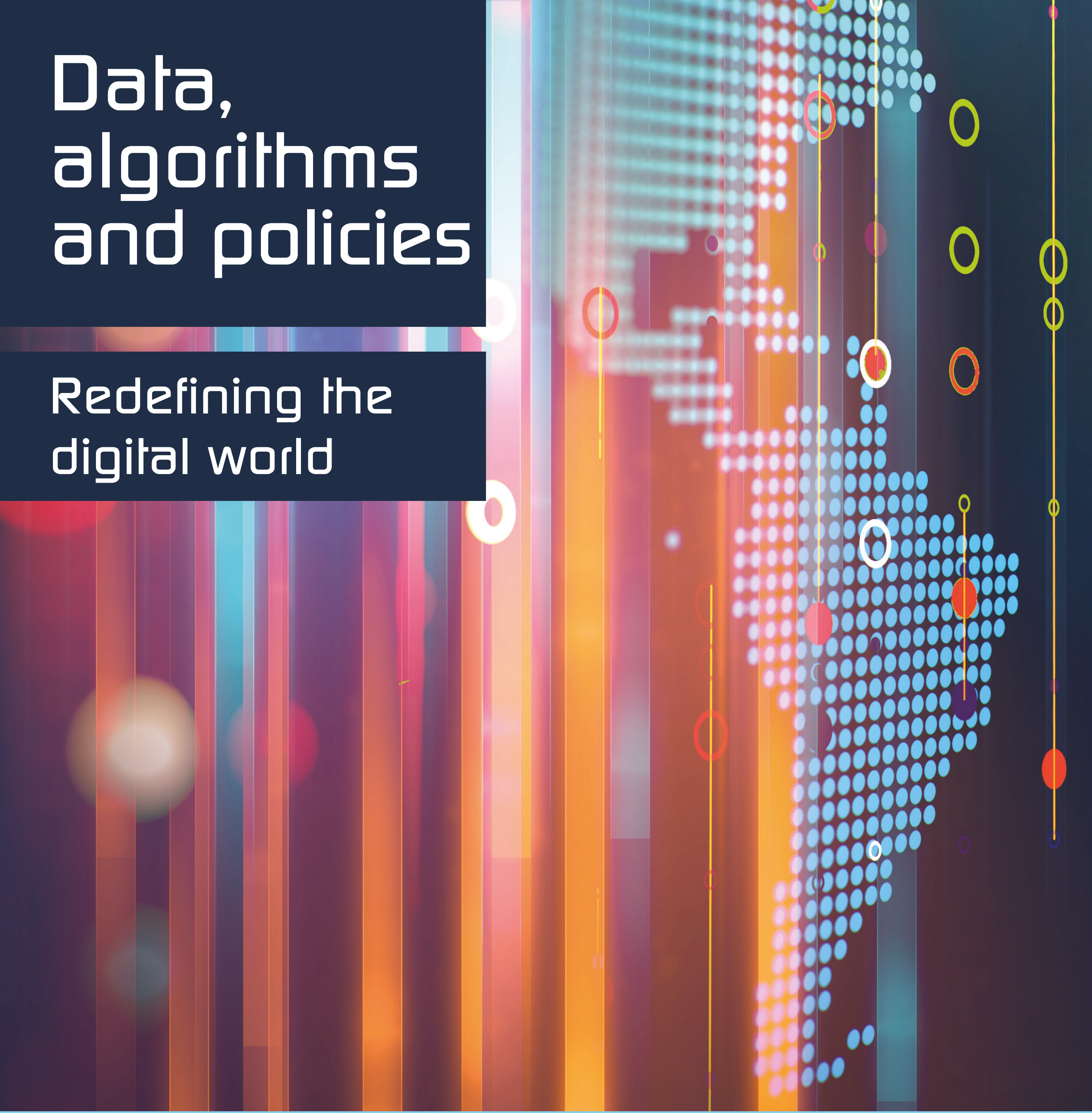
Data, algorithms and policies

Redefining the digital world



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Data, algorithms and policies

Redefining the digital world

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This document was coordinated by Mario Cimoli, Deputy Executive Secretary a.i. of the Economic Commission for Latin America and the Caribbean (ECLAC). The drafting was undertaken by Mario Castillo, Valeria Jordán, Jorge Patiño, Wilson Peres, Fernando Rojas, Sebastián Rovira and Nunzia Saporito.

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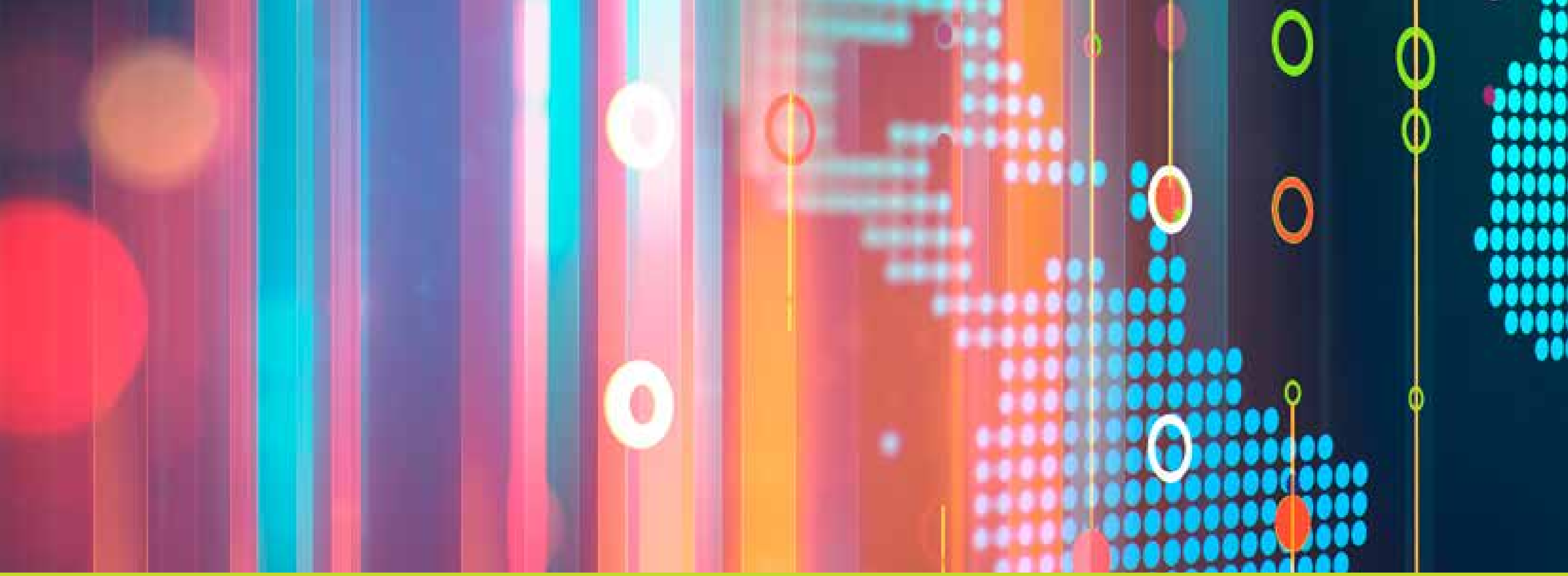


Foreword

In the three years that have elapsed since the Fifth Ministerial Conference on the Information Society in Latin America and the Caribbean, which was held in Mexico City from 5 to 7 August 2015, issues that were then considered only incipient, or even academic, have emerged strongly onto the agenda. The rapid pace of the digital revolution combines the implementation of fast-growing technological trajectories: the Internet of Things, blockchain and artificial intelligence. These technologies are based on global digital platforms and affect the economy and society on a cross-cutting and sectoral basis. This new configuration goes beyond the digital world of only a decade ago, when the key issues for Latin America and the Caribbean were linked to access to basic technologies (computers and telephones), fixed and mobile connectivity networks, expansion of broadband and the effort to convince sectoral authorities of the importance of putting digital technologies at the centre of their strategic decisions. This new reality, in which the physical and digital worlds are converging, creates an ecosystem whose dynamics and socioeconomic effects are not fully determined. In this sense, it remains an open road.

This document reviews three sets of topics. It begins with a description of the aforementioned technological trajectories, then analyses two enablers of these technologies: global digital platforms and training for upgrading human resources to operate advanced digital technologies, drawing on recent data for seven Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico, Peru and Uruguay). Next, it analyses the impact of these and other digital technologies in two vertical dimensions: manufacturing and advanced services, and digital financial technology (fintech) firms. In the latter, special attention is afforded to the services these firms can provide to small and medium enterprises, thereby fostering financial inclusion. The document closes with an analysis of the implications of artificial intelligence for achieving the Sustainable Development Goals.

This document embodies the historical thinking of the Economic Commission for Latin America and the Caribbean (ECLAC), in particular since 2010, when it launched its cycle of public policy proposals for moving towards more equal and rights-based economies and societies. In the process of developing these ideas, the Commission has stressed the potential role of digital technologies in helping the countries of Latin America and the Caribbean to drive an environmental big push in order to achieve structural change with greater production diversification, sustainability and equality.

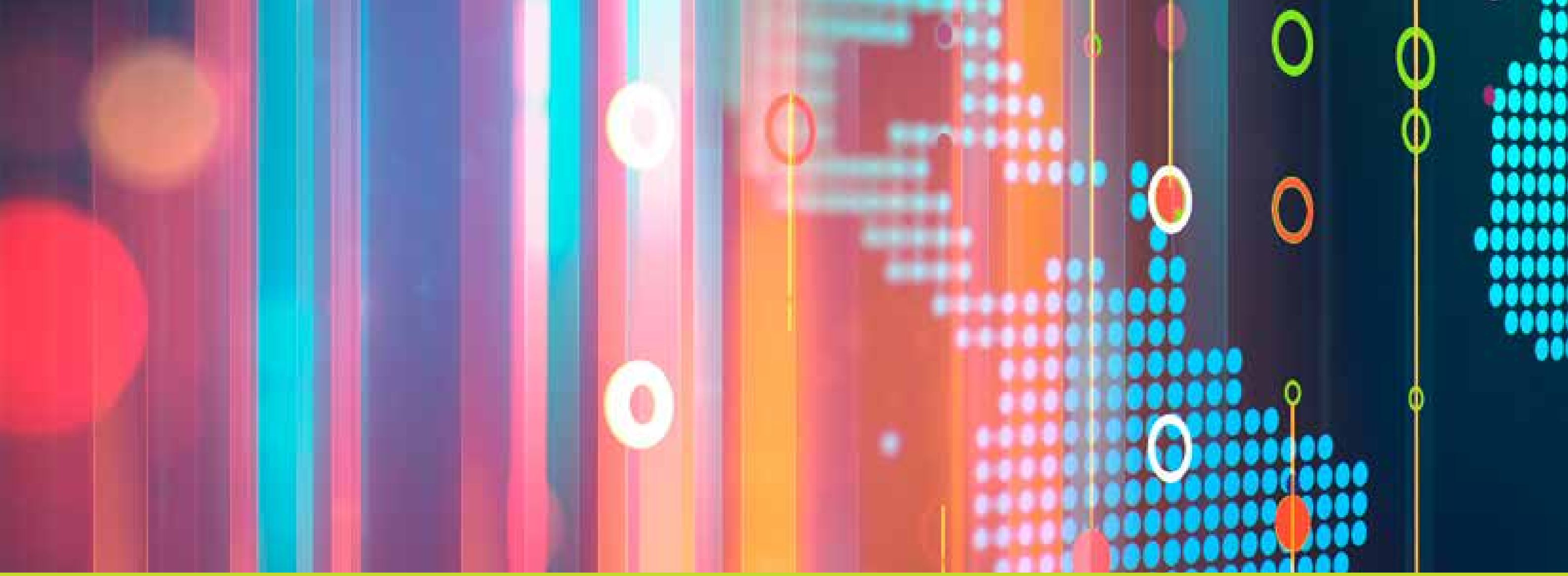
In particular, ECLAC has highlighted the importance of digital technologies in fostering the decarbonization of production and consumption patterns, which is closely linked to the sustainable and smart management of cities and the promotion of new renewable energy sources. The convergence of the physical and digital worlds makes it possible not only to make resource allocation and economic management more efficient, but also to greatly enhance transparency and citizen participation. All this is set in a context in which digitalization can reduce or even eliminate our societies' carbon and energy footprints. Accordingly, each chapter of the document concludes with policy recommendations aiming at enabling countries of the region to manage and take advantage of these technologies. The document also draws attention to the importance of the institutional continuity of the Digital Agenda for Latin America and the Caribbean (eLAC) for over a decade, and of pursuing progress towards a regional digital market.

Today, the region is better equipped for this technological revolution than it was for previous ones, during which it imported mature technologies with fully consolidated market structures. As is discussed in this document, the region has made significant progress in terms of human capital formation in fields related to digital technologies, including the most advanced ones; and it has also achieved major advances in terms of connectivity, particularly through 4G networks. Nonetheless, the pace of technological change requires a redoubling of efforts in a world in which competition among the digital technology leaders is ever fiercer and the business structure is becoming concentrated in just a few global platforms. In this context, the region has to increase its commitment to technological development, including advanced technologies, to be able to participate in the technical and political debate on the new standards and business models that are redefining the development pattern.

Topics that have been present in the debate for years, such as data security and privacy and the political and ethical issues involved in data management, have risen rapidly in the public agenda. The debate has also intensified on themes such as tax and regulatory regimes for the digital world, which have to be designed and implemented at the national, regional and global levels. These discussions are taking place in the framework of a wider debate concerning the changes in the rules of the game, such as those relating to network neutrality. In short, we are living at a time of decisions on the governance not only of the network but also across the entire economic and social system permeated by digitalization.

In this debate, the region's position should be clear: strengthen policies to promote innovation, diffusion and appropriation of the new technologies in order to move towards a new economic, social and environmental model aligned with the 2030 Agenda for Sustainable Development.

Alicia Bárcena
Executive Secretary
Economic Commission for
Latin America and the Caribbean (ECLAC)



Introduction

A. A world in vertiginous transformation

Since 2015, economic, technological and geopolitical changes have been transforming the global scenario with implications for the development model. Following nearly a decade of slow economic growth since the 2008 financial crisis, all the major regions of the global economy are now growing once again, which is fuelling greater dynamism in the countries of the region. Nonetheless, there is increasing uncertainty as to whether this will be sustained in the long term. Questions about globalization and its effects, particularly increasing income inequality, compounded by doubts about the future of the major multilateral trade agreements, provoke macroeconomic tensions alongside the gathering pace of the digital revolution.

The digital revolution entails disruptions that are triggering innovations in business models and production systems, the reorganization of economic sectors, new dynamics in the world of work, the supply of smart goods and services and new conditions of competitiveness. The United States, China and some Western European countries are pursuing strategies to lead the new technologies and thus ensure their predominance on the world stage. This dynamic will influence investment flows and the production structure in individual countries, which will have repercussions for the geopolitical order prevailing in the new industrial revolution (ECLAC, 2018).

The global economy and society are becoming increasingly immersed in the digital era, which is defined by the convergence of a set of emerging technologies, with dynamics that are shaping new ecosystems built on the infrastructure and innovations of the digital revolution. The pace of change resulting from the exponential nature of technological progress, the extent to which digital technologies are permeating all sectors and industries, and their profound capacity to transform complete production, management and governance systems, add opportunities and uncertainties to the development dynamic (Schwab, 2016).

A first stage of the digital transformation process involves moving from the cosumer Internet to the industrial Internet. Digitalization reduces both marginal costs of production and transaction costs; and it promotes innovations in digital goods and services, and fosters the development of consumption and production platforms. It therefore adds value by digitalizing goods and services that, in principle, are not themselves digital (ECLAC, 2016). The determinants of the current digital economy are not the same as those prevailing less than a decade ago. In a relatively short period, the focus of attention and innovation has shifted from mobile connectivity and cloud computing to the ecosystems of the Internet of Things (IoT), data management through artificial intelligence, robotics and blockchain, the applications of which will reveal their full potential with 5G networks.

These advances, which are converging rapidly and empowering each other, deepen the transformation process. The current context is not only a hyperconnected world in its economic and social spheres, but one in which the traditional economy —with its organizational, productive and governance systems— overlaps or merges with the digital economy —with its innovative features in terms of business models, production, business organization and governance. This results in a new, digitally interwoven system in which models from both spheres interact, giving rise to more complex ecosystems that are currently undergoing organizational, institutional and regulatory transformation with an urgency imposed by the speed of the digital revolution. In the short run, the coexistence of two schemes can be expected to give rise to uncertainties and frictions in the areas of greatest symbiosis.

The digital economy as such started to develop two decades ago, with a dynamic involving the creation of digital goods and services and online business models based on global platforms. These data-intensive models have grown rapidly to the point that their emblematic players have positioned themselves beyond the digital industry. Today these actors are the global leaders in terms of market value. In February 2018, Apple had a market capitalization of US$ 910 billion; Alphabet was valued at US$ 800 billion; Amazon at US$ 702 billion; Microsoft at US$ 699 billion; Facebook at US$ 522 billion; Tencent at US$ 520 billion; and Alibaba at US$ 479 billion. This position, which stems from the growth of activities in their original core businesses (hardware, software, advertising and digital goods and services), has enabled these digital natives to diversify their fields of activity and use their technical knowledge to permeate other areas, such as communications infrastructure, cloud computing, financial activities, retail and services, such as health care, thus spreading through sectors of the traditional economy. In this universe, firms based in the United States and China predominate (see diagram 1).

Diagram 1
Fields of action of some of the leading technology firms

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Statista, *Digital Economy Compass 2017*, Hamburg, 2017; *Digital Economy Compass 2018*, Hamburg, 2018

The expansion of production structures based on connected smart goods (Porter and Heppelmann, 2014) and on IoT ecosystems is driving the growing fusion between the digital and real or traditional economies. Currently, the activities undergoing the greatest transformation in terms of the degree of digitalization of the products and services supplied, and of the production process itself, are in the automotive industry and the financial sector. By 2020, the health, manufacturing, agriculture, mining, transport and energy (smart cities) sectors are likely to be most affected by the greater digitalization of their activities (ECLAC, 2018). To that end, their firms pursue two complementary strategies. Firstly, they develop their own digital capabilities and may even become digital service providers. Secondly, through mergers and acquisitions and strategic alliances with global platforms, they acquire capabilities that enable them to adapt their supply to the demands of the new era.[1] As a result, the boundaries between traditional industries are becoming blurred, which poses challenges as traditional players face new competitors, environments with new rules and modes of operation,

1 For example, compared to 2011-2015 when businesses linked to artificial intelligence were mainly acquired by the large technology firms, between 2016 and 2017 the range of buyers diversified to firms from other sectors, such as Ford Motor Company and General Electric (IDG Connect, 2018).

and production systems that are more digitally-intensive, all of which requires new technical, productive and management skills. Digital platforms have also been developed for intermediate services such as urban transport, tourism and hotels, thereby merging the gig economy and the sharing economy.

Thus, in just a few years, interaction and integration between the traditional and digital economies have increased, not only because these technologies permeate production processes in ways that directly improve efficiency, but also because of their indirect systemic impact. This convergence is shifting the boundaries of markets and industries, altering the rules of the game, affecting competition and challenging regulatory models.

Digitalization is permeating the entire economy with an intensity that creates new sources of value. Data have been dubbed the new oil, since they fuel the disruptive technologies of today's economy (*The Economist*, 2017). But data have their own characteristics and the effects of their use are not the same as those of oil: they are reproducible and non-rival in use; they have close-to-zero marginal and transport costs and increasing returns to scale (more data, greater precision in predictive and learning algorithms); and they also raise issues of privacy and security. In this sense, there appears to be a lack of understanding of the "power" of data, whether among consumers, who are willing to release their data in order to receive a free online service; or among many firms that fail to effectively or efficiently manage the data they possess; or among governments that are taken by surprise by new business models that challenge existing norms and regulations.

This poses challenges in terms of competition policy,[2] taxation,[3] privacy and security,[4] and equity in terms of access to key resources in the new economy. A debate has begun on regulatory issues in these areas; and both technological standards and trade and intellectual property issues are also being addressed. For example, the trade measures imposed by the United States on imports of aluminium and steel from China in March 2018, alleging unfair trade practices, could presage a greater problem relating to ownership of the technologies that are driving the future of the global economy (Dwoskin, 2018). Some United States firms have raised concerns about the rules that China applies to joint ventures with foreign firms, requiring valuable skills or technology to be transferred. Thus, in addition to national security concerns, an escalation of actions could lead to measures being adopted on investment linked to technology (Swanson, 2018).

The topic is further complicated by the need for international coordination to achieve minimal consistency when dealing with issues that transcend geographical borders. Thus, as the convergence between the digital and real worlds becomes ever more widespread, it causes the effects of the digital revolution to influence resource allocation, labour relations, and the social and power structure. These effects call for a reconsideration of the scope of the concept of economic development and the policies deployed to promote it.

B. Acceleration and rapid diffusion of technological progress

Digital technologies are becoming faster, cheaper and more powerful; and they are converging with each other in a more innovative way to expand their potential. Over the last three decades, the virtuous circle of technological progress has become a central driver of global economic growth, and its importance is growing. In 2016, the digital component accounted for 15.5% of the global economy and was growing twice as fast as it. By 2025 its share is expected to surpass 24%, which means that the digital economy would then be worth nearly US$ 23 trillion (Huawei Technologies/Oxford Economics, 2017).

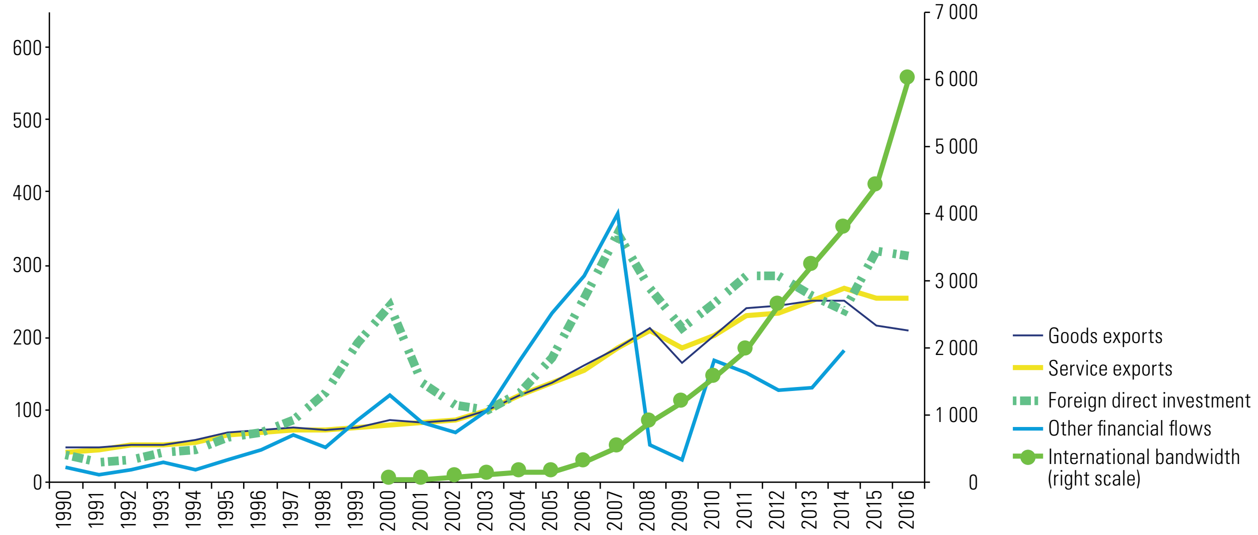
2 In the United States, there is concern over market concentration and the criteria for authorizing merger and acquisition are being reassessed —including an analysis of the impact of these operations. Mechanisms to tighten data security and privacy rules are also under study.

3 In Europe, it was announced that a proposal to establish common rules for taxation of the digital economy will be submitted by the end of 2018 (European Commission, 2017). At the same time, the finance ministers of several European Union economies called for a reform to enable earnings to be taxed where they are actually generated and not where profits happen to be recorded (Europost, 2017).

4 The European Union's General Data Protection Regulation, which will come into force on 25 May 2018, aims to strengthen the protection of people's rights and set a level playing field for all firms operating in the European market. The Regulation requires non-European Union firms that supply goods and services related to personal data, or track the behaviour of people in the European Union, to apply the latter's rules.

The dynamic pace of digitalization can be clearly seen in the exponential growth of international bandwidth capacity since 2007,[5] in a context in which international trade flows in goods and services, foreign direct investment (FDI) and financing fluctuated widely in the wake of the global financial crisis. Digital expansion, based on ever greater computing, storage and transmission capacities, was not affected by the problems measured by the traditional economic performance variables (see figure 1).

Figure 1
Global flows of trade in goods and services, foreign direct investment, other financial flows and Internet international traffic capacity, 1990–2016
(Index: 2003=100)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of International Monetary Fund (IMF), World Trade Organization (WTO) and International Telecommunication Union (ITU).

The rapid spread of digital technologies is revealed in many different indicators. In addition to those linked to traditional connectivity issues, such as Internet access and the use of mobile technologies, others measure the emergence and advancement of more recent innovations, such as the universalization of smartphones, intensity of the use of social networks and mobile applications, the advance of IoT, the adoption of blockchain and the use of artificial intelligence.

In 2017, about 4 billion people, representing over half the world's population, were Internet users, and 56% accessed it by subscribing to mobile services (ITU, 2018). In early 2018 there were over 5 billion unique mobile phone service users, which represented a penetration rate equivalent to 66% of the world's population. Fifty-seven per cent of those connections used smartphones; and 61% of mobile subscriptions were operating over 3G or 4G networks (GSMA, 2018).

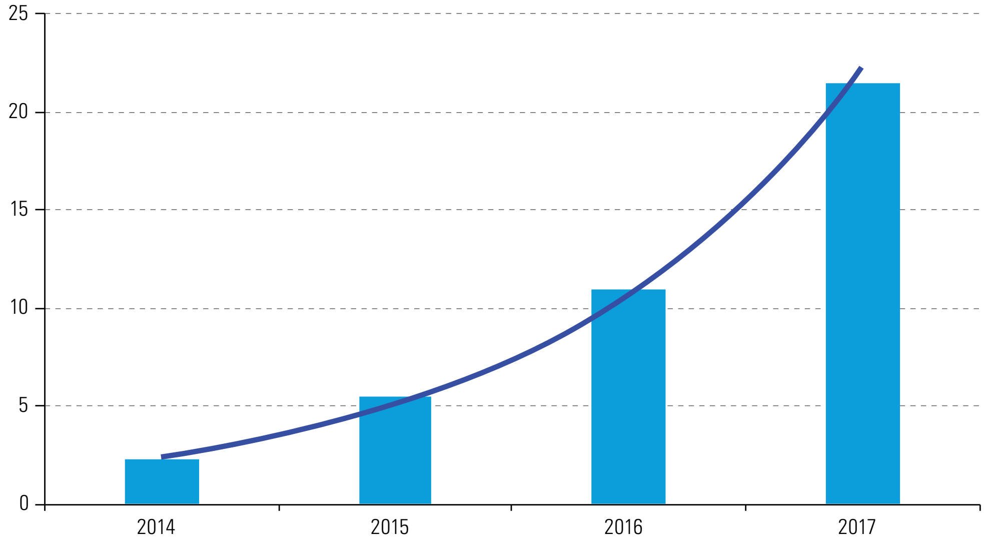
The growth in applications use has gathered pace, and the time taken to reach 100 million users has been cut from several years to one month in the most dynamic cases. In 2017, 175 billion applications were downloaded and around 40 were actively used in each smartphone, on which the average user spent about three hours a day (App Annie, 2018). In January 2018, over 3 billion people (42% of the world's population) used social networks per month, especially through mobile devices. Meanwhile, the use of e-commerce platforms to purchase consumer goods grew to 1.8 billion online shoppers worldwide (23% of the population) (Kemp, 2018).

Among the new technologies that are boosting digitalization, IoT is expected to have the greatest cross-cutting impact, both in the development of goods and services for consumers and for productive uses. In 2017 there were an estimated 8 billion IoT units installed, of which 63% represented solutions for personal consumption,

5 International bandwidth is the maximum amount of data that can be transmitted from a country to the rest of the world (ITU, 2010).

such as home automation, wearable technologies or connected cars. The remaining 37% was split between cross-sectoral solutions and others for specific verticals (Gartner, 2017). At the same time, the adoption of blockchain has been growing exponentially (see figure 2). After a minimum of 2 million blockchain wallet users was reached between 2011 and 2014, their growth accelerated to reach a level of 21.5 million by late 2017.

Figure 2
Number of blockchain wallet users, 2014–2017
(Millions of people)



Source: Statista, on the basis of Blockchain Luxembourg S.A. [online] https://blockchain.info/.

Digital technologies are spreading much faster than those of the industrial era. For example, around 1930, 60% of the population of the United States had access to electricity, while for many Latin American countries, particularly the least developed, this rate of coverage was only achieved in the 1980s. In the case of fixed-line telephony, 25% of households in the United States had access 76 years earlier than 25% of households in the countries of the region. These lags have decreased significantly in the digital era; and the number of Internet users reached 25% of the population of Latin America and the Caribbean only nine[6] years after the United States. The equivalent figure for mobile telephony was seven years and for smartphones three; and only one year for the use of online digital financial technologies (fintech) in some countries.

Thus, although a gap remains in access to digital technologies in the region's countries and efforts to reduce it must continue, the current technological wave is not producing disparities as large as in previous technological paradigms. This provides an opportunity to develop sectors based on the production of intangible goods and services; and it is becoming imperative to promote innovation and make new technologies affordable, as well as developing adequate capacities. This makes it necessary to strengthen institutional systemic complementarity to ensure effective policy coordination and resource allocation.

Latin American countries are rapidly adopting the new technologies. In 2017, there were 400 million cellular and non-cellular IoT connections in the region, which represents a fivefold increase since 2010 (GSMA, 2018). Seven per cent of IoT developers are in the region's countries, which is in line with its weight in the global economy. At the same time, the expansion of blockchain mining has become widespread in several countries, usually the largest ones.

International investment in the region's technology start-ups has more than doubled since 2013. In 2017, 25 new investors entered the region, including SoftBank Group, Didi Chuxing and The Rise Fund of the TPG enterprise, which has over US$ 1 billion in assets under management. Global corporate investors, such as

[6] In all cases except fintech, the number of years corresponds to a penetration rate of 25% of the population.

Naspers, American Express Ventures, FEMSA Comercio and Qualcomm Ventures, are also making some of the largest investments in areas such as transport and logistics and digital technologies for agriculture (agtech). Some of the leading Silicon Valley names are also active in Latin America, including Andreessen Horowitz, Accel, Founders Fund, Sequoia Capital and Y Combinator. These firms are investing in financing activities, mainly in Brazil, Colombia and Mexico (LAVCA, 2018).

The importance of the new initiatives is clearly shown by the fact that eight of the nine "unicorn" firms (start-ups valued at over US$ 1 billion) based in the region have business models focused on digital technologies: Mercado Libre, Despegar, Globant and OLX Group (in Argentina), B2W Digital Company and TOTVS (in Brazil) and KIO Networks and Softtek (in Mexico) (Arrieta and others, 2017).

Innovations are occurring at an exponential rate in various sectors; over the last year, the expansion of fintech firms and the use of cryptocurrencies have been at the forefront worldwide. As a result, many countries are trying to decide how to make the most of their advantages and minimize the risks. In the region, Brazil is the country with the largest number of cryptocurrency exchange sites; Argentina is the leader in terms of the number of firms; and Mexico has the largest volume of digital currency exchange. In that industry, 2017 was the year of initial coin offerings (ICO); and 2018 looks set to be the year of regulation. Mexico is the regional leader in the latter area, since on 1 March 2018, it passed the Law to Regulate Fintech Institutions, which seeks to establish standards regarding the provision of financial services such as electronic payments, crowdfunding and virtual assets. The application of this law requires nine others to be updated, including the Federal Law for the Prevention and Identification of Operations using Funds of Illegal Origin. The new law makes Banco de México responsible for authorizing virtual assets that can be used as means of payment on fintech platforms.

There are also various initiatives to advance in IoT. These include the strategic smart specialization programmes promoted by the Chilean Production Development Corporation (CORFO) in the areas of high-grade mining, healthy food and smart industry, among a total of 11 sectors. In addition, the Government of Brazil issued its Action Plan Report in October 2017, which highlights the unique opportunity represented by IoT and selects four targets for action: smart cities, health, agriculture and industry. Based on three mobilizing projects (innovation ecosystem, IoT observatory and IoT in cities), its final objective is a more competitive future, with more robust production chains and a better quality of life for the population.

Technological developments are being matched by a radical reorganization of the business structure. Global digital platforms with activities that dominate the online universe are being consolidated and are also having an ever greater impact on the analogue universe. It is still too early to predict the dynamics of this new business structure and how it will be received by governments in respect of regulatory (security, privacy) and taxation issues. This also heightens global uncertainty, since digital platforms are the most dynamic agents in terms of investment and the supply of digital goods and services, and their actions may challenge national regulations.

C. A governance under debate

The recent worsening of disputes over personal data privacy has abruptly revived discussion on how to regulate platforms, in particular how they manage personal data. Moreover, given the importance of these data for machine learning and the development of artificial intelligence, regulating them would have effects not only on the platform business model, but also on the variables that are likely to influence the social equilibrium (such as elections) or the international political balance (for example, autonomous weapons). These problems for platforms are compounded by tax and competition issues and by their potential effects on the quantity and quality of jobs.

Thus, using data through increasingly powerful algorithms not only redefines the digital world, but also requires new policies that operate under a governance structure suited to the new realities. The legal context of the digital world is at least under discussion, as shown by the debate and decisions on network neutrality in the United States in 2017, pressures to control foreign investments in American or European high-tech firms, the European Union's General Data Protection Regulation of 2018, and proposals for 5G network installations to be owned or controlled by the State.

The solutions to some of these issues are only now being proposed and it will take time to effectively implement them. Latin America and the Caribbean should use this time to innovate, move ahead in incorporating the new technologies and make their voice heard in international decisions on standards, regulation and taxation.

Bibliography

App Annie (2018), "2017 retrospective: a monumental year for the app economy" [online] https://www.appannie.com/en/insights/market-data/app-annie-2017-retrospective/#download.

Arrieta, A. and others (2017), *Tecnolatinas: Latin America Riding the Technology Tsunami*, Washington, D.C., Inter-American Development Bank (IDB), May.

Dwoskin, E. (2018), "While Trump fights over aluminum and steel, Silicon Valley braces for a real trade war", *The Washington Post*, 9 March.

ECLAC (Economic Commission for Latin America and the Caribbean) (2018), *The inefficiency of inequality* (LC/SES.37/3-P), Santiago, forthcoming.

___(2016), *The new digital revolution: From the consumer Internet to the industrial Internet* (LC/L.4029(CMSI.5/4)/Rev.1), Santiago, August.

European Commission (2018), "Stronger protection, new opportunities: Commission guidance on the direct application of the General Data Protection Regulation as of 25 May 2018", Brussels, 24 January [online] https://ec.europa.eu/commission/sites/beta-political/files/data-protection-communication-com.2018.43.3_en.pdf.

___(2017), "President Jean-Claude Juncker's state of the Union address 2017", Brussels, 13 September [online] http://europa.eu/rapid/press-release_SPEECH-17-3165_en.htm.

Europost (2017), "Turnover tax for digital giants sought", Sofia, 16 September [online] http://www.europost.eu/article?id=20616.

Gartner (2017), "Gartner says 8.4 billion connected 'things' will be in use in 2017, up 31 percent from 2016", Egham, 7 February [online] https://www.gartner.com/newsroom/id/3598917.

GSMA (2018), *The Mobile Economy 2018*, London.

Huawei Technologies/Oxford Economics (2017), *Digital Spillover: Measuring the True Impact of the Digital Economy*, Shenzhen.

IDG Connect (2018), "How AI M&A is going to rise", 10 January [online] http://www.idgconnect.com/blog-abstract/29139/how-ai-m-a-rise.

ITU (International Telecommunication Union) (2018), "Statistics" [online database] https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.

___(2010), "Definitions of world telecommunication/ICT indicators", March [online] http://www.itu.int/ITU-D/ict/material/telecomict_indicators_definition_march2010_for_web.pdf.

Kemp, S. (2018), "Digital in 2018: world's Internet users pass the 4 billion mark", New York, We Are Social, 30 January [online] https://wearesocial.com/blog/2018/01/global-digital-report-2018.

LAVCA (Latin American Private Equity and Venture Capital Association) (2018), "US investors in LatAm startups (2013-2017", New York, 26 February [online] https://lavca.org/2018/02/26/us-investors-latam-startups-2013-2017/.

Porter, M. and J. Heppelmann (2014), "How smart, connected products are transforming competition", *Harvard Business Review*, Brighton, Harvard Business Publishing, November.

Schwab, K. (2016), "The fourth industrial revolution: what it means and how to respond", Geneva, World Economic Forum, 14 January [online] https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

Swanson, A. (2018), "Looming China trade action divides industry and roils markets," *The New York Times*, New York, 2 April [online] https://www.nytimes.com/2018/04/02/business/china-us-trade-action-markets.html.

The Economist (2017), "The world's most valuable resource is no longer oil, but data", London, 6 May [online] https://www.economist.com/news/leaders/21721656-data-economy-demands-new-approach-antitrust-rules-worlds-most-valuable-resource.

CHAPTER

I

The digitalization of the physical world: the Internet of Things

A. The Internet of Things: connecting the physical and digital worlds[1]

The world is currently immersed in a new era of digital transformation in which the physical and digital worlds are converging, as shown by the advance of the Internet of Things (IoT). This technology connects a network of physical elements equipped with electronic components, sensors, actuators and software, to make it possible to capture, filter and exchange data on those elements and their environment. This generates information and practical knowledge that translates into intelligence for decision-making and resource allocation by using back-end applications.

The development of IoT has implications for public and private action, since greater connectivity between objects, machines and people makes it possible to improve knowledge of the environment and set new courses of action in all areas. This facilitates migration to a more complex economy, based on the intensive use of digital information combined with automation and artificial intelligence technologies. This convergence is, ultimately, what makes it possible to integrate the physical and digital worlds, to evolve in the information generation and decision-making processes, and to generate new possibilities for value creation.

The latter stem essentially from two elements. The first consists of innovations in the analysis of big data from IoT devices, which facilitates accurate and timely understanding of the environment and its components. This makes it easier to identify needs and preferences that can be satisfied by supplying new products and services (digital and physical), and the implementation of new business models and new operating processes, particularly in traditional industries. The second element is competitiveness based on the generation of information in real time and its analysis, combined with automation processes; and the optimization of operational processes helps to reduce costs and enhance productivity. For example, it is possible to optimize operations in areas as diverse as inventory management, predictive maintenance or the management of energy or transport networks. This also makes it easier to deal with urgent issues, with more nimble and appropriate responses. All the above results in lower costs and greater satisfaction among end-users.

In short, value creation will stem from the digital transformation of data generation, capture and analysis, as well as operational activities. This is essential in traditional sectors that have to face this process in response to changes in the environment and need to deal with technologies that do not form part of their original value-creation model.

IoT represents a major disruption to a system of merely connected objects. This technology connects smart objects that generate data as they operate or produce, which are then fed back to improve decision-making in the operational or production process. This new way to optimize the production of goods and the provision of services is driving an industrial revolution characterized by new competitive advantages based on a redefinition of traditional sectors and activities by technological assets.

The adoption of IoT has gathered pace in recent years; and it is estimated that global spending on this technology amounted to US$ 674 billion in 2017 (IDC, 2017). Three variables have been driving this process forward:

(i) Greater capacity for data capture, computation, storage and transmission at lower cost (in 2017 the average cost of sensors was 50 cents, compared to around US$ 1.30 in 2004; while the cost of processing a gigabyte plummeted from US$ 527 in 1990 to just 5 cents in 2012) (Atlas, 2016). IoT devices have also fallen steadily in price, including for basic processing and connectivity.

(ii) The development of data collection, storage and processing technologies, such as cloud solutions and big data analysis, which have also lowered costs by allowing infrastructure sharing.

(iii) The universalization of devices at lower cost (tablets, smart phones, sensors and others) and the proliferation of their connectivity (8.4 billion objects were connected to IoT in 2017) (Gartner, 2017).

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1 This chapter was prepared by Omar de León (ECLAC consultant), Valeria Jordán and Fernando Rojas.

The deployment of IoT will be empowered as it combines with progress in the following technologies (PWC, 2017; Marr, 2018):

(i) Artificial intelligence: data are valuable if they have the capacity to trigger an action (in other words, they are actionable). Artificial intelligence would increase that capacity because it supports more advanced IoT applications that enable patterning and analyses that are predictive (preventive interventions), prescriptive (corrective interventions) and adaptive (autonomy based on continuous learning).

(ii) Edge/fog computing: cloud computing capabilities are brought closer to devices to facilitate processing and storage, along with network services between terminal equipment and data centres. This makes it possible to have more powerful devices and reduce the information flows reaching the data centres and, mainly, to reduce response times to a few milliseconds. The introduction of 5G will strengthen edge computing.

