Israeli program and kick-start their own venture capital funds. India, for instance, has created the India Aspiration Fund (August 2015), with $306 million to invest in private venture capital funds to expand the pool of, and boost, Indian entrepreneurs (UNCTAD, 2017a).

Partnerships with global digital MNEs provide a way for domestic firms to gain exposure to foreign best practice and skills and gain new ideas from outside markets. Partnerships are also of interest to foreign companies to localize their offering for the domestic market, overcome language barriers and understand national regulations. These partnerships may lead to acquisitions, expanded business opportunities, or joint ventures in the host country or in nearby Asian countries.

Proactively participate in annual events held by leading digital MNEs and industrial integrators. At least 12 of the 19 digital firms and at four of the industrial integrators have large annual events designed to bring together other digital firms, customers and start-ups.

Develop an **investment promotion strategy around the digital economy** to raise awareness of Korea's capabilities and to put the country on the radar of locations foreign MNEs consider when setting up R&D, engineering, and innovation hubs in Asia. The digital MNEs and industrials profiled in this report only have a small sales office in Korea, and few mentioned any plans to expand involvement in the country. A more proactive approach is needed to put Korea on the map as a viable participant in the digital economy.

Ensure Korea's **human capital development strategy for IT services** aligns with emerging global trends which increasingly include short-term certifications. Indian firms, such as Infosys and Wipro, have invested significantly in digital training and have set up large campuses where they train high numbers of employees in specific certifications. Early software and service initiatives in India and Mexico focused on human capital development, skill certifications and providing opportunities for domestic and foreign firms to interact (Box 7-2).

Box 7-2. Government Support for Software & Service Development in India and Mexico

The establishment **of Software Technology Parks (STP)** is widely recognized as the most significant policy to enhance India's IT services exports growth. In late 1990s, STPs were created as entirely software-services-focused zones that offered tax benefit, office space and satellite uplinks, as well as import certifications and market analysis. Overall, STPs gave IT companies a tax-free status, physical space, connectivity and equipment, becoming a critical component of India's leadership in the offshore services industry. They significantly improved the overall conditions for FDI, encouraging many foreign firms to establish their business in India.

STPs also allowed Indian companies, such as TCS, Infosys and Wipro, to undertake large projects without having to incur high costs of sending engineers overseas for training. In addition, local companies benefited from the **growing presence of foreign firms**, and supported by their business relationships, they acquired quality certifications and captured a wide range of skills beyond programming, such as quality assurance, project scheduling, among others.

In another example, Mexico initiated a Program for the Development of the Software Industry (PROSOFT), under the Ministry of Economy in 2002. In the second stage (2008-2013), the program focused on creating the necessary enabling environment to increase the competitiveness of the IT industry globally. During this phase, key areas included human capital, export and FDI promotion with nearly half of the support channeled to certifications (e.g. CMMI) and skill development.

Source: Couto and Fernandez-Stark (2018)

Korea should focus on **specific areas** of the digital economy that capitalize on its strengths and fills a gap in the existing landscape. From the industrial side, shipping, transportation and construction are key areas. In ISS platforms, there has yet to be a technology or company that has managed to dominate the Asian market, with most having a domestic approach (evidenced by the high share of domestic revenue for Chinese and Korean firms).

Box 7-3. IIoT Opportunities Exist for Latecomers, but Challenges Remain

Despite the considerable benefits that have been identified for adopting digital services, and the estimates of potential market size, uptake has not been as explosive as predicted. Only 28% of industrials report having production scale IIoT operations (Buntz, 2018). While projections for growth in digital technology services remain strong, this may still take time. This leaves the door open for countries and firms that have yet to adopt a digital culture, if they can overcome common constraints including organizational inertia, legacy systems, human capital availability and cybersecurity.