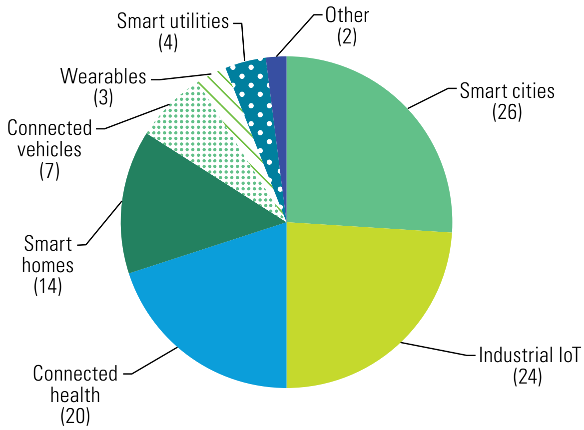
(iii) Convergence between information technologies and operational technologies (IT/OT): this will make connected objects smart, leading to more agile, flexible and efficient production processes, as well as lower operating costs.[2]

(iv) Blockchain: based on distributed and encrypted digital ledgers, these would add transparency, immutability and integrity to the millions of IoT transactions that can occur in value chains or in situations in which ownership of the objects changes.

These advances presage major adoption of IoT worldwide in the coming years. Estimates put the potential economic impact of the technologies in question at between US$ 3.9 trillion and US$ 11.1 trillion per year by 2025, surpassing other disruptive technologies such as mobile Internet or cloud computing (Ménard, 2017).

The solutions provided by IoT can be applied to activities of all kinds in the public and private domains. The best-known uses are: connected cars, industrial sensors/actuators, health sensors, logistics, temperature sensors, public and residential lighting and irrigation controllers. Use is expanding rapidly in solutions as varied as structural safety control in the public works area. It is thus possible to distinguish between consumer IoT (smart home, wearables) and production IoT, which considers both applications for industries and specific processes (management, manufacturing, marketing, distribution and others), such as multi-sectoral solutions (wearables for health monitoring, connected vehicles, smart cities and others). Future developments are expected to focus on applications for smart cities and industrial sectors, where value would be created from greater energy efficiency, increases in labour productivity, reduction of maintenance costs, optimization of inventory management and improvements in worker safety (see figure I.1). In the Latin American and Caribbean region IoT plans focus mainly on verticals specific to each country and all include smart cities.

Figure I.1
Internet of Things: global market share by area of application, 2017
(Percentages)



Source: Statista, *Market Pulse Report, Internet of Things (IoT)*, 2017.

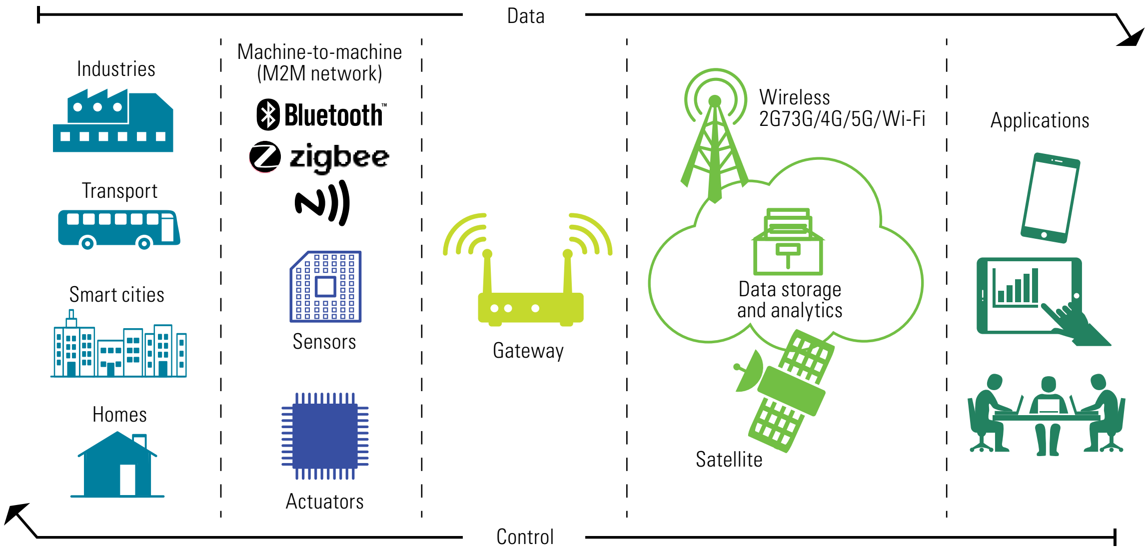
[2] The term "operational technology" refers to a category of hardware and software that monitors and controls physical devices.

IoT needs to be approached from the standpoint of its applications rather than as a concept. The technical and regulatory requirements for its implementation, ranging from the access technologies used to issues data security and protection, will vary according to the type of application and the associated devices.

B. The IoT ecosystem

The Internet of Things is more than connectivity between physical elements. It is an ecosystem enabled by a set of technologies in which value creation stems from the analysis of data generated by devices and the development of innovative solutions aimed at creating efficiency and well-being. In an IoT ecosystem, physical objects and end-user devices are connected to the Internet, or at least to a private Intranet, as is the case with applications such as an autonomous industrial plant. This enables them to communicate with each other and collect data using integrated electronic components and software. Connectivity and cloud computing technologies enable data transmission and processing, in addition to the use of big data analysis tools and artificial intelligence for the development of IoT solutions (i-SCOOP, 2018). Diagram I.1 illustrates the functional architecture of that ecosystem, consisting of devices, communication networks, software platforms and applications (ASIET/Deloitte, 2018).

Diagram I.1
Internet of Things: ecosystem architecture



Source: Moor Insights & Strategy, *Segmenting IoT (IoT)*, 2014 [online] http://www.moorinsightsstrategy.com/wp-content/uploads/2014/05/Segmenting-the-Internet-of-Things-IoT-by-Moor-Insights-and-Strategy.pdf.

1. Devices

Connectivity between devices originated in machine-to-machine (M2M) communications that include monitoring and control applications. Technologies such as radio frequency identification[3] (RFID) and near-field communication (NFC)[4] allow the connected elements to be unique and identifiable and to communicate with each other. That is why almost anything can be turned into an IoT component.

[3] Radio frequency identification is a technology that uses radio frequencies to identify physical objects. A wireless network is used where the electromagnetic radiofrequency fields transfer data from a label to a receiver device, in order to identify the product and automatically monitor it. This technology could even completely replace bar codes (Microsystem, 2015).

[4] Near-field communication is a short-range, high-frequency wireless communication technology for data exchange between devices.

Subscriber Identification Module (SIM) cards play an important role in IoT systems.[5] While changing a card from one computer to another is usually a simple task, the same operation is complicated or almost impossible in the case of IoT devices: there are thousands of devices in which the change has to be made, often located in places that are difficult to access, with cards generally welded on for security reasons or to avoid damage, and so forth. To overcome this problem, the GSM Association (GSMA) developed the embedded SIM technology, which makes it possible, through a procedure with agreed specifications, to change operator without physically accessing the equipment, thereby making global connectivity of SIMs possible. Simplifying the procedures for changing the provider and facilitating integration of the SIM to the device are two actions that enable the massive use of mobile IoT terminals at lower cost. These specifications are fulfilled in the embedded universal integrated circuit card (eUICC), which supports multiple SIM profiles and, thus, multiple sets of credentials, thereby allowing access to a different operator in each, although always one at a time. In this way, the terminals can have a principle operator and other secondary operators; and, depending on the policy defined for the service, it is possible to switch to a secondary operator if the principal one fails.[6]

IoT includes these aspects and technologies and adds a greater degree of integration between objects by incorporating cyberphysical systems[7] in networked systems. The systems operate as computational elements that work simultaneously to control a physical process using data from the sensors and actuators they control (for example, wireless sensor networks, autonomous driving systems or traffic management). They have real-time operating systems that contain software modules for Internet connectivity (TCP/IP stack). Thus, IoT platforms connect the sensors to the data network and provide information using back-end applications to analyse the data generated. The operating system and the connectivity modules are similar software components in any IoT device, so they can be acquired in a standardized way. What is not standard is the application in the device, since each one performs a unique task.

2. Communication networks

Each IoT component is connected through some type of communication network, depending on its functionalities and requirements. Although, in theory, every element of this ecosystem should be connected to the Internet, the cost and performance of the different connectivity technologies mean that, in practice, not all devices are connected directly to the cloud, but through IoT gateways that act as bridging mechanisms or work in private Intranets. These gateways connect devices in the field (factory, home and others) with the computing cloud where data is captured, stored and processed through applications, and with the end-user equipment (smart phones, tablets and others). They can have local storage and processing capacity to offer off-line services and control devices in the field in real time. This method, known as edge computing, makes it possible to optimize network performance.[8]

The gateways are located at the intersection between the Internet cloud and the M2M area of an IoT ecosystem. They provide downstream connectivity via Ethernet, WiFi, Bluetooth, ZigBee or some combination of the network technologies that they support. In general, upstream connectivity is done through a wide area network (WAN) router, an LTE base station (4G) or some other wide-ranging network (McGillicuddy, 2017). Table I.1 identifies and characterizes the main access networks according to their scope and uses.

5 The Subscriber Identification Module (SIM) is an integrated circuit that stores the international mobile subscriber identifier (IMSI), through which the card communicates with the mobile network. It also provides secure storage of data to authenticate users, identify the network used, identify the circuit card (ICC) and the authentication key (Ki) of the card in the mobile network, and identify the local area where the user is located.

6 Multihoming and load balancing are two additional elements that are required in IoT and are essential in critical applications. The first involves maintaining a permanent and simultaneous connection with more than one computer network. The second is the process of distributing data between disparate services to improve performance and provide redundancy and reliability.

7 A cyberphysical system is a mechanism (physical system) controlled or monitored by computer-based algorithms and tightly integrated with the Internet. In cyberphysical systems, the physical and software components are closely intertwined. Each element operates on different spatial and temporal scales, exhibits multiple behaviour patterns and interacts with others according to context.

8 The edge computing method is used to optimize cloud computing systems by processing data at the edge of the network, near the data source. This makes it possible to reduce bandwidth consumption in the transmission of data between sensors and the central computing cloud and mainly to reduce lag to a few milliseconds, which is necessary for critical applications.

Table I.1
Internet of Things: network access technologies by approximate reach and uses

Type	Technology	Reference ranges/ coverage	Data transfer rate	Frequency	Uses
NAN (near-me area network)	Radiofrequency identification	Low: <1 metre Depends on frequency and transceptors	Low	120–150 kHz (LF), 13.56 MHz (HF), 433 MHz (UHF), 865–868 MHz (Europe) 902–928 MHz (North America) UHF, 2 450–5 800 MHz (microwave), 3.1–10 GHz (microwave)	Access to buildings Inventory
	Near-field communication	Up to 10 cm	Low	13.56 MHz	Payment systems Access controls Smart tags for asset tracking in industrial applications
WPAN (Wireless personal area network)	Bluetooth	<100 metres	Low	2.4 GHz	Hands-free headset Personal devices of IoT (exercise and health monitoring)
	ZigBee	Up to 100 metres	Low/medium	915 MHz in the United States 868 MHz in Europe 2.4 GHz	Domotics (lighting control, thermostat, security and others)
	Z-wave	Up to 100 metres		800-900 MHz	Domotics
	EnOcean	300 metres outdoors and 30 metres indoors		315 MHz, 868 MHz, 902 MHz	Smart buildings (energy control) Manufacturing Transportation
WLAN (wireless local area network)	WiFi	100 metres		2.4 GHz, 3.6 GHz and 4.9/5.0 GHz bands	Devices Routers
	WiFi HaLow (Special for Internet of Things)	Over 1 500 metres		900 MHz band	Smart home Connected car Digital health care Industrial, retail and agricultural environments Smart cities
	DASH7 (open standard)	<5 km	Upload and download: 10/56 or 167 kbps	433 MHz, 868 MHz and 915 MHz ISM/ SRD (unlicensed)	Industrial applications of IoT
LAN (Local area network)	Ethernet				Building automation system
	Communication by electric power line				Building automation system using the power line
Wireless WAN (Wireless wide area network)	LPWAN (low-power wide-area network) non-cellular	Low			Large-scale implementations of low-power Internet devices such as wireless sensors
		Sigfox Rural: 30–50 km Urban: 3–10 km	Upload: <1 Kbps	868/915 MHz	Idem
		LoRaWAN Rural: 15 km Urban 2–5 km	Upload: 300 bps–25 Kbps Download: 300 bps–25 Kbps	433/868/780/915 MHz	Idem
		RPMA (Ingenu) Rural 5–20 km Urban 1–3 km	Upload: 624 Kbps Download: 156 Kbps, although notable mainly for its 3 Mbytes per month capacity	2.4 GHz	Idem
		Weightless Typically 2 km in cities	Low speed	Several ISM, such as 868, 915 and TV white spaces	M2M

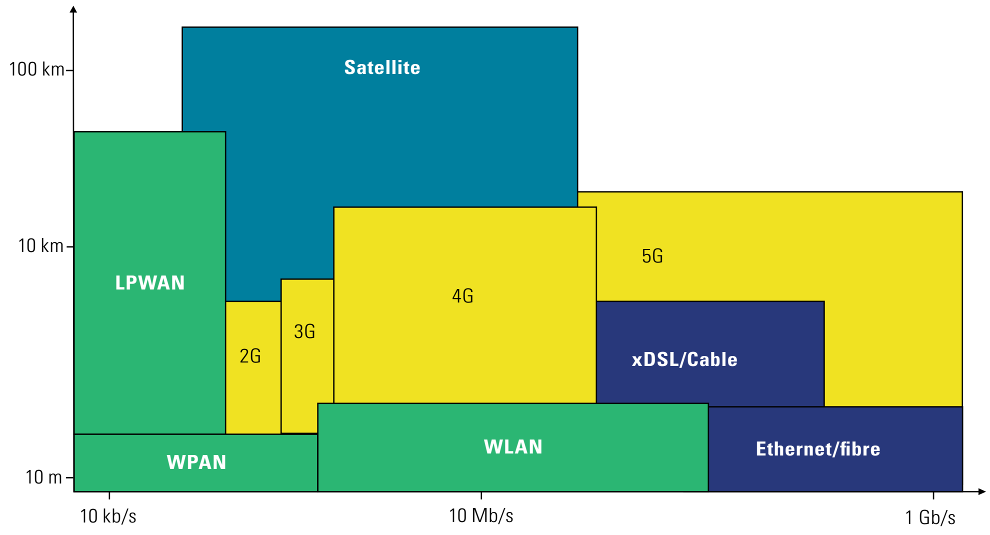
Table I.1 (concluded)

Type	Technology	Reference ranges/ coverage	Data transfer rate	Frequency	Uses
Wireless WAN (Wireless wide area network)	Cellular 2G, 3G, 4G and 5G				
	Cellular LPWANs	LTE-M 11 km	Upload: 375 Kbps Download: 300 Kbps	1.2 MHz (reception)	Object tracking Energy management and measurement of services City infrastructure Portable devices
		NB-IoT 15 km	Upload: 20 Kbps Download: 250 Kbps	200 kHz/180 kHz (reception)	
	Satellite				Monitoring of cargoes in long-distance transport by sea or land Remote locations (agriculture, oil and mining)
WAN (wide area network)	xDSL				
Backbone (trunk infrastructure)	Fibre optic				

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

In choosing the access technology used by the components of the IoT system, the criteria to be considered include the number of devices to be connected, their geographical dispersion, the bandwidth required, the reliability of the service and the cost of network deployment (Kranz, 2015). Figure I.2 illustrates the relationship between bandwidth and the reach of the main access technologies.

Figure I.2
Internet of Things: access technologies by bandwidth and reach



Source: M. Kranz, "Number of Access Technologies and IoT Deployments Is Skyrocketing", Cisco Blogs 2015 [online] https://blogs.cisco.com/digital/number-of-access-technologies-and-iot-deployments-is-skyrocketing.

The connectivity solution should identify the main ways IoT applications will be used internally or by the end customer. This will form the basis for identifying optimal solutions that will require personalized contracts with suppliers in many cases (Baroudy and others, 2018).

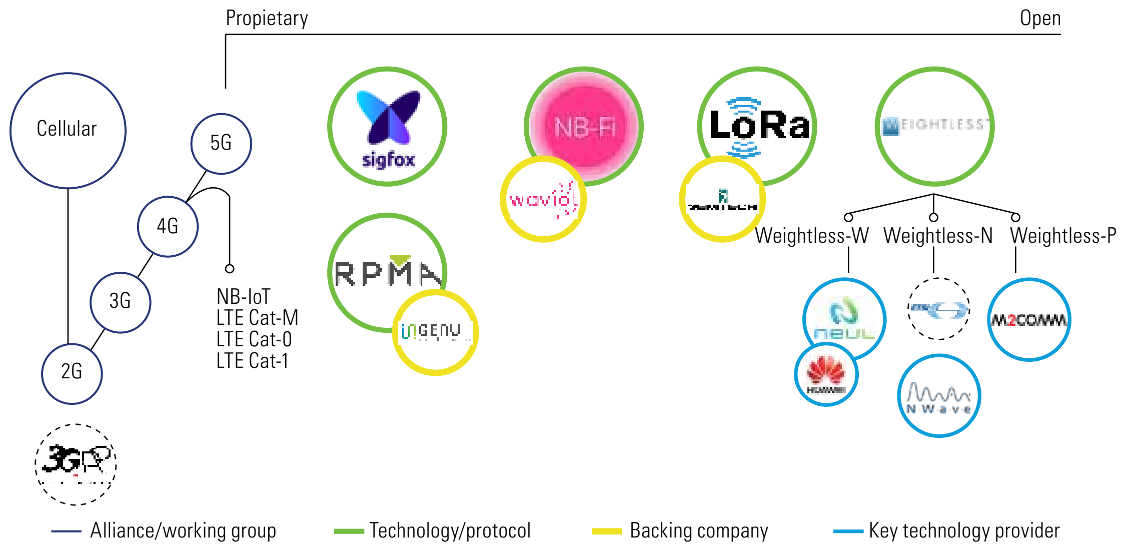
(a) Low-power wide-area networks (LPWANs) give a new direction to IoT development

The most recent and fastest-developing technologies are low-power wide-area networks (LPWANs), both proprietary and cellular, from the Third Generation Partnership Group (3GPP),[9] which was deployed later. Because 3GPP technologies are related to mobile technologies, they inherit some of the security and privacy features of mobile networks, such as user identity confidentiality, authentication, data integrity and device identification.

An IoT ecosystem involves connections between many devices which generally emit small packets of data at regular intervals or on demand. These devices also need to be connected across vast areas, sometimes a long way from traditional telecommunications and energy infrastructure (Postscapes, 2018). Low-power wide-area networks facilitate low-cost interconnection and use little bandwidth, low-data transmission speeds over long distances, powered by batteries that allow devices to operate continuously for up to 10 years or more. An LPWAN can be used to create a private network of wireless sensors; but it can also be a service or infrastructure supplied by a third party that allows sensor owners to use them without investing in cloud-connection technology.

LPWAN technologies, such as those of the 3GPP LTE-Cat M1 and NB-IoT group, overlap cellular networks and use their infrastructure, and are useful in reaching large distances and inside buildings and facilities (for example, basements where meters are usually located). 3GPP has also developed a technology for specific use in 2G networks, called EC-GSM (Extended Coverage GSM), which has potential use in some countries. Alongside the development of 3GPP access technologies for IoT, proprietary technologies such as Long-range Wide-area Network (LoRa), Sigfox and Random Phase Multiple Access (RPMA) have emerged (see diagram I.2). The first two appeared about 18 months earlier than similar 3GPP technologies, which gave time to deploy them and serve the initial demand for IoT connectivity. This allowed their operators to enter the market, and then rely on the convergence of management of both types of access. Having gained space in the market, they currently compete with 3GPP technologies, although they also act as complements to the traditional telecom operator networks.

Diagram I.2
Internet of Things: low-power wide-area network market



Source: Postscapes, "LPWAN Internet of Things (IoT) Networking Technology: A guide to the standard and its coverage, protocol stack, range and compatible chips and gateways", 2018 [online] https://www.postscapes.com/long-range-wireless-iot-protocol-lora/.

9 3GPP is an important partnership of stakeholders leading standardization and development of mobile technologies, including 4G and 5G, as well as specific systems for the Internet of Things, despite its historical name.

LPWAN technologies have the following characteristics:

- Spectrum: in general, 3GPP technologies employ licensed or unlicensed spectrum, while other proprietary technologies operate in unlicensed spectrum.
- Reach: wide, up to 10 km from the gateway through which they enter the network.
- Power: low (10-25 mW), designed for battery autonomy of ten years or more, depending on intensity of use.
- Transmission speed: low, generally less than 5 Kbps and with data volumes ranging from 20 bytes to more than 256 bytes per message and sometimes per day. The low transmission speeds allow for highly sensitive receivers. The LTE-Cat M standard allows higher speeds for applications that require them.
- Cost of chip set (radio chipset): no more than US$ 2.
- Radio subscription cost: US$ 1 per device per month.
- Topology: star, in most cases.
- Maximum coupling loss: they support high losses, since they can operate with 140-over 160 db.
- Receiver sensitivity: more than -130 dbm, which explains the high losses supported and therefore the high coverage values.

(i) Cellular LPWAN (based on 3GPP standards)

In 2016, the mobile telephony industry launched the LTE-M and NB-IoT technologies under the 3GPP standards, specially designed to operate with IoT. These solutions use the mobile wireless network (in licensed bands) and offer greater scalability, service quality and security compared to unlicensed LPWAN.

The LTE-M technology uses the same spectrum and the same base stations as the 4G mobile network (Long Term Evolution – LTE), but is designed with greater energy efficiency (the batteries of IoT devices last for ten years while those of smartphones last around a day). 4G network operators only have to make software adjustments to use them, without the need for major investments in network infrastructure, such as antennas or base stations. LTE-M technology has a higher data speed than NB-IoT technology and can transmit large amounts of data (Ray, 2017).

The NB-IoT radio technology standard allows broad device connectivity using the 2G, 3G and 4G mobile networks spectrum. It can be deployed in the spectrum assigned to LTE, using resource blocks of a normal LTE carrier, or in a dedicated spectrum for independent deployments (GSMA, 2016). For traditional telecom operators it provides a way to compete with technologies such as LoRa and Sigfox, by optimizing the use of their networks.

According to GSMA, cellular LPWANs have the following specific characteristics in addition to those of LPWANs generally:

- Optimization for short messages of similar size to an SMS.
- Good indoor and outdoor coverage, even in previously unreachable places, located far from the energy sources.
- Ease of installation on current networks, reusing cellular infrastructure whenever possible.
- Scalability (allowing a large number of devices in a wide geographical area).
- Secure integrated connectivity that supports proper authentication of the IoT application.
- Possibility of integration to the unified IoT platform of a mobile phone operator.

In 2017, the rapid evolution and remarkable growth of this market was demonstrated by numerous announcements of cellular LPWAN deployments by operators such as AT&T, Orange or Verizon (LTE-M) and China Telecom, Deutsche Telekom, Telefonica or Vodafone (NB-IoT), in addition to non-cellular network deployments by Sigfox and LoRa in over 40 countries each (see diagram I.3).

Diagram I.3
Deployment of low-power broad area networks (LPWANs), by technology

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of GSMA, "GSMA mobile IOT initiatives licensed low power wide area technology", *Internet of Things* [online] 2018 https://www.gsma.com/iot/mobile-iot/; Sigfox, "Coverage" 2018 [online] https://www.sigfox.com/en/coverage and LoRa Alliance, "LORAWAN Network" 2018 [online] https://www.lora-alliance.org.

Contrary to expectations —that traditional operators would adopt cellular technologies, while third parties would opt for non-cellular ones— a diversity of business models emerged, including partnerships between technology owners and incumbents, and combined uses of cellular and non-cellular technologies by telecom operators. Although it was originally thought that the emergence of LTE-M and NB-IoT technologies would displace the other LPWAN technologies, by 2022 there are expected to be 400 million low-power M2M lines that use unlicensed spectrum, and 100 million supported by licensed spectrum. The momentum is likely to come from the main growth vertical, the development of smart cities (Pautasio, 2018). Nonetheless, the mobile segment has advantages associated with the possibility of offering secure over-the-air and long-range communications based on IP, broader geographical coverage and higher data transfer rates, which is fundamental for applications in other sectors. The development of 5G networks will be decisive in this equation, considering that, given its higher data transmission speed, low latency and the possibility of transferring greater intelligence at the network's edge, it will support not only a wide variety of connected devices, but also critical applications that require high speed and low latency.[10] Table I.2 shows the quality requirements for Industrial Internet of Things (IIOT) applications.

[10] The deployment of 5G networks will require a larger fibre optic network for the backhaul network and the intermediate (fronthaul) network (Networks Asia Special Projects Team, 2018).

Table I.2
Requirements for the use of Industrial Internet of Things

Cases of use	Key requirements	Values	Cellular access technology
Industrial cell automation	Latency Reliability	0.5 ms 99.9999999	5G (uMTC)
Driverless vehicles	Mobility Reliability	10 m/s 99.99999	LTE, 5G
Process automation	Reliability	99.9999999	LTE, 5G (mMTC, uMTC)
Transport logistics tracking	Number of devices Coverage	100 000 por km^2 Global	LTE
Component tracking	Number of devices Mobility	1 000 000 por km^2 Static	LTE
Remote assistance	Reliability	99.999%	5G (uMTC)
Augmented reality	Data speed	10 Gbps	5g (xMBB)
Remote control of robots	Reliability	99.999%	5G (uMTC)

Source: *Ericsson Business Review*, "Manufacturing reengineered: robots, 5G and the Industrial IoT", No. 4, 2015 [online] https://www.ericsson.com/assets/local/publications/ericsson-business-review/issue-4--2015/ebr-issue4-2015-industrial-iot.pdf.

(b) Spectrum management

Progress in the use of IoT will increase spectrum use, so regulators are weighing the possibilities of enabling more spectrum in both the licensed and the unlicensed bands. In principle, there are no impediments for IoT applications to operate in both types of bands; but the decision will depend on the applications that each can support.[11] In critical applications, such as those used in health or aeronautics, maximizing the security of connectivity implies using the licensed spectrum, along with other measures. At the other extreme, for example, applications to capture moisture data on irrigated land would not be affected by possible interference and would be used in unlicensed spectrum bands.[12]

Management of the unlicensed band is less predictable owing to the conjunction of multiple "non-disciplined" technologies that operate in it, because they are not subject to the conditions that exist in licensed bands. These aspects are crucial for updating the regulations on spectrum use, given the thousands or hundreds of thousands of IoT terminals that will have a useful life of ten years or more. Providing regulatory stability to suppliers for one or two decades entails predicting spectrum use for technologies that are not yet fully defined, and for future technologies or projected demands. A case to be analysed is the use of 2G networks: although these are being replaced by more advanced technologies, they still have a presence in the networks and could remain effective through the 3GPP EC-GSM-IoT standard that operates precisely over 2G networks.

In general, all of the spectrum suitable for IoT (not very high frequencies) is occupied by other services, so choosing which band to use poses problems. While regulators aim to release bands for this and other uses under efficient conditions, users sometimes encounter connectivity offers from service operators in licensed bands that are not competitive, so they exploit regulatory arbitrage and use unlicensed bands. These provide an additional advantage by enabling service providers to alter the access technology they use with fewer restrictions, which reduces the costs of making changes. In general, they are a good spectrum solution for deploying technologies from scratch or with new investments (greenfield), which can foster innovation and emerging-technology start-ups.

Of the unlicensed bands, the most saturated is the 2.4 GHz band because, despite initially being universally allocated to industrial, scientific and medical applications (ICM), it was progressively used for others (it is one of the most widely used in WiFi and Bluetooth). This suggests that there will be a marked increase in the use of the 900 MHz band in Region 2 (mainly the Americas and the Caribbean), enabling good coverage and energy savings. Some studies, such as that of the European Conference of Postal and Telecommunications Administrations (CEPT), propose developing technologies that improve the coexistence of different technologies and find ways to make more efficient use of a shared spectrum for IoT, in which harmful interference would be mitigated.[13]

11 When an IoT application is developed, the choice of the spectrum band (licensed or unlicensed) determines the size of the devices. The higher the frequency, the smaller the size; but also the lower the coverage and penetration in buildings.
12 Applications that work in this type of niche have repetition protocols which, availing themselves of the fact that there are no critical deadlines, ensure data fidelity.
13 See [online] http://www.cept.org/.

In terms of access technologies in the licensed spectrum, the requirements of user equipment for mobile voice and data impose high energy consumption, for which reason efforts are being made to improve the service. This is not a problem for the current mobile terminals, but it would be a problem if similar terminals were to be used for IoT. Accordingly, 3GPP terminals have been created with a view to lowering energy consumption; and technology concept tests are under way to reduce battery consumption and the use of expensive networks. An example is a connectivity project in the United Kingdom for smart meters that use a combination of cellular infrastructure and an IPv6-based access grid, using other meters as intermediate nodes with the 802.15.4 protocol.[14] In this case, the contract lasts 15 years, which shows how access technologies and business models are becoming established.

3. Software platforms and applications

Apart from object connectivity infrastructure, IoT consists of tools that allow for data storage and processing, big data analytics and applications that enable automation and activities in multiple areas.[15] As IoT ecosystems are in the development stage, their enabling technologies are still highly fragmented in terms of device connectivity, communication protocols and software languages. In particular, platforms need to aggregate and integrate the different protocols to make them interoperable and integrate the various processes (IoT Analytics, 2015; ASIET/Deloitte, 2018; IBM, 2018). In short, IoT platforms serve as the support software that connects the entire system: device management, communication, data flow and application functionality. These platforms are made up of the following components:

(1) Connectivity management software

  (a) Device management: ensures the functioning of connected objects, executing patches and updates of the software and the applications that run on the devices or gateways.

  (b) Connectivity and normalization: adds different protocols and data formats in a single software interface that enables transmission and interaction between devices.[16]

(2) Data management software

  (a) Database: scalable cloud-based storage tools with capacity to manage structured (SQL) and unstructured (NoSQL) data.[17]

  (b) Big data analytics: ranges from basic data grouping to predictive, prescriptive and pattern analysis aimed at extracting value from the data flow. It increasingly incorporates artificial intelligence capabilities, such as analysis based on machine learning.

  (c) Visualization: allows users to identify patterns and trends through visualization boards where data is represented through 2D or 3D graphics and models.

  (d) Automatic activation: intelligent actions based on real time data processing using rules that encode the decision process.

[14] IEEE 802.15.4 is a protocol that defines the physical level and control of access to the medium (MAC) for low-rate wireless personal area network).

[15] In each case, security is essential to avoid unwanted leaks of information and provide confidence to users. Thus, security must encompass the devices and communication networks along with the cloud and applications.

[16] This component operates with IoT protocols that can be mapped in the TCP/IP model. These include: GSM, CDMA, LTE, Ethernet and WiFi in the access network layer; IPv6 and 6LoWPAN in the Internet layer, and HTTPS, CoAP and MQTT in the application layer (IBM, 2018).

[17] Although local storage is possible, the use of tools in the cloud is more frequent when handling large data.

(3) Applications and user interfaces

(a) The physical-virtual interaction occurs through applications and interfaces consisting of software tools that make it possible to view and navigate through the information, and interact quickly and easily with devices to establish or regulate their behaviour through digital twins, for example.

(b) Value creation in the ecosystem is based on four elements: design, integration, specific solutions and actors.

(i) Although designs are predominantly targeted on devices that use screens as an interface, greater use will be made of other media (voice, sounds, gestures or movements) related to cognitive technologies driven by advances in artificial intelligence.[18]

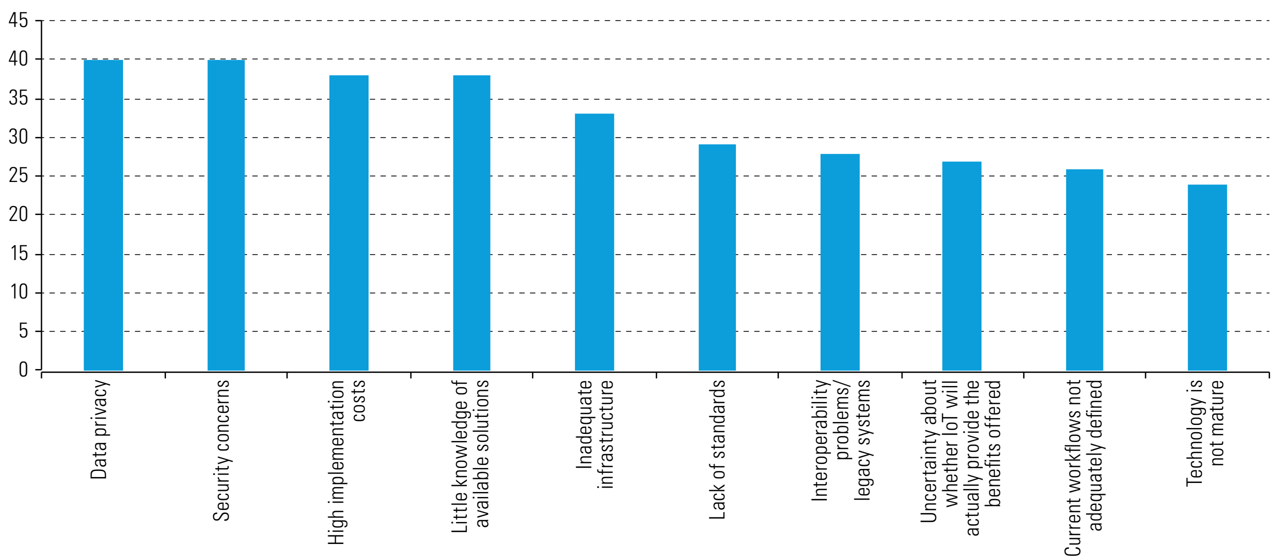
(ii) The total integration of ecosystem components, including systems developed or operated by third parties, can occur through application programming interfaces (API), software development kits and gateways.

(iii) The result of the ecosystem depends on providing specific IoT solutions, targeted on processes of functional, vertical, transversal or territorial scope. These solutions, especially those aimed at verticals or territories, often require ad hoc creations. Rapid change in these ecosystems requires the continuous creation of new solutions, for which laboratories are fundamental for testing prototypes and trialling the solutions themselves.

(iv) There is interaction between different stakeholders, such as sector experts, designers of device drivers, system and application developers and network managers.

The incorporation of IoT into production processes needs to consider the alternative ways that firms can acquire and use this technology, and how they perceive the associated benefits. Figure I.3 reports the reasons why some firms in the United States are reluctant to adopt this technology.

Figure I.3
United States: main reasons for not adopting IoT in firms
(Percentages of responses)



Source: Statista, *Market Pulse Report, Internet of Things (IoT)*, 2017.

[18] Examples of these technologies include computer vision (identification of objects, scenes and activities in images), speech recognition and natural language processing.

This situation gives rise to the concept of IoT "servitization", supported by the development and strong implementation of the Internet of Things in some production processes, which consists of turning the sale of a product into the sale of the service it provides. A single purchase payment is replaced by a system of recurrent payments, which may either be fixed (subscription fee) or according to consumption. Servitizing can include the provision not only of the service, but also of the hardware, software and connectivity necessary for its provision and supervision, along with a platform where users can design, develop and maintain their applications.

Thus, IoT as a service (IoTaaS) is a combination of services provided in the cloud, such as software as a service (SaaS), platform as a service (PaaS) and infrastructure as a service (IaaS). This avoids having to purchase excess capacity (own equipment) to support maximum workloads, which will then only be used partially and thus cause inefficiency in resource management. The services are provided on platforms with redundant capacity and contracts can have flexibility to adjust supply to demand. The efficiency of infrastructure sharing is the conceptual support of this modality.

This represents a change of business model that improves the value offered to customers, increases internally-generated revenues, reduces costs, and deepens and stabilizes the relationship between firms and customers. Although it is a model that has been functioning for years in other areas, its universalization implies a change of concept. By converting capital expenditure into operating expenditure, this model boosts the earnings of IoT suppliers and users. This is particularly important for small businesses, which lack the scale to implement IoT solutions.

There are several business models for providing IoTaaS derived from the characteristics of its value chain: some focus on telecom network operators, while others are provided by software companies or platforms originating in the digital technologies sector.

Telecom operators have adopted strategies based on their ability to provide connectivity, which is their core service. On that basis, they are scaling the value chain by purchasing IoT platforms or, more frequently, partnering with new market entrants to build them. The aim is to provide an end-to-end service for a customer base that performs business-to-business (B2B) or business-to-consumers (B2C). They could scale-up even more if they developed chains that included their customers' customers, in other words a business-to-business-to consumers (B2B2C) model. Nonetheless, few operators have the knowledge and experience needed to make headway in this area, although the advances have been important. In order to complete the chain, some telecom operators have set up strategic partnerships, mergers or other types of relationship with firms specialized in specific sectors. For example, Vodafone has created a separate structure to build a complete ecosystem of global and vertical end-to-end IoT services, based on partnerships with dozens of specialized companies.[19] The health sector provides another example of partnering with specialists to complete the chain, where firms such as Telstra or Telefónica seek to provide a complete platform, even embracing data analytics.

In general, all of the major operators in the world are striving to enter the IoT-as-a-service business, which explains associations such as the IoT World Alliance, which includes operators such as Etisalat, KPN, NTT DOCOMO, Rogers, Singtel, Telefónica, Telstra and Vimpelcom. In particular, this alliance offers a global solution that speeds up the adoption of IoT communications in more than 60 countries. Its Single Global SIM service operates through a single contract, a single invoice and a single payment that encompasses the service of all operators.[20] The main growth areas of this alliance include: connected cars, heavy-duty equipment, smart meters, small electronic devices, portable devices, and remote health and safety solutions. Other telecom firms are following similar paths, although some only focus on specific verticals.

Telecom operators have been joined by large digital technology firms as suppliers of IoTaaS platforms.[21] For example, Microsoft has launched its IoT software service on the Microsoft IoT Central platform of Microsoft Azure, which enables users to create IoT applications without having to worry about management of the

[19] See [online] https://iotpartners.vodafone.com/partner_list.html.
[20] The alliance follows the GSMA specification for integrated SIM cards.
[21] These include Amazon Web Services (AWS) IoT, Microsoft Azure IoT, Google Cloud Platform, ThingWorx IoT Platform, IBM Watson IoT Platform, ArtiK by Samsung Electronics, Cisco IoT Cloud Connect, Universal of Things (IoT) Platform (Hewlett Packard) and Salesforce IoT Cloud (Singh, 2018).

support infrastructure.[22] Similarly, AWS IoT helps to collect and send data to the cloud, facilitates data entry and analysis, and offers device management possibilities to enable customers to concentrate on developing applications that meet their needs. The IBM Watson IoT Platform is a service that is wholly managed in the cloud, designed to simplify the extraction of value from IoT devices. It offers features such as device registration, connectivity, control, quick visualization and data storage.

Even firms whose origin and core activity are not in digital technologies, such as Bosch or General Electric, have started to venture into the IoT sector. For example, General Electric has developed Predix, which offers industrial intelligence services to combine asset modelling, big data processing, and application analysis and development. Many other large firms are developing platforms, but they do not yet have solutions that are sufficiently complete to be considered IoTaaS, since they offer software solutions without including aspects such as connectivity, terminals and their management.

C. Areas of action

The implementation and universalization of IoT involves actions on various levels. First, changes need to be made in the demand for these services, which will depend on elements linked to each country's development pattern and the dynamic of its structural shift towards more technologically advanced activities, in other words more digital-focused. These elements were analysed in ECLAC (2015) when considering the need to move from the Internet of consumption to the Internet of production. The conclusion of this chapter will focus on factors that directly affect the supply of services or those that link supply and demand, such as policy and regulation models.

1. Harmonization of standards and interoperability

Standards are important when creating markets for new technologies. The operation of IoT involves several layers of services that need to be compatible with similar layers of different manufacturers or operators, and also vertically compatible, to avoid market dominance and development-blocking positions. Access incompatibility is clearly a risk when using proprietary technologies, even with centralized or decentralized topologies, although it could be resolved with gateways on the data aggregation layer. There may also be incompatibilities in the layers of initial data processing, data preselection, storage, integration, processing and device activation. For that reason, it is important to promote standards and interoperability, not only in the aforementioned elements but also in terms of data formats and security and privacy-protection mechanisms. These must be evaluated relative to objectives of standardization and interoperability with the greatest possible geographical reach (both regional and global).

2. Transition to the IPv6 protocol and numbering systems

The IPv6 protocol has many advantages over IPv4 for IoT deployment. In addition to enabling multi-homing, it allows sufficient IP addresses for the large number of terminal devices that will connect to the Internet, thus avoiding the need to share IPv4 addresses. In the transition from one protocol to another, attention must be paid to potential numerical restrictions when expanding access to IoT user equipment.

[22] See [online] https://news.microsoft.com/es-es/2017/12/05/microsoft-iot-central-ofrece-las-herramientas-necesarias-para-acelerar-el-uso-del-iot-en-las-emrpesas/.

3. Radio spectrum management

Since the spectrum is the basis of access networks, as noted in section I.B, the authorities must consider its allocation in advance. Given the uncertainty surrounding estimates of its future use, it would be advisable to establish a light-touch policy when allocating bands, liberalizing their use as far as possible to facilitate network deployment. This involves analysing current requirements and their trends in the spectrum bands used in IoT (both licensed and unlicensed), identifying which other bands can be allocated for those accesses and deciding on actions to be taken.

The allocation of IoT bands around the world reflects different situations. In general, there is no defined trend in terms of band preference, although there is consensus that the spectrum should be carefully analysed as a critical input. Although in 2015 CEPT indicated that the allocation of exclusive bands for IoT was not justified in Europe, by mid-2016 it was studying the feasibility of enabling the 700 MHz spectrum. At the end of that year, the Radio Spectrum Policy Group (RSPG) started to analyse the issue in detail through an IoT spectrum roadmap. For its part, the United Kingdom communications regulator (OFCOM) has allocated unlicensed bands for use by IoT applications in that country. Following consultations, in September 2015 it concluded that a new license was not needed to deploy services in the 55-68 MHz, 70.5-71.5 MHz and 80-81.5 MHz bands, and that licences in these bands were able to provide IoT and M2M services.

In the case of Latin America, de León (2018) argues that a defined spectrum for IoT is not yet urgent, because the relationship between IoT demand and spectrum allocation is in an incipient evolutionary process. Nonetheless, it is important to make sure that licensing conditions do not contain undesirable restrictions for the deployment of IoT access technologies.

4. Public sector demand as an IoT development policy

Government entities always have a powerful tool available to promote the deployment of new technologies: their own institutions' demand for the services supported by them. This encourages current and potential operators to design business models to supply those services and include IoT deployment in their plans. It also avoids having to go through processes of case validation, concept testing and other usual phases prior to commercial deployment. The opportunity to obtain a contract with the State, and publicize it, is an additional incentive, particularly when it comes to high-impact public services. If this dynamic occurs early, it makes it possible to address issues related to workforce IoT skills, as well as the country's readiness for these technological advances.

5. Policies and regulations on data privacy, protection and use

The privacy policy should develop a model for using IoT data which, in addition to respecting privacy, enables shared use through clear and public guidelines that include users' consent, address their concerns about the use of sensitive data and avoid constraints on IoT development. Serious cases of information leakage undermine confidence in the technology and hamper its development. Current applications collect a large amount of personal information without the user being able to restrict its use. In IoT there will be a greater volume and depth of information, almost certainly with far fewer prior warnings, as happens with mobile applications. End user devices are small and have low capacity, so they do not allow reliable interaction with the user such as requiring specific permissions that can viably be displayed the mobile users' computer screens.

In the domain of industrial applications, the complete system is under centralized and stricter control than in applications for individual users. In those cases, the type of information to be provided may be limited. From a different perspective, however, restricting the type and amount of information would lose a positive externality for designing policies based on big data analytics. The analysis of information generated from IoT in areas such as health or transport could lead to more efficient and effective policies that benefit society at large. On this issue, it is important to anonymize the data as soon as possible after it leaves the user's computer or from the first data concentration point. There are also technical difficulties owing to the low processing capacity of such equipment to prevent identification from the moment the user enters the system.

IoT devices can collect information in one jurisdiction and process, store, analyse and use it in others. This stems both from the operation itself, in which there are applications that require this, and from the search for efficiency and improving the quality of services by centralizing information. Thus, localization regulations that prevent the provision of cross-border services using centralized servers, in particular hosting national data abroad, could restrict the development of IoT solutions.

6. Security policies

Due to its universal deployment and the low cost of terminals, IoT presents a high-risk profile in terms of susceptibility to hacking. The low cost prevents the use of sophisticated security systems through encryption. Criminal activities can hack devices and access links and servers, many of them hosted in the cloud, thereby potentially gaining access to valuable bulk information or capturing critical controls. For example, a public services control system could be rendered inoperative, or the operation of a health care system could be distorted, or accidents could be caused with connected cars.

Although it is impossible to have a solution that prevents all attack, the risks can be reduced through the careful design of security in the user equipment, the circulation of essential information through the access and transport networks, the establishment of several levels of security in the core of the network, the reinforcement of controls on access to devices and, above all, the design of user equipment that accepts software updates to eliminate vulnerabilities. The latter is important because these devices have to be operational for very long periods and in places of difficult access.

As security flaws are a negative factor for IoT development, strengthening network resilience is fundamental for maintaining users' trust in the IoT ecosystem.

Bibliography

3GPP (2018), *About 3GPP Home* [online] http://www.3gpp.org/about-3gpp/about-3gpp [date of reference: 26 February 2018].

ASIET (Inter-American Association of Telecommunication Enterprises)/Deloitte (2018), *IoT para el Sector Empresarial en América Latina*.

Atlas (2016), "The average cost of IoT sensors is falling", *Atlas* [online] http://www.theatlas.com/charts/BJsmCFAI [date of reference: 8 March 2018].

Baroudy, K. and others (2018), *Unlocking value from IoT connectivity: Six considerations for choosing a provider*, McKinsey & Company, March.

ECLAC (Economic Commission for Latin America and the Caribbean) (2015), The New Digital Revolution: From the consumer Internet to the industrial Internet (LC/L.4029(CMSI.5/4), Santiago.

Gartner (2017), *Gartner Says 8.4 Billion Connected* [online] https://www.gartner.com, https://www.gartner.com/newsroom/id/3598917 [date of reference: 6 March 2018].

GSMA (2018), "GSMA mobile IOT initiatives licensed low power wide area technology", *Internet of Things* [online] https://www.gsma.com/iot/mobile-iot/ [date of reference: 27 February 2018].

___(2016), *3GPP Low Power Wide Area Technologies*.

IBM (2018), "Connecting all the things in the Internet of Things. A guide to selecting network technologies to solve your IoT networking challenges.", 3 January 2018 [online] https://www.ibm.com/developerworks/library/iot-lp101-connectivity-network-protocols/iot-lp101-connectivity-network-protocols-pdf.pdf.

IDC (2017), *IDC Forecasts Worldwide Spending on IoT to Reach $772 Billion in 2018*, 7 December [online] https://www.idc.com/getdoc.jsp?containerId=prUS43295217.

IoT Analytics (2015), *IOT PLATFORMS The central backbone for IoT*.

i-SCOOP (2017), *The Internet of Things (IoT) - essential IoT business guide* [online] https://www.i-scoop.eu/internet-of-things-guide/ [date of reference: 19 February 2018].

Kranz, M. (2015), *Number of Access Technologies and IoT Deployments Is Skyrocketing*, Cisco Blogs [online] https://blogs.cisco.com/digital/number-of-access-technologies-and-iot-deployments-is-skyrocketing.

LoRa Alliance (2018), *LORAWAN Network* [online] https://www.lora-alliance.org [date of reference: 27 February 2018].

Marr, B. (2018), "The Internet of Things (IOT) will be massive in 2018: here are the 4 predictions from IBM", *Forbes*, 4 January.

McGillicuddy, Sh. (2017), "The Role of IoT Gateways in the Network", *Network Computing* [online] https://www.networkcomputing.com/cloud-infrastructure/role-iot-gateways-network/1896121351 [date of reference: 21 February 2018].

Mclelland, C. (2017), *What is an IoT Platform?* [online] https://www.iotforall.com/what-is-an-iot-platform/.

Ménard, A. (2017), *How can we recognize the real power of IoT?*, McKinsey & Company, November.

Microsystem (2015), "RFID, ¿Qué es y para qué sirve?", *Microsystem* [online] https://www.microsystem.cl/rfid-que-es-y-para-que-sirve/ [date of reference: 21 February 2018].

Networks Asia Special Projects Team (2018), "IoT, 5G and the significance of fiber", *Networks Asia* [online] https://www.networksasia.net/article/iot-5g-and-significance-fiber.151537031 [date of reference: 20 February 2018].

Pautasio, L. (2018), "Los operadores van por tecnologías 3GPP pero el mercado IoT en espectro sin licencia es potencialmente mayor", *TeleSemana.com*, 20 February.

Postscapes (2018), *LPWAN Internet of Things (IoT) Networking Technology: A guide to the standard and its coverage, protocol stack, range and compatible chips and gateways* [online] https://www.postscapes.com/long-range-wireless-iot-protocol-lora/.

PWC (2017), *Leveraging the upcoming disruptions from AI and IoT how artificial intelligence will enable the full promise of the Internet-of-Things* [online] https://www.pwc.com/gx/en/industries/communications/assets/pwc-ai-and-iot.pdf.

Ray, B. (2017), "LTE-M & 2 other 3GPP IoT technologies to get familiar with", *LTE-IoT-Technologies* [online] https://www.link-labs.com/blog/lte-iot-technologies.

Santosh, S. (2018), "Top 20 IoT Platforms in 2018 (Updated)", *Internet of Things Wiki* [online] https://internetofthingswiki.com/top-20-iot-platforms/634/.

Sigfox (2018), *Coverage* [online] https://www.sigfox.com/en/coverage [date of reference: 27 February 2018].

CHAPTER

II

Blockchain: the Internet of trust

A. Blockchain and decentralized computing[1]

The world has witnessed the creation and spread of a new generation of "super tools", and some of the most prominent of these tools are being provided by the new and game-changing distributed ledger, or blockchain, technology.[2] When a number of different people need to arrive at a shared understanding about any given matter, the usual procedure is to designate a central authority to keep an official and accepted record of the proceedings. In addition, each participant must keep his or her own records and continually check them against those of all the other counterparts. They are then compared with the final outcome of the version issued by the designated central source.

With the appearance of blockchain technology as the operating platform for the bitcoin cryptocurrency in 2008, a new paradigm emerged that supersedes this model. This technology focuses on maintaining a record —in this case, a ledger— of past transactions and the current balance of a number of different accounts. What is special about this technology is that it does not require a central entity of any sort in which all the participants have to place their trust. In fact, the participants who make this system work do not even have to trust each other or even know each other. What is more, it is assumed and accepted that there will be a considerable number of malicious actors. This is what is known as a "zero-trust system".

It is often said that trust is a necessary condition for any community to run smoothly, whether that community is a political system, a market, a company or any other grouping. It is also widely believed that those necessary trust relationships are now in crisis. Rebuilding those types of relationships seems to be as crucial as it is unrealistic, since doing so entails achieving something as difficult as restoring innocence at a time when the factors that triggered or at least paved the way for that crisis (such as the spread of the ability to generate replicable information and the extensive use of social networks associated with today's era of smart phones) are constantly expanding and becoming more and more deeply rooted. This is why the solutions offered by blockchain technology are so valuable: they offer a way of instantly overcoming that crisis in a radically new way by making trust unnecessary. To be more precise, rather than doing away with trust, the locus of trust changes: participants no longer have to place their trust in persons or institutions but instead transfer it to the method being used to interact with those persons and institutions.

This technology also offers a new way of coping with uncertainty because it makes it possible to engage in dealings that are censorship-resistant, tamper-proof, immutable and self-executing (doing away with the need for a counterpart who has entered into an obligation to be willing to honour that commitment in the future). It thus extends the zero-trust system to include the coordination of present and future actions between agents. This generates a valuable externality: the fact that transactional expectations are met, while perhaps not producing trust per se, gives rise to something that is indistinguishable from it. Trust therefore ceases to be a prerequisite and instead becomes an outcome of a successful interaction. It thus comes as no surprise that blockchain technology provides a suitable ecosystem for the development of collaborative economies and business models. Any participant can append transactions entailing new information that is added to the existing chain so long as that participant follows the agreed rules that make a transaction valid. One rule that is inherent in this technology is that pre-existing information must not be changed; it is permissible only to add new information.

In order for this shared environment to be constructed in a way that not only does not require the presence of a central authority to control the process but in which it is impossible for there to be one, there has to be a decentralized means of managing the operation. This includes a logic whereby a participant can enter or exit the network, a method for updating the rules used to determine whether or not a transaction is valid and a way of regulating the speed with which new information is added to the shared database.

[1] The authors of this chapter are José Bravo de Goyeneche and Jens Hardings, both of whom are staff members of Kawin SpA, Santiago.

[2] The Bitcoin network, which can be regarded as the first proof-of-concept of this technology, appeared on the scene in 2008, whereas Ethereum, which represents an evolutionary leap forward, did not make its appearance until 2015.

Although most of the theoretical concepts and methods needed to create a blockchain already existed, in 2008, Satoshi Nakamoto[3] succeeded in combining a number of existing technologies, generating optimizations that would make it feasible to manage a large system and, most impressively of all, fashioning an ecosystem that is maintained in equilibrium by incentives that paved the way for the creation of the Bitcoin network. Today, that network and its underlying technology are at the centre of technological, financial and political discourse. A large part of the motivation for this technology's creation was to generate a mechanism that would allow direct person-to-person payments to be made without the intermediation or authorization of institutions such as governments, central banks or financial institutions. And that motivation arose out of the failure of all those types of institutions to ward off the global financial crisis and its ramifications. The first block in the Bitcoin chain —the genesis block— includes a text message that reads: "*The Times* 3 January 2009 Chancellor on brink of second bailout for banks" (Elliott, 2009).

This marked the inception of a movement that emerged completely outside the bounds of traditional standards and circles of scientific research, technology development and commercial channels. This mechanism was unveiled in a way that provided no clear idea of its origin and in an incomplete form that was then scaled up through its spontaneous adoption by a vast number of independent individuals who were motivated, in large part, by a crisis of confidence in the institutions in charge of ensuring that the world's economy functioned properly. The objective was to make use of monetary tools not controlled by any centralized power that could be used to benefit "the other 99%" rather than a favoured few —a goal that echoes the slogans of movements such as "Occupy Wall Street". Its incentive scheme, decentralized structure and potential for handling extremely large information systems and data sets have made bitcoins and the underlying blockchain technology an increasingly central issue in today's political debate.

1. How it works

(a) Nomenclatures

With a few exceptions, the creation of this technology has not resulted in the coinage of new terms but rather in the use of existing words to analogize the roles that new elements play or, more accurately, one of the roles that they may play. These terms fall far short of expressing the essence of these elements or of marking their boundaries, however. They are very useful for attaining the beginnings of a partial understanding or for reinforcing some notion of what these elements represent or suggest —especially in public announcements or the media— but they can be misleading and may hinder the attainment of a deeper and more accurate understanding of the system.

In order to understand how a blockchain works, a few basic concepts must first be introduced.

(i) Cryptographic hash function

A hash function is a process that converts input (a text sequence or any binary string) into a sequence of letters of a fixed length, called a hash, and that does so reliably in a replicable fashion. In cryptography and, hence, with blockchain, the idea is for the conversion to be a one-way street, such that it is easy to calculate a hash code for given input but very difficult to locate the input that generated it by looking at the hash code. Thus, the easiest way to find a hash code that fits a certain pattern (e.g., one in which the first *n* digits are zero) is simply to search through input strings at random until finding one that fits the pattern.

(ii) Public and private keys

These terms refer to asymmetrical encryption systems that use one key to encrypt a message or file and another key to decode it. One of their features is that having the public key does not enable the holder of that key to obtain information about the private key. Another is that there is a computationally easy way to generate both keys at the same time. It is therefore assumed that whoever holds the private key is the person

[3] The pseudonym of the person or persons who devised the Bitcoin protocol and its reference software, Bitcoin Core.

who created both keys and is therefore the owner of what the keys represent. The use of the private key is proof of its ownership without there being any need to demonstrate this, thereby converting the message or file into content that can then be verified using the public key.

(iii) Tokens

A token is a unique identifier that represents a certain asset and is subject to controls that prevent double spending. Thus, at any given point in time, there is just one token associated with one owner who exercises control over that token and may transfer it to another agent using the owner's private key or some other mechanism established for that purpose. The token may represent anything, including simply a unit of value, equity shares, rights to given objects or votes. The term "tokenization" refers to the process of associating rights and rules with different tokens that can then be transferred in a blockchain.

(b) Chained blocks

As a basic principle, transactions are grouped into blocks. New information is added to the database by following the accepted rules for creating a new valid block and then to sending it to the other known participants for replication. While there are some methods for adding transactions individually and in parallel rather than sequentially in blocks, the basic principle remains the same, which is that new transactions (whether grouped into blocks or not) validate the preceding ones. This validation process is based on the idea that, since new transactions refer to preceding ones, they are only valid if all those transactions are valid as well.

(c) Mining and incentives

The process of searching for new blocks in which to incorporate the transactions that have been shared is known as "mining", and the persons who engage in this form of mining are rewarded for their efforts. In the case of bitcoins, for example, there is a predetermined fee for each new block that is found, and there may also be a fee for each transaction that is incorporated into the block, which is set by the transaction's originator. While, in some blockchains, the payment for each transaction is determined by specific rules, in the Bitcoin network and the majority of other cryptocurrency networks, transaction fees are determined by a balance between supply and demand. Persons who want their transactions to be added to the database quickly may offer a higher fee, which will serve as an incentive for miners to favour those transactions over others when building the next block, especially if there is some technical constraint that prevents them from adding all the pending transactions at the same time. The existence of predetermined fees performs two functions:

1. These fees are the way in which new cryptocurrencies are created and distributed. To use the terminology generally employed when talking about money (although cryptocurrencies are not, strictly speaking, money), these fees are the only way to add currency to the system or, in other words, to increase the "money supply". Since, just as in the case of fiduciary money, the value of a cryptocurrency ultimately depends on its potential owners' confidence in its ability to hold its value over time, the fact that the increase in cryptocurrencies is linked to their use and is programmed on a rational basis promotes confidence in the system's neutrality and stability and thereby endows these currencies with value.
2. The fees function as the incentive that prompts large numbers of potential cryptocurrency miners to devote their time and effort, make use of their hardware and bear the corresponding electricity charges in order to validate transactions and blocks, thus supporting the premise that there is a critical mass of independent miners. Mining is what allows blockchain to function properly, provided that there are many participants in the process —measured in terms of computing power in the case of the proof-of-work function— and that participation is widely distributed, such that no one participant or coordinated

group of participants accounts for anything near 50% of the total decision-making power.[4] This is what averts abuses in the determination of what transactions and what blocks are accepted, and it is also what ensures that the rules that are laid down are consensus-based rather than being determined by any one party in such a way as to serve that particular party's interests.

(d) Consensus algorithms

In order to provide different participants who do not know each other with a decentralized method for coordinating the process of adding a block to the chain, what is known as a "consensus algorithm" is used. This algorithm has to specify how to determine which participant will add the next block in a system where, at any given moment, new participants may decide to join in and other participants may decide to leave. This has to be managed without any centralized ledger, since having one would prevent the system from remaining decentralized, which is its essential characteristic.

The best-known consensus algorithm, and the one used for Bitcoin, is the proof-of-work algorithm. Its rules are quite simple and can be summed up as follows:

1. Each block is linked to the previous one by incorporating the hash code of the preceding block into the newly added block.
2. A block is valid only if its hash code is below a certain target number. In addition, each transaction in the block has to be valid (consistent).
3. If a blockchain splits into two or more chains, the longest chain is the genuine one.
4. People who use their systems to search for blocks and validate them are responding to two incentives: (i) a transaction that generates a new value that is assigned to an address chosen by the person who finds the block; and (ii) the fee paid by the originator of a transaction to the person who adds that transaction to a valid block.

The target number referred to in the second rule is calculated periodically such that the level of difficulty increases when the average amount of time between blocks is less than the targeted period of time and decreases if that average exceeds the target time. The ramifications of these rules are varied and significant:

1. If an existing block were to be altered, all subsequent blocks would be invalidated, since the preceding block's hash code would no longer match up.
2. Searching for and finding a valid block requires a great deal of computing power, and the probability of finding a block therefore increases in proportion to the amount of computing power devoted to the search.
3. In order to search for a block, the hash of the preceding block must have been solved, and it is therefore impossible to calculate blocks ahead of time.
4. The initiator of any attempt to defraud the system is not pursued and penalized but is instead simply ignored. The incentives are designed in such a way that it is more profitable to follow the rules than to try to sidestep them.
5. Any entity can create new blocks without registering or being vetted. The person or group can simply start to search for blocks using the information that is shared in the network and can stop searching at any time.

[4] This becomes impossible once a network reaches a certain size. In 2014, Campbell R. Harvey calculated that mounting a successful attack on the Bitcoin network would require computing power equivalent to 50,000 of what was then the largest supercomputer in existence (the Chinese Tianhe-2, of which there was only one). The attacks would have to be coordinated in a single pulse of synchronization and propagation (approximately 10 minutes in the case of bitcoins). Since then, the Bitcoin network has grown exponentially, and its hash rate has jumped from 150 petahashes per second (PetaHPS) to 23.6 eptahashes (EptaHPS) per second, which amounts to a 15,733% expansion of the network and of the difficulty of tampering with it.

(e) Alternative consensus algorithms

The proof-of-work algorithm has come in for criticism because of the huge amount of electricity that is consumed to achieve the computing power required to perform the necessary tasks and because of its artificially high level of difficulty. While bitcoin mining requires a certain critical mass of participants, the proof-of-work algorithm also rewards miners for the excessive amounts of power that they use; this has led to a concentration of mining activity (in order to attain the necessary economies of scale and amass enough bargaining power for brokering deals with power generating facilities) and of specialized hardware production. If these processes continue to intensify, they could wind up by undermining trust in the system and depleting its resilience.[5]

Although the predetermined fee per block is a distortion that is going to have less of an impact in the future —the fee is halved every two years or so— the criticism focusing on the excessive energy use that is an inherent part of the proof-of-work algorithm remains valid. This is not the only possible consensus algorithm, however; a number of alternatives have been proposed, with the most satisfactory one being the proof-of-stake algorithm. This concept is based on the idea that, because the participants in the system own assets and thus have a stake in the system, there is a tacit incentive for ensuring that the value represented in the system is maintained. Thus, rather than using the computing power employed by a miner to determine to whom the creation of a block should be attributed, the amount of value in the cryptocurrency that a miner has is multiplied by the amount of time that the miner has held that amount of value. Once a block is generated, the number representing the amount of time corresponding to the maintenance of that value is rolled back to zero.

(f) Smart contracts

While the most direct application of blockchain is the creation and maintenance of a cryptocurrency based on rules that are determined at the level of the chain (with the bitcoin success story serving as the proof-of-concept), the ledgers associated with certain addresses or accounts is not the only way that this technology can be used. One interesting example of another way in which this technology can be used is the "colored coins" system, which is built on top of the Bitcoin blockchain. In this system, a coin of the smallest denomination (one that cannot be subdivided) is associated with a right or object that exists in the real world and that can later be traded using the logic of the blockchain. This smallest-denomination coin thus becomes a token whose effective possession can then be tied in with the right to receive a given good or service.

A more general example is one in which processing capacity is added to the blockchain so that the specific rules and logic governing the use of the value stored at a particular address can be defined dynamically —although, in its most well-known form, it can be defined only once— by the person or entity controlling that address. In this model, each time that an address receives a transaction, the associated code is executed and the cost of processing the transaction, which is proportional to the computing power used by the miners, is paid by the initiator of that transaction. This method of combining value, system logic and data storage is known as "smart contracts" (Szabo, 1996); these contracts are in line with Lawrence Lessig's maxim that "code is law" (2000), as no external authority is needed to ensure that contracts are honoured, since the coding ensures that they self-execute. The best-known platform that applies this concept in its blockchain is Ethereum, which will be discussed in section A.3.

5 For example, when, in December 2017, bitcoins were being valued at nearly US$ 20,000 and 12.5 new bitcoins per block were being generated every 10 minutes, on average, the system of incentives justified an expenditure on electrical power of far more than US$ 1 billion per month.

2. Governance

(a) Transparency and privacy: public and private keys

The blockchain technology is totally transparent by design, and anyone can participate by simply using publicly available information, without the need to have access keys. Another outstanding feature of this technology is the privacy that it affords, although this would, at first glance, seem to be a contradiction in terms. The way in which the technology provides privacy works quite differently from the logic of bank secrecy, whereby the identities of the parties involved are protected by the fact that the transactions are visible only to the institutions that are handling them.

Transactions performed using the blockchain technology, on the other hand, are permanently and immutably registered in the distributed database; the entire transaction history, starting from the creation of the asset to the present, is maintained. But the transactions are registered with reference only to their pair of public and private keys, and no information on the identity of the persons involved in the transactions is recorded. Consequently, there is no way to identify the person who controls a particular address or the assets associated with it. The only way to use an asset associated with a pair of keys is by generating a new transaction that can be initiated only if the corresponding private key is known.

(b) Legal logic versus Boolean logic

It is important to assess the importance of private keys as the only method for modifying the asset or value of an asset stored at a given address, since their use has implications that are not entirely evident for a Western nation-State that has the power to regulate many aspects of the personal lives of its people. The differences between these two systems is illustrated in table II.1, which highlights the dichotomy between the principles of the legal code and the principles of the software codes on which blockchain trading is based.

Table II.1
Legal codes versus software codes

	Law	Software
Logic based on:	Subjective minds, analogy	Boolean logic, bits
Security	Contempt charges, imprisonment	Replication + cryptography
Predictability	Flexible	Rigid
Maturity	Highly evolved, many cases	In its infancy, few experiences
Areas	Jurisdictional silos	Independence from political and financial institutions and seamless operation across borders
Costs	Lawsuits, very expensive	Extremely low

Source: Based on N. Szabo, "History of the blockchain", presentation at DEVCON1, London, Ethereum, 9-13 November 2015 [online] https://www.youtube.com/watch?v=7Y3fWXA6d5k.

Another category that could be added to table II.1 to reflect the ideas put forward by Lessig (2000) is the scope of application, since, as will be discussed later on, the interaction between a blockchain and the real world is not a trivial consideration. While a legal code is applicable throughout a given national territory, blockchain requires connectors. The two types of codes also differ in terms of the elements that interact: in legal systems, transactions invariably occur between specific persons but, in blockchain, transactions are conducted between public keys that may be used and controlled by persons but that may also be controlled by entities that have no legal status or even simply by objects.

The way in which a problem with transactions in a blockchain —the loss of a private key, legal settlements, inheritance cases and so forth— is solved cannot entail modifications that are not allowed by the rules established by the community of miners in that particular chain. By its very nature, a peer-to-peer (P2P) network —which is ultimately what blockchain is— is not linked to any of the jurisdictional silos established by nation-States. In addition, most of the miners in a properly functioning chain are presumably not subject to any one particular nation-State, and the miners are not directly identifiable. Given these factors, it is extremely difficult to envisage any way in which a chain could base itself on rules that grant a central entity (including the justice system or any other national entity) the authority to incorporate transactions that go beyond the bounds of the rules established by the community of participants. This could not even be done by a universally accepted global authority if such a thing were to exist one day.

It is not inconceivable, however, that the essential characteristic of a blockchain system —the fact that it is not open to human intermediation in the sense that it entails the execution of a sequence of deterministic steps that define the result of a transaction— may change in some way in the future. An informative precedent for this is provided by what happened with The DAO in the Ethereum chain in mid-2016, when a coding error allowed a hacker to siphon off most of the ether tokens held at a certain address (Madeira, 2018). In that instance, since the problem was a programming error in a smart contract rather than a flaw in the technology, it was decided that, since the original owners of the assets involved in the controversial transactions did not intend for those transactions to be made, the values of those transactions were rolled back to those owners on the basis of rules established specifically for the case at hand, which were voted on and approved by over 50% of the Ethereum mining community. While it is unlikely that a solution of this type will be repeated in the future (Ethereum was in its infancy, its mining community was still relatively small and the persons who were affected by the hack included many influential members of the project), it shows that the idea that software code outweighs human intermediation or intentions is a decision rather than an immutable aspect of a chain and that it is possible for decisions to be made that will have an influence on a large majority of the members of a mining community by establishing rules for the express purpose of dealing with a specific case.

3. Ethereum: a virtual machine

Although the Bitcoin blockchain allows a certain degree of scripting to personalize the way in which the assets stored at a given address can be used, its scope is intentionally limited to prevent miners from running routines —whether by mistake or maliciously— in an endless loop. In the computer sciences, this is known as the "halting problem". This can be dealt with by deferring the use of an asset for a certain amount of time (measured in blocks), requiring a given number of signatures from a defined group, using a secret key rather than a signature with a private key, or using a number of other approaches that are fairly simple to program without requiring cycles or the storage of information in variables in a persistent state. In addition, the use of coloured coins and other such systems makes it possible to use optimizations that work well in determining when an asset is being spent but do not track a given token.

An alternative that is now the world's second-largest cryptocurrency market is the Ethereum platform, which was created in 2015. This blockchain has its own cryptocurrency —ether— but its rules are such that its use is not confined to a system for handling a digital currency but instead functions as a virtual machine.[6] It accomplishes this by incorporating the concept of a "smart contract"; it allows random complex executable code to be associated with an address and permits the storage of variables that are generated and used by these contracts.[7] This platform thus turns the blockchain technology into a generic system that can perform an array of functions in addition to the creation of a cryptocurrency.[8] In essence, it can function as an open-access, very low-cost, shared global computer that can be used both to develop and run applications.

[6] The ether does have a given exchange value, but it is primarily a prepayment medium (the "gas") for the Ethereum Virtual Machine (EVM) and the execution of smart contracts.

[7] Ethereum is the first and leading blockchain to do this, but it is far from the only one. Similar blockchains include the Chinese NEO and the Argentine RSK, which use the Bitcoin blockchain. See [on line] https://neo.org/ and https://www.rsk.co/. There are also smart contract platforms that run on partially decentralized permissioned infrastructure, such as Hyperledger and Stellar. See [on line] https://www.hyperledger.org/ and https://www.stellar.org/.

[8] Seventy of the top 100 cryptocurrencies run on Ethereum.

4. Links with the real world

Every transaction involving an address associated with a smart contract must be able to be validated by all the miners at any point in time —even years after it was added to the chain. This means that the execution of transactions must be entirely deterministic and make use only of information that has been secured within the chain. The problem that then arises is how to deal with the interface between these smart contracts and elements in the real world.

The way around this problem is provided by what are known as "oracles", which transmit information or interpretations of events in the physical world generated by professional or amateur sources to the platform. These data feeds are used redundantly on the basis of an incentive- and reputation-driven system designed to induce accurate, reliable inputs. The link with the real world is not time-bound. Today there are many models and tools that are intended to provide future information by means of prediction or performance-based strategies. They include elements of artificial intelligence (in the sense of machine learning) that can be integrated into blockchain solutions and decentralized forecasting market platforms (peer-to-peer oracle and prediction exchanges focusing on the outcomes of any future event whatsoever) that natively support blockchain systems.[9]

Making the connection in the opposite direction, from the blockchain to the physical world, is much easier, since any node on the chain can serve as a bridge. This makes it possible to program any device that is part of the Internet of Things to operate according to the instructions it receives from a specified smart contract. Thus, a physical object of this type becomes "smart property" that can be sold or rented out for a set period of time that is determined by the rights assigned by a smart contract stored on a blockchain.

Another option is to use the traditional sort of legal obligation by entering into a contract covering the delivery of a product or service to the owner of a token that represents the right to ownership of that good or service.

5. Public networks, private networks and consortiums

Thus far, all non-trivial aspects of blockchain has been viewed as being decentralized, but that is nothing more than a design decision. In fact, there are applications that do not follow this path but instead generate a more or less centralized platform by defining who may participate and who may determine the operating rules. There are public networks (that allow anyone who wishes to participate to do so, without even knowing the person's identity), private networks (controlled by a single, central entity) and consortium-led networks (in which different pre-defined institutions share a chain and in which the rules usually require the involvement of more than one institution in order to add new information). In the case of private and consortium-led networks, the role of miners disappears and, along with it, the need for the infrastructure that mining involves. The hardware used by the nodes is provided and maintained by the owner of the private network or the members of the consortium. While, with this model, the attribute of decentralization is lost and, along with it, the advantages it affords, it makes sense to think about having somewhat centralized blockchain for certain types of uses or agents, as in the case of chains used to optimize coordinated action in oligopolies, including regulated markets such as the banking system or large-scale power generation and transmission systems.

6. Scalability

The massification of these technologies and the intense interest that they have aroused among the general public have greatly increased the number of operations being run on these networks, particularly in the case of the Bitcoin and Ethereum blockchain, which are the two cryptocurrencies (although the latter is more than that) with the highest market capitalization. This has brought them up against certain limits in terms, for

9 Examples include Augur, Gnosis and Stox. See [on line] http://www.augur.net/; https://gnosis.pm/; https://www.stox.com/.

example, of the size of the blockchain and, consequently, the number of transactions that can be processed per unit of time. Along with these constraints, other frequent criticisms (especially in the case of the Bitcoin network) have focused on the system's high energy consumption because of its mining component and the amount of time that it takes for a transaction to be incorporated into the chain and to be validated by the addition of subsequent blocks.

The technology has not yet matured and its scalability challenges have yet to be resolved, but none of these problems is an intrinsic part of the concept of blockchain. Strategies have been proposed that are in the process of being validated prior to their actual incorporation into different blockchain and their production environment. Examples include payment channels such as Red Lightning for bitcoins (Poon and Dryja, 2016) and Plasma for Ethereum, neither of which group transactions into blocks or perform transaction-by-transaction validations (Popov, 2017).

B. New disruptive resources

So what does all this mean? What types of disruptive tools will this new way of doing things put in the hands of society? Some of the possibilities will be explored in the following pages, along with the systems that they may overturn.

1. Nature of the records

The compilation and archiving or storage of information have always been delicate, problematic issues, and they are becoming increasingly important. Maintaining accurate records and handling them properly are essential in many different types of public and private processes, including accounting procedures.

Insofar as accounting is the language of business dealings, it helps to shape the way in which the world that speaks that language is represented. Double-entry accounting reflects and is structured around one basic economic fact: every debtor has a creditor. The existence of this symmetry, as mirrored in a company's accounts, means that each transaction requires two entries to be made: one as a debit and one as a credit. This method facilitates the detection of errors, makes it more difficult to alter financial data and links up different accounts.

The blockchain technology is now providing the world with a super tool: immutable records, generated in real time, that will always be readily available for consultation. When an immutable record is fed into a chain, it can be classified as a third accounting column. An unassailable record can be extracted from that column for use in any sort of analysis or inspection, including those inherited from traditional accounting schemes. Actually, however, it is not that a third column is being added but that this third column can replace the other two. This is known as a triple-entry accounting system.

This has far-reaching implications in terms of accounting. Traditionally, when two commercial agents conduct a transaction, their individual entries should match: if one enters a credit, the other should enter a debit. If, by mistake or by intention, the creditor demands payment of a greater amount, the other agent will consult its ledger and supporting documentation. If the creditor persists in demanding a larger payment than had been agreed upon, it will be seen that the ledgers and the supporting documentation of the two parties are at odds, and a third party (usually the courts) will be needed to resolve the dispute. However, as will be seen below, the parties could both view the third-column entry, which is unassailable. This does away with this type of dispute and with the need to have recourse to a third party to resolve the issue.

2. Handling double spending

If it were possible to ensure that the owner of an asset was the only one who could dispose of it and could only do so once, a large part of the frauds that have been committed would be impossible. This is what the blockchain technology can do, although in its own way: the ownership of an asset that is the subject of a transaction is translated into the ownership of a private key, which transfers the responsibility for taking care of that asset and of using it properly to the person who generated that key. Double spending becomes impossible, since the ledger's consistency over time is what validates the transactions conducted within the system.

Preventing double spending may not seem like such a significant achievement in the case of transactions involving physical goods, but it is quite a different matter in the world of debt instruments and securities, and even more so in the digital world, where one of the principal attributes is that information does not degrade when it is replicated: the copy and the original are identical. The way that double spending has been blocked until now has been based on the traditional approach of resorting to intermediation by trusted agents: a third party centralizes and manages the information, its ledgers are the ones used to establish who has what and how much, and it lays down the rules about how those accounts may be modified. For regulated markets, such as the money market, governments are also involved. By endowing digital units that represent value with the attributes associated with material goods and doing away with intermediaries, this technology profoundly alters a long-standing process.

In the traditional banking model, the fiduciary agent (the bank) limits the double spending of all other agents but itself. This is the foundation of the fractional-reserve banking model, which carries an inherent risk of bank runs or financial panics and, therefore, cannot function without public trust. This is what largely justifies and acts as the motivation for government regulation of the banking system, including the practice of allowing only government-licensed banks to operate. The efficiency with which blockchain technology controls double spending renders extraneous many of the safeguards built into systems that lack such control. It also implies that the fractional banking model is incompatible with the tokenization of fiduciary money.[10] These options are being explored in a number of different countries.[11]

3. Real-time collaborative distributed databases

A pool of information is valuable per se, but it is much more valuable for the agent of trust that sets its official value. For that same reason, its integrity and accuracy have to be safeguarded. Until now, the basic strategy for this has been to build a firewall which, in theory, prevents outside parties from accessing the data and ensures that persons with access and writing privileges behave properly and with due diligence. Use is also made of secure (often dedicated) channels for communication between the trusted agent and all the other persons who interact with that agent when they are consulting a record or initiating a transaction. This is true both of paper ledgers and SQL databases in the cloud.[12]

Pooling reliable information in distributed databases changes everything, since trust in the integrity of the information is placed in the system itself, thereby doing away with the need for a trusted agent to validate the information and for that agent's security system. It therefore shifts the whole challenge of maintaining data security to another realm, to the interaction between centralized databases and systems and the blockchain, which is where all the hacks and different forms of embezzlement associated with the cryptoeconomy have occurred.

10 The two models could be compatible if the State were to authorize banks to create fiduciary money, not by using and circulating the funds that they already possess but by generating and distributing fully government-backed tokens on behalf of the State as a means of minting new money. In this connection, proposals for a banking system with full reserves, such as the Swiss Vollgeld Initiative, are of particular interest. See [on line] www.vollgeld-initiative.ch/english/.

11 They include the Project Ubin in Singapore and other projects soon to be launched in the Russian Federation and India. See Monetary Authority of Singapore (MAS), "Project Ubin: central bank digital money using distributed ledger technology" [online] http://www.mas.gov.sg/Singapore-Financial-Centre/Smart-Financial-Centre/Project-Ubin.aspx.

12 Structural query language (SQL) can be used to manage relational databases.

As discussed earlier, the system of using paired public and private keys provides a way of attaining both transparency and privacy at one and the same time, so freely accessible information can be compiled without sacrificing its confidentiality. There are also two super tools that can be used to safeguard privacy: (i) self-sovereign identity systems, which make it possible to link information to an individual while still leaving the control and use of that information in the hands of that person;[13] and (ii) zk-SNARK non-interactive zero-knowledge proofs, which can be used, for example, to share market information with a competitor while hiding any sensitive content and while still compiling and distributing information in the same public-access system.[14] The marketing strategies embedded in some smart contracts are just one example.

This is a new paradigm for the compilation and consultation of information configured around blind signatures that allow the information to be made public while synchronizing shared ledgers using pulses generated by miners and the rhythmic packaging and linkage of the blocks of executed transactions. All the consolidated information is then available, nearly in real time, to anyone who wants to look at it, making it possible to execute autonomous processes for the integration of complex systems while they are running, which in turn can optimize many of these system processes. This also can provide support and enhance the technical viability of constructs such as smart cities and the Internet of Things.

It will also have an impact on the approach and scope of auditing procedures, which will shift to an ex post analysis of randomly chosen transactions based on the assumption that the samples will be statistically representative, together with in-depth examinations of smart contracts and other aspects of automated management programming. This will increase the degree of confidence in the correctness of program execution, provide a clearer overall and nearly real-time picture of the transactions that are conducted and, perhaps, lead to the development of warning systems capable of issuing alerts each and every time that abnormalities arise, as soon as they arise.

4. Smart contracts

Apart from value transfer, the disintermediation of economic traffic was one of the main goals of the persons who devised blockchain technology. Notarization is an important legal tool in what are known as smart contracts.

In a centralized world, there are often situations in which leaps of faith are required that are difficult to resolve for the parties concerned. For example, when a house or other real estate is being sold, the buyer will not be willing to pay for it until it is registered under the buyer's name in the corresponding registry, while the seller will not be willing to register it under the buyer's name until payment has been received. This stand-off is usually resolved by having recourse to someone that both parties trust (a notary). The agreed payment is handed over to the notary, who will then deliver it to the seller once the seller has provided proof that the deed has been signed over to the new owner. A smart contract can take the place of a notary in a blockchain.

The programming of a smart contract can vary in its level of complexity. In some cases, it simply involves incorporating a simple rule or condition (meeting a deadline or fulfilling some other requirement) but, in other cases, it may entail coordinating a complete business model. The only upper limit is the willingness of the originator to pay the price for executing that package of instructions, which is known as the "gas" that fuels the Ethereum network (i.e., freely transferrable ether tokens). This is what links up the distributed supercomputer with the hardware providers and the electrical power providers (the miners), creating a formally established direct match between cost and payment.

This makes it possible to replace complex business structures and complete systems with a simple code, thereby taking disintermediation to a whole different level. And since this is a self-executing code lodged in a blockchain, its integrity and stability is guaranteed. Because this technology combines all of these elements, it takes automation to an entirely different level as well.[15] For example, the automated disintermediation of

[13] See uPort [on line] www.uport.me.

[14] See C. Reitwiessner, "zkSNARKs in a nutshell", Ethereum, 5 December 2016 [online] https://blog.ethereum.org/2016/12/05/zksnarks-in-a-nutshell/.