Organizational inertia is a major challenge for the adoption of digital services. Management specialists highlight that the changes these services bring, including new business models and tools, are highly disruptive to existing models and thus there is a considerable level of resistance across organizations to adopt them, from senior management to sales representatives and field technicians (Buntz, 2018; Columbus, 2018; Forrester, 2018b; McAfee & Brynjofsson, 2012; UNCTAD, 2017b). Part of this is due to general company cultures and incentive structures which need to adapt considerably to adopt digital technologies.

Manufacturing operations are often dominated by **legacy equipment** and technologies, with limited opportunities to introduce major sweeping changes (Buntz, 2018). Large-scale systems integration must either take place in greenfield operations, or in expansion or renovation of brownfield operations. Thus, incorporating new technologies will be incremental as discrete equipment is made increasingly smart and integrated into control systems. For example, having demonstrated the efficacy and benefits of its autonomous haul system (AHS) with ten years of commercial experience for new trucks, Komatsu developed a retrofit system to convert legacy haul trucks to AHS with its first order from Rio Tinto for 29 trucks ("Autonomous Haulage Technology Reaches the 10-Year Mark," 2018).

Data analytics requires **new talent resources**. The lack of know-how, expertise and manpower for implementation are the most frequently cited barriers for adoption amongst executives (Bosch Software Innovations & Frost & Sullivan, 2016). High demand for limited human capital capable of undertaking these tasks makes it more expensive and slows adoption. While private, public and educational institutions are responding to these needs, it will take at least four to five years for workers to emerge from educational programs with the correct skillsets for widespread adoption.

Cybersecurity has been identified as one of the most important hurdles to deploying IIoT systems (Accenture, 2015; Kagermann et al., 2016). The industrial operations served by emerging digital services are considered extremely vulnerable to cyberattacks. The impact of an attack on controls systems of oilrigs, aircraft, power supply systems or refineries can be catastrophic for the environment, economic stability and population health and safety.

8. Appendix

Table A-8-1. Digital MNE GVC Companies

		Firm	HQ Country	Year Est.	Revenue Sources	Revenue (US$, billion)	Emp.	Ownership	Industrial/Consumer; Brands/Products	Non-Domestic Sales %	Asia Revenue %
Software	1	Citrix	US, FL	1989	Software support/ renew: 60%; Software: 37%; Services: 5%	$2.8 Dec17	7,500 Dec17	Public: NASDAQ: CTXS	Industrial: B2B (Communication)	46%	10%
	2	Microsoft	US, WA	1975	Software (OEM & aftermarket), Products (Games), Services: 36%	$90.0 June17	124,000	Public: NASDAQ: MSFT	Consumer/Industrial Windows, Xbox, Office, Skype, LinkedIn, Azure	50%	--
	3	Oracle	US, CA	1977	Software 80%; Services 9%; Hardware 11%	$37.7 May17	138,000	Public: NYSE	Industrial	53% 63% (emp)	16% 36% (emp)
	4	Red Hat	US, NC	1993	Software ~ 90% (operating)	$2.4 Feb17	10,500	Public: NYSE: RHT[46]	Industrial	42%	14%
	5	Salesforce	US, CA	1999	Software: 95%	$10.5 Jan18	29,000 Jan18	Public: NYSE: CRM	Industrial: B2B (Sales)	31% FY18	10%
	6	SAP	Germany	1972	Software	$26.4	88,543	Public:	Industrial: SAP HANA; SAP Leonardo; IIoT Platform (semi-open); IT-OT integration	>54%	16%
	7	SAS	US, NC	1976	Software; Analytics	$3.2 Dec17	14,216	Private	Industrial	>51%	15%
	8	Kakao	Korea	1995 2006 2010 2014	Advertising 30%, Content 50%, Other Service Fees 20%	$1.7 Dec17	5,832 incl. subsidiaries	Public: KRX 035720	Consumer: Daum (search), KakaoTalk (mobile message), Kakao Story (SNS), KakaoPay, KakaoT, KakaoBus		--
IT	9	IBM	US, NY	1911	Tech Services/ Cloud (IaaS): 38%; Business Services: 23%; Software: 31%; Hardware: 8%	$79.1 Dec17	366,600	Public	Industrial: Watson	62%	21%

[46] Acquired by IBM (November 2018) during project; Initial IPO 1999: $936M valuation.

		Firm	HQ Country	Year Est.	Revenue Sources	Revenue (US$, billion)	Emp.	Ownership	Industrial/Consumer; Brands/Products	Non-Domestic Sales %	Asia Revenue %
	10	Samsung SDS	Seoul, Korea	1985	Logistic BPO: 45%; Application Outsourcing: 42%; IT Consulting: 13%	$8.2 Dec17	22,871	Public (since 2014)	Industrial Customer: Samsung	53%	74%
	11	Infosys	India	1981	Services: 100%	$10.2	200,364		Finance (33%), Mfg. (23%), Retail (23%)	97%	12%
	12	TCS	India	1968	Services: 100%	$17.6	394,998		Banking (39%), Communications/Media/Tech (17%), Retail (17%)		10%
	13	Wipro	India	1945	Services: 95%	$8.1	181,482		Banking (26%), Mfg. (23%) Retail (16%), Health (16%)		11%
ISS/Platform	14	Alphabet/ Google	US, CA	1998	Advertising: 86%; Cloud	$110.9 Dec17	80,110	Public	Consumer Brands: YouTube, Waze, Nest	53%	15%
ISS/Platform	15	Baidu	Beijing, China (Cayman Islands)	2000	Advertising: 86%; video platform (14%)	$13.0 Dec17	39,343	Public: NASDAQ: BIDU	Consumer: Brands: Baidu, QiYi Areas: Search, Maps, Navigation, Wallet, messaging, social network, cloud, video (QiYi)	2%	100%
ISS/Platform	16	Naver	Seongnam, Korea	1999	Advertising: 74% Dec16	$4.1 Dec17	2,793	Public	Consumer: Brands: Line, Band	29%	≥99%
ISS/Platform	17	Amazon	US, WA	1994	Product: 67%, Services: 24% Cloud (AWS): 9%	$177.9 Dec17	341,400[47] Dec16	NASDAQ: AMZN	Consumer/Industrial Brands: Alexa, Kindle, Echo, AWS, Zappos, Ring	32%	7-17%
ISS/Platform	18	Alibaba Group	Hangzhou, China	1999	Advertising: 53%; Commission: 27%; Cloud: 3%	$23.0 Mar17	50,097	Cayman Islands	Consumer/Industrial Brands: Taobao, Tmall, Alibaba,	7.5% FY16	--
ISS/Platform	19	Tencent	Shenzhen, China	1998	Online games; social sites: 65%; Advertising: 17%; Payment & cloud: 18%	$36.5 Dec17	44,796	Holding Company: SEHK: 700	Consumer: Brands: WeChat, Weixin, Tenpay, WeChat Pay, Tencent Cloud	3%	≥97%

Source: Authors; annual reports, company websites, market reports. Data is for FY17 unless otherwise noted.

47 FY17 was 566,000, but increase due to acquisition of Whole Foods, so not particularly relevant. Employment represents full and part-time employees.