[15] These self-executing applications, which do not require human intervention, are known as "decentralized applications" (or "DApps").

private-sector (social) lending[16] can eliminate interest-rate spreads. It is also possible to automate insurance schemes so that the cost of the insurance premium will ultimately be identical to the distributed cost of the claims paid to all insurance policy holders (with or without correction factors), with no surcharge and with no need for the involvement of any sort of traditional insurance company at all.[17]

5. New corporate capitalization models

(a) Decentralized autonomous organizations

Usually, when a company or a venture wants to raise capital, it issues a prospectus for potential shareholders that sets out what the funds will be used for, the rights that an investment will convey (such as the election of a member to the board of directors from among the participants in the investment round), the minimum funding target and information about the by-laws and structure of the firm, along with the expected yield of the investment and any safeguards or guarantees that may be on offer. If an agreement is reached, due diligence procedures are undertaken that may give rise to further negotiations. If the funding target has been reached, the next step is the notarial documentation of the transactions and only after that is completed will the new shareholders be registered and the investment capital transferred to the firm.

If a similar offer were to be received but was expressed in terms of a package of smart contracts that established the exact use to which the funds would be put and precisely defined the political and economic rights associated with the investment and all the conditions pertaining to their use, then the registration (against payment) of those smart contracts, totalling a figure above the minimum target, would automatically trigger the start-up of the venture. Put more precisely, the package of smart contracts governing the organization of the investment capital would be the company, which would be a special type of company: a decentralized autonomous organization (DAO).

This concept was put into practice in 2016 with the inception of Slock.it, whose resounding success prompted its creators to launch *The DAO* project in an effort to extend the concept's application to an investment fund for decentralized companies.[18] However, as noted earlier, a programming error in one of the smart contracts created problems that cast a shadow over the name (or, actually, the acronym); nevertheless, the concept remains sound.

(b) Initial coin offerings (ICO)

The opportunity offered by a zero-trust system —such as blockchain— for a given agent to interact easily and securely with large numbers of other actors or agents around the globe, combined with the flexibility and certainty afforded by smart contracts, has made it possible not only to construct efficient crowdfunding mechanisms, but also to redefine the potential role of capital in a business enterprise.

Joint stock companies (and especially corporations) are vehicles for the creation and capture of value by their owners and are designed for the sole purpose of maximizing those owners' returns. This approach does not fit in with the logic or the business models of blockchain or distributed economic systems. This mismatch is occasioned by the fact that the legitimate expectation of a return on investment, when it is significant, inhibits or at least hinders the transference of the savings derived from disintermediation or automation to the end users and thus gives rise to concentrative or intermediation-based business models.

An alternative approach would be to fund a project by making advance sales of services that are not yet in existence but that are to be developed once the project is up and running. These projected services are "tokenized" and put on offer in the hope that enough of them can be sold to fund the venture. The tokens representing these crypto-assets are, like all tokens, freely tradable, so their value is subject to speculation,

16 See Lendoit [on line] https://lendoit.com/ and Celsius [on line] https://celsius.network/.
17 See Dynamis [on line] http://www.dynamisapp.com/.
18 See Slock.it [on line] https://slock.it/.

but this model ensures that the solution or service will be ramped up as soon as the necessary funding has been obtained. It also prompts a critical mass of users to generate network externalities, which improves the project's chances of success. This approach makes it possible to create a company that can absorb development costs without having to satisfy investors' profit expectations.

One problem is that the creation of standardized cryptocurrency tokens is so simple to do on platforms like Ethereum. Another is that many people are willing to buy those tokens without fully understanding what is on offer and there are also people who are poised to abuse the system if they can. Since the symbols of value are the same, no matter how different the underlying assets, people failure to distinguish between sales of equity in business enterprises, sales of future services, sales of units of value within the framework of payment systems and smokescreen sales, all of which could come under the heading of an initial coin offering (ICO). As in the case of DAOs, the term is inexact. Nowadays ICOs have a somewhat negative connotation and the way that they are conducted has evolved, but the initial concept is still sound.

C. An open technology for Latin America and the Caribbean

The State centralizes data and serves as the vehicle for official versions of the truth, while the government bureaucracy is its operating system. However, the rules and inferences under which blockchain operate are not altogether compatible with those of the nation-State because that technology sidesteps or disregards some of the State's essential aspects (such as the existence of jurisdictional silos) and can deprive it of some of the valuable resources that it relies on to control and influence social, political and economic events that occur within its territory or that have an impact on the population. It calls into question or challenges the State's monopoly on the delivery of public or government services and the need for a (single) legal order to prevail throughout the territory under its jurisdiction. The work done by Bitnation in exploring these paradigm shifts is particularly engaging and enlightening.[19] This development is a disconcerting one for nation-States, but it is one that they will need to analyse and take on board soon, not least because it is the source of powerful new tools for the administration of government procedures and services that should be taken advantage of.

The emergence of blockchain technology opens up a number of opportunities for Latin America and the Caribbean. A first and fortunate circumstance is that, unlike the case of other types of technologies, there is nothing to prevent the region from taking up this challenge. The logic of this technology is such that it is being developed in a distributed and decentralized manner. There is thus no central location where everything is happening and where physical distance from that central location would be a disadvantage, as has invariably been the case with the development of other technologies. In this field, capture logics regarding advances or underlying knowledge do not abound as they do in other spheres of technology. Not only is the code open source, but extremely high-level resources for learning about this technology are readily available, and more are constantly being developed.

A second factor is that this technology does not require huge investments in hardware or other equipment or facilities. In fact, the Ethereum platform is characterized as a "zero-infrastructure" system; the necessary hardware and energy are generated, made available and paid for autonomously. All that is required is training and effort —and a great deal of determination. The development costs of Ethereum applications are comparatively low and thus are affordable for any country in the region.

[19] See Bitnation [on line] https://bitnation.co/.

In addition, the technical strengths of blockchain technology would enable the countries of the region to alleviate many of the weaknesses or threats that some of them are dealing with, such as corruption, shortcomings in terms of enforcement and oversight, and difficulties with tax collection.[20] The ability to create tamper-proof records would have a tremendous impact on the traceability of public funds or registration systems, as would the introduction of self-executing and self-enforcing smart contracts.

The region has resources that it can draw upon to attain these objectives. There are active communities of blockchain entrepreneurs and developers in Argentina, the Bolivarian Republic of Venezuela, Brazil, Chile, Colombia, Mexico and Nicaragua), and there are teams of miners in nearly all the countries (and especially large teams in Argentina, Chile and Mexico). Interest in this technology and its applications is on the rise, and this is being reflected in a growing number of studies, related activities and start-ups. Mexico is playing a pioneering role in promoting the use of this technology by means of targeted programmes and the development of an ad hoc regulatory framework.[21]

Blockchain technology profoundly disrupts both our mindsets and the operation of the economy and is therefore an enormously powerful force for change. The region is poised to become part of this new wave of modernization.

Bibliography

Elliott, F. (2009), "Chancellor Alistair Darling on brink of second bailout for banks", *The Times*, London, 3 January [online] https://www.thetimes.co.uk/article/chancellor-alistair-darling-on-brink-of-second-bailout-for-banks-n9l382mn62h.

Lessig, L. (2000), *Code and Other Laws of Cyberspace*, New York, Basic Books.

Madeira, A. (2018), "The DAO, the hack, the soft fork and the hard fork", London, CryptoCompare, 28 February [online] https://www.cryptocompare.com/coins/guides/the-dao-the-hack-the-soft-fork-and-the-hard-fork/.

Poon, J. and T. Dryja (2016), "The Bitcoin Lightning Network: scalable off-chain instant payments", January, unpublished [online] https://lightning.network/lightning-network-paper.pdf.

Popov, S. (2017), "The tangle", IOTA Foundation, October [online] https://iota.org/IOTA_Whitepaper.pdf.

Szabo, N. (1996), "Smart contracts: building blocks for digital markets", *Extropy*, No. 16, Extropy Institute, [online] http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html.

20 For example, the Department of Public Administration in Mexico and the organization Transparencia Mexicana are planning, in cooperation with Brazilian and Colombian institutions, to create a token for use in keeping track of government resources allocated for the organization of elections. See Z. Salgado, "Se realizó con éxito el 'Panel Blockchain: Aplicaciones de Blockchain en México", *Criptonoticias*, 25 February 2018 [on] https://www.criptonoticias.com/eventos/realizo-exito-panel-blockchain-aplicaciones-blockchain-mexico/.

21 On 12 March 2018, Mexico's Digital Strategy Coordinating Office announced that it would continue to promote the use of emerging technologies such as blockchain and was focusing on smart contracts and certificates of deposit, both of which are innovative distributed and traceable mechanisms for registering transactions. See Y. Martínez, "Compartimos los avances y retos de la Estrategia Digital en el Foro OCDE México 2018", Mexico City, Government of Mexico, 12 March 2018 [on line] https://www.gob.mx/mexicodigital/articulos/compartimos-los-avances-y-retos-de-la-estrategia-digital-en-el-foro-ocde-mexico-2018.

CHAPTER

III

An economy and society based on digital platforms

Introduction[1]

The growth of the Internet and other digital technologies paved the way for the emergence of a great diversity of digital platforms in different regions of the world. These have allowed the development of new business models and the diversification of the range of goods and services.

Digital platforms are present in multiple sectors of the economy. Amazon, Alibaba, eBay, Taobao and Rakuten facilitate transactions between e-commerce buyers and sellers; Airbnb connects property owners with renters; Uber puts drivers in contact with passengers for urban trips; Facebook links users to each other and to advertisers, content developers and third party affiliates; Apple's iOS links application developers with their users; Google's Android puts device manufacturers, application developers and users in touch with each other; Sony PlayStation and Microsoft Xbox consoles facilitate interaction between game developers and users; American Express, Paypal and Square connect sellers with consumers through digital payment systems; and Ticketmaster sells event space to consumers (Hagiu, 2014). Likewise, Kickstarter connects entrepreneurs with financiers and Upwork connects independent professionals with clients.

Digital platforms are important agents of the Internet economy: the top five firms by market capitalization in 2017 —Apple, Google/Alphabet, Microsoft, Amazon and Facebook— were platform companies (KPCB, 2017). Platforms are major contributors to the economy, because they create new connections between supply and demand for goods or services in different markets, help to make asset use more efficient and open up new business and productivity opportunities for micro, small and medium-sized enterprises (MSMEs). They are also important sources of innovation. For example, Evans and Gawer (2016) find that nine digital platforms originating in the United States were awarded 11,585 patents in 2014. By introducing new products, services and business models, they become factors of disruption in sectors as varied as transport, accommodation, banking, education and the media.

The Center for Global Enterprise conducted a survey of 176 platform companies representing five continents and found that their total combined value exceeded US$ 4.3 trillion (Evans and Gawer, 2016). They are concentrated in the United States and Asia much more than in other regions. While the United States is the home country of 64 platforms with a market value of US$ 3.12 trillion (72% of the value of all the firms interviewed) and Asia is home to 82 platforms with a value of US$ 930 billion (22% of the global value), Latin America and Africa (which the study grouped together) created only 3 platforms, with a value representing just 2% of the sample.

A. Definitions

Accenture (2016) defines a digital platform as a technology-enabled business model that creates value by facilitating exchanges between two or more interdependent groups. It usually connects users to producers, facilitates transactions and allows firms to share information to increase collaboration or innovation in products or services. According to the World Economic Forum (2017), platforms are technology-enabled business models that create value by facilitating exchanges and interactions. They are built on a shared and interoperable infrastructure, fuelled by data and characterized by multistakeholder interactions.

Many digital platforms have a common characteristic: they allow third parties to develop complementary systems that can be offered to end users as applications or services. In this respect, De Reuver, Sorensen and Basole (2017) indicate that the digital technologies used by platforms have specific characteristics, such as data homogenization and editability, reprogrammability, disaggregation and self-reference. These characteristics facilitate technological arrangements in which there is no single party owning the information and defining the design hierarchy. In this context, digital platforms may be defined in two ways. From the technical viewpoint,

[1] This chapter was written by Guillermo Cruz, consultant with the Economic Commission for Latin America and the Caribbean.

they are a codebase to which third-party modules can be added. From a socio-technical perspective, they are a set of hardware and software elements that includes the related organizational standards and processes. In general, a digital platform has modules that extend software functionality and may be considered software subsystems in the form of add-ons designed and developed by third parties.

International economic organizations have also analysed the concept and characteristics of digital platforms. In 2010, the Organization for Economic Cooperation and Development (OECD) proposed a definition of Internet intermediaries which is very akin to the concept of digital platforms: they bring together or facilitate transactions between third parties on the Internet and give access to, host, transmit and index content, products and services originated by third parties on the Internet or provide Internet-based services to third parties. The European Commission (2016), in a public consultation held in 2015, defined the digital platform as an undertaking operating in two (or multi)-sided markets, which uses the Internet to enable interactions between two or more distinct but interdependent groups of users so as to generate value for at least one of the groups. According to the European Commission, although there is no consensus on the definition of digital platforms, many of them share six characteristics:

(i) The capacity to facilitate and extract value from direct interactions or transactions between users;

(ii) The ability to collect, use and process personal and non-personal data in order to optimize the service and experience of each user (economies of scope);

(iii) The capacity to build networks where any additional user will enhance the experience of all existing users (network effects);

(iv) The ability to create and shape new markets into more efficient arrangements that bring benefits to users but may also disrupt traditional ones;

(v) The ability to organize new forms of civil participation based on collecting, processing, altering and editing information; and

(vi) Reliance on information technology as the means to achieve all of the above.

The main attributes characterizing digital platforms and differentiating them from other technological systems are:

(a) Interdependence

Most digital platforms provide a medium in which one set of platform users can interact and transact with another set of platform users, which sets up interdependencies. According to the European Commission (2016), interdependencies may exist between different types of users, such as: (i) producers and consumers of goods, (ii) advertisers and readers, (iii) buyers and sellers, (iv) job seekers and recruiters, (v) accommodation providers and accommodation seekers, (vi) transportation providers and passengers. Thus, the demand of one group of users is related to the supply of other platform customer groups.

(b) Network effects

A network effect refers to the effect that one user of a good or service has on the value of that product to other existing or potential users. Digital platforms have such network effects: the value of using the platform depends directly on the number of users it has in its various categories.

The European Commission (2016) distinguishes between direct and indirect network effects. Direct effects occur when a new user joining the platform makes it more worthwhile for other users in the same group (for example, users of social networks such as Facebook). Indirect effects exist where users of one group benefit from an increased presence of users from a different group (for example, sellers on an online marketplace benefit from a higher number of buyers and vice versa).

Indirect network effects are an important characteristic of most digital platforms. They are usually asymmetric, insofar as one group of users can benefit more than another. Asymmetries are generally smaller in marketplaces (more sellers benefit from more buyers and vice versa) and larger in the case of advertising platforms (advertisers benefit from the existence of a large number of consumers, but the consumers do not necessarily benefit directly from the existence of a large number of advertisers).

These direct and indirect network effects mean that platforms have to achieve a critical mass of users on different sides. Because of this, to overcome issues of coordination failure (potential users of group A will be attracted to the platform by a minimum number of users from group B and vice versa), platform start-ups deploy strategies to encourage users from different groups to join. Some platforms use cross-subsidies whereby certain groups are offered services cost-free (European Commission, 2016).

(c) Economies of scale and scope

As the number of users on a platform increases, it can collect larger quantities of persona and non-personal data, which may be of great value. Data analytics can be used to better match the preferences of consumers, optimize their business processes, reduce costs and identify new market trends or opportunities. Certain online platforms are well placed to take advantage of big data thanks to economies of scale (volume of data) and scope (variety of data) associated with data collection and analysis (European Commission, 2016). Shared data can be mined intelligently by specialists, including those from adjacent industries, to create new forms of value, such as complementary applications or services (Accenture, 2016).

(d) Technological confluence

In the past few years, digital platforms have developed in a dynamic technological environment, characterized by the confluence of multiple technologies, such as cloud computing, big data, artificial intelligence and the Internet of Things (IoT). According to Accenture (2016), this concurrence of technologies is creating a new "as-a-service" economy, where services are dynamic, on-demand and targeted. The new technologies have equally significant effects on cost to serve, investment levels and speed to market. Because these services integrate business processes, software and infrastructure and making them available "on demand," companies can benefit from plug-in, modular, scalable services.

(e) Single-homing and multi-homing

Customers may use one or more platforms for the same purpose. Customers "single-home" when they only use one platform for a particular purpose and therefore interact only with users on the other side of that platform (e.g. users of a single operating system on a single device). Customers "multi-home" when they use two or more platforms for a single purpose and interact there with users on any of the platforms they use (for example, users with more than one payment card). A platform aiming to develop a single-homing business model will try to ensure that a customer spends as much time as possible on that platform and will usually try to become an ecosystem in itself, in which the user experience is important (European Commission, 2016).

(f) Control and risk management

Many online platforms facilitate transactions between buyers and sellers without having full control over the provision of the respective goods or services. Lack of control over transactions, which distinguishes platforms from traditional businesses, generates risks that platforms must manage. Operators of online platforms are generally aware that, in order to attract users, they need to provide a transaction environment that mitigates risks. Most operators internalize risk management through strategies such as self-regulation based on codes of conduct, user reviews, ex ante control of suppliers' credentials, dispute resolution protocols, insurance schemes and content blocking and filtering (European Commission, 2016).

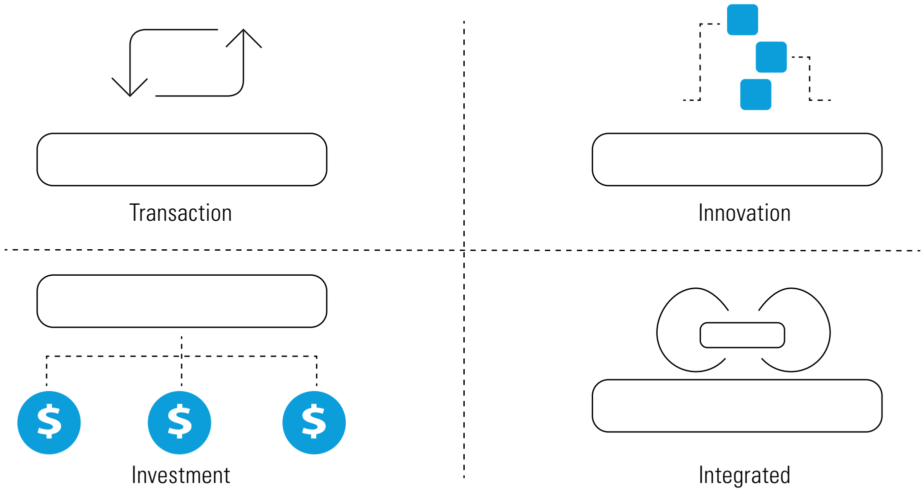
B. Typologies

Three important typologies of digital platforms are the classification developed by the Center for Global Enterprise, the typology of the European Commission and the firm-based proposal advanced by the consultancy firm Oxera.

1. Classification of the Center for Global Enterprise

According to the Center for Global Enterprise, platforms create value through two mechanisms (see diagram III.1). The first —transaction platforms— facilitates transactions between different types of individuals who would otherwise have difficulty finding each other. These are also known as multi-sided markets; examples are Airbnb, Amazon, eBay, Google Search and Uber.

Diagram III.1
Types of platform according to the Center for Global Enterprise



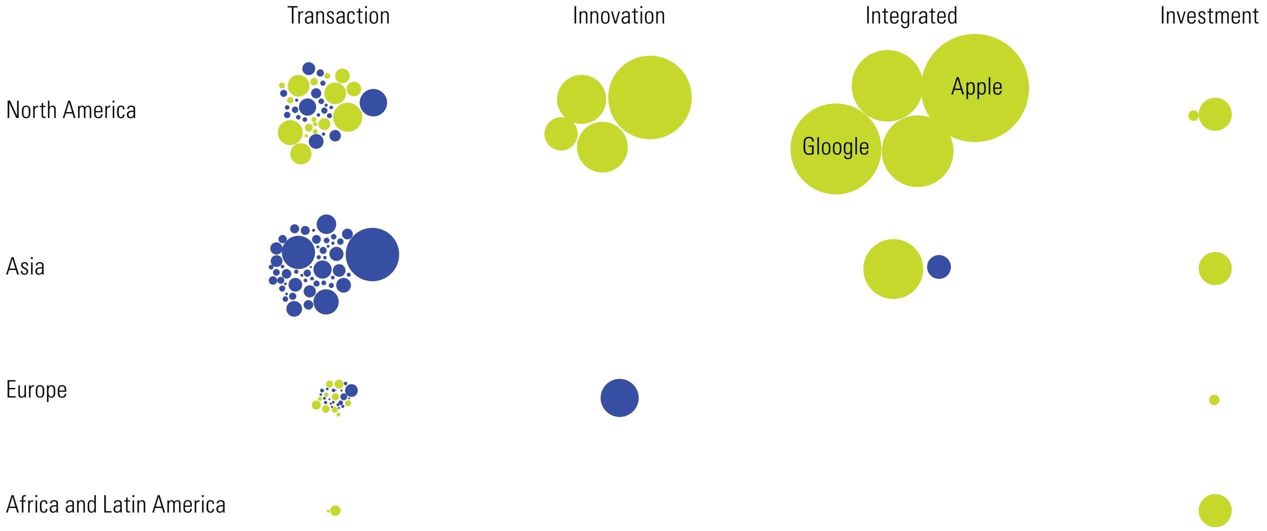
Source: P. C. Evans, and A. Gawer, "The rise of the platform enterprise: a global survey", *The Emerging Platform Economy Series*, No. 1, Center for Global Enterprise, 2016.

The second mechanism is the facilitation of innovation processes. The Center for Global Enterprise describes innovation platforms as technological building blocks that are used as a foundation on top of which a large number of innovators can develop complementary services or products, forming an innovation ecosystem around the platform. An example is the iPhone: innovators in that ecosystem have developed hundreds of thousands of applications (apps) using Apple technology that the company makes available through application programming interfaces (APIs). De Reuver, Sorensen and Basole (2017) note that the innovation dynamics of a digital platform often depend on its dependencies with platforms on different levels of the technical architecture. For instance, in the context of mobile platforms, the iOS operating system is closely linked with the Apple iTunes app store platform. Similarly, an open data platform on smart cities for app developers may contain a diversity of platform components such as databases, app development kits or reusable application components.

A special case of innovation platforms are platforms for participation or open services in the context of digital government initiatives or smart cities. The European Parliament (2014) describes these two types of platform. Participation platforms involve the participation of citizens through ICT-enabled platforms, with the aim of developing better public services. Examples are open data platforms, crowdsourcing and co-creation platforms and other forms of citizen participation and ideation. Through open data platforms, the government creates an interface that opens up government data and services and invites entrepreneurs or citizens to develop apps and other solutions to improve public services. This sort of platform has been developed, for example, in Barcelona, Helsinki, Copenhagen, Malmö, Amsterdam and Dublin. Evans and Gawer (2016) define two other types of platform. Industrial digital platforms connect firms in the industrial sector to other firms with which they can collaborate and coordinate design, production and commercial activities, as well as with developers of industrial apps and services. Integrated platforms are both transaction and innovation platforms (Apple, for example), while investment platforms consist of companies that have developed a platform portfolio strategy or act as a holding company that invests in platforms.

In their global survey of platform companies, Evans and Gawer (2016) analysed the distribution of the four types of platform by geographical origin. As seen in diagram III.2, Asia and North America were the regions with the most transaction platforms, with Europe beginning to have a significant share. The United States leads the development of innovation and integrated platforms in both number and value terms. Africa and Latin America have produced a few transaction and investment platforms, but lack innovation and integrated platforms. China has become consolidated as a leader in digital innovation in the last few years, including in the development of digital platforms. According to MGI (2017), China is in the top three venture capital investors in digital technologies, has the largest e-commerce market (40% of global transactions by value) and is the home country of one in three emerging technology firms valued at over US$ 1 billion globally (also known as "unicorns").

Diagram III.2
Platform companies by region and type, according to the Center for Global Enterprise



Source: P. C. Evans, and A. Gawer, "The rise of the platform enterprise: a global survey", *The Emerging Platform Economy Series*, No. 1, Center for Global Enterprise, 2016.
Note: The size of the circles represents the market value of the respective platform. coloured green trade on the stock market and those in blue are private companies.

Evans and Gawer (2016) also analysed the sectors in which the surveyed platform firms were found. The largest number were in e-commerce, financial technology (fintech), software and Internet services, social networks, transport and tourism. The platforms with the highest market value were concentrated in the software and Internet services sectors, e-commerce, search and advertising, social networks, media and Internet of Things (manufacturing).

2. Typology of the European Commission

The European Commission (2016) defines five types of digital platforms (see table III.1): (i) marketplaces and e-commerce platforms, which facilitate transactions in goods and services between buyers and sellers, (ii) mobile ecosystems and application distribution platforms, which enable third-party development of software, services and content, (iii) Internet search services, (iv) social media platforms, which enable users to communicate and express themselves or share content online; and (v) online advertising platforms, which facilitate the buying and selling of advertising space on websites and other platforms.

Table III.1
Typology of platforms according to the European Commission

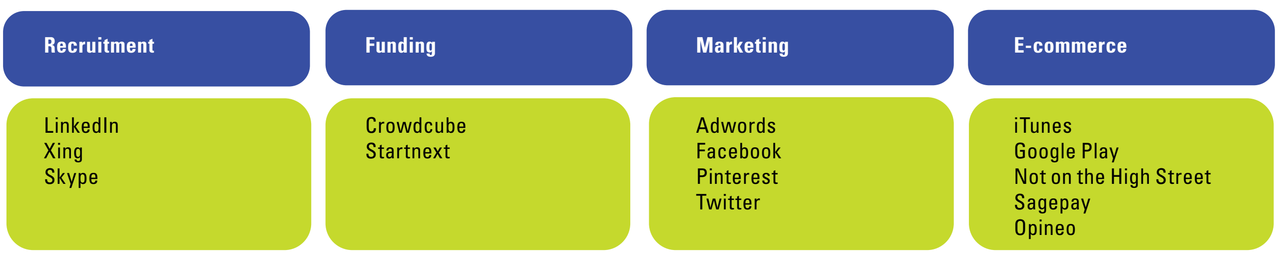
Type	Scope	Examples
Marketplaces and e-commerce platforms	Online platforms on which transactions between sellers and buyers of goods or services take place	eBay, Amazon, Rakuten
Mobile ecosystems and app distribution platforms	Ecosystems of software, services and content built on the operating systems of smartphones and tablets	Android, iOS
Internet search services	Services that help Internet users find the relevant answers to their search requests from among tens of billions of web pages.	Google, Yahoo!, Bing
Social media platforms	Services which enable users to connect, share, communicate and express themselves online or through a mobile app.	Facebook, LinkedIn, Twitter, YouTube, Flickr, Soundcloud, WhatsApp, Instagram, Pinterest
Online advertising platforms	Platforms that facilitate buying and selling of advertising space on website, blogs and other platforms.	Awin, AdUX, Tradedoubler, Doubleclick, Rightmedia

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of European Commission, "Commission Staff Working Document. Online Platforms: Accompanying the document Communication on Online Platforms and the Digital Single Market" (COM(2016) 288), 2016 [online] https://ec.europa.eu/digital-single-market/en/news/commission-staff-working-document-online-platforms.

3. Oxera classification

The consulting firm Oxera (2015) proposes a classification of platforms based on the firm's perspective and identifies the value chain processes where the online platforms deliver most benefits. In selecting the types of platforms with highest impact, Oxera uses the conceptual framework of the value chain developed by Michael Porter. In this framework, there are five primary activities in a value chain: inbound logistics, operations, outbound logistics, marketing and sales, and the provision of customer services. These are supported by four secondary activities: procurement, human resources management, infrastructure and information technology development. According to this framework, Oxera distinguishes four types of digital platform that deliver the greatest benefits for firms (see diagram III.3): (i) recruitment platforms, which facilitate the identification and hiring of staff; (ii) funding platforms, which allow firms access to new sources of financing for their projects; (iii) marketing platforms, which facilitate development, advertising and promotion of goods and services; and (iv) e-commerce platforms, which connect buyers and sellers of goods and services and facilitate transactions.

Diagram III.3
Main types of digital platforms for firms according to Oxera



Source: Oxera, "What are the benefits of online platforms?", 2015 [online] https://www.oxera.com/Latest-Thinking/Publications/Reports/2015/What-are-the-benefits-of-online-platforms.aspx.

C. Characterization of ecosystems

The ecosystems of digital platforms bring together various stakeholders and interest groups, which vary depending on the type of platform. The World Economic Forum (2017) distinguishes the following typical stakeholders and their respective roles (see diagram III.4):

(i) Orchestrator: the owner or manager of the platform, driving the strategic and operational framework, stakeholder interactions and the architecture of the ecosystems and platform;

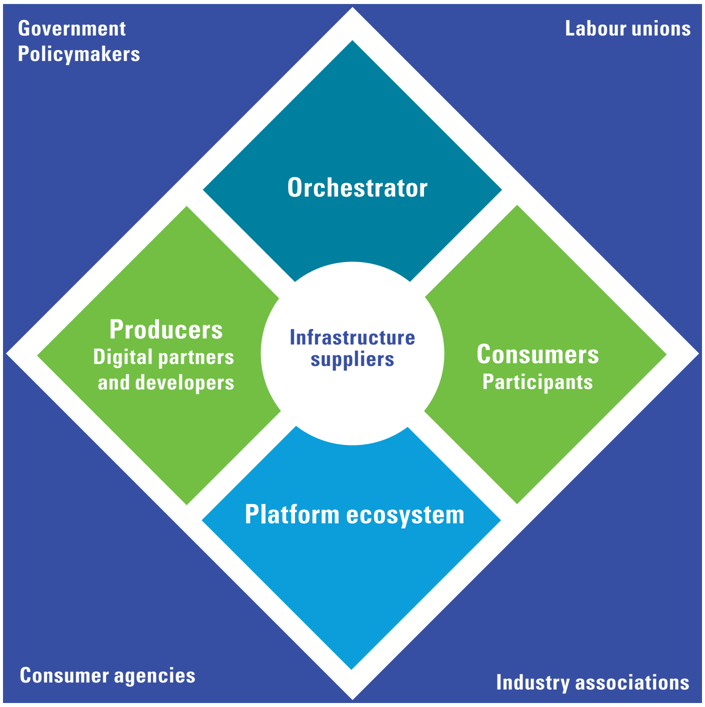
(ii) Producers: supply-side producers or goods and services for the platform. They create value units for exchange;

(iii) Consumers: demand-side consumers of value units in exchange for some form of currency such as money, attention, reputation;

(iv) Government and policymakers: local, national and regional governments, regulators and international organizations. They establish regulatory and policy frameworks for the operation of the platform; and

(v) Infrastructure suppliers: technical infrastructure providers (communications, software, systems integration and developments). They build, administer and monitor the underlying technology of the platform.

Diagram III.4
Platform ecosystems



Source: World Economic Forum, *Digital Transformation Initiative: Unlocking B2B Platform Value*, 2017 [source] http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-platform-report-final-3-26-17.pdf.

Digital platform ecosystems involve multiple stakeholders with specific roles and interests. Platform orchestrators can be start-ups, consolidated technology firms, foundations or even governments. Supply-side producers may be suppliers of goods or services, online publishers, advertisers, investors or app developers. The demand-side stakeholders may be consumers of goods or services —individuals or firms— people consuming or sharing content, Internet users performing searches, advertisers or entrepreneurs seeking project financing, or employers.

Bearing in mind the different classifications described, table III.2 distinguishes eight important types of platform which, according to the typology of the Center for Global Enterprise, fall into two categories. Transaction platforms are divided into six types: marketplaces, social media and content, Internet search services, marketing and digital advertising, funding and talent management. Innovation platforms include mobile ecosystems and app distribution platforms, and platforms for participation and open services.

Table III.2
Types of platform

Category	Type of platform	Examples
Transaction	1. Marketplaces	Amazon, eBay, Rakuten, Alibaba, Etsy, MercadoLibre, Google Play, Apple App Store, Origin, Airbnb, Uber, Upwork, Ticketmaster, Despegar, PayPal, Sagepay, PayU
	2. Social media and content	Facebook, Twitter, Youtube
	3. Internet search services	Google, Bing, Yahoo!
	4. Digital advertising	Adwords, DoubleClick, Tradedoubler, AdECN, ONE by AOL
	5. Funding	Kickstarter, Crowdcube, Startnext, Indiegogo
	6. Talent management	LinkedIn, Monster, Careerbuilder, Glassdoor, Indeed
Innovation	7. Mobile ecosystems and app distribution platforms	Android, iOS
	8. Industrial digital platforms	AWS IoT, Azure, Google Cloud Platform, IBM Watson IoT, Thingworx, Predix, MindSphere
	9. Participation and open services	Citadel, CitySDK, HRI Helsinki, FIWARE, Universaal, Amsterdam Smart City Platform, Busan Smart City Platform

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Oxera, European Commission and McKinsey Global Institute (MGI).

1. Marketplaces

Digital marketplaces connect buyers and sellers of goods and services and facilitate transactions between them (see diagram III.5). According to the European Commission (2016), they include platforms for e-commerce in physical goods, such as Amazon, eBay, Alibaba, Rakuten, Etsy and Mercado Libre; platforms for commerce in services, such as Airbnb, Uber, Upwork, Ticketmaster and Despegar; online payment platforms, such as Paypal, Sagepay and PayU; and platforms for commerce in digital goods (apps and digital content), such as Google Play, Apple App Store and Origin.

Diagram III.5
Digital marketplaces

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

According to Copenhagen Economics (2015), such platforms open up opportunities for SMEs, which can use marketplaces like Amazon, eBay or Etsy to sell their products. They can also use business-to-business (B2B) platforms to connect with other firms and pool resources, as in the case of Floow2, which allows firms to share resources being used at under maximum capacity (equipment, space, materials and human resources, among others), and 3D Hubs, which connect owners of 3D printers with firms requiring the service.

Digital marketplaces generally offer online space and tools for transactions with third-party vendors of goods and services, in exchange for a commission. For some participants, these platforms can reduce transaction costs by grouping sellers in a single space, making recommendations to buyers, establishing ground rules and codes of conduct, or providing convenient payment methods (European Commission, 2016).

Wertz and Tran Kingyens (2015) classify three types of marketplace by the supply- or demand-side participants: (i) peer-to-peer platforms (P2P), where transactions are conducted mainly between private individuals (for example, eBay and Airbnb in their early days); (ii) business-to-consumer platforms (B2C), where sellers are firms (Amazon); and (iii) business-to-business platforms (B2B), where both buyers and sellers are firms (Alibaba, Kinnek, Tradeindia, Capterra, 3D Hubs, Floow2).

Marketplaces implement different business models. According to the European Commission (2016), most specialize in certain types of product or service. Some are relatively open and exert limited control over the goods and services on offer (Craigslist), while others are relatively closed and their operator has greater control over supply. This is the case of Steam, a firm that vets the list of sellers admitted to the platform.

In some cases, platforms also act as resellers of goods and services. Hagiu and Wright (2014) mention Amazon, which began as a reseller of goods and developed into a marketplace where third parties conduct transactions directly with consumers on its website. Conversely, supplier of digital content such as DirecTV, Apple iTunes and Netflix operate as sellers and resellers only, not as marketplaces.

Wertz and Tran Kingyens (2015) have developed another typology for online marketplaces:

(i) On-demand marketplaces: these connect consumers with independent contractors offering services or products on demand (Uber, Lyft, Upwork).

(ii) Managed marketplaces: as well as connecting buyers and sellers, these take on additional parts of the value chain to improve the user experience. An example is Beepi, a marketplace for buying and selling cars whose operator inspects the cars on offer and gives sellers a guarantee.

(iii) Community-driven marketplaces: buyers and sellers visit the marketplace not just to complete a transaction, but also for a sense of identity and belonging to a specific community (for example, Etsy in communities of artists, creators and independent sellers).

(iv) SaaS-enabled marketplaces: these are businesses that offer software as a service (SaaS) tools to consolidate a marketplace. They attract users by offering free software tools, then encourage them to participate in the marketplace. An example is OpenTable, which offers reservation management tools for restaurants and has also built up a related market.

(v) Decentralized marketplaces: these are free, non-hierarchical marketplaces in which rules, trust, identity and payment are defined at the user level (OpenBazaar, Lazooz, OpenName, among others).

Payment platforms that connect businesses to buyers to authorize and perform electronic payments safely online also play an important role in e-commerce. The service may be provided for purchases made directly in e-commerce businesses or those made on other digital platforms (for example, PayPal, Stripe, Adyen and PayU).

Marketplaces generate income in different ways. The most common is by charging a commission for each transaction, calculated as a percentage of its value. Each marketplace sets the commission it charges: OpenTable charges 1.9%, eBay 10% on average, Airbnb 11% on average, Expedia 11.9%, Amazon 12% on average, Ticketmaster an estimated 26%, Steam 30%, GroupOn an estimated 38.2% and ShutterStock 70% (Gurley, 2013).

There are other financing models too. Some marketplaces are financed by sign-up fees, such as the home-swap sites LoveHomeSwap and Home Exchange and dating sites like Match.com. Some classified adverting sites, like Craigslist, charge a fee for each advertisement for goods or services published in determined categories. Etsy and Peerby use the "freemium" model, whereby basic services are free and users have the option of paying a fee for more advanced —premium— services, such as insurance, delivery, promotions, special payment arrangements or shipping. Some platforms, such as Etsy and Gumtree, also receive income from adverting on the site (Makkonen, 2015).

Marketplaces collect vast quantities of personal and non-personal user data. By using big data analytics, they increase their income while generating more value for their users. This is achieved by, for example: (i) better personalization of deals and prices and user rights protection; (ii) increased operational efficiency through better inventory management; (iii) attraction of new users; (iv) market analysis and knowledge of trends under way; and (v) the sale of information to advertisers in compliance with data protection rules (European Commission, 2016).

Marketplaces are divided into three subcategories: marketplaces for goods (e-commerce), marketplaces for services and payment platforms.

E-commerce marketplaces have grown steadily in the past few years. In the United States, e-commerce sales rose from around US$ 170 billion in 2010 to almost US$ 400 billion in 2016. In that time, parcel commerce expanded at a yearly average rate of 9% (KPCB, 2017). Table III.3 lists the largest global and regional platforms by user numbers (Linnworks, 2016) and shows the January 2018 position of each website in the global classification Alexa,[2] which is an indicator of their importance in Internet.

Table III.3
Main e-commerce marketplaces

Region	Platform	Number of active users in 2016 *(millions)*	Position in Alexa global ranking January 2018
Mundo	Amazon	304	10
	eBay	167	40
	Etsy	25	169
	Fruugo	25	233 045
Europe	Allegro	9	292
	Cdiscount	8	672
	FNAC	20	1 225
	PriceMinister	22	2 087
	Real.de	3	5 165
	GAME	4	8 068
	Not On The High Street	2	9 116
	La Redoute	11	45 851
	Flubit	10	115 778
	Pixmania	10	192 458
	OTTO	9	234 301
North America	Newegg	30	483
	Sears	...	2 062
	Jet	4	3 017
Asia	Alibaba Tmall	400	12
	JD	188	19
	Rakuten	105	110
	Flipkart	75	154
	Kaola	30	6 109
Oceania	Trade Me	4	2 723
Africa	Jumia	...	953
	Bidorbuy	...	7 639
Latin America	Mercado Libre	160	1 919
	Linio	20	61 974

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Alexa and Linnworks, "A complete list of online marketplaces across the globe", 2016 [online] http://blog.linnworks.com/complete-list-of-online-marketplaces.

2 Alexa classifies millions of web pages according to a combination of estimated number of single visitors and the number of pageviews of each website over a three-month period. See Alexa [online] https://www.alexa.com/.

The largest global marketplace is Amazon, with 304 million users, followed by eBay, with over 167 million. According to the Alexa ranking, the top e-commerce marketplaces by region are: Allegro in Europe, Newegg in North America, Alibaba Tmall in Asia and Mercado Libre in Latin America.

In the case of services marketplaces, a review was conducted of the main platforms mentioned in the literature and listed on the website Crunchbase.[3] Table III.4 lists the platforms found, their region of origin and the sector where they operate. It also shows each platform's funding or its market capitalization at December 2017 according to Crunchbase, as well as their Alexa ranking.

Table III.4
Main services marketplaces

Country or region of origin	Platform	Sector	Total funding December 2017 *(millions of dollars)*	Market capitalization December 2017 *(millions of dollars)*	Position in Alexa global ranking January 2018
United States	Coinbase	Finance	225	...	267
	Zillow	Housing		5 430	298
	Udemy	Education	173	...	362
	Airbnb	Accommodation	4 398	...	370
	Uber	Transport	22 112	...	1 094
	DoorDash	Home delivery	187	...	5 890
	Lyft	Transport	4 112	...	7 201
	Instacart	Home delivery	675	...	7 885
	Postmates	Logistics	278	...	9 352
	Robinhood	Finance	176	...	15 903
	Blablacar	Transport	335	...	65 618
	Munchery	Home delivery	125	...	102 909
Asia	Quikr	Services	430	...	1 607
	Ola	Transport	3 009	...	14 643
	Didi Chuxing	Transport	19 738	...	21 647
	GO-JEK	Transport	1 750	...	62 244

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Crunchbase and Alexa.