Table A-8-2. Industrial Equipment GVC Companies

Type		Firm Name	HQ	Year Est.	Revenue (US$B, 2017)	Emp. (2017)	Services % Rev. (2017)	IIoT Roles	Cloud Platform, Year, Type	Field	Asia Rev. %
Integrators	1	ABB	Switzerland	1988 (1883)	$34.3	134,800	18%	Analytics; PLM	ABB Ability, 2016 (Closed)	Energy, Factory Automation, Marine, Mining	39%
	2	Bosch	Germany	1886	$88.0	402,166	--		Bosch IOT (Open)	Automotive, Factory Automation Energy; Consumer goods	30%
	3	General Electric	US	1892	$120.5	313,000	48%	Analytics	Predix, 2015, 16 (Open)	Energy, Power, O&G (52%), Aerospace (22%), Health, Marine, Rail	19%
	4	Hitachi	Japan	1910	$83.5	307,275	--	Cloud Infrastructure; Analytics; PLM	Lumada, 2017 (Open)	Electronics, Automotive, Construction, Mining, Rail, Energy, Water	72%
	5	Honeywell	US	1906	$40.5	131,000	20%	Analytics	Honeywell Sentience, 2017	Aerospace (36%), Oil & Gas, Mining, Factory Automation	18%
	6	Siemens	Germany	1847	$93.6	363,000	--	Analytics	Mindsphere, 2016 (Open)	Energy, Power & Gas (35%), Marine, Rail, Mining, Factory Automation	19%
Discrete Manufacturers	7	Caterpillar	US	1925	$45.5	98,400	--	Analytics; Post-sales services; Smart Factory	N/A	Mining & Construction, Marine, Energy, Rail	22%
	8	Komatsu	Japan	1921	$22.3	59,632	--	Analytics; Post-sales services; Smart Factory; Product-as-a-Service	N/A	Mining & Construction (91%)	34%
	9	Rolls Royce	UK	1906	$20.5	50,000	47%	Product-as-a-Service; Analytics	N/A	Aerospace (68%), Marine, Energy, Rail	24%

Source: Authors; based on annual reports and websites. Note: Asian firms fiscal years end March 31, 2018. (--): data not available. N/A: not applicable.

Table A-8-3. WIR: Digital MNEs and ICT MNEs (other classifications, SIC, PwC, CBI, S&P)

WIR Type	WIR Subtypes & Revenue Source	WIR Rev., US$B, 2015	WIR Firms	WIR Avg. Rev./Co. US$B, 2015	Companies	SEC: SIC Codes	PwC Global Innovation 1000[48]	CBI	CFRA/S&P
Internet Platforms (Digital)	Advertising		11	$11.3	Google, Naver, Red Hat, Baidu	7370: Services-Computer Programming, Data Processing	(1) Communications: Internet: Web Portals/ ISP (Naver only firm)		
	Search engines	$82.7	3	$27.6	Alphabet, Naver, Yahoo				
	Social networks	$27.3	5	$5.5	Facebook, IAC, LinkedIn, Twitter				
	Other platforms	$13.8	3	$4.6	eBay, Groupon, Red Hat				
E-Commerce (Digital)	Commission from sellers		18	$9.9	Amazon, Alibaba	7389: Services-Business Services, nec.	(3) Consumer Discretionary: Retailing: Internet & Direct Marketing Retail (Amazon)	Internet: eCommerce	
	Internet retailers	$154.9	13	$11.9	Amazon, Alibaba				
	Other e-commerce	$23.9	5	$4.8					
Digital Content (Digital)	Direct or content rights sale		45	$7.8	Tencent				
	Digital media	$261.1	22	$11.9					
	Info/data	$59.1	16	$3.7					
	Games	$31.7	7	$4.5					
Digital Solutions (Digital)	Transaction-based commission fees		26	$4.2	Salesforce, Citrix			Mobile & Telecom: Mobile commerce	IT: Software & Services: Software & ISS (& row below)
	Other	$77.4	21	$3.7					
	Electronic payments	$30.8	5	$6.1					
Software & Services (ICT)	--	Software, IT Services	21	$19.5	Microsoft, HPE, Oracle, Accenture, SAP, Infosys,	7371: Services-Computer Programming Services	IT: Software & Services (3) Internet Software and Services	Internet: ISS Mobile & Telecom: Mobile	

[48] UNCTAD WIR and PwC taxonomy do not coincide for most categories. PwC places all companies in IT: Software & Services and WIR lists Software & Services as a separate category.