The main services marketplaces are based in the United States or Asia and, by sector, are found chiefly in finance, housing and accommodation, logistics and transport. The marketplaces with the highest Internet traffic indices are Coinbase, Zillow, Udemy, Airbnb and Uber, all based in the United States. The real estate platform Zillow is the only one that trades on the stock market (Nasdaq), with market capitalization of US$ 5.3 billion in 2017. The private marketplaces having received the most funding are Uber (US$ 22 billion), Didi Chuxing (US$ 19 billion), Airbnb (US$ 4.3 billion) and Lyft (US$ 4.1 billion).

The third subcategory is payment platforms. Table III.5 shows the main ones, along with information on their country of origin, funding received or market value and their places in the Alexa ranking. Seven of the 11 payment platforms identified are based in the United States and the rest in European countries. The largest is Paypal, which ranks number 66 in the Alexa classification and has a market capitalization of US$ 94 billion on Nasdaq. Other major payment platforms are Stripe, Payoneer, Square, Adyen, Worldpay and PayU.

3 See Crunchbase [online] https://www.crunchbase.com/.

Table III.5
Main payment platforms

Platform	Country of origin	Total funding from market launch to 2017 *(millions of dollars)*	Total acquisition *(millions of dollars)*	Market capitalization December 2017 *(millions of dollars)*	Position in Alexa global ranking January 2018
Paypal	United States	...	...	94 000	66
Stripe	United States	440	...	...	1 594
Payoneer	United States	270	...	...	2 124
Square	United States	...	...	15 990	2 495
Adyen	Turkey	266	...	...	3 931
Worldpay	United Kingdom		9 950 (2017)	...	6 730
PayU	Netherlands	235,5	...	...	8 186
Payline	France	7	...	...	18 655
Mangopay	United States		...	...	99 658
Dwolla	United States	39	...	...	110 145
Vantiv	United States	...	...	13 750	149 866

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Crunchbase and Alexa.

2. Social media and content platforms

Social media and content platforms allow users to share information and content, communicate and express themselves online or using a mobile app (see diagram III.6). Some specialize in a certain type of user-generated content: Twitter in opinion, YouTube in videos, Instagram and Flickr in images, Soundcloud in music, Tumblr in blogs, and Reddit in web content.

Diagram III.6
Social media and content platforms

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Social media and content platforms are usually financed from three sources. The main source of income for most social media platforms is the hosting of advertising visible to users. Secondly, some platforms charge fees for premium or advanced services, such as YouTube with its YouTube Red service, which allows access to advertisement-free content, offline reproduction of videos and background playback on mobile devices, among other services. Some platforms also receive income from resales and the reuse of user data. Other sources of income may include commissions for transactions performed on the platform and charges for the use of specific applications or content, such as videogames (European Commission, 2016).

Table III.6 lists the main social media and content platforms according to Statcounter.[4] It includes information on the country of origin, funding received or market value, place in the Alexa global ranking, and market share as a percentage of total monthly visits. The seven social media platforms studied are based in the United States. YouTube is the largest in terms of Internet traffic (it ranks second in the Alexa classification). It was acquired by Google in 2006 for US$ 1.7 billion. Facebook is the platform with the largest market share by number of visits (75%) and had a market capitalization of US$ 542 billion in 2017. Reddit, Twitter, Instagram, Tumblr and Pinterest are other examples of major social media platforms.

Table III.6
Main social media and content platforms

Platform	Country of origin	Total funding from going public to 2017 *(millions of dollars)*	Total acquisition *(billions of dollars)*	Market capitalization in 2017 *(billions of dollars)*	Position in Alexa global ranking January 2018	Market share December 2017 *(percentage of website visits)*
YouTube	United States	...	1.7	...	2	4.8
Facebook	United States	...	...	542.95	3	75.5
Reddit	United States	350	...	...	7	0.7
Twitter	United States	...	...	18.06	13	5.7
Instagram	United States	58	1.010	...	17	1.4
Tumblr	United States	125	1.10	...	55	0.6
Pinterest	United States	1 466	...	...	77	10

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of StatCounter, Crunchbase and Alexa.

3. Internet search services

Search platforms connect Internet users seeking information with website publishers providing content (see diagram III.7).

Diagram III.7
Internet search services

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

[4] See StatCounter [online] http://gs.statcounter.com/.

Internet search platforms operate in three steps: (i) crawling: the engine accesses a large amount of websites and collects and stores the information about each; (ii) indexing: the search engine archives the information found on the websites in a logical and organized index which makes it possible to find the information quickly; and (iii) serving: the process whereby the user is provided with the result that best corresponds to the search entered. These platforms use algorithms and computer processes to select and classify the most relevant websites (European Commission, 2016).

Search engines can be general or vertical. General platforms allow users to search for any type of information (for example, Google, Yahoo! and Bing). Vertical engines provide search results for specific categories of information and tend to be used by niche users. A few examples of vertical search engines are: Booking, TripAdvisor, Kayak and Trivago, which specialize in travel information, Eventful in events, Grooveshark in music, and YouTube and AOL Video in videos.

Most Internet search platforms do not charge their users directly; advertising provides their main source of income. Most commonly, advertisers are changed a rate per user click on the website links shown on each search results page.

Table III.7 shows the main general Internet search platforms, according to StatCounter. It also gives information on funding received and market capitalization, place in the Alexa global ranking and market share as a percentage of total monthly visits to the website. Google is the largest search platform by market share (92%), occupies first place in the Alexa ranking and has the largest market capitalization (US$ 773 billion). Other major platforms are Baidu in China, Yahoo! and Bing in the United States and Yandex in the Russian Federation.

Table III.7
Main general Internet search platforms

Platform	Country of origin	Total funding from going public to 2017 *(millions of dollars)*	Market capitalization December 2017 *(billions of dollars)*	Position in Alexa global ranking January 2018	Market share December 2017 *(percentage of website visits)*
Google	United States	36.1	772.97	1	91.8
Baidu	China	26.2	87.71	4	1.7
Yahoo!	United States	6.8	66.73	6	1.6
Yandex	Russian Federation	5.3	11.12	29	0.6
Bing	United States	...	681.31 (Microsoft)	43	2.8

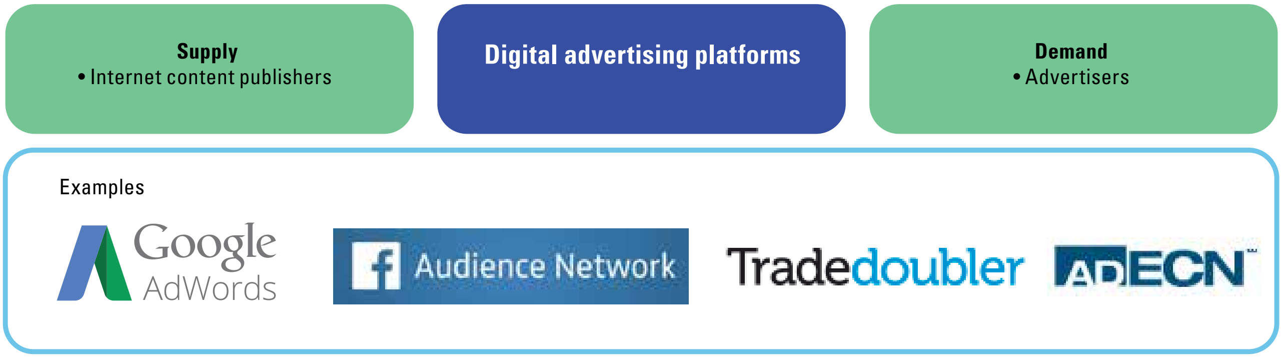
Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of StatCounter, Crunchbase and Alexa.

4. Digital advertising platforms

These platforms connect advertisers with Internet content publishers, who place advertisements in their online content (see diagram III.8). They facilitate the buying and selling of advertising space on websites, blogs and other Internet platforms.

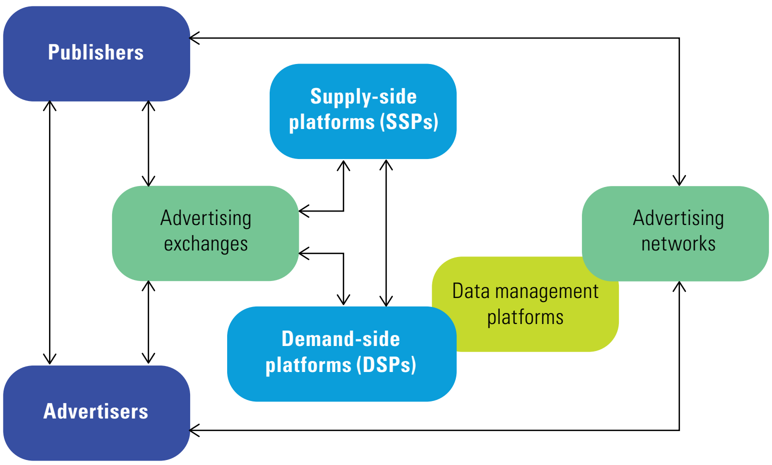
The European Commission (2016) describes five types of platforms: advertising networks, advertisement exchanges, supply-side platforms (SSPs), demand-side platforms (DSPs) and data management platforms (see diagram III.9). Some of these types may be integrated with each other.

Diagram III.8
Digital advertising platforms



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Diagram III.9
Map of digital advertising platforms



Source: European Commission, "Commission Staff Working Document. Online Platforms: Accompanying the document Communication on Online Platforms and the Digital Single Market" (COM(2016) 288), 2016 [online] https://ec.europa eu/digital-single-market/en/news/commission-staff-working-document-online-platforms.

(i) Advertising networks provide services to website publishers interested in hosting advertisements and to advertisers wishing to run advertisements on those sites. The platform operators aggregate online advertising space and resell this to advertising clients and also provide them with additional services, such as payment management and access to tools to monitor the effectiveness of their campaigns. Certain advertising networks also provide publishers or advertisers with advertising tools that allow the delivery of personalized advertisements to consumers within the correct advertisement space of a website and the tracking of consumer behaviour in order to improve the accuracy of this targeted advertising.

(ii) Advertisement exchanges are online marketplaces that facilitate auction-based transactions between publishers and acquirers of online advertising space. They may act as buyers or sellers in these marketplaces, which can be open or private.

(iii) Supply-side platforms provide publishers with the tools needed to sell their advertising space to multiple advertisers via a single interface. They are usually linked with several advertisement exchanges through which the space is sold.

(iv) Demand-side platforms offer a single interface to advertisers to manage their advertising campaigns across multiple publishers.

(v) Data management platforms, often integrated with demand-side platforms, collect, aggregate and assess user data from multiple sources and allow advertisers to target their campaigns.

Advertising networks generally obtain revenue by arbitraging the cost of advertisement space against the price that advertisers are willing to pay for it. They pay publishers a fixed remuneration by number of clicks or views of advertisements published on their website and sell access to this space to advertisers at a profit. Advertisement exchanges derive revenue from intermediation fees: commissions on transactions concluded or subscription fees (European Commission, 2016).

Some of the main advertising networks are operated by Internet search engines or social media platforms. Google, for example, administers the platforms Google Adwords and Google Adsense. Google Adwords allows advertisers to publish advertisements in users search results in Google or in affiliate websites such as Gmail or YouTube. Google Adsense allows publishers to host Google Adwords advertisement on their website, blogs or applications in exchange for a payment based on user clicks on the respective advertisements. Facebook functions as an advertising platform by hosting advertisements directly on its site or mobile application and runs the platform Audience Network, through which is places Facebook advertisements on third-party websites or mobile applications.

The increase in Internet use drove the growth of the global digital advertising market. According to The Wall Street Journal (2017), revenue from digital advertising worldwide reached US$ 204 billion in 2017, equivalent to 40% of the global market. That year, for the first time, revenue from digital advertising exceeded revenue from television advertising, which represented 36% of the global market. The share of mobile advertising in total digital advertising is also on the rise. In the United States, mobile advertising increased from 3% of digital advertising revenue in 2011 to 50% in 2016 (PwC, 2017).

Table III.8 shows a non-exhaustive list of the main digital advertising platforms, their country of origin, funding received or market value and ranking in the Alexa global classification. Eight of the ten platforms included are based in the United States, one in Sweden and one in India. By Alexa rank, the platforms associated with the highest traffic websites are Google Adwords and Google Adsense, Facebook and Facebook Audience Network, Right Media and AdECN. Google and Facebook are the largest players in global digital advertising, receiving almost 70% of digital advertising revenue in the United States (KPCB, 2017).

Table III.8
Main digital advertising platforms

Platform	Country of origin	Total funding up to 2017 *(millions of dollars)*	Total acquisition *(millions of dollars)*	Market capitalization in 2017 *(millions of dollars)*	Position in Alexa global ranking January 2018
Google Adwords and Adsense	United States	…	…	…	1 (Google)
Facebook and Audience Network	United States	…	…	… …	3 (Facebook)
Right Media	United States	…	850	…	6 (Yahoo)
AdECN	United States	3.2	…	…	47 (Microsoft)
Tradedoubler	Sweden	…		17.5	1 277
DoubleClick	United States	…	…	…	53 806
InMobi	India	320.6	…	…	92 272
Tapad	United States	…	360	…	99 176
ONE by AOL	United States	…	…	…	221 781

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Crunchbase and Alexa.

5. Funding platforms

Funding platforms connect investors with entrepreneurs or firms (see diagram III.10). They broaden the supply of financing, allow start-ups to find additional resources to grow and widen investment possibilities for professional and non-professional investors. According to Oxera (2015), such platforms can enable projects where returns on investment are less certain, such as projects of primarily artistic or cultural benefit, to obtain funding.

Diagram III.10
Funding platforms

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Funding platforms have development multiple business models. Wilkinson (2017) mentions five:

(i) Rewards-based crowdfunding. These platforms list products, services or projects that are looking for financing. Each project has a funding target that must be reached for the project to go ahead. Backers or sponsors pledge a certain amount then, if the project meets its target, they pay the amount pledged in exchange for a reward defined by the project developer (for example, a copy of the product or a related experience). Such platforms charge a percentage commission on the funding received, ranging from 3% to 5%. This reduces the risk for entrepreneurs because they will not be charged if the project does not receive funding. Platforms operating under this business model include Kickstarter, Indiegogo and Crowdfunder.

(ii) Donation-based crowdfunding. These platforms are structured similarly to the rewards-based crowdfunding model, the difference being that backers receive no reward and donate for altruistic reasons. JustGiving is an example of this type of platform.

(iii) Microlending platforms. These connect people or small firms needing small loans with individuals or foundations willing to extend the credit. Donations fund business start-ups or the costs of improving living conditions, among others. They are usually non-profit. One example is Kiva, which operates in 82 countries and has had 2.7 million borrowers and 1.7 million lenders. The minimum loan is US$ 25. To date, Kiva has facilitated loans for US$ 1.09 billion.[5]

(iv) Debt-based crowdfunding. These platforms connect people or businesses seeking credit to investors seeking financial returns. Loan rates generally vary from 2% to 7% depending on the degree of risk, term of the loan and interest rate variations. Investors may opt for specific projects or invest in a general fund whose distribution is managed by the platform. They may have provision funds to avoid investor losses. They generally obtain revenue from commissions on repayments. Some examples are Zopa and Rateseller in the peer-to-peer (P2P) segment and Funding Circle in peer-to-business (P2B) lending.

[5] See Kiva [online] https://www.kiva.org/.

(v) Equity crowdfunding. These platforms allow small or professional investors to invest in companies that have growth potential. Investors acquire shares or an equity stake in the respective firms, in the expectation of making a return when the company grows within a given period, is sold or goes public. In general, the recommendation is to invest in different firms to obtain a balanced portfolio and lessen the associated risk. Equity crowdfunding platforms usually charge commissions for successful funding, such as a percentage of the investment received, and for payment processing. The main example of this type of platform is Crowdcube, based in the United Kingdom, through which 630 firms have received investment totalling 91 million euros.[6]

Table III.9 shows a non-exhaustive list of the main funding platforms, their country of origin, resources raised to fund enterprises or funding provided up to 2017, funding received for the development of the platform up to 2017 and its Alexa ranking. Five of the eight platforms are based in the United States and the other three in the United Kingdom. In terms of resources raised to fund clients or amounts actually financed, the largest are Kickstarter and GoFundMe in the United States and Zopa and Funding Circle in the United Kingdom. Each has raised funding of over US$ 3 billion in enterprise financing.

Table III.9
Main funding platforms

Platform	Country of origin	Total collected or client funding from creation until 2017 *(millions of dollars)*	Total financing received from creation until 2017 *(millions of dollars)*	Position in Alexa global ranking January 2018
Kickstarter	United States	3 460	10	584
GoFundMe	United States	4 000	...	1 550
Indiegogo	United States	800	57	1 914
Crowdcube	United Kingdom	360	28	41 291
Zopa	United Kingdom	3 500	112	73 761
Funding Circle	United Kingdom	3 700	413	49 028
Crowdfunder	United States	120	17	197 397
CircleUp	United States	390	53	361 886

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Crunchbase, Alexa, Kickstarter, Indiegogo, CircleUp and Funding Circle.

6. Talent management platforms

Talent management platforms connect employers to potential employees and facilitate staff hiring and management (see diagram III.11). They reduce the cost of seeking and hiring professionals and expand the candidate pool by allowing searches in broader universes. They also facilitate the search for and hiring of independent professionals for specific tasks. In general, they gather large amounts of information regarding both individual workers and employers or work projects, then synthesize these data to match individuals with job opportunities, according to the requirements indicated (MGI, 2015).

According to MGI (2015), talent management platforms help firms to increase productivity before, during and after the recruitment process. They: (i) facilitate hiring of the right candidates for the profiles required, (ii) offer tools to raise employee productivity and well-being, and (iii) may be a mechanism for strategic planning of future skills and leadership needs.

Talent management platforms facilitate firms' search for staff as well as hiring and staff management. MGI (2015) describes three types of talent management platform: (i) platforms that match individuals to traditional jobs and facilitate the search for and hiring of candidates; (ii) platforms that match individuals to contingent or

6 See Crowdcube [online] https://www.crowdcube.com/.

seasonal projects or tasks and facilitate transactions between workers and employers, and (iii) platforms that offer functionalities for improving onboarding, location, definition of compensation, retention and leadership development (see table III.10).

Diagram III.11
Talent management platforms

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Table III.10
Talent management platforms

	Digital tools that enable users to:	Examples (2015)
Matching individuals with traditional jobs	– Post full-time or part-time jobs – Create online resumés – Search for talent or work opportunities – Provide transparency on company or worker reputations, skills and other traits	Careerbuilder Glassdoor Indeed LinkedIn Monster Vault Viadeo Xing
Online marketplaces for contingent work	– Connect individuals with contingent or freelance projects or tasks – Facilitate transactions by providing transparency on reputation and ratings	Amazon Home Services Angie´s List TaskRabbit Uber Upwork
Talent management	– Assess candidates' attributes, skills or fit – Personalize onboarding, training and talent management – Optimize team formation and internal matching – Determine the best options for training and skill development	Good.co PayScale Pymetrics beta ReviewSnap

Source: McKinsey Global Institute.

Talent management platforms usually obtain revenue from subscription or membership fees. For example, StackOverflow charges firms a subscription fee for access to its database of professionals. LinkedIn uses the freemium model for individual users. Basic services, like creating a profile and contacting other professionals, are free, while users wishing to access premium or advanced services —direct access to recruiters, information on profile searches, information on other candidates, aptitude training— pay a monthly fee.

Table II.11 lists the main talent management platforms, the funding they have received or their market value and their position in the Alexa global ranking. Fourteen of the sixteen platforms identified are based in the United States and the other two in Europe. The largest talent platform is LinkedIn, with over 400 million users. It ranks thirtieth in the Alexa classification and was bought by Microsoft for US$ 26.2 billion in 2016. Other important platforms are Indeed, Glassdoor and Upwork.

Table III.11
Main talent management platforms

Platform	Country of origin	Total financing from going public until 2017 *(millions of dollars)*	Total acquisition *(millions of dollars)*	Market capitalization in 2017 *(millions of dollars)*	Position in Alexa global ranking January 2018
LinkedIn	United States		26 200		30
Indeed	United States	5			181
Glassdoor	United States	204			454
Upwork	United States	169			521
Xing	Germany			1 550	1 416
Monster	United States		429		1 872
CareerBuilder	United States				4 116
PayScale	United States		100		4 803
Viadeo	France	57			6 955
Thumbtack	United States	273			7 284
Angie's List	United States			764	7 476
TaskRabbit	United States	38			40 424
Handy	United States	111			83 694
Pymetrics	United States	17			138 554
Good.co	United States	10			166 980
Reviewsnap	United States				368 236

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Crunchbase and Alexa.

7. Mobile services ecosystems and application distribution platforms

Mobile services are an innovation ecosystem in themselves, given that they are platforms on which third parties can develop and commercialize applications, software and digital content. The main mobile platforms are the operating systems iOS (Apple) and Android (Google), which have app stores (App Store and Google Play, respectively) where developers can offer applications and users can download them free or upon payment (see diagram III.12).

Diagram III.12
Mobile ecosystems and application distribution platforms

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Mobile ecosystems have developed on the operating systems of smartphones and tablets and allow the development and use of applications and services. The developers of operating systems provide the support infrastructure: software development tools, app stores, payment mechanisms and technical support spaces.

The European Commission (2016) distinguishes three main types of mobile operating system: (i) proprietary operating systems owned by the hardware manufacturer that created them (e.g. Apple's iOS and Blackberry's OS); (ii) third-party proprietary operating systems where the developer licenses the operating system to hardware manufacturers for a fee (e.g. Microsoft Windows), and (iii) open source operating systems where the developer releases the operating system via open source licence (e.g. Google's Android).

The main application distribution platforms usually charge developers a registration fee and a commission on downloads of paid applications. Google Play has a registration fee of US$ 25 and charges a 30% commission on each app download. For subscription products, the commission is 30%, falling to 15% after 12 months.[7] App Store charges developers a US$ 99 yearly membership fee and a 30% transaction commission on downloads of apps and related products.[8]

Table III.12 shows the main mobile ecosystems and their market share in 2016, as a percentage of global smartphone sales. Android has the largest market share of the operating systems, with 81%, while iOS has18% and Windows less than 1%.

Table III.12
Main mobile ecosystems

Platform	Country of origin	Market share, fourth quarter of 2016 *(percentage of global smartphone sales)*
Android	United States	81.7
iOS	United States	17.9
Windows	United States	0.3

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Statista.

8. Industrial digital platforms

This is a time of transformation for industries around the world. One of the main factors of change is the industrial Internet. This trend is based on the digitalization of horizontal and vertical value chains and the adoption of digital technologies to optimize production processes and drive innovation in products and services. The industrial Internet will continue to expand in the coming years. In 2017, the firm Capgemini surveyed 1,000 executives in large manufacturing companies in eight countries[9] and found that 76% of firms had planned or implemented a smart manufacturing initiative and that 56% had invested US$ 100 million or more in this type of initiative (Capgemini, 2017).

Industrial platforms are operating systems that integrate technologies, applications and services, connecting firms, suppliers and clients. They integrate data from firms and make them available to stakeholders and for third-party development of applications (see diagram III.13).

The European Union (2017) distinguishes three aspects or roles of industrial digital platforms:

(i) Community: industrial digital platforms may connect actors in a value chain, including users. Communities created in this fashion are where third-party producers create value.

(ii) Infrastructure: these platforms provide infrastructure and functionality and allow users and partners to build applications and create value on top of this infrastructure. They also channel the data that the platforms unlock and integrate different technologies and systems.

(iii) Data: they make relevant data from value chains accessible and use and process data. In many cases, data are made available from connected applications, sensors and devices.

[7] See Google Help [online] https://support.google.com/?hl=en.
[8] See Apple [online] https://www.apple.com/.
[9] The countries included in the survey were China, France, Germany, India, Italy, Sweden, the United Kingdom and the United States.

Diagram III.13
Industrial digital platforms

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

The European Commission (2017) identifies five domains for the development of industrial digital platforms in the coming years. Three of them are vertical —connected smart factories, smart agriculture and digital transformation of health and care— and two are horizontal —industrial data platforms and the Internet of Things.

Platforms for connected smart factories enable firms, including MSMEs, to undergo digital transformations and be fully connected with their input and product supply chains. Smart agriculture platforms permit progress towards precision farming and support for rural communities. Industrial digital platforms in the health sector help to transform the sector by integrating technologies to improve diagnoses and treatments.

Industrial data platforms (IDPs) are virtual environments facilitating the exchange and connection of data between different companies within a shared architecture and common governance rules. They may take the form of open, multi-company-led environments or single company-led initiatives where an individual company establishes its own platform and opens it to others for commercial purposes (European Commission, 2017). IoT platforms enable the development of applications that supervise, manage and control connected devices in firms. The main comments of these platforms are developer environments, data analytics services, visualization services, e-commerce services, security services, data management and device management.

IoT-enabled platforms are among the most developed. According to Bhatia and others (2017), over 400 firms offer this type of platform worldwide. Most of them share some common characteristics: they are cloud-based under the platform as a service model, and enable the collection, analysis and use of data generated by IoT devices. They include developer tools and APIs that enable users to create their own applications and services to improve productivity and optimize the firm's operation.

IoT platforms are developed and offered by cloud services providers, network service providers and hardware manufacturers, among others. They include Amazon's AWS IoT, Microsoft Azure, Google Cloud Platform, ThingWorx, Watson de IBM, Samsung's Artik, Cisco Systems' IoT Cloud Connect, Hewlett Packard's Universal Internet of Things, Salesforce, Datav of Bsquare, Siemens' MindSphere and General Electric's Predix.

In a survey of member States conducted in 2017, the European Commission counted 56 industrial digital platforms under development or in operation. Three of the platforms mentioned in the survey were: (i) S3P, a public-private platform for software development and execution for the Internet of Things, aimed at enabling the rapid development and exploitation of IoT-capable devices and applications; (ii) Optician 2020, which was created by a consortium of European firms with the aim of providing computational services to automate the design, manufacturing and logistics of the manufacturing of personalized spectacles in mini-factories, and to automate communication between designers, opticians, laboratories and manufacturers; and (iii) FIspace, a smart agriculture digital platform funded by the European Union that adds functionality through applications development, incorporates collaborative processes between firms and integrates data sources of users.

9. Participation and open services platforms

Digital participation and open services platforms are developed by governments to enable the participation of citizens and firms in the design and development of public applications and services (see diagram III.14). Examples include open data platforms, crowdsourcing and co-creation platforms and other forms of ideation and citizen participation.

Diagram III.14
Participation and open services platforms

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Participation and open services platforms make available to the public open data and tools for developing services and applications that are in the public interest. Some platforms also include a public catalogue that allows citizens to access and download third-party applications. These platforms are financed from the public budget at the national or regional level or through public-private financing mechanisms.

Table III.13 lists some examples of participation and open services platforms. Most are located in European and Asian countries. The European Commission has led the development of two of these platforms (Citadel and CitySDK) in countries of the European Union. These platforms are aimed at promoting the development of smart city services and applications and facilitate access by citizens and entrepreneurs to open databases, app development tools (interfaces, processes, guides and interoperability standards) and catalogues of applications developed.

Another important initiative under way in Europe is FIWARE, which provides an open architecture and a kit of specifications and cloud capacities to facilitate the development of applications in the areas of smart cities, smart logistics and smart factories. The standard proposed homogenizes the collection of data from different IoT networks. It also includes the program FIWARE Accelerator, for SMEs and start-ups, which promotes the development of FIWARE technologies. In association with FIWARE, in 2014 the European Union spearheaded an initiative that has mobilized 80 million euros to support SMEs and entrepreneurs in developing innovative FIWARE-based applications.[10]

[10] See FIWARE [online] https://www.fiware.org/.

Table III.13
Examples of participation and open services platforms

Platform	Region, country or city	Scope	Responsible party or backer
Citadel	European Union	Promotes the use of open data published by cities for the development of mobile applications. Includes an index of open databases in European cities, a database format converter, a toolbox for app development and a catalogue of applications created.	European Commission, Competitiveness and Innovation Framework Programme
CitySDK	European Union	Offers a toolkit for the development of digital apps and services for cities. The tools include open and interoperable digital service interfaces, as well as processes, guidelines and usability standards. It is aimed at citizen participation, mobility and tourism.	European Commission
CitySDK	United States	Offers simple tools for using United States Census Bureau data to develop applications and services. It includes tools to facilitate the use of application programming interfaces (APIs) and link-up with other open databases.	Government of the United States: Census Bureau, Department of Commerce, Department of Housing and Urban Development, Department of Agriculture
FIWARE	European Union	Provides an open architecture (open code), a set of specifications and application programming interfaces (APIs), and cloud capabilities to facilitate the development of apps for the Internet of the future in terms of smart cities, smart logistics and smart factories.	European Commission
Amsterdam Smart City	Amsterdam	Connects citizens, firms, the academic sector and the government to promote the development and testing of projects for city development. Any individual or firm can share a project idea and seek partners or backers.	National government, city government, Liander (private backer)
Helsinki Region Infoshare	Helsinki	Open data platform aimed at making the regional information of public organizations more easily accessible to the public (firms, academic sector, citizens, government). It includes a website (gallery) showcasing applications and service development on the basis of the data published.	Government of Helsinki and cities in the metropolitan area, national government
Global Smart City	Busan, Republic of Korea	A project to develop a shared open platform based on international IoT standards (oneM2M). It provides a development environment where SMEs and individuals can develop smart city applications and services. The data collected by sensors and devices are shared to promote the creation of new information-based services.	Government of Busan, SK Telecom

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Citadel, CitySDK, FIWARE, Telefónica, Amsterdam Smart City and Global Smart City.

As set out in table III.13, some European and Asian cities, like Amsterdam, Helsinki and Busan, are developing platforms to promote the creation, testing and use of smart city applications by third parties. These platforms generally contain open data modules and catalogues of solutions developed.

D. Determinants of the development of platform ecosystems

The conceptual framework for studying the determinants of platform ecosystem development comprises seven categories of development factors and a set of enabling conditions, which are described below on the basis of the existing literature, in particular the European Commission report *Digital Entrepreneurship Scoreboard:*

(i) Knowledge base: refers to the country's capacities to generate and use scientific and technological knowledge. It includes factors such as investment in research and development (R&D), the pool of technology firms, the university-business link and the level of development of innovation systems.

(ii) Normative, regulatory and institutional framework: refers to the level of sophistication of the norms, institutions and procedures that determine the ease of starting, operating and scaling up a digital business in a country. This includes aspects such as the ease of opening or closing a company, the complexity of corporate and labour regulation, the strength and stability of regulatory frameworks, the level of protection of intellectual property, ease of tax payment, ease of enforcing contracts and complexity of dispute settlement procedures.

(iii) Technological infrastructure: considers the level of ICT development and includes factors such as broadband penetration, mobile Internet penetration, broadband speed and uptake of digital technologies.

(iv) Funding availability: refers to the availability of sources of financing for digital innovation and includes factors such as access to debt financing, the existence of angel investors, the supply of venture capital and the sophistication of capital markets.

(v) Talent: considers the availability of skilled human capital for digital innovation and enterprise. It comprises factors such as the quality of primary and university education, the pool of professionals trained in science, technology, engineering and mathematics (STEM) and the pool of experts in advanced digital technologies (big data, IoT, artificial intelligence, blockchains, and so on).

(vi) Culture: refers to the culture of enterprise in society. Includes factors such as tolerance of risk, the perception of entrepreneurship as an employment option and the status of entrepreneurs.

(vii) Enabling conditions: refers to the physical, economic and social characteristics that affect the development of digital platform ecosystems. They include such aspects as the level of development of transport infrastructure, the state of internal logistics, the bankarization of the population and the level of use of electronic payment means, among others.

Below are presented the results of an analysis of the barriers to digital innovation and, thus, to the development of digital platform ecosystems in six Latin American countries (Argentina, Brazil, Chile, Colombia, Mexico and Peru). For this exercise, indicators were selected to evaluate the ecosystem development factors mentioned above, and compared with the result for each of the six countries (see table III.14). Where the value of the indicator is less than 40% of the value registered for the United States, the result is considered insufficient and the respective value is shaded in red. Where the value is between 40% and 80% of the value registered in the United States, the result is considered moderate and is shaded in yellow. Where the value is over 80% of the value for the United States, the country is considered to have a high result and the value is shaded in green.

As may be seen in table III.14, in general in general the countries of the region have moderate results in the indictors relating to enabling conditions. The worst results —those interpreted as critical barriers to digital innovation— refer to the use of e-commerce and access to and use of electronic payment methods. In relation to the knowledge base, the critical barrier to digital innovation found in all the countries, with the exception of Brazil, is the low level of R&D spending in relation to GDP. With regard to the normative, regulatory and institutional framework, most of the countries presented a moderate performance. Notable is the high performance of Chile, Colombia, Mexico and Peru on the World Bank's ease of doing business index, Chile's good performance on regulatory development and the poor performance of Argentina on the regulatory quality indicator.

Most of the countries scored moderate results on technological infrastructure. However, the speed of cloud computing services is inadequate, with the exception of Chile. All six countries show a moderate performance in relation to the funding factor. Under the talent factor, most of the countries showed a high percentage of STEM graduates. However, the private sector in all six countries perceives a low or moderate availability of scientists and engineers. Lastly, all six countries scored high on the culture factor.

Table III.14
Latin America (6 countries) and the United States: barriers to digital innovation

Factor	Indicator	Source	Argentina	Brazil	Chile	Colombia	Mexico	Peru	United States
Enabling conditions	E-commerce index, 2017	UNCTAD	45.0	62.0	64.0	55.0	42.0	41.0	87.0
	Buyers on the Internet, 2017 (as a percentage of the population)	UNCTAD	16%	23%	26%	6%	6%	3%	67%
	Logistics performance index, 2016	World Bank	3.0	3.1	3.3	2.6	3.1	2.9	4.0
	Population with an account in a financial institution, 2014 (percentages)	World Bank	50%	68%	63%	38%	39%	29%	94%
	Population with a credit card, 2014 (percentages)	World Bank	27%	32%	28%	14%	18%	12%	60%
Knowledge base	Spending on research and development (R&D) as a percentage of GDP, 2015	World Bank	0.6%	1.2%	0.4%	0.2%	0.6%	0.1%	2.8%
	University-business collaboration, 2017 (index)[a]	INSEAD	40.4	37.4	41.1	44.3	43.4	31.8	76.2
Normative, regulatory and institutional framework	Ease of doing business index, 2017	World Bank	58.1	56.5	71.2	69.4	72.3	69.5	82.5
	Intellectual property protection, 2017 (index)	WEF	3.7	4.2	4.4	4.0	4.1	3.5	5.8
	Regulatory quality index, 2015[a]	INSEAD	17.7	36.7	76.7	53.7	52.4	54.8	74.9
	Development of laws on ICT, 2014-2015 (index)	WEF	3.0	3.7	4.5	4.1	3.9	3.4	5.3
Technological infrastructure	Absorption of technology by businesses, 2015 (index)	WEF	4.0	4.8	5.2	4.4	4.6	4.5	6.1
	Mobile broadband penetration, 2016 (subscribers per 100 inhabitants)	ITU	80.5	89.5	69.0	45.5	58.5	62.0	120.0
	Cloud services speed, 2017 (Kbps download)	CISCO	7.0	13.2	26.4	7.4	14.6	8.5	46.2
Funding	Venture and investment capital attraction index, 2018 (index)	IESE	56.2	57.4	68.1	63.3	62.8	53.2	100.0
	Availability of venture capital, 2016 (index)	WEF	2.0	2.5	3.3	2.7	2.8	3.1	4.5
Talent	Percentage of graduates in science, technology, engineering and mathematics (STEM), 2015	RICYT	10%	15%	20%	23%	28%	-	17%
	Availability of scientists and engineers, 2018 (index)	INSEAD	30.3	23.2	61.8	36.5	43.8	21.2	84.7
Culture	Entrepreneurship as an employment option, 2017 (percentages)	GEM	60.4	-	73.8	68.4	50.7	64.7	63.1
	Entrepreneurship intent, 2017 (percentages)	GEM	13.4	15.3	45.8	52.5	13.2	43.2	14.5

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of World Bank, United Nations Conference on Trade and Development (UNCTAD), World Economic Forum, European Institute of Business Administration (INSEAD), World Intellectual Property Organization (WIPO), Cornell University, IESE Business School, Ibero-American Network on Science and Technology Indicators (RICYT), Global Entrepreneurship Monitor (GEM), International Telecommunication Union (ITU) and Cisco Systems.

Note: WEF = World Economic Forum.

[a] The index was generated by INSEAD, WIPO and Cornell University.

E. Policy recommendations

1. Enabling conditions

(a) Develop e-commerce. The countries of the region need to spread e-commerce broadly, between businesses and consumers (B2C), among businesses (B2B) and among consumers (C2C) and boost the share of e-commerce in the economy. This will require the development of national strategies that engage all stakeholders and reduce or eliminate existing barriers to the adoption of e-commerce.

(b) Improve logistical systems. The challenges in this area relate to the topographical conditions and population in some of the countries, transport infrastructure deficiencies and inefficiencies at critical points of these systems, such as ports, airports and border crossings. Improving logistical systems requires investment in infrastructure and technology and the optimization and digitization of the related processes.

(c) Progress with financial inclusion. The countries need to expedite the access of the population to the financial system and the use of electronic systems and means of payment. In some cases, financial inclusion policies have been implemented and the regimes that regulate the provision of these services have been made more flexible.

(d) Consolidate regional integration. One way to leverage economies of scale in the region's markets is to deepen trade integration processes, in order to enable firms in one country to supply goods and services in other countries. On the basis of a proposal made by ECLAC in 2015, the Pacific Alliance has proposed to create a regional digital market to enable local digital industries to compete in a world of global platforms (Pacific Alliance, 2017). According to CAF-Development Bank of Latin America and ECLAC (CAF/ECLAC, 2018), to develop a market of this sort the Latin American countries must address aspects such as harmonization of the international data and voice roaming market, the deployment of infrastructure for Internet exchange points (IXPs), regulatory harmonization in areas such as privacy, data protection, digital security and copyright, and the coordination of consumer protection efforts.

2. Knowledge base

(a) Foster investment in R&D. The Latin American countries exhibit low levels of investment in R&D: in five of the six countries analysed R&D investment represented less than 1% of GDP, compared with almost 3% in the United States. Higher public and private investment in R&D is essential for the development of digital platform ecosystems. With this in mind, the countries could build R&D investment incentives into their competition policies and tax regimes.

(b) Increase government data openness. Government open data strategies are an important mechanism for fostering digital innovation and digital platform ecosystems. The governments thus have the opportunity to intensify their open data strategies, by including more departments and dataset, to generate stronger effects on digital innovation.

3. Normative, regulatory and institutional framework

(a) Reduce red tape and administrative charges. The administrative regimes in the Latin American countries generate high business costs. Argentina and Brazil are the countries that score worst on the World Bank's ease of doing business index. Although the other countries scored better, they still face challenges in some components of the index that are important for digital enterprise, such as ease of starting a business, tax payment and bankruptcy proceedings. The region's countries should simplify administrative and tax charges that could affect the creation and growth of technology-based enterprises, including digital platforms.

(b) Develop regulation for the digital economy. The countries of the region should modernize their regulatory frameworks to adapt them to the new market realities. Important aspects for promoting digital platforms include: (i) the consolidation of safe harbour provisions to limit the liability of intermediaries (including platforms) for user-generated content, and (ii) the adoption of flexible regulatory intervention criteria that allow permissionless innovation, supported by evidence-based, case-by-case review, and subject to cost-benefit analysis of the regulation.

(c) Strengthen digital security and privacy protection. The countries need to consolidate policies and flexible regulations on digital security, data protection and consumer protection directed towards policy aims such as strengthening security, privacy and personal data protection, and fostering technological innovation. Regulations on digital security should also promote proper management of Internet risks by government, firms and citizens.

(d) Promote cross-border digital commerce. Platforms originating in Latin America could have the opportunity to offer goods and services in a regional market of over 600 million inhabitants. To tap this opportunity, the countries must make progress towards harmonizing their regulations on cross-border digital commerce and eliminate regulatory and access barriers that hinder that commerce. In her study on accelerating digital commerce in Latin America, Suominen (2017) makes specific recommendations including: (i) eliminate obstacles to market access and customs procedures that hamper digital commerce, through mechanisms such as "trusted e-operators" programmes, online presentation of customs requirements through single windows and the simplification of procedures for returning articles; (ii) avoid data localization requirements for online services abroad; (iii) progress with mutual recognition of online suppliers between countries, and (iv) ensure payment interoperability.

4. Technological infrastructure

(a) Accelerate broadband deployment and improve broadband quality. The countries of the region face the challenge of accelerating the deployment of broadband infrastructure and services to greatly increase access by citizens and firms to these services. They also have the challenge of improving broadband quality to support the development and use of advanced cloud applications and services. The policy options for achieving this include the allocation of spectrum for 4G Internet, the regulation of infrastructure sharing and the establishment of roadmaps for uptake of fifth generation mobile services (5G).

(b) Progress with the deployment of IoT connections. The countries must make progress in implementing connected smart devices over machine-to-machine (M2M) systems. Policy options in this regard are: (i) accelerate the adoption of Internet Protocol version 6 (IPv6); (ii) define policies to coordinate the efforts and regulations of different government agencies regarding IoT, spectrum management and smart cities, and (iii) promote tariff reduction for IoT hardware and sensors.

(c) Support MSMEs in digitalization and digital commerce. If the benefits of digital platforms are to extend to MSMEs, progress must be made in the adoption of digital technologies to increase their share of local and cross-border digital commerce. Governments can expedite these processes through programmes to support technology adoption and the use of e-commence by MSMEs.