WIR Type	WIR Subtypes & Revenue Source	WIR Rev., US$B, 2015	WIR Firms	WIR Avg. Rev./Co. US$B, 2015	Companies	SEC: SIC Codes	PwC Global Innovation 1000[48]	CBI	CFRA/S&P
					Wipro, CSC (DXC)			software & services;	
		Software				7372: Services-Prepackaged Software	IT: Software & Services (5) Software	Internet: Software (non-Internet/mobile): all 35 industries	
		IT Services			Samsung SDS	7370: Services-Computer Programming, Data Processing 7389: Services-Business Services	IT: Software & Services (4) IT Services		IT: Software & Services: IT Services
Hardware: Devices & Components (ICT)	Components, Devices	Goods	52	$31.5	Samsung Electronics, IBM	3570: Computer & Office Equipment		Computer Hardware and Services (Industry)	IT: Technology, Hardware and Equipment; IT: Semiconductors & Equipment
Telecommunications (ICT)	--		27	$31.3	Verizon, AT&T	4813: Telephone Communications (No Radio Telephone)	Telecommunication Services: “”	Mobile & Telecom: Telecom services; Telecom devices & equipment; fiber optics (3/5)	
								Internet: Stealth Mode (small)	
Taxonomy Structure/ Notes							Industry sector: Industry group: Industry: Primary industry. Digital covers two industry groups (Internet and Software & Services) and all but one company in Retailing.	Sector: Industry: Sub-industry; three main sectors; not incl. computer hardware & services	Main segment is IT. IT has three parts.

Sources: UNCTAD (2017a). See Mapping the Digital Economy Global Value Chain for details.

Table A-8-4. Industry Segments by Industrial Classifications: ISIC4, KSIC-07, NAICS

Type	ISIC Rev4 (2008-present)	ISIC4 Code	KSIC-07 Description	KSIC Codes (4-digit)	NAICS	VC Stage
Digital & Traditional	**Programming and broadcasting** Radio broadcasting TV programming and broadcasting activities	60 6010 6020			515: Broadcasting (except Internet) (NAICS02-17) 51511 Radio Broadcasting 51512 TV Broadcasting 5152 Cable and Other Subscription Programming	
Digital & Traditional	**Telecommunications** Wired Wireless Satellite Other	61 6110 6120 6130 6190	611: Postal Services 612: Telecommunications 6121: Wired Telecommunications 6122: Wireless Telecommunications 6123: Satellite Telecommunications 6129: Other Telecommunications		5171: Wired Telecommunications Carriers NAICS02-12; NAICS17: 517311[49] 5172 Wireless Telecommunications Carriers NAICS02-12; NAICS17: 517312 5174: Satellite Telecommunications Providers NAICS02-17 5179: Other Telecommunications (NAICS07-17). Two: 517911 & 517919	
Digital	62: Computer programming, consultancy and related activities 6201: Computer programming activities 6202: Computer consultancy and computer facilities management activities 6209: Other IT and computer service activities	62 6201 6202 6209	62: Computer programming, consultancy and related activities 6201: Computer Programming Services 6202: Computer System Integration Consultancy, Establishment and Management Services 6209: Other IT and Computer Operation Related Services	6201 6202 6209	5415: Computer Systems Design and Related Services (NAICS97-17)	IT Services
Digital	**63: Information service activities** 6311: Data processing, hosting and related activities 6312: Web portals	63 6311 6312	63: Information service activities 6311: Data Processing, Hosting and Related Service Activities 6312: Portals and Other Internet Information Media Service Activities	6311 6312	518: Data Processing, Hosting, and Related Services (NAICS02-17); as of NAICS07, only 5182 51913: Internet Publishing and Broadcasting and Web Search Portals (NAICS07-17); NAICS02: 516110[50]	ISS Platforms
Digital & Traditional	Other information service activities News agency activities	639 6391 6399	639: Other Information Service Activities 6391: News Agency Activities		519110: News Syndicates NAICS02-17 519190: All Other Information Services NAICS02-17	

[49] NAICS17: 5171 and 5172 change to 5173.
[50] NAICS 516: only used in NAICS02 and only one code 516110 Internet Publishing and Broadcasting. Changes to 519130 in NAICS07.

Type	ISIC Rev4 (2008-present)	ISIC4 Code	KSIC-07 Description	KSIC Codes (4-digit)	NAICS	VC Stage
	Other information service activities n.e.c.		6399: Other Info Service Activities nec **--63991: Database and online information provider**[51]			
Digital & Print	**Publishing activities** Book publishing Publishing directories and mailing lists Publishing newspapers, journals, periodicals Other publishing activities	58 5811 5812 5813 5819			5111: Newspaper, Periodical, Book, and Directory Publishers (NAICS97-17)	
Digital	5820: Software publishing	5820	582: Software Development & Supply 5821: Game "” 5822: System and Application "”	5821 5822	5112: Software Publishers (NAICS97-17)	Software
Digital & Traditional	Motion picture, video and TV program production, sound recording, music publishing Sound recording and music publishing	59 5920			512: Movie, Video and Music Production (NAICS97-17)	

Source: Author; based on ISIC4 classifications; see Mapping the Digital Economy Global Value Chain for context. Notes: Digital definition includes all codes in 62; part of 63 (not 639); part of 58 (not 581). KSIC Codes (4D column) are the ones used in analysis.

[51] Relevant, but there isn't an international or US comparison code.

Table A-8-5. Types of Software (IBIS, CFRA, CBI)

Segment (all Software)	NAICS	US Revenue (US$, B), 2017	US Emp., 2017	Firms	Notes	Source	Software (CFRA, 2017c)	CBI
Systems							Microsoft, Oracle	
Operating Systems & Productivity	51121a	$61.5	140,520	Microsoft, Apple	Largest by revenue	(IBISWorld, 2011, 2017q)	Operating Systems (Microsoft, Apple)	Operating Systems & Utility
Database, Storage & Backup	51121b	$44.1	100,625	Microsoft, Oracle, IBM, EMC		(IBISWorld, 2012b, 2015b, 2017c)	Database Software (Oracle, IBM, Microsoft)	DB Mgmt.
Application							Salesforce, Adobe	
							Communication & Collaboration: Outlook (Microsoft), WebEx (Cisco), GoTo (Citrix)	Networking & Connectivity; Conferencing & Communication
Business Analytics & Enterprise	51121c	$49.6	117,943	IBM, Salesforce, SAP, Oracle	Second in growth in revenue and employment	(IBISWorld, 2012a, 2017a)	ERM (SAP, Oracle, Intuit, Microsoft, ADP, Sage Group, Workday), CRM (Salesforce)	Business Intelligence, Analytics & Performance Mgmt.; Supply Chain & Logistics
Design, Editing & Rendering	51121d	$10.0	20,820	Adobe, Dassault Systemes, Autodesk	Smallest	(IBISWorld, 2012c, 2017d)	Content Creation (Adobe, Microsoft, Apple)	Multimedia & Graphics
Video Game	51121e	$22.9	123,974	Activision Blizzard, EA, Sony, Microsoft, Nintendo	Fastest growth, but half size of analytics. Most emp.	(IBISWorld, 2012f, 2015f, 2017y)	Home Entertainment (Activision, Electronic Arts (EA), Take-Two)	Gaming
Security	51121f	$13.4	33,923	Symantec, McAfee		(IBISWorld, 2012d, 2018f)		Security
Electronic Medical Records	OD4172	$10.3	17,118	Epic Systems		(IBISWorld, 2017i)		Healthcare Software
Online Payment Processing	OD4521	$19.7	33,682	PayPal, First Data, Square	Merchants to authorize/manage credit card transactions via internet	(IBISWorld, 2017p)	IT: IT Services: Data Processing & Outsourced Services	