5. Funding

(a) Increase and diversity the sources of funding for technology enterprise. It is important that the countries work to increase and diversify the range of funding available for entrepreneurship. Policy options for this include devising normative standards for crowdfunding, attraction and creation of risk capital funds and the promotion of angel investor activity.

6. Talent and enterprise culture

(a) Increase the pool of professionals in science, technology, engineering and mathematics. The region's countries must put in place strategies to increase the pool of professionals in these subjects over the short and medium terms. Useful initiatives in this regard are the co-financing of undergraduate or postgraduate studies in these areas, the creation of incentives (visas, facilities) to attract international talent and the promotion of training programmes developed by the private sector. To stimulate digital platform start-ups, it is also important that educational programmes and models for STEM-based professions include the development of skills such as business administration, negotiations, leadership and teamwork.

(b) Increase the pool of talent specialized in advanced technologies. To develop digital platform ecosystems the countries will need to increase the pool of professionals specialized in advanced technologies, such as big data analytics, IoT, artificial intelligence and blockchain. Strategies for this include co-financing for postgraduate studies or measures to attract international talent.

Lastly, the development of digital platforms and their ecosystems requires the consolidation or, in some cases, even the creation of a culture that fosters technological entrepreneurship. The countries studied —and possibly all the countries in the region— have the opportunity to strengthen cultures capable of driving the development of highly dynamic technological enterprises. These are often difficult propositions to tackle, insofar as they depend on rather imprecise variables and actions that are hard to formulate and implement. These difficulties notwithstanding, the countries of the region are called upon to strengthen their spirit of enterprise, encourage individuals to take risks and drive technological innovation. In this effort, primary, secondary and tertiary education establishments, government bodies, firms, business associations and civil society organizations all have broad scope for action.

Bibliography

Accenture (2016), *Five Ways to Win with Digital Platforms*, G20 Young Entrepreneur' Alliance [online] https://www.accenture.com/us-en/_acnmedia/PDF-29/Accenture-Five-Ways-To-Win-With-Digital-Platforms-Full-Report.pdf.

Bhatia, A. and others (2017), "Who will win the IoT platform wars?", Boston Consulting Group (BCG), 29 June [online] https://www.bcg.com/en-cl/publications/2017/technology-industries-technology-digital-who-will-win-the-iot-platform-wars.aspx.

Bouskela, M. and others (2016), "The road toward smart cities: migrating from traditional city management to the smart city", I*DB Monograph*, No. 454, Inter-American Development Bank (IBD).

CAF/ECLAC (Development Bank of Latin America/Economic Commission for Latin America and the Caribbean) (2018), "Mercado digital regional", *Project Documents*, Santiago, forthcoming.

Capgemini (2017), "Smart factories: how can manufacturers realize the potential of digital industrial revolution" [online] https://www.capgemini.com/wp-content/uploads/2017/05/dti-smartfactories-webversion.pdf.

Copenhagen Economics (2015), *Online Intermediaries: Impact on the EU Economy*, EDiMA [online] https://www.copenhageneconomics.com/dyn/resources/Publication/publicationPDF/2/342/1454501505/edima-online-intermediaries-eu-growth-engines.pdf.

COTEC (COTEC Foundation for Innovation) (2016), *Iniciativas empresariales y políticas públicas para acelerar el desarrollo de un ecosistema digital iberoamericano* [online] http://cotec.es/media/inf_CIPC_vfinal.pdf.

Cullen International (2016), *Hacia la estrategia para el mercado único digital de América Latina*, Development Bank of Latin America (CAF).

De Reuver M., C. Sorensen and R. Basole (2017), "The digital platform: a research agenda", *Journal of Information Technology*.

eBay (2015), *European Small Online Business Trade Summary 2015*.

European Commission (2016), "Commission Staff Working Document. Online Platforms: Accompanying the document Communication on Online Platforms and the Digital Single Market" (COM(2016) 288) [online] https://ec.europa.eu/digital-single-market/en/news/commission-staff-working-document-online-platforms.

___(2015a), *Digital Entrepreneurship Scoreboard 2015* [online] https://ec.europa.eu/growth/content/digital-entrepreneurship-scoreboard-2015-0_en.

___(2015b), "Public consultation on the regulatory environment for platforms, online intermediaries, data and cloud computing and the collaborative economy" [online] https://ec.europa.eu/digital-single-market/en/news/public-consultation-regulatory-environment-platforms-online-intermediaries-data-and-cloud.

___(2013), *Use of Social Media by European SMEs*, Directorate-General of Communications Networks, Content and Technology.

European Parliament (2014), *Mapping Smart Cities in the EU*, Directorate-General for Internal Policies.

European Union (2017), *Roundtable on Digitising European Industry: Working Group 2 – Leadership in Industrial Platforms* [online] https://ec.europa.eu/futurium/en/system/files/ged/dei_wg2_1st_report_20161223.pdf.

Evans, D. and R. Schmalensee (2007), "Industrial organization of markets with two-sided platforms", *Competition Policy International*, vol. 3, No. 1.
Evans, P. C. and A. Gawer (2016), "The rise of the platform enterprise: a global survey", The Emerging *Platform Economy Series*, No. 1, Center for Global Enterprise.
FedEx (2017), "Estudio de FedEx indica que las pymes en América Latina muestran crecimiento y optimismo", FedEx Newsroom [online] about.van.fedex.com.
García Zaballos, A. and E. Iglesias Rodríguez (2017), "Economía digital en América Latina y el Caribe: situación actual y recomendaciones", *IDB Monograph*, No. 570, Inter-American Development Bank (IBD).
Gurley, B. (2013), *A Rake Too Far: Optimal Platform Pricing Strategy,* Above the Crowd.
Hagiu A. and J. Wright (2015), "Multi-sided platforms", *Working Paper,* No. 15-037, Harvard Business School.
___(2014), "Marketplace or reseller?", *Working Paper,* No. 13-092, Harvard Business School.
___(2014), *Decisiones estratégicas para plataformas multilaterales,* Harvard Deusto Business Review, No. 237, Harvard Deusto.
IBD (Inter-American Development Bank) (2015), "Inclusión financiera en América Latina y el Caribe: coyuntura actual y desafíos para los próximos años", *Documento para Discusión,* No. IDB-DP-385, June.
IMD (IMD World Competitiveness Center) (2017), *IMD World Digital Competitiveness Ranking 2017.*
ITU (International Telecommunication Union) (2016), *A Review of Micro, Small and Medium Enterprises in the ICT Sector.*
KPCB (Kleiner Perkins Caufield Byers) (2017), "Internet Trends 2017 – Code Conference" [online] kpcb.com/InternetTrends.
Linnworks (2016), "A complete list of online marketplaces across the globe" [online] http://blog.linnworks.com/complete-list-of-online-marketplaces.
McKinsey Digital (2015), *Industry 4.0: How to navigate digitization of the manufacturing sector* [online] https://www.mckinsey.de/files/mck_industry_40_report.pdf.
MGI (McKinsey Global Institute) (2017), "How to counter three threats to growth in Latin America" [online] https://www.mckinsey.com/global-themes/employment-and-growth/how-to-counter-three-threats-to-growth-in-latin-america.
___(2016), *Digital Globalization: The New Era of Global Flows* [online] https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/digital-globalization-the-new-era-of-global-flows.
___(2015), *A Labor Market that works: Connecting Talent with Opportunity in the Digital Age.*
Makkonen J. (2015), "How to choose the right business model for your marketplace", Marketplace Academy [online] https://www.sharetribe.com/academy/how-to-choose-the-right-business-model-for-your-marketplace/.
Martens B. (2016), "An economy policy perspective on online platforms", *Digital Economy Working Paper*, No. 2016/05, Institute for Prospective Technological Studies Digital Economy.
OECD (Organization for Economic Cooperation and Development) (2016), *Entrepreneurship at a Glance 2016*, Paris, OECD Publishing.
OECD/ECLAC (Organization for Economic Cooperation and Development/Economic Commission for Latin America and the Caribbean) (2012), *Latin American Economic Outlook 2013: SMEs policies for structural change* (LC/G.2545), Paris, OECD Publishing.
Latin American Economic Outlook 2013: SME Policies for Structural Change.
Oxera (2015), "What are the benefits of online platforms?" [online] https://www.oxera.com/Latest-Thinking/Publications/Reports/2015/What-are-the-benefits-of-online-platforms.aspx.
Pacific Alliance (2017), "Hoja de ruta: Subgrupo de Agenda Digital" [online] https://alianzapacifico.net/?wpdmdl=8783.
PwC (2017), *IAB Internet Advertising Revenue Report 2016.*
Rochet J. and J. Tirole (2006), "Two-sided markets: a progress report", *RAND Journal of Economics.*
___(2003), "Platform Competition in Two-Sided Markets", *Journal of the European Economic Association*, vol. 1, No. 4.
Suominen, K. (2017), *Aceleración del comercio digital en América Latina y el Caribe*, Late.
Telefónica (2016), "FIWARE, el estándar que necesita el IoT" [online] https://iot.telefonica.com/blog/2016/09/es-fiware-estandar-iot.
The Wall Street Journal (2017), *Global Advertising Growth to Slow Slightly This Year* [online] https://www.wsj.com/articles/global-advertising-growth-to-slow-slightly-this-year-1497412803.
WEF (World Economic Forum) (2017), *Digital Transformation Initiative: Unlocking B2B Platform Value* [online] http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-platform-report-final-3-26-17.pdf.
Wertz, B. and A. Tran Kingyens (2015), *A Guide to Marketplaces,* Versionone.
Wilkinson M. (2017), *Crowdfunding Models Explained,* Crowcube.

CHAPTER

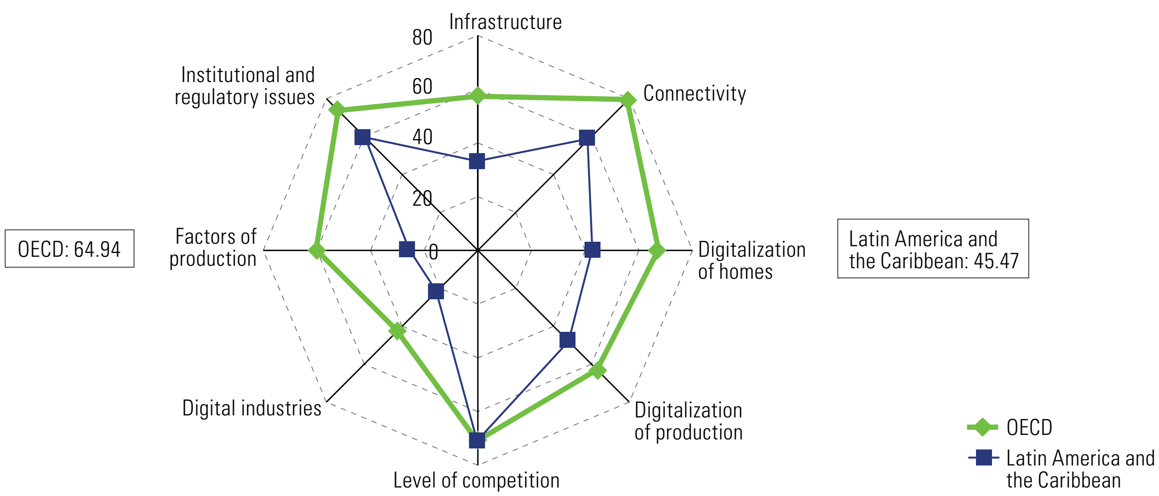
IV

Human capital formation for digital technologies in Latin America

A. The human capital deficit[1]

Developing digital industries in a country requires firms to have access to investment resources, human capital and innovation capacity. In particular, human capital is an indispensable input for the digitalization of the production structure; and access to it is fundamental, not only for developing digital industries but also for transforming traditional ones. In recognition of this need, this chapter quantifies and studies the situation of technical and vocational human resource training that affects the use of digital technologies in Latin America. This is particularly important because, as Katz and Callorda (2017) show, one of the largest gaps between the region and the developed world is in the factors of production used to calculate the digital ecosystem development index published by the Development Bank of Latin America (CAF), which include human capital (see figure IV.1).

Figure IV.1
Latin America and the Caribbean and Organization for Economic Cooperation and Development (OECD): digital ecosystem development index of the Development Bank of Latin America (CAF), 2015

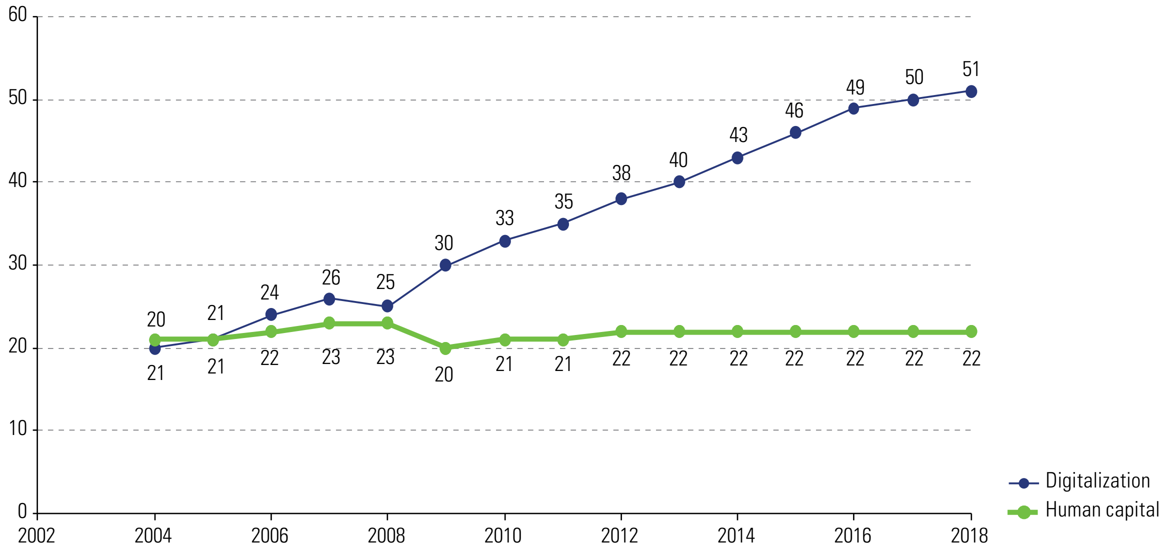


Source: Telecom Advisory Services, *Hacia la transformación digital de América Latina y el Caribe: el Observatorio CAF del Ecosistema Digital*, Caracas, Development Bank of Latin America (CAF), 2017; Development Bank of Latin America (CAF), Observatorio del Ecosistema Digital en América Latina y el Caribe 2017 [online] https://www.caf.com/app_tic/.

In the region, the increase in the index shown in figure IV.2 was not matched by a rise in the human capital index, which combines the percentage of engineers in the labour force and the percentage of the work force with higher-than-secondary education (Katz and Koutroumpis, 2013). The different trends in these indices can be at least partly explained by the fact that progress in digitalization is largely determined by an innovation diffusion process, for which the explanatory variables are communication between the adopters of the innovation and the value proposition of the new product, in other words, how it is expected to generate value. Nonetheless, as human capital development is highly inertial, it evolves with the characteristic slowness of all social dynamics. Moreover, the fact that the human capital index has risen by 23%, and the digitalization index by 145% between 2004 and 2014, shows the region's limited capacity to add local value to digital products and services, thus hampering productivity and economic growth.

[1] This chapter was prepared by Raúl L. Katz, Director of Business Strategy Research at The Columbia Institute for Tele-Information (CITI), Columbia University, New York.

Figure IV.2
Latin America: digitalization and human capital indices, 2004–2014



Source: R. Katz, F. Callorda and M. Lef, *Iniciativas empresariales y políticas públicas para acelerar el desarrollo de un ecosistema digital iberoamericano*, Madrid, Ibero-American Council for Productivity and Competitiveness (CIPC)/Cotec Foundation, 2016.

The design of these policies requires a diagnostic assessment of the size and reasons for the gap that exists. Firstly, what is the main reason for the human capital gap in the technical and professional disciplines that contribute to the degree of digitalization development? Is it due to an insufficient supply of training programmes or the lack of interest among students in technical, statistical, mathematical or scientific courses? In other words, is it the result of deficits in supply or in demand?

The answers to these questions help determine the areas that need to be prioritized in public policies. If the problem lies in the supply of educational infrastructure in technical courses, measures to overcome it will include the following: (i) the implementation of teacher training programmes, (ii) coordination of the priorities of higher education with system stakeholders, and (iii) incentives to create short courses. Conversely, if the problem is on the demand side, efforts should be made to: (i) deepen and universalize initiatives to incorporate computer science training in schools; ii) promote a sustained increase in enrolment rates on technical courses; (iii) generate public and private signalling mechanisms to increase the demand for technical courses; and (iv) set up monitoring systems between the secondary school level and tertiary technical and scientific programmes, to steer student choices towards technological courses.

Although closing the human capital gap is likely to require public policies targeting both supply and demand, this chapter focuses on identifying and quantifying technical training programmes in disciplines related to the formation of human resources to drive the digitalization process forward. In cases where relevant statistics are available, trends in student enrolment and graduation on technical courses are analysed to better understand the dynamics of demand.

The available analyses on human capital in the digital technology sphere are based on statistics such as the number of engineers and scientists as a percentage of tertiary education graduates, or the percentage of the work force with university education (information that is generally obtained from the United Nations Educational, Scientific and Cultural Organization – UNESCO).[2] Nonetheless, these statistics do not include the availability of resources trained in disciplines related to digitalization —for example, business management or certain graphic arts— that do not clearly form part of technical courses. Therefore, to understand and quantify

[2] See UNESCO Institute for Statistics (UIS), 2016 [online] http://uis.unesco.org/.

the human capital deficits, the study of supply needs to be broadened to analyse the availability of courses in other university faculties or departments in addition to those of engineering and exact sciences.

As generic formulations on the region conceal major differences between countries, the diagnoses must be performed at a national level to identify and understand the fundamental areas on which public policies for the development of human capital in digital technologies should be targeted.

Lastly, any analysis of training programmes must consider the level of the university degree awarded. Although there may be many undergraduate training programmes, the supply of postgraduate training (especially doctorates) in digital technologies could be relatively limited, which could reduce the intensity of basic and applied high-level research in the countries studied. This situation could perpetuate the region's dependency on the industrialized countries for digital product development.

In short, this chapter seeks to analyse the Latin American situation in terms of four key issues:

(i) The supply of training programmes in digital technologies apart from engineering;

(ii) Human resource training programmes in advanced digital technologies;

(iii) The supply of training programmes in relation to short courses, undergraduate degrees, master's degrees and doctorates; and

(iv) The number of teachers available in these disciplines.

To answer these questions, the availability of university programmes was analysed in detail for the following seven countries: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Uruguay.

Having mentioned advanced digital technologies that require human resource training in specific disciplines at the beginning of this chapter, the structure of the university departments and the programmes that offer academic training and the type of course are identified for each country. Based on these statistics, a comparative analysis is made of the situation of the seven countries. Lastly, public policy recommendations are formulated to make it possible to overcome some of the problems encountered. A detailed country-by-country analysis is presented in the annex.

B. Mature and advanced digital technologies

The distinction between mature and advanced digital technologies was highlighted in Katz (2017a). The former include broadband, computer-assisted management and mobile telecommunications, while the latter encompass robotics, artificial intelligence (machine learning), cloud computing, the Internet of Things (IoT), 3D printing and smart sensors. Therefore, a diagnostic assessment of the status of technical and vocational training should not analyse training programmes in a generic way (for example, electrical engineering), but instead should identify specialized courses in advanced technologies and quantify them. This is important because an abundance of training programmes in basic technologies could coexist with an inadequate supply in the technologies of the new industrial revolution.

The distinction between mature and advanced digital technologies is based on their status in terms of their widespread adoption in a three-stage life cycle: development, adoption and economic impact. The fact that an advanced technology is already developed (at least in the essential technical aspects that enable it to be incorporated into a production process) does not mean that it has been widely adopted. The timings and consequent lags vary according to each technology's stage in its life cycle.

Like other technological revolutions —such as those driven by the steam engine, electricity or the automobile— digitalization evolves in waves (Katz, 2017a). The first wave of digital technologies related to the introduction and adoption of technologies that are now in the mature stage, such as computerized management systems, automatic data processing applied to businesses and telecommunications technologies that enable remote data access. The second wave entailed the diffusion of the Internet and its platforms (search engines, e-marketplaces, among others), which link consumers to businesses and businesses to other businesses for the purchase and sale of inputs and the distribution of products in the market. Lastly, the third wave includes the diffusion of technologies that aim to enhance management decision-making and the automation of routine operations in goods and services production. The duration of the stages of the life cycles varies in each wave (see table IV.1).

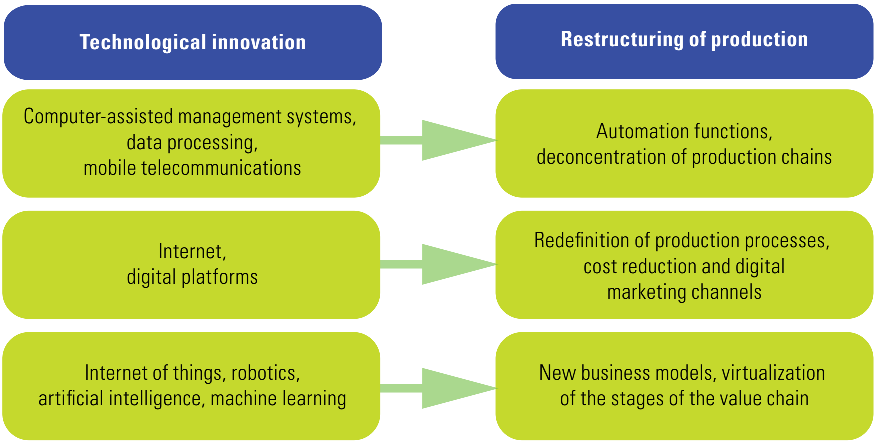
Table IV.1
Digitalization: technological innovation, adoption and impact

Technological innovation	Development	Adoption	Period of economic and social impact
First wave: computer management systems, automatic data processing and mobile telecommunications	1950–1975	1960–2000	1990–2010
Second wave: universalization of the Internet, digital platforms, cloud computing	1970–1990	1995–ongoing	2005–ongoing
Third wave: IoT, robotics, artificial intelligence, machine learning, blockchain	1980–ongoing	2010–ongoing	As from 2020

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

Each wave has an increasing effect on production processes (see diagram IV.1). The first enabled the automation of discrete functions, such as inventory management and production line management. It also facilitated the decentralization of functions, by optimizing access to factors of production. This enabled firms to locate certain productive functions in regions affording better access to resources, such as raw materials and labour, while the technology allowed them to maintain a centralized structure.

Diagram IV.1
Technological development waves and stages in the restructuring of production



Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

The second wave —based on the introduction of the Internet— allowed production processes to be reconfigured from start to finish. Internet-based platforms reduced operating costs and the costs of searching for goods and services at the best price. At the same time, the Internet enabled the deployment of digital distribution channels to reach the consumer, thereby extending the markets' reach and coverage. The third wave —consisting of the set of advanced technologies— makes it possible to relaunch traditional firms by generating new business models, the virtualization of the stages of the value chain and redefinition of the boundaries of business efficiency (Williamson, 1985).

In this context, human capital needs for each wave and for the stage of the life cycle in which it is located must be identified. For example, human capital gaps at the development stage refer to the limited training of researchers involved in the creation of new products and services; while the lack of human capital at the adoption stage refers to insufficient provision of resources for the assimilation of technologies in firms. At the highest level, a researcher involved in developing digital technologies must have a bachelor's degree and a postgraduate degree (at least a master's degree or, better still, a doctorate/PhD). On the other hand, a professional working on the incorporation of digital technology in production processes must possess a certification of undergraduate studies and perhaps a master's degree, although he/she may also have a short-course qualification (such as a technical diploma or certificate).

These generic concepts must be adapted to each wave of digitalization. For example, the human capital needed to assimilate mature technologies requires training in basic areas of management informatics, while the incorporation of advanced technologies in the production chain requires specialized training in areas such as artificial intelligence and robotics. Accordingly, the following analysis of the situation of human capital training programmes in the framework of digitalization focuses on each of the digital innovation waves and each stage of their life cycle.

C. The situation in seven Latin American countries

More specifically, this chapter aims to identify and measure the supply of training programmes in courses related to digitalization, distinguishing between basic and advanced digital technologies. Owing to the lack of detailed information by country, programmes and courses were gradually compiled, starting with the total number of universities, university- and non-university tertiary institutes in each country. From this universe, institutions that do not offer diplomas in computer science, electrical or electronic engineering, statistics or similar programmes were discarded.[3] Having compiled the list of establishments offering at least a diploma in these disciplines, the analysis identified those with courses on: (i) robotics and control; (ii) artificial intelligence and machine learning, and (iii) big data and analytics.

In cases where the course name was somewhat vague, an inference was made according to the following categorization map (see table IV.2).

Table IV.2
Classification of courses

Course nomenclature	Mapping
- Systems control - Simulation - Automation	Robotics and control
- Business intelligence - Business analysis - Digital marketing - Data mining	Big data and analytics
- Artificial intelligence - Man-machine interaction - Intelligent systems - Machine learning	Artificial intelligence and machine learning

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

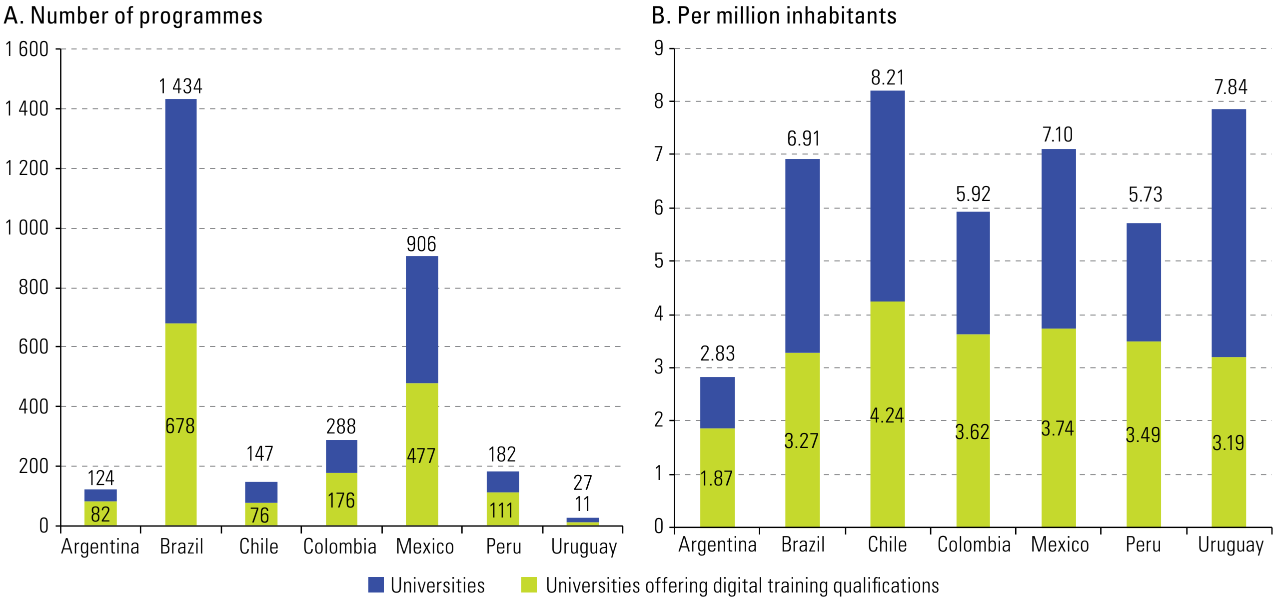
This made it possible to list all diplomas and courses on these topics available in each of the seven countries. In many cases, attempts were made to contact the corresponding department or the faculty directly to request information, but the response rate was very low. Efforts were also made to estimate the number of teachers in the aforementioned disciplines —information which appears on the websites of universities

3 Statistics are included since the departments in question have many machine-learning programmes.

or institutions in some cases. When the data were not obtained directly in the sections that should provide the information, an intensive search was made on linked official portals.[4] This made it possible to identify all programmes and courses available in each country.

These data revealed an abundant supply of training programmes in digital technologies in the seven countries analysed. In total, there are 1,611 higher education institutions offering training programmes in digital technologies, equivalent to 52% of the total number of institutions. The largest proportion is recorded in Argentina, where 66% of institutions offer digital technology training programmes; and the lowest (41%) corresponds to Uruguay (see figure IV.3).

Figure IV.3
Latin America (7 countries): universities offering formal training programmes in digital technologies
(Number of universities and per million inhabitants)



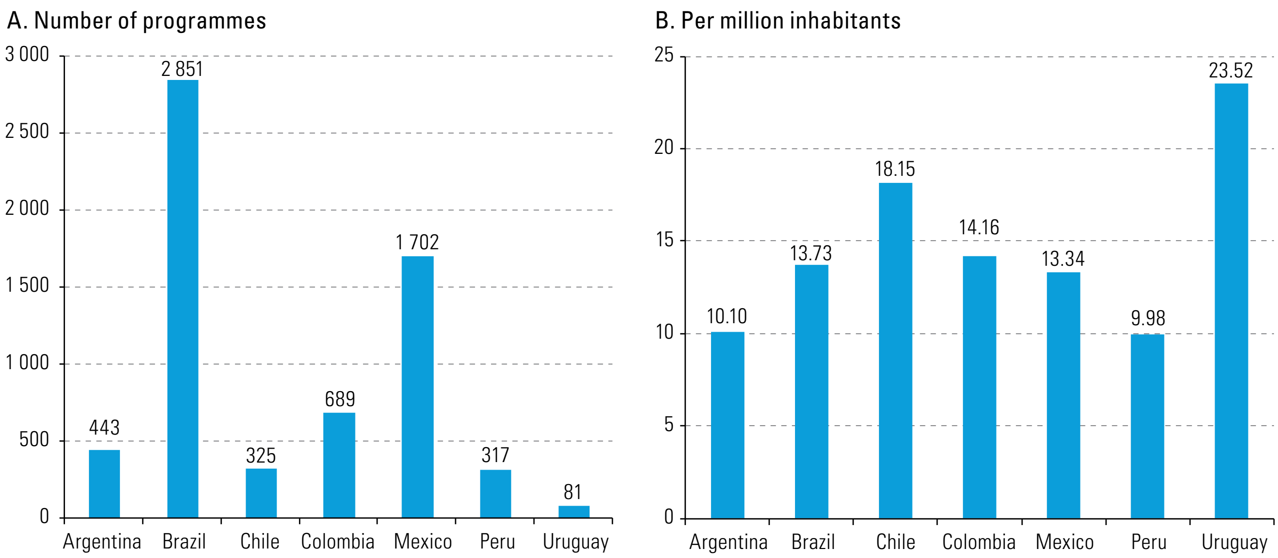
Source: R. Katz, "Capital humano para la transformación digital en América Latina", Production Development series, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

Nonetheless, when the number of universities is normalized with respect to each country's population, the highest training institution densities are registered in Chile, Mexico and Colombia. The lowest is observed in Argentina, with 1.87 institutions per million inhabitants offering formal training programmes in digital technologies, and the highest is 4.24 in Chile.

It is usual for an institution to offer more than one training programme in digital technologies. In the seven countries analysed, 6,408 formal programmes are offered. The largest number corresponds to Brazil, followed by Mexico, Colombia, Argentina, Chile, Peru and Uruguay (see figure IV.4).

4 University yearbooks or microsites of the institutions' official portals.

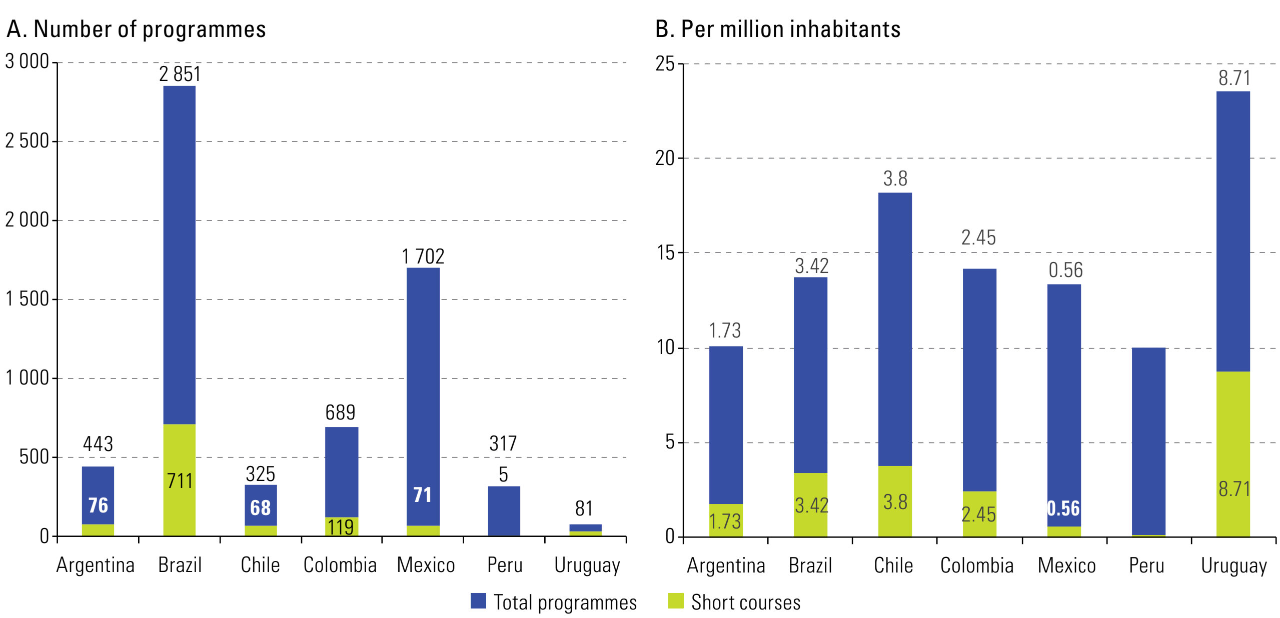
Figure IV.4
Latin America (7 countries): formal training programmes in digital technologies
(Number of programmes and per million inhabitants)



Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

When the number of formal programmes is measured per million inhabitants, Uruguay (23.52) and Chile (18.15) top the ranking, while Peru (9.98) and Argentina (10.10) are lower. In addition, 1,080 short courses in digital technologies were identified in the seven countries. Uruguay has the largest share of short programmes (technical diplomas or certificates) in the total number of formal programmes at 37% (see figure IV.5).

Figure IV.5
Latin America (7 countries): formal programmes and short training courses in digital technologies
(Number of programmes and per million inhabitants)

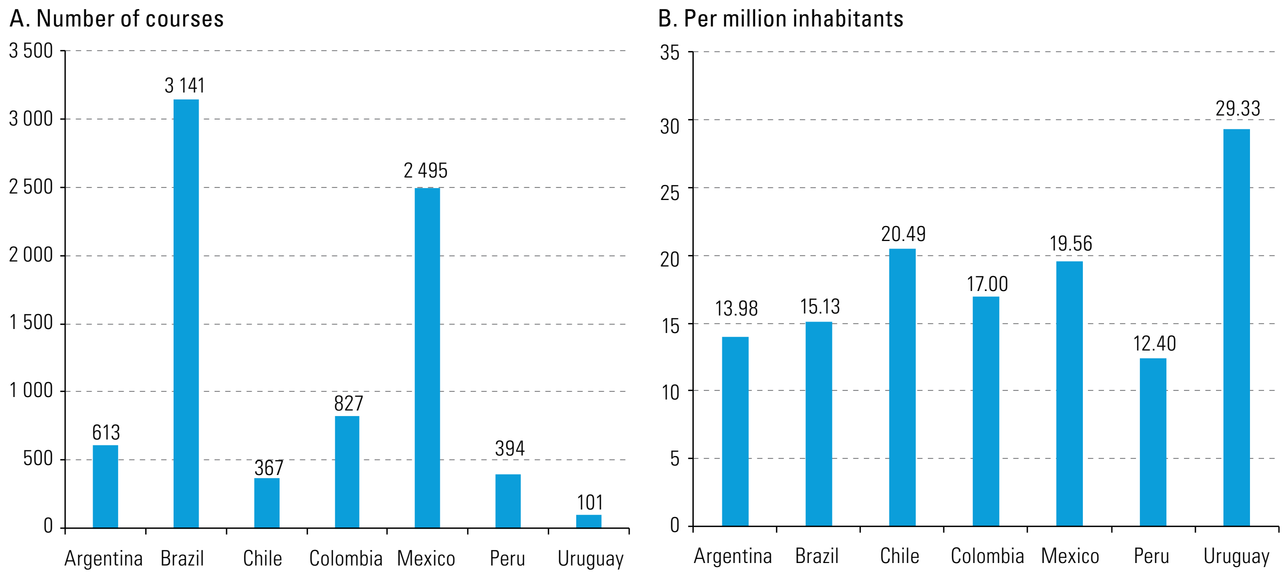


Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

When the supply of short courses is expressed per million inhabitants, Uruguay again heads the group of countries studied (with a value of 8.71), while Peru and Mexico are lagging behind. The availability of short courses in digital technologies is essential to close the short-term human capital formation gap. The normalized statistics suggest that Uruguay is the country best prepared to overcome this deficit.

Most of the programmes studied include courses on robotics and control, artificial intelligence and machine learning, or big data and analytics, totalling 7,938 courses. Brazil offers the largest number of courses in advanced digital technologies (3,141), while Uruguay offers the fewest (101) (see figure IV.6).

Figure IV.6
Latin America (7 countries): training courses in advanced digital technologies
(Number of courses and per million inhabitants)



Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

When these data are expressed per million inhabitants, Uruguay is once again the country with the highest density of courses on advanced digital technologies (29.93), while Peru has the lowest density (12.40).

Robotics and control and artificial intelligence and machine learning are the advanced digital technologies with the largest number of courses (2,989 and 2,815 respectively), while there are 2,134 courses on big data and analytics (see table IV.3). Brazil and Mexico jointly account for 71% of courses on advanced technologies in the seven countries studied.

By normalizing the availability of courses to university enrolment through an index calculated as the number of courses multiplied by one million and divided by the enrolment, shows that Mexico and Uruguay have the highest density of courses on subjects related to advanced digital technologies (see table IV.4). Argentina displays the lowest density of total courses offered. In specific subjects, the lowest value corresponds to big data and analytics courses in Chile. The tables for each country included in Annex IV.A1 show that there are 19 formal training programmes in advanced digital technologies in Argentina, 96 in Brazil, 12 in Chile, 12 in Colombia, 48 in Mexico, 4 in Peru and 3 in Uruguay.

Although the figures obtained show a significant number of teachers working in disciplines related to digital technologies (at least 32,337, excluding Mexico), the small number of institutions that disclose this data makes it impossible to provide a complete view of the statistics in question. In particular, data for Mexico are seriously lacking (see table IV.5).

Table IV.3
Latin America (7 countries): training courses in advanced digital technologies, by area

Country	Robotics and control		Artificial intelligence and machine learning		Big data and analytics		Total	
	Number	Per million inhabitants	Number	Per million inhabitants	Number	Per million inhabitants	Number	Per million inhabitants
Argentina	196	4.47	216	4.93	201	4.58	613	13.98
Brazil	1 032	4.97	1 218	5.87	891	4.29	3 141	15.13
Chile	194	10.83	89	4.97	84	4.69	367	20.49
Colombia	441	9.06	208	4.28	178	3.66	827	17.00
Mexico	907	7.11	944	7.40	644	5.05	2 495	19.56
Peru	183	5.76	111	3.49	100	3.15	394	12.40
Uruguay	36	10.45	29	8.42	36	10.45	101	29.33
Total	2 989	6.22	2 815	5.85	2 134	4.44	7 938	16.51

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

Table IV.4
Latin America (7 countries): index of advanced digital technology courses and university enrolment
(Index and number of students enrolled)

Country	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Total	University enrolment
Argentina	113.55	125.14	116.45	355.14	1 726 099
Brazil	128.22	151.33	110.70	390.25	8 048 701
Chile	253.88	116.47	109.93	480.28	764 133
Colombia	322.10	151.92	130.01	604.02	1 369 149
Mexico	298.11	310.27	211.66	820.04	3 042 546
Peru	218.03	132.25	119.14	469.42	839 328
Uruguay	274.93	221.47	274.93	771.34	130 941
Total	187.74	176.81	134.04	498.59	15 920 897

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, ECLAC, 2018, unpublished, on the basis of national university censuses.

Table IV.5
Latin America (7 countries): teachers in digital technology programmes

Country	Number of teachers
Argentina	3 999
Brazil	21 983
Chile	1 107
Colombia	2 059
Mexico	n.a.
Peru	1 625
Uruguay	1 564
Total	32 337

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.
Note: In the case of Mexico the available data are insufficient to make an adequate estimate.

Lastly, the availability of postgraduate training (especially PhD/doctoral programmes) in digital technologies is relatively sparse, which could reduce the intensity of basic and applied high-level research in the countries studied (see table IV.6).