Segment (all Software)	NAICS	US Revenue (US$, B), 2017	US Emp., 2017	Firms	Notes	Source	Software (CFRA, 2017c)	CBI
Speech & Voice Recognition	OD4531	$12.6	32,963	Nuance (6%)		(IBISWorld, 2017w)		
Electronic Design Automation Software Dev.	OD4540	$4.8	10,726	Cadence Design Systems (31%)		(IBISWorld, 2015c, 2017h)		
Tax Preparation	OD4549	$3.4 (2018)		Intuit (59%)		(IBISWorld, 2018i)		
HR & Payroll	OD4552	$6.7	14,989	ADP, Workday		(IBISWorld, 2017l)	IT: Software: Application Software	HR & Workforce Mgmt.
CRM System Providers	OD4592	$15.2	34,654	Salesforce, SAP, Oracle		(IBISWorld, 2017b)		Customer Relationship Mgmt.
e-Trading	OD4749	$10.3	24,240	Charles Schwab (20%)		(IBISWorld, 2017g)		Asset & Financial Management & Trading
Personal Finance & Money Mgmt.	OD4756	$0.31	780	Intuit (37%), Envestnet (9%)		(IBISWorld, 2017r)		Accounting & Finance
Insurance Claims Processing	OD4793	$10.3 (2018)	22,475	--		(IBISWorld, 2018b)		
e-Discovery Software Publish.	OD4816	$1.3	4,445	HPE	Search data for court evidence	(IBISWorld, 2017f)		Legal
Urban Planning	OD5397	$1.8	4,009	Trimble, ESRI, Autodesk		(IBISWorld, 2017x)		Scientific, Engineering Software
Motion Capture Software Dev.[52]	OD5815	$1.5	3,361			(IBISWorld, 2014a, 2017o)		
Website Creation Software Dev.	OD5816	$8.2	18,885	Adobe	HTML editing to design websites	(IBISWorld, 2014b, 2017aa)		
Point of Sale	OD5897	$1.5	3,822	Square (26%)		(IBISWorld, 2017s)		Retail & Inventory

Source: IBISWorld US Reports: all reports in NAICS 5112 'software publishers.' Additional software reports in the specialized report section also included.

[52]Operators that develop software used in the process of recording movement of one or more objects or persons. Video game developers are primary market.

Table A-8-6. Key Institutional Stakeholders in the Digital Economy GVC

Name		Geographic Scope	Focus	Description	Website
IoT Institute	IOTI	World			www.ioti.com
Software & Information Industry Association	SIIA	US, Washington, DC	Industry Association		www.siia.net
World Information Technology and Services Alliance	WITSA	World	Industry Association		www.witsa.org
International Association of Outsourcing Professionals	IAOP	World	Industry Association	BPO	www.iaop.org
Industrial Internet Consortium	IIC	World Needham, MA	Industry Association	Definitions	www.iiconsortium.org
Institute for the Certification of Computing Professionals	ICCP		Certification		www.iccp.org/index.html
	ISACA				www.isaca.org
CompTIA					https://certification.comptia.org
International Data Science in Schools Project	IDSSP	World	Education	Est. 2018; Data science curriculum development	www.idssp.org
Webopedia		World		Definitions: Online dictionary and search engine for computer and Internet technology.	www.webopedia.com
Federal Communications Commission	FCC	US	Government Agency	Regulates interstate and international communications by radio, TV, wire, satellite, & cable.	www.fcc.gov
Federal Trade Commission	FTC	US	Government Agency	Ensures the nation's markets function competitively, and are efficient, and free of undue restrictions; educates public on personal information privacy.	www.ftc.gov
Digital Content Next			Industry trade organization	Represent online content providers to the advertising community, media, government, and the public; disseminates relevant research online.	http://digitalcontentnext.org
StatCounter		World Data by regions and countries	Market Research	Market shares for: browser (& version), search engine (& host), operating system (OS), screen resolution, social media, device vendor & mobile/tablet/ desktop. Years: 2009-2018: daily, weekly, monthly, quarterly, yearly	http://gs.statcounter.com

Notes: see **Error! Reference source not found.** section.

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