Table IV.6
Latin America (7 countries): postgraduate programmes in digital technologies
(Number of programmes and per million inhabitants)

Country	Master's degrees		Doctorates		Total	
	Number	Per million inhabitants	Number	Per million inhabitants	Number	Per million inhabitants
Argentina	37	0.84	35	0.80	72	1.64
Brazil	152	0.73	72	0.35	224	1.08
Chile	36	2.01	10	0.56	46	2.57
Colombia	68	1.40	13	0.27	81	1.66
Mexico	187	1.47	67	0.53	254	1.99
Peru	49	1.54	14	0.44	63	1.98
Uruguay	11	3.19	3	0.87	14	4.07
Total	540	1.12	214	0.45	753	1.57

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

A total of 214 doctoral programmes in digital technologies were identified in the seven countries, with the largest number per million inhabitants corresponding to Uruguay (0.87), followed by Argentina (0.80). It is also important to consider the number of graduate programmes offered by the 20 best-ranked universities in each country (see table IV.7). In this universe, the number of PhD courses drops to 130 and the number of master's degree courses falls to 223.

Table IV.7
Latin America (7 countries): postgraduate programmes in digital technologies in the 20 best-ranked universities in each country

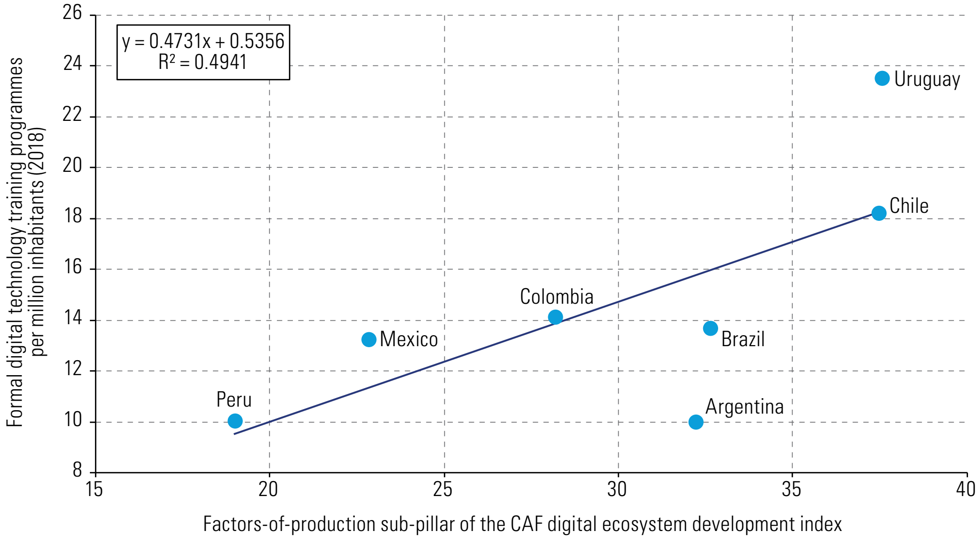
Country	Master's degrees	Doctorates	Total
Argentina	22	24	46
Brazil	55	43	98
Chile	30	10	40
Colombia	42	13	55
Mexico	43	29	72
Peru	20	8	28
Uruguay	11	3	14
Total	223	130	353

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.

The information presented shows that the availability of training in digital technologies is adequate in general terms, but there are deficits in some countries and in some areas. For example, Argentina has insufficient courses in digital technologies; Peru and Mexico have deficits in short courses. All countries have few formal courses and programmes in advanced digital technologies, except Brazil and Mexico; while Brazil and Colombia have a shortage of PhD programmes.

The availability of formal training programmes in digital technologies per million inhabitants can be related to the factors-of-production pillar or subindex (which includes human capital) of each country's digital ecosystem development index. Figure IV.7 displays a positive correlation between these programmes and the subindex. Uruguay has many more formal training programmes in digital technologies than would be expected. While Mexico displays a slightly higher than expected development level, Peru, Colombia and Chile have formal training programmes in digital technologies that are consistent with their factors of production. Lastly, Brazil and especially Argentina show a significant lag in the development of these programmes. In some cases, this comparative perspective stands in contrast to the absolute numbers reported for each country.

Figure IV.7
Latin America (7 countries): correlation between formal training programmes in digital technologies per million inhabitants and the factors-of-production subindex of the digital ecosystem development index of the Development Bank of Latin America (CAF)



Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of Development Bank of Latin America (CAF), Observatorio del Ecosistema Digital en América Latina y el Caribe 2017 [online] https://www.caf.com/app_tic/.

In terms of the demand for training programmes in digital technologies, an analysis of recent years' university enrolment in four of the seven countries studied shows the extent to which the greatest barrier to digital human capital formation is on the supply side or is lack of demand:[5]

- In Argentina, the percentages of new entrants and graduates in courses related to the digital transformation are falling year by year. This could be because the difficulty of these courses leads to dropout or to a course change; so it is not only necessary to encourage young people to enrol in the courses in question, but also to complete graduation. An analysis of engineering courses between 2003 and 2013 reveals a slight increase in absolute numbers, consistent with population growth, but a steady fall relative to the total number of students, new entrants or graduates. This confirms the existence of a deficit on the demand side of human capital.
- The number of students enrolled in technology careers in Chile doubled between 2005 and 2016, which shows that the lack of demand up to 2015, in terms of the percentage of graduates in engineering and sciences, reflected a negative legacy effect that can be reversed in the near future.
- A similar change is happening in Colombia, where the number of engineering and science graduates grew at an annual rate of 8.25%, rising from 37,949 in 2004 to 105,506 in 2016.
- In Uruguay, the increase in the percentage of university enrolments and graduates in courses related to the digital transformation could indicate a situation similar to that prevailing in Chile and Colombia.

[5] See country enrolment tables in annex IV.A1.

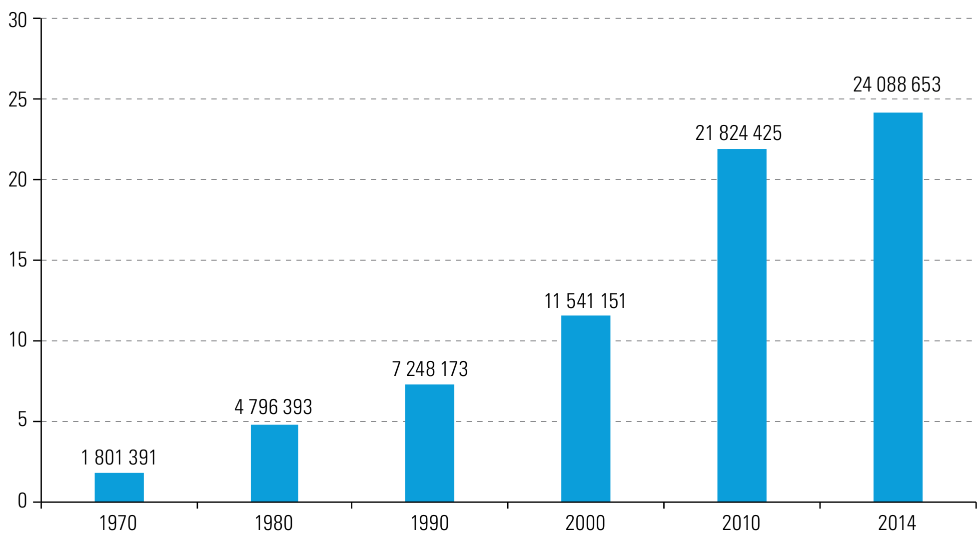
D. Public-policy implications

The analysis performed in this chapter shows that, with certain exceptions, the availability of human capital formation in the region, especially in terms of short courses and undergraduate degrees, is adequate in terms of absolute numbers, but there is a shortage of postgraduate courses especially doctorates. There are only a few formal programmes related to advanced technologies. On the demand side, although the evidence reveals a shortage of students, particularly graduates in the disciplines associated with digitalization, the trend is reversing in Chile, Colombia and Uruguay. It can thus be concluded that in some countries of the region the demand for training in mature digital technologies is insufficient (in other words, there is an adequate range of programmes available), compounded by a limited supply of degree courses in advanced technologies and graduate programmes in digital technologies generally. These conclusions form the basis of the public policy recommendations.

1. Promoting demand

The region shows clear progress in terms of enrolment. In 1970, 2 million young people of college age were enrolled in higher education. The figure had risen to 11.5 million by 2000 and to 22 million in 2008, equivalent to 13.8% of tertiary enrolment worldwide and exceeding the region's share of the world's population (CINDA, 2011). In 2014, enrolment surpassed 24.1 million (see figure IV.8).

Figure IV.8
Latin America: trend in higher education enrolment, 1970–2014
(Millions of enrolled students)



Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of Inter-University Centre for Development (CINDA), Educación Superior en Iberoamérica. Informe 2011, J. Brunner and R. Ferrada (eds.), Santiago, 2011; United Nations Educational, Scientific and Cultural Organization (UNESCO), Global Education Digest 2009: Comparing Education Statistics Across the World, Montreal, 2009; Global Education Digest 2010: Comparing Education Statistics Across the World, Montreal, 2010; UNESCO Institute for Statistics (UIS), 2016 [online] http://uis.unesco.org/.

The growth in enrolment does not imply a proportional increase in the number of graduates, which is much smaller.[6] In Latin America there was a total of about 36,000 graduates on engineering and technology courses in 2013. Some countries were better placed in terms of graduation rates in engineering and technology courses. While in Brazil and Argentina these courses produced about 9% of all graduates, in Chile they generated 16%, in Colombia 22% and in Mexico 24% (RICYT, 2015).

Development of the digital ecosystem requires a larger number of graduates in these disciplines; and this means improve learning at the secondary school level to provide an adequate base for those courses. Reducing information asymmetries is a priority, to enable university candidates, under pre-existing access conditions, to choose technical courses. The dissemination of relevant information on expected salaries and employability in these areas should be encouraged; and business associations and chambers can play an important role by running information campaigns to highlight the economic advantages associated with these courses.

Similarly, greater enrolment in tertiary level courses on digital technologies should be promoted from the primary and secondary school levels. Computer science needs to be incorporated into educational systems organically for organizational, pedagogical and innovation reasons. The organizational advantages arise from the fact that computer science is an input to implement processes to improve education administration. This discipline, in turn, could benefit from a critical mass of students and teachers who learn and teach their methods to improve education or other public policy entities. Pedagogical improvements stem from the fact that computer skills stimulate creativity, critical analysis and logical thinking; and they make it possible to apply knowledge to social and scientific problems on a cross-cutting basis. Innovation originates in the fact that its contribution has a positive impact on the ability to understand and transform reality, since social, political and economic issues are increasingly resolved in the digital information spheres.

Digital technologies should thus be another instrument promoting quality education, insofar as they allow complex problems to be addressed with specific solutions and provide adaptability and flexibility skills that complement the social and emotional skills that public education systems aspire to develop. They are also an increasingly necessary tool to add value to manufacturing and service industries and to production chains.

Computer sciences should be incorporated across the board and highly flexibly, to avoid restricting students technologically and prepare them for the disruptions that they can create or manage. Computer science need to be given the same weight as traditional scientific subjects, such as chemistry, physics and biology (Nager and Atkinson, 2016). Beyond initiatives driven by technological enthusiasm, sustainable change requires programmes to be rethought. Thus, computer science should be a priority on the educational policymaking agenda and requires the support of a coalition. At this point, professionals in the subject, teachers and the private sector play a very important role and must make themselves heard so that society interprets and demands development of digital technologies as the basis of students' training.

2. Promoting the supply of programmes

In many of the region's countries, higher education is a fragmented and diversified system in which private education models prevail over public ones. Institutions offering higher education programmes proliferate haphazardly, without responding to a standard matrix of educational development aimed at increasing the human capital endowment.

Higher education is characterized by the award of a first academic degree after five or more years of study, or between three and four years in Spain and Portugal, following the modifications introduced by the Bologna Process (CINDA, 2011).[7] Among other things, this process favoured the standardization of study plans based on an academic measurement unit referred to as a credit, with two alternatives: degrees requiring 240 credits (four years) or those requiring 180 credits (three years). Students thus complete shorter labour-market-oriented courses.

6 In terms of qualifications by discipline, in 2013 the social sciences were ranked first in Latin America, representing 54% of the total, followed by engineering and technology courses with 14% and medical sciences with 15%. The humanities disciplines accounted for 7% and natural sciences 6% (RICYT, 2015).

7 The Bologna Declaration of 1999 is a voluntary agreement signed by 30 nations, which laid the foundations for the construction of a European Higher Education Area, organized under principles of quality, mobility, diversity and competitiveness. Its aims were to increase employment in the European Union and convert the European Higher Education System into a pole of attraction for students and teachers from elsewhere in the world (Garay Sánchez, 2008).

Latin America monitored this experience closely through coordination initiatives such as the European Union's Tuning Latin America project. Nonetheless, regional integration in terms of standardization is still incipient. In order to make headway in a similar process, the top political and academic authorities must lead the debate and promote the integration and reform of higher education curricula.[8]

Policies should aim to create higher education systems that can absorb rapid changes in disciplines, maintain their orientation towards knowledge production, and promote socioeconomic development without descending into technological determinism. This requires flexible programmes that allow for adaptation of formats and contents and generate demand for continuous updating of knowledge. Reform of the programmes must include basic knowledge that stimulates creativity, critical and logical thinking, and teamwork skills, together with the learning and use of technological tools during the first few years of higher education. Similarly, specialization should be promoted in subsequent two-to-three-year modules. Computer sciences support this reform because they fulfil the pedagogical and productive aspect of teaching and enable students to create models, formulate hypotheses and test them with a high level of theoretical and practical meaning.

There are many advantages in reorganizing programmes, including the ability to motivate students with general considerations and prepare them for rapid changes in the generation and application of knowledge and its necessary reformulation and updating. Making education spending more efficient would avoid constantly having to restructure the programmes in response to changes in the dominant technologies.

When planning higher education policies it is essential to establish channels for dialogue between the different stakeholders, to improve coordination and, thus, increase the efficiency of investment in education and establish more fluid systems for collaboration between the labour market and the academic world.

It is also necessary to increase horizontal cooperation between public and private higher education institutions, going beyond curricular contents. Cooperation mechanisms should be institutionalized beyond the formal agreements that currently exist, including by setting up councils covering more than one jurisdiction. New institutions should also be created to formulate multisectoral educational policies capable of facing the challenges of primary, secondary, and tertiary education and of providing education system governance, legitimizing a system of authority that transcends political/electoral cycles. All of this would foster progress towards the goals of making the policies sustainable and creating territorial and sectoral representation mechanisms.

8 The creation of the National Education Evaluation Institute (INEE) in Mexico is an interesting example of educational governance. This entity helped manage the conflict of interests in the education sphere and made it possible to overcome union opposition, by incorporating contributions from civil society and specialists at a time when society had high expectations and were demanding change.

Bibliography

CINDA (Inter-University Centre for Development) (2011), *Educación Superior en Iberoamérica. Informe 2011*, J. Brunner and R. Ferrada (eds.), Santiago, October.

Garay Sánchez, A. (2008), "Los Acuerdos de Bolonia; desafíos y respuestas por parte de los sistemas de educación superior e instituciones en Latinoamérica", *Universidades*, No. 37, Mexico City, Metropolitan Autonomous University, April-June.

Katz, R. (2017a), "Social and economic impact of digital transformation on the economy", *GSR-17 Discussion Paper*, Geneva, International Telecommunication Union (ITU) [online] https://www.itu.int/en/ITU-D/Conferences/GSR/Documents/GSR2017/Soc_Eco_impact_Digital_transformation_finalGSR.pdf.

___(2017b), "Digitalización e industrialización inclusiva y sostenible en América Latina", document presented at the Fourth Summer School "Transformación e Innovación Digital en América Latina", Barcelona, 12 June [online] http://docplayer.es/63174982-Digitalizacion-e-industrializacion-inclusiva-y-sostenible-en-america-latina.html.

___(2015), *El ecosistema y la economía digital en América Latina*, Madrid, Fundación Telefónica/Economic Commission for Latin America and the Caribbean (ECLAC)/Editorial Ariel, August.

___(2018), "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), unpublished.

Katz, R. and F. Callorda (2017), "Accelerating the development of Latin American digital ecosystem and implications for broadband policy", *Telecommunications Policy*, Amsterdam, Elsevier, December.

Katz, R., F. Callorda and M. Lef (2016), *Iniciativas empresariales y políticas públicas para acelerar el desarrollo de un ecosistema digital iberoamericano*, Madrid, Ibero-American Council for Productivity and Competitiveness (CIPC)/Cotec Foundation, September.

Katz, R. and P. Koutroumpis (2013), "Measuring digitization: growth and welfare multiplier", *Technovation*, vol. 33, No. 10-11, Amsterdam, Elsevier, October-November.

Nager, R. and R. Atkinson (2016), "The case for improving U.S. computer science education", Washington, D.C., Information Technology and Innovation Foundation (ITIF), May [online] http://www2.itif.org/2016-computer-science-education.pdf.

RICYT (Network for Science and Technology Indicators) (2015), *El Estado de la Ciencia: Principales Indicadores de Ciencia y Tecnología Iberoamericanos/Interamericanos 2015*, Buenos Aires.

Telecom Advisory Services (2017), *Hacia la transformación digital de América Latina y el Caribe: el Observatorio CAF del Ecosistema Digital*, Caracas, Development Bank of Latin America (CAF), June.

Williamson, O. (1985), *The Economic Institutions of Capitalism*, New York, The Free Press.

Annex IV.A1
Country analysis

Argentina

In Argentina there are 124 post-secondary training institutions, which include universities, university institutes and non-university tertiary institutes.[9] In 82 of these, training programmes are offered in computer science, electrical and electronic engineering, information systems or similar subjects. Some institutions offer more than one programme. For example, the University of Buenos Aires offers 15 programmes in these disciplines, while the National University of La Plata has 16 (see table IV.A1.1).

Table IV.A1.1
Argentina: examples of the programmes offered in two universities

Classification	University	Programmes
1	Universidad de Buenos Aires	Electrical engineering
		Electronic engineering
		Information technology engineering
		Industrial engineering
		Mechanical engineering
		Naval engineering and mechanics
		Bachelor's degree (*licenciatura*) in systems analysis
		Specialization in industrial automation
		Specialization in data exploitation and knowledge discovery
		Specialization in telecommunications services and networks
		Specialization in embedded systems
		Master's degree in industrial automation
		Master's degree in data exploitation and knowledge discovery
		Master's degree in telecommunications engineering
		Master in embedded systems
2	Universidad Nacional de la Plata	Bachelor's degree (*licenciatura*) in information technology
		Bachelor's degree (*licenciatura*) in systems
		Computer engineering
		University programmer analyst
		ICT analyst
		Doctorate in computer science
		Electrical engineering
		Electro-mechanical engineering
		Electronic engineering
		Industrial engineering
		Mechanical engineering
		Specialization in computer graphics, images and computer vision
		Specialization in software engineering
		Master's degree in engineering
		Master's degree in software engineering
		Master's degree in data networks

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of official data.

9 See "Ranking web of universities" [online] http://webometrics.info/en. Although the official source records 2,239 institutions, many of these are private organizations, sponsored by companies that provide specific training for the purpose of recruiting students into the labour market. This means that many cases could involve qualifications that are even lower than technical certificates and, therefore, mere training courses.

The 82 institutions identified offer a total of 443 programmes[10] in information systems and management control, computer science, electrical and electronic engineering or telecommunications.[11] The courses leading to degrees, such as a bachelor's degree or professional engineer diploma, last at least four years (engineering courses are longest at five years or more); while the technical courses (*tecnicaturas*) and the professional technologist diplomas last between two and three years. Master's degrees, doctorates and specialization courses also last between two and three years, although in some cases they may require four. Lastly, there are basic courses lasting less than two years, including intensive courses of between five and eight months.

Of these 443 tertiary programmes, 402 include courses in robotics and control, artificial intelligence and machine learning, or big data and analytics, for a total of 613. Programmes without this type of course include certain doctoral and master's courses that provide personalized study plans; in other words they are defined on the basis of the subject chosen by the student, so they cannot be classified in advance.

To summarize, table IV.A1.2 shows the number of courses or subjects related to advanced digital technologies and the number of universities that award first or graduate degrees in digital technologies.

Table IV.A1.2
Argentina: supply of training and qualifications in digital technologies

	Number of courses			Number of professional qualifications[a]		
	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Doctorates	Master's degrees	First degrees, technical diplomas and certificates
20 best-ranked universities	95	72	68	24	22	147
Other universities	101	144	133	11	15	224
Total	196	216	201	35	37	371
Total per million inhabitants	4.47	4.93	4.58	0.80	0.84	8.46

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of official data.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

Of the 371 undergraduate degrees, diplomas, technical certificates, teacher training and other courses, just 225 are undergraduate degrees, 26 are diploma and specialization courses, and the rest are the other lower-level qualifications mentioned that complete that classification group. Postgraduate training (leading to PhDs or master's degrees) in digital technologies is relatively scarce. This could reduce the intensity of basic and applied high-level research in Argentina (for example, the development of sophisticated tools or operating systems) and limit the capacity of the education system to train new teachers. This type of training is highly concentrated (64%) in the 20 best-ranked universities in the country.

In terms of emphasis on the availability of courses in advanced digital technologies, although there is parity between the three types of training considered in this chapter, there is a slight bias in favour of artificial intelligence, followed by big data, with robotics and control the least favoured.

As in the case of the other countries in the sample, training in advanced technologies is generally given in isolated courses within generic programmes in electrical or electronic engineering, telecommunications, or related to systems analysis. Programmes specializing in some of the three advanced technologies are restricted to a few universities, particularly in big data and, to a lesser extent, in robotics and automation. In all, there are 19 programmes that offer a degree in one or more of the three advanced technologies. The 20 best-ranked universities have most doctoral and master's degree programmes in advanced technologies in absolute number terms, while other institutions predominate in the other qualification categories.

In addition to the number of programmes and qualifications, the number of teachers was quantified in some of the universities and non-university institutions. When the number of teachers per programme was not

[10] Universities that have undergraduate or engineering programmes often offer the possibility of graduating with an intermediate qualification in the same subject as the degree, but at an intermediate level (such as a technical certificate).
[11] Several of the universities included in this analysis have various campuses in Argentina, since many of them are regional. This means that the same programme can be delivered in several branches of the same institution.

specified, the overall number of teachers in the faculty of engineering, exact sciences, computer science, or wherever the courses were given, was used to calculate the average corresponding to the courses analysed. A total of 3,999 teachers were identified in just some of the 371 programmes on which the information needed for the study was obtained. In some cases, the average number of teachers was calculated from the entire department in which the courses considered are taught.

To gauge the demand for courses, the number of students registered on courses that could be assimilated to the development of digitalization, was calculated as a percentage of the total student population —35.8% in short undergraduate courses and 36.76% in postgraduate courses (see table IV.A1.3).

Table IV.A1.3
Argentina: students, new enrolments and graduates of engineering courses in state-run institutions, 2013
(Number of students and percentages)

	Undergraduate degrees			Graduate degrees		
	Students	New enrolments	Graduates	Students	New enrolments	Graduates
Statistics	630	89	17	0	0	0
Industries	50 809	12 687	3 180	15 013	4 947	1 274
Information technology	64 695	14 458	2 624	13 284	2 924	1 026
Engineering	100 892	21 356	4 303	4 349	893	301
Mathematics	9 528	2 435	332	347	90	16
Information and communication sciences	50 960	10 193	2 264	11 986	3 220	1 253
Economics and management	237 138	47 682	12 223	99 529	29 336	9 541
Subtotal	514 652	108 900	24 943	144 508	41 410	13 411
Total	1 437 611	315 593	80 343	393 132	110 057	37 376
Subtotal/Total	35.80%	34.51%	31.05%	36.76%	37.63%	35.88%

Source: "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of Ministry of Education of Argentina, *Anuario 2013: Estadísticas Universitarias Argentinas*, Buenos Aires, 2013.

Nonetheless, the statistics show that the percentage is decreasing with respect to both the number of new enrolments and the number of graduates. This could be because the difficulty of these courses leads to dropout or to a course change; so there is a need not only to encourage the young people to enrol in courses associated with digitalization but also to persevere to graduation.

The specific analysis of engineering courses between 2003 and 2013 shows a slight increase in absolute numbers, consistent with population growth, but a constant drop in relative terms in the number of students, new enrolments and graduates (see table IV. A1.4).

Table IV.A1.4
Argentina: students, new enrolments and graduates of engineering courses in state-run institutions, 2003, 2009 and 2013
(Number of students and percentages)

	2003			2009			2013		
	Students	New enrolments	Graduates	Students	New enrolments	Graduates	Students	New enrolments	Graduates
Computer science	1 093	386	7	1 454	492	25	2 276	737	49
Electrical engineering	4 860	1 192	179	4 485	960	132	4 952	840	162
Electromechanics	5 045	1 243	129	5 862	1 266	190	7 372	1 502	267
Electronics	18 038	3 793	590	16 632	2 874	664	16 181	2 715	557
IT and systems	35 742	8 723	994	32 627	6 844	1 040	29 630	4 887	852
Telecommunications	1 166	219	10	832	104	83	671	94	52
Subtotal	65 944	15 556	1 909	61 892	12 540	2 134	61 082	10 775	1 939
Total	124 455	29 009	4 120	138 576	30 079	4 924	151 885	29 969	5 050
Subtotal/Total	52.99%	53.62%	46.33%	44.66%	41.69%	43.34%	40.22%	35.95%	38.40%

Source: "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of Ministry of Education of Argentina, *Anuario 2013: Estadísticas Universitarias Argentinas*, Buenos Aires, 2013.

Thus, in terms of the demand for tertiary training in disciplines related to digitalization in Argentina, there is a significant reduction in the number of students enrolled and a declining share of engineers in the total university population. An analysis of the situation from the standpoint of supply and demand shows that public policies need to encourage young people to choose courses related to digitalization and to complete them.

Brazil

In Brazil there are 1,434 post-secondary training institutions, including universities, university institutes and non-university tertiary institutions.[12] Training programmes are offered in computer science, electrical and electronic engineering, information systems or similar in 678 of them (47.28%).

These institutions offer a total of 2,851 programmes in information systems and management control, computer science, electrical and electronic engineering or telecommunications. As noted in the case of Argentina, courses leading to degrees, such as bachelor's degree or professional engineer diploma, last at least four years, while technical courses and professional technologist diplomas last between two and three years. Master's degrees, doctorates and specialization courses also last between two and three years, although in some cases they may take four to complete.

The 2,851 tertiary programmes offer a total of 3,141 courses on robotics and control, artificial intelligence and machine learning, or big data and analytics. As in the case of Argentina, there are many PhD and master's degree programmes with customizable work plans, in which the curriculum depends on the topic chosen by the student, so these cannot be classified in advance.

Table IV.A1.5 shows the number of topics, courses and subjects related to advanced digital technologies and the number of universities that award undergraduate or graduate degrees in digital technologies.

Table IV.A1.5
Brazil: supply of training and professional qualifications in digital technologies

	Number of courses			Number of professional qualifications[a]		
	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Doctorates	Master's degrees	First degrees. technical diplomas and certificates
20 best-ranked universities	95	96	70	43	55	159
Other universities	937	1 122	821	29	97	2 468
Total	1 032	1 218	891	72	152	2 627
Total per million inhabitants	4.97	5.87	4.29	0.35	0.73	12.65

Source: "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of official data.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

The availability of postgraduate training (doctorates or master's degrees) in digital technologies is relatively sparse for a country the size of Brazil, compared to the number of programmes at the various levels of qualification offered. This could reduce the intensity of basic and applied high-level research in the country, and also diminish the ability of the education system to train new teachers. This type of training is also highly concentrated in the 20 best-ranked universities. The number of PhD programmes in these universities (43) is far outweighs the total number offered by the other 658 universities.

The largest number of courses related to advanced digital technologies specialize in artificial intelligence and machine learning (1,218), followed by robotics and control (1,032) and, lastly, big data and analytics (891). Of the 2,627 degree-level, technical and specialization qualifications, 1,764 are undergraduate degrees, 152 are specializations and the rest are technical certificates in this classification group.

[12] See "Ranking web of universities" [online] http://webometrics.info/en. The official statistics generated from the Higher Education Census mention 2,111 institutions. Nonetheless, as in Argentina, many of these are private organizations, sponsored by firms interested in providing specific training to quickly prepare trainees for entry into the labour market. This means that many cases could involve qualifications that are even lower than technical certificates and, therefore, mere training courses.

As is true of the other countries studied in this chapter, the availability of training in advanced technologies generally involves isolated courses given as part of generic programmes in electrical engineering, electronics, telecommunications, or else linked to systems analysis. Programmes specializing exclusively in some of the advanced technologies are confined to a few universities, which offer a total of 96 programmes.

The number of teachers was counted in some of the universities or non-university centres analysed. As explained in the case of Argentina, when the number of teachers per programme was not available, in several cases the overall number of teachers in the faculties of engineering, exact sciences, information technology, or those in which the courses are given was used; and the average corresponding to the courses in question was calculated. A total of 21,983 teachers were counted in just some of the 2,851 programmes for which the necessary information was obtained.[13]

Chile

In Chile there are 147 universities,[14] 76 of which offer training programmes in computer science, electrical engineering or information systems. These universities run 325 programmes in information systems and management control, computer studies, electronic engineering or telecommunications, which include 367 courses on robotics and control, artificial intelligence and machine learning, or big data and analytics.

Table IV.A1.6 shows the number of programmes or courses related to advanced digital technologies and the number of universities that award undergraduate or graduate degrees in digital technologies.

Courses providing postgraduate training (leading to PhDs or master's degrees) in digital technologies are relatively scarce. This could reduce the intensity of basic and applied high-level research in the country and weaken the capacity of the education system to train new teachers.

Table IV.A1.6
Chile: supply of training and professional qualifications in digital technologies

	Number of programmes/courses in advanced digital technologies			Number of qualifications[a]		
	Robotics/control	Artificial intelligence and machine learning	Big data/ analytics	Doctorates	Master's degrees	First degrees. technical diplomas and certificates
20 best-ranked universities	83	31	29	10	30	103
Other universities	111	58	55	0	6	176
Total	194	89	84	10	36	279
Total per million inhabitants	10.83	4.97	4.69	0.56	2.01	15.58

Source: "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

Training in advanced digital technologies focuses on robotics and control;[15] and it is generally concentrated in isolated courses given within generic programmes in electrical engineering or system analysis. Programmes specializing in some of the advanced technologies is restricted to just a few universities (for example, the major in Autonomous Systems and Robotics offered at the Catholic University of Chile, or Automation and Robotics Engineering at Universidad Andrés Bello). Programmes in advanced technologies are mostly concentrated in the top 20 universities in the Chilean ranking (10 of which are private), which account for over 50% of courses, all doctoral programmes and most master's programmes in the subjects in question.

In addition to the number of programmes, the number of teachers of digital technologies was counted in some of the universities analysed. In just some of the 76 departments, there was a total of 1,107 teachers.

13 As noted in the comparison with other countries, the significant difference between Brazil and the other countries arises mainly because Brazilian universities tend to disclose more data on the number of teachers.

14 See "Ranking web of universities" [online] http://webometrics.info/en. The official statistics mention 152 institutions.

15 Training in artificial intelligence and big data is limited to a few courses, because Chile lacks training programmes that award qualifications in advanced digital technologies (for example, bachelor or master's degrees in machine learning).

There is an abundant supply of tertiary programmes and courses in digital technologies, except, possibly, at the postgraduate level, especially for doctorates. This would indicate that the availability of training is not a major bottleneck. In this context, it is appropriate to investigate the situation from the demand side. Are university students adequately steered towards digitalization-related courses? An analysis of university enrolment up to 2016 shows a sustained increase in the number of students taking technological courses (see table IV.A1.7).

Table IV.A1.7
Chile: university students by subject, 2005–2016

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of students enrolled	637 434	668 853	713 701	755 177	816 578	904 109	989 394	1 035 267	1 080 569	1 126 019	1 152 951	1 168 901
Management and commerce	107 195	102 343	109 688	122 314	133 363	151 463	170 299	178 812	189 094	200 929	212 827	226 165
Agriculture, forestry, fishing and veterinary science	29 957	30 363	31 134	31 268	30 114	29 472	28 869	28 205	27 486	26 741	27 372	28 447
Art and architecture	44 674	48 631	50 255	52 082	52 566	55 148	55 092	54 214	53 378	52 004	51 286	51 043
Sciences	12 010	12 171	12 509	13 587	13 841	14 284	14 531	14 458	14 887	16 075	16 518	16 647
Social sciences	59 472	61 691	61 804	62 528	65 411	70 548	75 211	77 552	79 734	83 585	85 342	88 902
Law	47 058	55 512	59 704	44 350	43 094	42 280	43 161	41 348	39 875	40 015	39 937	40 464
Education	96 472	97 616	104 213	113 751	120 775	131 655	139 589	140 603	137 144	135 994	133 600	133 878
Humanities	8 898	10 503	11 263	11 865	11 967	12 914	13 468	13 516	13 350	13 305	12 845	13 097
Health	68 171	84 800	98 558	114 575	136 673	161 208	188 119	204 155	208 564	217 168	222 936	226 522
Technology	163 527	165 223	174 573	188 857	208 774	235 137	261 055	282 404	317 057	340 203	350 288	343 736
Technology (percentages of total)	0.26	0.25	0.24	0.25	0.26	0.26	0.26	0.27	0.29	0.30	0.30	0.29

Source: "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of National Education Council (CNED), "Matrícula sistema de educación superior", Santiago [online] https://www.cned.cl/indices/matricula-sistema-de-educacion-superior.

The number of students enrolled on technology courses doubled between 2005 and 2016. This leads to the conclusion that the disadvantage observed until 2015 in terms of the proportion of graduates in engineering and sciences (see table IV.A1.8) reflected a negative legacy trend from the past that can be reversed in the near future.

Table IV.A1.8
Chile: tertiary graduates in engineering and sciences

Year	Total graduates	Engineering and science graduates	Percentage of total graduates	Engineering and science graduates per million inhabitants
2004	67 185[a]	16 289[a]	24.24[a]	1 018[a]
2005	70 129[a]	17 003[a]	24.24[a]	1 052[a]
2006	73 203	17 748	24.24	1 087
2007	87 485	20 839	23.82	1 263
2008	92 230	20 521	22.25	1 230
2009	121 915	24 928	20.45	1 477
2010	120 464	24 164	20.02	1 416
2011	133 448[a]	26 149[a]	19.59[a]	1 515[a]
2012	147 549	28 297	19.18	1 622
2013	176 217[a]	34 303[a]	19.47[a]	1 946[a]
2014	191 141	37 767	19.76	2 119
2015	195 713[a]	38 670[a]	19.76[a]	2 148[a]
2016	198 420[a]	39 205[a]	19.76[a]	2 155[a]
2017	197 301[a]	38 984[a]	19.76[a]	2 122[a]
Annual compound growth rate	8.64%	6.94%	-1 .56%	5.81%

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of United Nations Educational, Scientific and Cultural Organization (UNESCO) and National Education Council (CNED).

[a] Estimate.

In short, the analysis of the supply of and demand for training in courses on the digital transformation in Chile reveals an abundance of qualifications, programmes and courses in digital technologies. The only deficit identified on the supply side concerns graduate degrees, which affects the country's capacity to produce researchers. On the demand side, there has been a progressive increase in the enrolment of tertiary-level students on courses related to digitalization, so the human-capital gap is starting to close.

Colombia

In Colombia there are 288 higher education institutions,[16] of which 176 offer programmes in computer science, electrical engineering or information systems. These universities offer a total of 689 programmes in information systems and management control, computer science, electronic engineering or telecommunications, teaching 827 courses on robotics and control, artificial intelligence and machine learning, or big data and analytics.

Table IV.A1.9 shows the number of programmes or courses related to advanced digital technologies and the number of universities that award undergraduate or graduate degrees in those subjects.

PhD programmes in digital technologies are relatively scarce, with just 13 programmes being identified, all at universities in the top 20. As in the case of Chile, the emphasis is again on courses and programmes in robotics and control, while those on artificial intelligence and big data are a minority, and programmes and courses in big data/analytics are few and far between. The 20 best-ranked universities account for over 50% of all doctoral and master's programmes.

Table IV.A1.9
Colombia: supply of training and qualifications in digital technologies

	Number of programmes/courses			Number of qualifications[a]		
	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Doctorates	Master's degrees	First degrees, technical diplomas and certificates
20 best-ranked universities	90	30	29	13	42	106
Other universities	351	178	149	0	26	502
Total	441	208	178	13	68	608
Total per million inhabitants	9.06	4.28	3.66	0.27	1.40	12.50

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

The number of teachers in some of the institutions was also counted — a total of 2,059 teachers in just some of the 261 programmes.

Colombia is experiencing a change similar to that of Chile in terms of the production of university talent (see table IV.A1.10).

This conclusion is also supported by table IV.A1.11, which shows the growth in the number of engineering and science graduates in Colombia.

The number of engineering and science graduates grew at an annual rate of 8.25%, increasing from 37,949 in 2004 to 105,506 in 2016.

[16] See "Ranking web of universities" [online] http://webometrics.info/en. The official statistics mention 295 institutions. The difference is due to the fact that some of these are private organizations, sponsored by firms interested in providing specific training to quickly prepare trainees for entry into the labour market. This means that many cases could involve qualifications that are even lower than technical certificates and, therefore, mere training courses.

Table IV.A1.10
Colombia: university students enrolled by subject, 2004–2016

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Agronomy, veterinary sciences and the like	2 270	2 515	2 037	2 586	2 981	3 090	3 339	8 032	8 302	7 599	7 666	6 487	6 733
Fine arts	3 827	4 775	4 967	6 567	7 002	7 732	6 837	9 336	10 938	10 948	11 289	12 951	12 780
Education sciences	16 436	11 000	11 432	17 248	21 139	23 654	31 630	39 137	44 049	34 938	35 747	36 174	40 303
Health sciences	14 191	14 277	13 416	16 087	16 777	16 488	18 127	23 793	26 519	26 727	26 956	28 058	30 905
Social and human sciences	25 637	24 055	32 651	39 405	50 934	47 744	48 479	50 589	58 454	57 658	52 992	57 873	61 884
Economics, management, accounting and the like	46 039	42 411	43 913	51 553	57 632	63 248	68 589	95 016	114 342	127 552	133 553	141 541	164 034
Engineering, architecture, urban planning and the like	35 690	38 083	35 095	41 330	46 218	46 630	46 040	66 983	74 850	80 154	84 305	84 974	99 054
Mathematics and natural sciences	2 259	2 637	3 032	3 171	3 625	3 820	4 007	4 902	5 236	5 679	6 198	5 747	6 452
Unclassified	0	0	0	0	0	39	330	2 004	2 214	535	901	933	1 037

Source: Ministry of Education of Colombia.

Table IV.A1.11
Colombia: tertiary-level graduates in engineering and sciences

Year	Total graduates	Engineering and science graduates	Percentage of total graduates	Engineering and science graduates per million inhabitants
2004	146 349	37 949	25.93	896
2005	139 753	40 720	29.14	949
2006	146 543	38 127	26.02	878
2007	177 947	44 501	25.01	1 013
2008	206 308	49 843	24.16	1 121
2009	212 445	50 450	23.75	1 122
2010	227 378	50 047	22.01	1 100
2011	299 792	71 885	23.98	1 561
2012	344 904	80 086	23.22	1 719
2013	351 790	85 833	24.40	1 822
2014	359 607	90 503	25.17	1 899
2015	374 738	90 721	24.21	1 882
2016	423 182	105 506	24.93	2 169
Annual compound growth rate	8.92%	8.25%	-0.62%	6.98%

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of United Nations Educational, Scientific and Cultural Organization (UNESCO) and Ministry of Education of Colombia.

Mexico

Mexico has a total of 906 post-secondary education institutions, including universities, university institutes and non-university tertiary institutions.[17] In 477 of these (52.67%) training programmes are offered in computer science, electrical and electronic engineering, information systems or similar.

[17] See "Ranking web of universities" [online] http://webometrics.info/en. The official statistics mention 3,766 institutions. Nonetheless, many of these are private organizations, sponsored by firms interested in providing specific training to quickly prepare trainees for entry into the labour market. This means that many cases could involve qualifications that are even lower than technical certificates and, therefore, mere training courses.

These institutions offer a total of 1,702 programmes in information systems and management control, computer science, electrical and electronic engineering or telecommunications. Degree qualifications, such as *licenciaturas* or engineering degrees, last four years or more (engineering degree courses are the longest, taking five years or more to complete), while technical certificates and technologist qualifications take between two and three years. Master's, doctorates and specializations also take between two and three years to complete, although in some cases they can take four.

Of the 1,702 tertiary-level programmes, 1,488 offer a total of 2,495 courses in robotics/control, artificial intelligence and machine learning, or big data/analytics. Programmes that do not have this type of course include a large number of PhD and master's programmes with flexible work plans, which may include subjects such as those studied in this chapter even if they are not mentioned.

Table IV.A1.12 summarizes the number of topics, courses or subjects related to advanced digital technologies and the number of universities that award undergraduate or graduate degrees in digital technologies.

Table IV.A1.12
Mexico: supply of training and professional qualifications in digital technologies

	Number of courses			Number of qualifications[a]		
	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Doctorates	Master's degrees	First degrees. diplomas and technical certificates
20 best-ranked universities	123	107	63	29	43	126
Other universities	784	837	581	38	144	1 322
Total	907	944	644	67	187	1 448
Total per million inhabitants	7.11	7.40	5.05	0.53	1.47	11.35

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of official data.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

The availability of postgraduate training (doctorates or master's degrees) in digital technologies is relatively small compared to the total number of programmes offered at the various qualification levels. This could reduce the intensity of basic and applied high-level research. Moreover, this type of training is highly concentrated in the top 20 universities in the country.

In terms of the emphasis in advanced digital technologies, there is broad parity between the robotics and artificial intelligence programmes, albeit with a slight bias towards the latter, while programmes specializing in big data are much scarcer.

Of the 1,448 undergraduate degree, diploma, technical certificate, teacher training and other courses, 1,356 lead to undergraduate degrees, 21 to diplomas and specializations and the rest to the other lower-level qualification options that complete that classification group.

As in the other countries, courses in advanced digital technologies are mostly concentrated in isolated courses within generic programmes of electrical engineering, electronics, telecommunications, or else linked to systems analysis. Programmes specializing in some of the advanced technologies are limited to a few universities and represent just 3.3% of the qualifications analysed (only 48 programmes). Lastly, it is important to note that the National Technological Institute of Mexico has a large number of regional offices located across the country, thereby demonstrating the importance that the Mexican Government places on technology training.

The number of teachers was measured in some of the universities or non-university centres analysed. In several cases, as the number of teachers per programme was not available, the general number of teachers from the technological institutes and faculties was used to calculate the average that would correspond to the courses being analysed. Considering only some of the 1,702 programmes on which the information needed for the study was obtained, a total of 1,265 teachers were identified; but this clearly underestimates the real number.

Peru

Peru has 182 universities,[18] of which 111 offer training programmes in computer science, electrical engineering, information systems, management control, electronic engineering or telecommunications. These institutions offer 317 tertiary-level programmes, with 394 courses in robotics and control, artificial intelligence and machine learning, or big data/analytics.

Table IV.A1.13 shows the number of programmes or courses related to advanced digital technologies and the number of universities that award first or higher degrees in digital technologies.

Table IV.A1.13
Peru: supply of training and professional qualifications in digital technologies

	Number of programmes/courses			Number of qualifications[a]		
	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Doctorates	Master's degrees	First degrees. technical diplomas and certificates
20 best-ranked universities	50	25	22	8	20	57
Other universities	133	86	78	6	29	197
Total	183	111	100	14	49	254
Total per million inhabitants	5.76	3.49	3.15	0.44	1.54	7.99

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

The availability of postgraduate training in digital technologies is moderate; it includes 14 doctoral programmes, mostly concentrated in Peru's 20 best-ranked universities.

The emphasis in training in advanced digital technologies is placed on robotics and control, while artificial intelligence and big data are minority topics.[19] The top 20 universities in the Peruvian ranking account for over 50% of all PhD programmes, while master's and bachelor's degrees in the subjects considered are much more widely distributed.

Lastly, 1,625 teachers involved in training in digital technologies were identified in just some of the 111 departments.

Uruguay

Uruguay has 27 post-secondary training institutions, including universities, university institutes and non-university tertiary institutions.[20] Computer science, electrical/electronic engineering, information systems or similar programmes are offered in 11 of these. These universities offer a total of 67 programmes in information systems and management control, computer science, electrical and electronic engineering or telecommunications, including three short courses, three PhD programmes, 11 master's and 50 undergraduate degree programmes. Of the 67 tertiary-level programmes, 65 include courses on robotics and control, artificial intelligence and machine learning, or big data/analytics.

The number of teachers was counted in some of the universities or non-university centres analysed. In the case of the University of the Republic, since the number of teachers per programme was not available, the overall number of teachers from the Faculty of Engineering was used, which includes Centro Universitario Regional del Este (CURE).

To summarize, table IV.A1.14 shows the number of topics, courses or subjects related to advanced digital technologies and the number of universities that award undergraduate or graduate degrees in digital technologies.

18 See "Ranking web of universities" [online] http://webometrics.info/en.
19 In many cases, training in artificial intelligence and big data is limited to a few courses because the country lacks training leading to qualifications in advanced digital technology (for example, bachelor or master's degrees in machine learning).
20 See "Web Ranking of Universities" [online] http://webometrics.info/en and Ministry of Education and Culture of Uruguay [online] http://www.mec.gub.uy/. The official statistics of the Higher Education Census mention 18 institutions.

Table IV.A1.14
Uruguay: supply of training and professional qualifications in digital technologies

	Number of courses			Number of qualifications[a]		
	Robotics and control	Artificial intelligence and machine learning	Big data and analytics	Doctorates	Master's degrees	First degrees. diplomas and technical certificates
20 best-ranked universities	28	24	32	3	11	52
Other universities	8	5	4	0	0	15
Total	36	29	36	3	11	67
Total per million inhabitants	10.45	8.42	10.45	0.87	3.19	19.45

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018.
[a] Takes account of the fact that a university can award more than one degree in different specialties.

The range of postgraduate training (PhD or master's degrees) available in digital technologies is relatively limited. This could reduce the intensity of high-level basic and applied research in Uruguay and impair the capacity of the education system to train new teachers.

Training in advanced digital technologies is distributed equally between robotics and control and big data, whereas courses in artificial intelligence are a minority.

As in other countries, training in advanced digital technologies is generally provided through isolated courses given within generic programmes in electrical engineering, electronics, telecommunications, or else linked to systems analysis. Programmes specializing in some of the advanced technologies are confined to just a few universities (for example, the specialization diploma course in big data analytics offered by the ORT University).

Lastly, programmes in advanced technologies are concentrated in the top 20 universities of the Uruguayan ranking (only the University of the Republic and CURE, which is attached to it, are public). These account for more than 80% of courses, all PhD programmes and most of the master's degree courses in the subjects considered.

Considering just some of the 67 programmes for which the necessary information was obtained, 1,564 teachers were identified. This encompassed all teachers in the faculties of engineering of the University of the Republic and the University of Montevideo, because there is no breakdown by programme since most of these faculties are oriented towards the subjects considered in this chapter

Statistics from the University of the Republic, Uruguay's largest higher-education institution, were analysed to ascertain the demand for courses related to digitalization (see table IV.A1.15).

Table IV.A1.15
Uruguay: new entrants and graduates by subject at the University of the Republic, 2013–2014

Faculty	2013		2014	
	New entrants	Graduates	New entrants	Graduates
Information and communication	677	161	874	153
Economic and management sciences	2 980	729	4 093	805
Engineering	1 884	314	1 852	248
Subtotal	5 541	1 204	6 819	1 206
Total	23 636	6 269	25 106	5 450
Subtotal/Total	23,44%	19,1%	27,16%	22,13%

Source: R. Katz, "Capital humano para la transformación digital en América Latina", *Production Development series*, Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2018, unpublished, on the basis of Ministry of Education and Culture and University of the Republic.

Although it is difficult to identify trends from statistics for just two consecutive years, the percentage of registered and graduating students has increased. This could indicate a situation relatively similar to those prevailing in Chile and Colombia.

CHAPTER

V

Fintech for inclusion, what do the region's countries think?

A. Characterization of fintech

1. Location in the financial services value chain[1]

There is no agreement over the scope of fintech concept. Its origin dates to 1972, when the term was used for the first time in an academic article describing mechanisms for resolving banking problems. It was then used as an acronym referring to the use of financial technology, combined with banking experience and automated management techniques (Bettinger, 1972). More recently, Schueffel (2016) reviewed over 200 academic articles that refer to the concept, applying semantic analysis methodologies and considering expert opinions to conclude that the expression refers to a new financial industry that uses technology to improve financial activities. Other approaches to the concept highlight the application of technological innovations to financial services and new business models, processes or products (KPMG, 2017). IDB/Finnovista (2017) defines "fintech" as the technological developments and new business models that have been applied in the financial sector over the last decade.

The International Organization of Securities Commissions (IOSCO) defines fintech as the use of technology and innovative business models in financial services or, alternatively, as non-bank institutions that use advanced technologies to engage in traditional banking activities (IOSCO, 2017).[2] This approach introduces an additional dimension: the distinction between traditional banks and non-bank entities.

These approaches provide an important starting point for this chapter. The analysis focuses on start-up firms that provide financial services using the new digital technologies. These firms, or groups of them, can be referred to as "fintechs", or even the fintech industry. Although the introduction of new technological trends can radically change the speed, quality and scope with which services are provided, the greatest impact occurs when new business models change value propositions, market segments and industry boundaries.

The financial functions affected by fintechs can be classified in various ways. One of the most widely accepted, CEF (2017), highlights five areas: (i) payments, clearing and settlement; (ii) deposits, loans and capital funding; (iii) insurance; (iv) investment management; and (v) market support. The consulting firm CB Insights (2018) identifies emerging trends and technology firms with a potential impact on the financial industry, with a classification that includes: (i) loans; (ii) payments and invoicing; (iii) management of personal finances and wealth management; (iv) money transfer and remittances; (v) cryptocurrencies; (vi) capital markets and tools for financial institutions; (vii) collective loans; and (viii) insurance.

Another view is provided in an IDB/Finnovista study (2017) where a cadastre is made of emerging Latin American fintech start-ups. This taxonomy is based on the main activity of the business: (i) alternative financing platform; (ii) alternative score (scoring); (iii) payment solutions; (iv) personal finance management; (v) business finance management; (vi) wealth management; (vii) trading in financial assets (trading) and the securities market; (viii) technology firms for financial institutions; (ix) digital banks; and (x) insurance.

In terms of technological innovations with the potential to improve small-business access to financing, Ventura and others (2015) identify five types of product: (i) peer-to-peer (P2P) lending; (ii) e-commerce and e-commerce finance; (iii) financial invoicing; (iv) financial supply chain; and (v) trade financing.

The following paragraphs draw on Tapscott and Tapscott (2016) to classify financial services in which fintech can play a disruptive role (see diagram V.1).

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1 This chapter was prepared by ECLAC staff members Jorge Patiño and Laura Poveda and the consultant Leonardo Mena.

2 IOSCO is an association of organizations that regulate securities and futures markets worldwide. Its members are usually the main financial regulator of each country or the lead regulators of the securities or futures market in a given national jurisdiction.

Diagram V.1
The fintech system

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Financial Stability Board (FSB), "Financial stability implications from fintech: supervisory and regulatory issues that merit authorities' attention", Basel, 2017 [online] http://www.fsb.org/wp-content/uploads/R270617.pdf.

(a) Authentication, custody and trust in value

Traditional intermediaries are currently used to establish trust and verify identity in a financial transaction; they are the main brokers when accessing basic financial services, such as bank accounts and loans. Fintechs can reduce and sometimes eliminate the need for that type of intermediary in certain transactions. They also allow a verifiable, robust and cryptographically secure identity to be established in a P2P relationship —through digital identification tools and distributed accounting technologies (blockchain), for example.

(b) Payments and transfers

Financial systems enable movements of money, valuables, bonds and securities, at the national or international level; and networks, practices and standards have been established for this purpose. Some established firms have designed and implemented alternative solutions for these transfers. Examples include the payment platforms provided by Google (Google Pay), Apple (Apple Pay) and Samsung (Samsung Pay), and mobile telecommunications operators that offer payment services. Between 2011 and 2016, the number of commercial mobile money solutions in Latin America grew from 10 to 33, while the number of markets with services of that type grew from eight to 17 (Rralthatha and Sanín, 2017).

(c) Credit

Financial institutions provide resources through credit cards, mortgages, bonds and asset-backed securities; and they have generated a credit evaluation industry, using mechanisms such as credit scores in the case of individuals or credit ratings for firms. This system suffers from two major shortcomings, however: (i) lending capacity depends heavily on the ability to determine risk; and (ii) there are frictions when adjusting or renegotiating rates and collateral, which raises costs and excludes customers with no credit history (or with a history of defaults), or those without real collateral. New technologies have the ability to reduce intermediation in the activities of registration, negotiation and settlement of debt instruments, as well as to reduce the risk of the operation. E-commerce platforms, such as Amazon and AliExpress, offer their users working capital financing and factoring services.

(d) Instruments of exchange (cryptocurrencies)

Global markets facilitate trading in assets and financial instruments for the purpose of transferring value. Digital exchange instruments, especially cryptocurrencies, are one of the most disruptive innovations in the traditional financial system. Firms and individuals can benefit from these innovations if transaction costs (spreads) are reduced, operations are streamlined, and intermediaries are eliminated. Moreover, blockchain technology offers advantages in terms of security, integrity and even transparency. Cryptocurrencies have grown exponentially: in January 2017 there were around 1,384 of them, of which the best known were bitcoin, ethereum, ripple, bitcoin cash and cardano (CoinMarketCap, 2018). Nonetheless, their use in illegal activities and a number of unresolved tax issues are reason for analysis and controversy.

(e) Investment

In many cases, making an investment involves multiple actors (banks, insurers and legal services). As new technologies reduce transaction costs and make risk assessment more efficient, market opportunities grow, and firms can tap new funding sources. Crowdfunding solutions based on digital platforms allow for P2P financing models and reduce information asymmetries and financial costs. These mechanisms make it easier to finance new ventures of all kinds, particularly those of a social, environmental or artistic nature. There are two forms of alternative crowdfunding: (i) one based on incentives, where the entrepreneur makes an advance sale of a product or concept without having to borrow or give up part of the business; and (ii) one in which part of a firm's share capital is offered online (Hsieh, 2014).

(f) Insurance and risk management

In the financial market, products and instruments designed to protect against financial losses have been developed as a form of risk management. Firms that apply new technologies to insurance businesses (an activity referred to as "insurtech") are attracting funds in large amounts.[3] In 2015 it was estimated that about US$ 2.7 billion had been invested in this type of enterprise worldwide. The firms in question focus on the distribution and sale of property, along with accident, health and life insurance. Products such as microinsurance or P2P insurance are based on technologies such as machine learning, automatic advising (robo-advisors) and the Internet of Things (Tanguy and others, 2017). Some countries, such as China, the Russian Federation and India, are amending their regulations to make insurance services more accessible through digital technologies (CEF, 2017).

(g) Audit and accounting

These activities face challenges in terms of reducing costs, increasing efficiency and maintaining quality. Fintechs make it possible to design accounting and auditing systems that use online platforms and integrate other business functions, such as payroll management and tax returns. These types of solution can also make it easier for regulators and other stakeholders to examine a firm's financial records.

3 The term "insurtech" was inspired by "fintech".

2. Disruptive potential

The transformative potential of fintech is empowered by the speed at which the technologies are absorbed and by the capacity of new firms to challenge the established ones. The strategies of the new firms tend to target customers at the lower end of demand (where profits are lower), or else they are based on the inclusion of new market segments. In the first case there is room for new firms because the established ones are serving the most profitable segments and ignore the needs of the rest. In the second, disruptive innovations aim to create a market where there is none, or else turn non-consumers into consumers (Christensen, Raynor and McDonald, 2015).

According to the World Economic Forum (2017), several forces are driving disruption in the financial industry: transformation of the fixed costs of asset purchase into the variable costs of acquiring a service; potential profit redistribution; the transfer of power to firms that connect directly with customers; the possibility of connecting platforms to multiple institutions; potential data analysis monetization; the ability of machines to replicate human behaviour; and increasing dependence on firms that are technological leaders and on regulatory differences.

In this way, firms are increasingly providing services and specializing in improving the user experience. The current threats to established firms vary according to the type of business. Despite being protected by regulation, the activities of retail banks (deposits, loans, account management and insurance) face new competitors that are emerging as aggregators that seek to enter the final sales market as intermediaries. This competition reduces profit margins among the established firms (McKinsey Global Institute, 2015). The impact is clearer in payment systems owing to disruptive innovations and the appearance of non-bank agents. This phenomenon is enhanced by the emergence of e-commerce and the sparse coverage of banking services in many developing countries. Banking for small and medium-sized enterprises (SMEs) is a segment that is relatively open to the entry of new players, whereas corporate banking, which includes more sophisticated services (syndicated loans, asset-based loans and others), could be less affected.

In short, McKinsey Global Institute (2015) estimates that, by 2025, revenues and profits could be significantly lower for the five most important activities of retail banks: consumer finance, payments, loans to SMEs, asset management and mortgages (especially among the first of these) (see table V.1).

Table V.1
Effects of the disruption of new digital financial technologies in five retail markets by 2025
(Percentages)

Markets	Change in profits	Change in income
Consumer financing	-60	-40
Payments	-35	-30
SME lending	-35	-25
Wealth management	-30	-15
Mortgages	-20	-10

Source: McKinsey Global Institute, *The Fight for the Customer: McKinsey Global Banking Annual Review 2015*, New York, 2015.
Note: Changes are expressed relative to 2025 projections without the impact of fintechs. Profits are expressed after tax and include savings in operating costs as a result of digitalization. Revenues are after deducting the cost of risk. Deposits are not included in the case of wealth management.

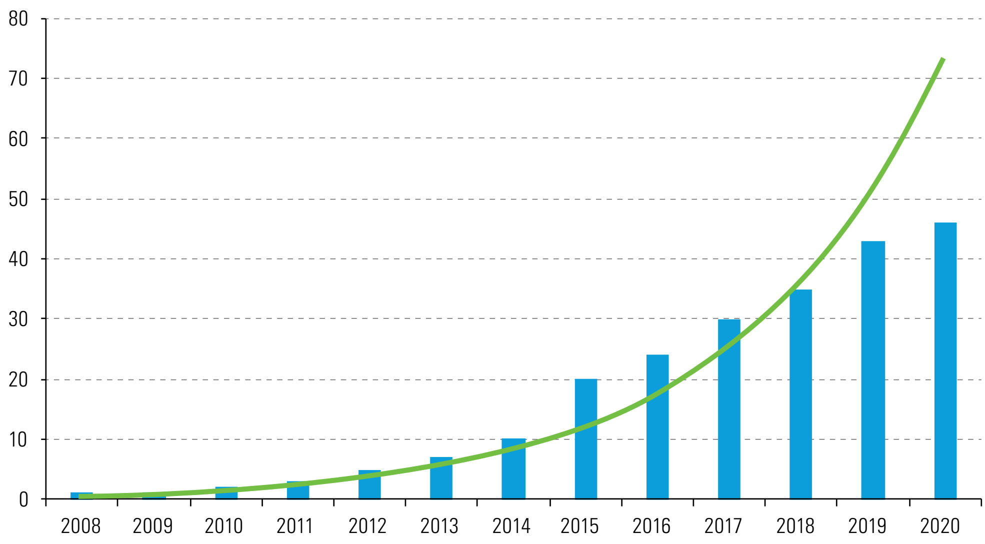
In the less advanced countries, sparse bank coverage provides an opportunity for the emergence of new services. In Africa and Asia, for example, mobile payment solutions have been widely deployed; and regulations to reduce the circulation of paper money (as have been launched in India) stimulate the use of digital media, such as electronic wallets. On the other hand, new platforms reduce profit margins in money transfer services: solutions such as TransferWise, which has cut the costs of sending money by more than 80%, is offering new alternatives to users.

Although the methods of providing services and the actors involved are changing rapidly, it is not clear that fintech trends are fundamentally changing intermediation in the financial system or economic functions (CEF, 2017). Although there are significant spaces for disruption in the industry, the impact will depend not only on innovation, but also on users' preferences. The strategies pursued by the regulatory authorities will also condition these transformations and their scope.

3. The recent dynamic

Investment in fintech is expected to grow rapidly, to reach a level of US$ 46 billion by 2020 (see figure V.1 and Deloitte, 2015). Although the trend is mainly being driven by technological innovation, user preferences and regulatory changes are also playing a role. The key trendsetting markets are the United States and China. According to EY (2017), the rates at which populations are adopting these technologies are led by China (69%), India (52%), the United Kingdom (42%), Brazil (40%), Australia and Spain (both with 37%) and Mexico (36%). Of the 27 unicorn fintech firms that exist worldwide, 14 are in the United States and eight in China.[4] Nonetheless, the value of such firms in China far exceeds that of their American counterparts (Citigroup, 2017).

Figure V.1
Global investment in fintech, 2008–2020[a]
(Billions of dollars)

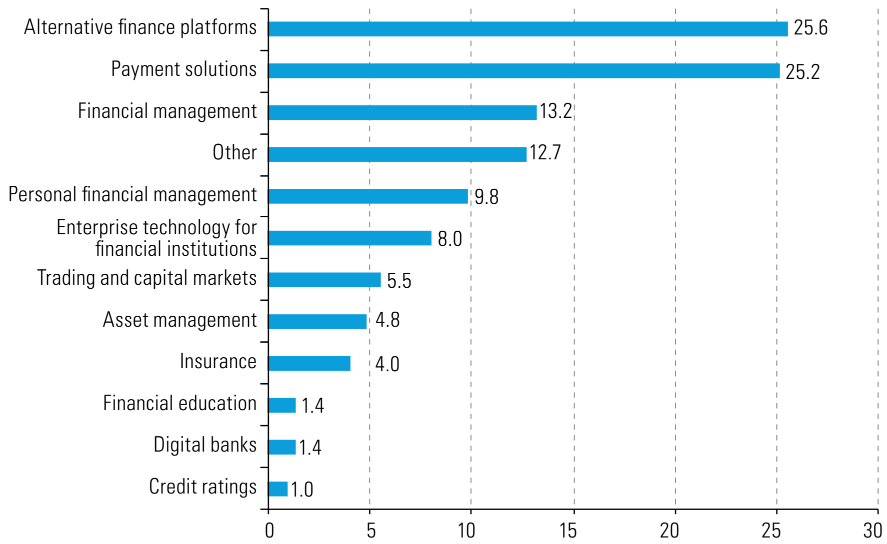


Source: Deloitte, "2016 Financial services M&A predictions: rising to the challenge", London, 2015 [online] https://www2.deloitte.com/uk/en/pages/financial-services/articles/2016-financial-services-ma-predictions.html.
[a] Figures from 2015 to 2020 are estimates.

In Latin America there is also a growing trend in the development of fintech firms. According to IDB/Finnovista (2017), there are 703 fintech start-ups in 15 of the region's countries, with 90% of them in just five: Brazil and Mexico (58% between them), along with Colombia, Argentina and Chile. Sixty per cent of firms offering services of this type in the region were created between 2014 and 2016 (IDB/Finnovista, 2017). In 2016, half of these firms were providing mainly crowdfunding and payment services (see figure V.2).

[4] A unicorn company is a private start-up with a market valuation of more than US$ 1 billion.

Figure V.2
Latin America: fintech initiatives by segment, 2016
(Percentages)



Source: Inter-American Development Bank/Finnovista (IDB/Finnovista), *Fintech: Innovations You May Not Know Were from Latin America and the Caribbean*, Washington, D.C., 2017.

The distribution of the number of fintech firms by activity segment and country reveals that the most important segments are: payments and remittances, loans, business and personal financial management, and crowdfunding (see table V.2).

Table V.2
Latin America (7 countries): distribution of fintech firms, by activity segment
(Percentages of total number of firms)

	Argentina	Brazil	Chile	Colombia	Ecuador	Mexico	Peru
Payments and remittances	25	26	21	22	16	20	21
Payments: cryptocurrencies	8	5				2	
Peer-to-peer (P2P) lending	5	2	7			6	
Loans	8	10	4	17	3	17	24
Trading and caoital markets	3	3	4	6	3	1	11
Business financial management	18	15	11	12	32	15	9
Crowdfunding	7	8	14	8	13	9	9
Wealth management	7	7	4	1	6	3	
Insurance	7	5	5	5	3	6	4
Scoring, identity and fraud	5	5	5	12		3	
Personal financial management	7	11	9	12	3	10	4
Financial education and savings		1	7	5		5	
Digital banking		2			3		
Bitcoin			9				
Enterprise technology for financial institutions					16	4	6
Alternative scoring							6
Savings							6

Source: Finnovista.
Note: Figures subject to rounding.

B. Solutions for MSME financial inclusion

1. Access to financing

Access to financing is one of the main challenges faced by micro, small and medium enterprises (MSMEs); and digital financial technologies are enabling new business models to emerge with the potential to significantly alleviate this problem. Ventura and others (2015) highlight five products that offer solutions to this business segment: P2P lending platforms, the operational financing offered by certain e-commerce firms, factoring, supply chain financing and international trade financing. These services are described below.

(a) Peer-to-peer lending platforms

While business models vary from one platform to another, they basically provide solutions that facilitate connections between borrowers and lenders, where collateral is generally not requested and innovative risk rating models are used, based on data analysis and employing semiautomatic mechanisms. Information sources are digital platforms or social networks; and loans applied for through these platforms are usually easier to obtain than in the banking system.

(b) E-commerce financing platforms

Platforms such as Amazon, eBay or Alibaba provide credit lines and working capital to their users. In many cases, these platforms are better prepared to evaluate credit risk than the banks, since they have more detailed information on their users' commercial transactions. Collection can also be more efficient, since transactions are made through their systems, and payments can be deducted directly from users' accounts.

(c) Factoring

Credit sales generate accounts receivable in a firm's balance sheet, which are often offloaded at a discount to obtain liquidity. Thus, online factoring solutions are offered to make it possible to monetize accounts receivable. These solutions can be directly integrated into accounting programs, which reduces the costs of loan applications for SMEs.

(d) Supply chain financing

This consists of solutions that give service providers better payment options in their supply chain. Suppliers can use a platform to can send invoices to buyers, with the option of a third party offering quicker payment at a discount. These operations, which are being streamlined by technological options and the integration of online business resource planning systems, are not considered credits; and they enable small firms providing goods and services to receive their payments more quickly.

(e) International trade financing

MSMEs have few alternatives for accessing this type of financing because they lack the resources to deal with the complex processes involved. Nonetheless, recent innovations allow for integrated online systems that replace traditional letters of credit. As with other financial products, there are alternatives in which third parties can finance this type of operation.

2. New value propositions

The new value propositions of firms that use fintech tend to target specific or customized solutions, designed to offer products or services that are not available from traditional banks. Solutions of this type can have positive effects on MSMEs by providing greater liquidity, improving the management of working capital and providing new financing channels. The following paragraphs draw on IDB/Finnovista (2017) to review Latin American examples of this type of firm.

(a) Authentication, custody, and trust in value

RSK (Argentina) is a decentralized platform of smart contracts based on blockchain, which aims to add value through the implementation of smart contracts and instantaneous payments.[5] In March 2016, the firm raised US$ 1 million to develop its platform and expand into Europe, Asia and the United States.

(b) Payments and transfers

Clip (Mexico) offers businesses or individuals a solution to accept payments with credit or debit cards directly on a smartphone or tablet, using a reader that connects to the device's audio output.[6] This was the first Mexican start-up to attract capital from Silicon Valley.

(c) Alternative or collective credit

Creditas (Brazil) is an online lending platform created in 2013 that funds loans for which borrowers post their homes or cars as collateral.[7] As of December 2016, it had an active loan portfolio of nearly US$ 6 million.

(d) Exchange instruments

Bitso (Mexico) offers inclusive and low-cost financial services.[8] It has been operating since 2014, targeted on the regulation and compliance of its customers' due diligence. In September 2016, it raised US$ 2.5 million in a financing round with institutional investors (Variv Capital, Monex Group, FundersClub and Digital Currency Group).

(e) Alternative or collective investment

Kubo Financiero (Mexico) is the first online P2P financial services community in the country and also the first authorized by the National Banking and Securities Commission (CNBV).[9] It is a platform in which borrowers with a good credit history obtain better interest rate and maturity conditions, while investors earn higher returns. Kubo Financiero has made 6,729 loans, has 6,616 clients and is growing at an annual rate of 300%.

(f) Insurance and risk management

Comparamejor (Colombia) is an online platform that makes it possible to compare and offer insurance for automobiles and motorcycles.[10] Since its launch in 2011, it has partnered with more than 11 insurance firms and has sold over 15,000 policies. Its website receives around 200,000 hits per month. It is the largest independent insurance portal in the country and the digital intermediary with the highest sales turnover in this segment.

5 See [online] https://www.rsk.co/.
6 See [online] https://clip.mx/.
7 See [online] https://www.creditas.com.br/.
8 See [online] https://bitso.com/.
9 See [online] https://www.kubofinanciero.com/.
10 See [online] https://comparamejor.com/.

(g) Audit and accounting

Nubank (Brazil) is an emerging firm that has launched a service through which accounts and credit cards can be applied for through a mobile application.[11] By offering a fully digital service, it has low operating costs and does not charge account maintenance fees. It has also developed a customer database and a credit rating system: while banks only use about 10 variables to evaluate customers, Nubank uses between 2,000 and 3,000. Founded in 2014, it has received over 8 million applications and raised more than US$ 170 million for investment.

C. Regulation: systemic efficiency and stability

1. Risk factors

The main risk associated with the entry of new financial agents is their potentially adverse effect on the stability of the sector and consumer protection (Zetzsche and others, 2017). In terms of financial sector stability, CEF (2017) distinguished between microfinancial and macrofinancial risks. The former make individual firms, the financial market infrastructure or certain sectors vulnerable to shocks, while the latter are vulnerabilities that can amplify shocks in the financial system and thus make financial instability more likely.

Magnuson (2017) identifies four factors as the main contributors to financial stability risk: (i) the extent to which individual actors are vulnerable to sudden and adverse shocks; (ii) the existence of multiple channels for adverse shocks to spread from one institution to another; (iii) the degree of information asymmetry prevailing in the market; and (iv) the total size of the market. Although the mere presence of one of these characteristics may not be enough to conclude that there is a systemic risk, its existence is indicative.

In terms of consumer protection, the risks vary according to services and technologies. For example, in P2P platforms, anonymity can facilitate fraud; while in blockchain, any doubt about the legality of a smart contract can introduce uncertainty. On the other hand, investment and asset management platforms that operate with robo-advisors can have errors in their systems and algorithms, which lead to undesired results (IOSCO, 2017).

2. Alternative models

The financial system faces technological changes as a result of the digitalization of its operations, transactions and currencies. As fintechs provide services offering alternatives to traditional financial activities, governments, regulatory bodies and the financial system itself must innovate in public-private international cooperation processes for the transfer and security of data and funds, if they want to continue hosting this type of business within the framework of the logic of traditional banking.

The regulatory debate on these firms must consider two aspects. First, they need to be recognized as agents of change that can contribute to greater competition in the financial sector in the short term, provide a more diversified banking service, reduce prices, increase the possibility of using the services and improve efficiency in the different links of the value chain, thus contributing to financial inclusion. Second, the risks associated with uncertainty and undesired effects must be reduced, safeguarding the goals of financial stability, consumer protection, competition and market development.

The regulatory approach for fintechs varies from country to country and depends on the structure of each market. The most recent experiences point in two directions: the United Kingdom, which is moving from product- to principles-based regulation, is targeting consumer protection and introducing regulatory test environments (sandboxes) and greater cooperation with industry; China in contrast, where regulation continues to be product-based, is segmenting the treatment of transactions (the smaller ones can be made through Internet firms but the larger ones must be handled by the established institutions (State banks)) (Arner, Barberis and Buckley, 2016).

[11] See [online] https://www.nubank.com.br/.

The regulatory work is particularly complex. Product-based approaches can be technically attractive in principle; but they pose problems if implemented in a context where multiple entities engage in multiple activities. The cross-cutting scope of the regulations and the need for capacity to control them may render them inapplicable. On the other hand, regulation by type of entity may be simpler, but at the same time it may leave relevant players unregulated, or else not extend the regulations to those of other activities.

A balance needs to be struck between innovation and protecting both consumers and financial stability. Given the presence of uncertainty, one alternative may be to adopt a flexible approach that allows technology to develop and markets to mature before intervening. For the regulator, it is a question of finding a solution that allows a gradual transition, while making it possible to gather more information before deciding on any type of action.

3. Constraints

The following are some of the issues that regulators need to consider in the treatment of digital financial technology firms.

(a) Regulatory technology

The application of digital technologies to regulation provides an opportunity. Regulatory innovation could improve processes and make more detailed market information available. In this case, the regulators would not just be spectators of the technological advance, but also innovators interacting with the industry. In several countries, such as the United Kingdom, there are spaces for cooperation between regulators and firms, and they are considered investments in regulatory technology. These new technologies include: pattern analysis, predictive programming to detect irregular actions, and big data analysis (Arner, Barberis and Buckley, 2016).

(b) Improving the quality of information and dialogue

In many areas, fintechs operate differently to established financial institutions, which raises the need for mechanisms to gain a better understanding of their behaviour. Regulators can, for this purpose, create incentives that facilitate interaction with these firms and their monitoring. An instrument already mentioned is the creation of regulatory test environments, where new products can be tested and launched in unregulated contexts. Another initiative that can facilitate interaction with this type of firm is the creation of specific fintech divisions or units in the regulatory institutions, and the promotion of organizations encompassing these firms (Annex V.A1 contains a list of the main fintech associations in the region).

(c) Promoting international cooperation

Most of the activities of fintechs are cross-border by nature; so regulations that apply in a particular jurisdiction may affect other markets. For example, many crowdfunding sites operate internationally by connecting actors in different countries; blockchain technologies operate in a decentralized manner; and robo-investment advisers provide online services to customers around the world. In this scenario, it is important that regulators from different countries cooperate with each other to improve their understanding of these innovations and act in a coordinated way, thereby reducing systemic risks. This cooperation does not mean that the regulations are uniform, but that there is an exchange of experiences between different approaches to the phenomenon (Magnuson, 2017).

(d) Promoting innovation

New technologies do not have to overcome all existing ones; it is sufficient that they make it possible include customers who are currently are outside the market or have to pay exclusionary prices. An example is portfolio management through automatic consultants. As a large proportion of individuals and firms are excluded from these services, because they require highly qualified personnel, the action of such advisers can allow them to venture into new instruments and opportunities, albeit in a limited way.

D. Perception of digital financial technologies in Latin America and the Caribbean

To gain an overview of the status of regulation of the fintech industry in the region, a survey conducted by the Economic Commission for Latin America and the Caribbean (ECLAC)[12] of a group of 11 countries sought opinions from financial regulators on three topics. The results are discussed below: (i) potential impact, (ii) legal and regulatory treatment; and (iii) opportunities and risks. Table V.3 lists the countries and institutions that responded to this survey.

Table V.3
Latin America and the Caribbean: countries and institutions that responded to the questionnaire on the status of the legal and regulatory framework of the fintech industry

Country	Institution
Argentina	Central Bank of the Argentine Republic
Brazil	Central Bank of Brazil
Colombia	Financial Superintendency of Colombia
Costa Rica	General Superintendency of Financial Institutions (SUGEF)
Dominican Republic	Banking Superintendency of the Dominican Republic
El Salvador	Superintendency of the Financial System (SSF)
Guatemala	Banking Superintendency
Honduras	National Banking and Insurance Commission (CNBS)
Mexico	National Banking and Securities Commission (CNBV)
Paraguay	Banking Superintendency
Uruguay	Central Bank of Uruguay, Superintendency of Financial Services

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

1. Potential impact

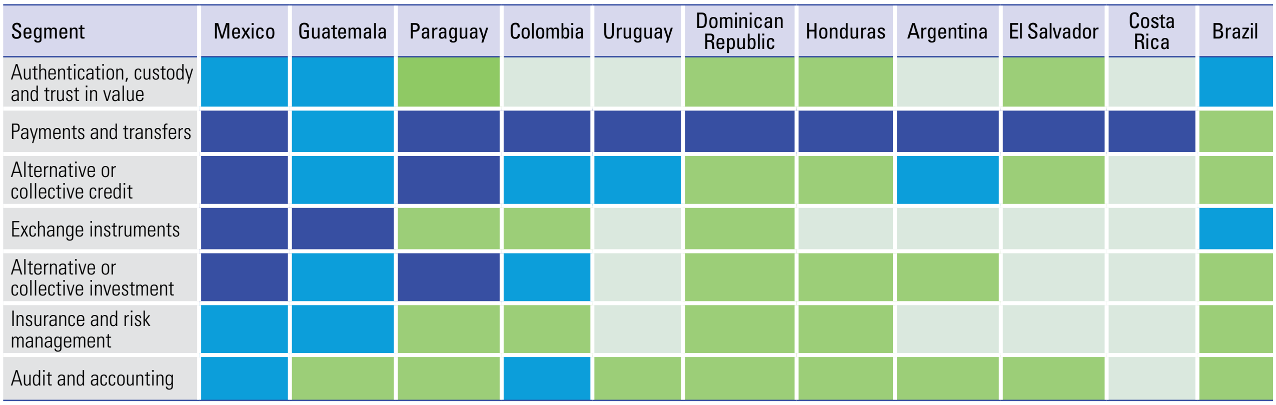
Table V.4 reports perceptions of the expected effect of fintech firms in seven segments of the financial market, in terms of the activities classification presented at the start of the chapter. The authorities that were consulted considered the payments and transfers segment as having the highest impact, followed by collaborative credit and alternative or collaborative investment. These results coincide with the importance of investment by firms that use these new technologies in these segments.

Mexico, Guatemala, Paraguay and Colombia are the countries that consider fintechs as having the greatest potential and capacity to permeate a wide range of financial activities. In contrast, Brazil does not take such an optimistic view, despite being one of the leading countries in the region in this activity.

In addition to the included segments, some countries consider that services supporting digital technologies, stock exchange trading platforms, biometric identity validation and personal finance management are other activities that could be greatly affected by the development of these technologies.

12 The survey was conducted between January and February 2018. The individuals questioned were working as directors of studies (*intendentes de estudios*), operational risk managers, analysts, advisors or regulators, among others.

Table V.4
Latin America and the Caribbean (11 countries): intensity of the expected effect of the fintech industry, by market segment
(Financial market segments)



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the questionnaire on the status of the normative and regulatory framework of the fintech industry.
Note: The colours indicate the intensity of expected effect; the darker the colour, the greater the expected effect.

2. Regulatory treatment

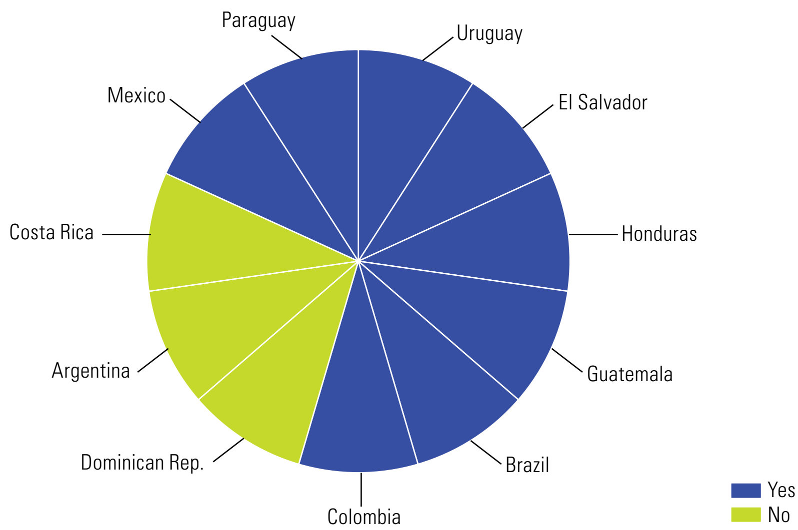
Of the 11 countries that responded to the survey, eight have recent regulations on fintechs, or expect to have some type of regulation of fintech activities in the near future (see table V.5). These include Mexico, which, in March 2018, passed the Law Regulating Financial Technology Institutions to provide a framework for these services. This legislation, which puts Mexico at the forefront of provisions for the development of these services in the region, addresses aspects of electronic payment funds, crowdfunding and virtual assets (see figure V.3).

Table V.5
Latin America (8 countries): recently adopted regulations or regulatory projects under way for fintech activities

Country	Regulation	Institution promoting the initiative	Main legal instruments that would be or were modified or adapted by the regulations
Paraguay	Electronic means of payments entities (EMPE), electronic wallets	Central Bank of Paraguay and National Securities Commission (CNV)	Securities Market Law and draft law on crowdfunding
Uruguay	Financial Inclusion Law (No. 19.210)	Central Bank of Uruguay and Ministry of Economy and Finance	Circular No. 2198 amended the Central Bank of Uruguay's compilation of payment system regulations. The draft regulation on peer-to-peer lending will alter the compilation of regulations and rules governing the financial system produced by the Superintendency of Financial Services of the Central Bank of Uruguay
El Salvador	Law to regulate electronic money	Central Reserve Bank of El Salvador	Law to Facilitate Financial Inclusion (Legislative Decree No. 72)
Honduras	Electronic money regulation	National Banking and Insurance Commission (CNBS)	Law on Payment Systems and Securities Settlement. Rules were created on the supervision of non-bank institutions that provide payment services using electronic money
Guatemala	Issuance of law on digital financial technology	Banking Superintendency and others	Law on Banks and Financial Groups and the respective regulations
Brazil	Law No. 12.685 of 2013; Central Bank Resolution. 4282 of 2013; Central Bank Circulars Nos. 3680/2013, 3681/2013, 3682/2013 and 3683/2013[a]	Central Bank of Brazil, Ministry of Finance, Securities Commission (CVM), Securities Market Commission and Private Insurance Superintendency (SUSEP)	Law No. 12.865 of 2013 (payment schemes); Law No. 10.214 of 2001 (records); National Council of Private Insurance (CNSP) Resolution No. 294 of 2013 (use of remote media in operations relating to insurance plans and open supplementary pension plans)
Colombia	Draft decree on the administration of electronic crowdfunding platforms	Ministry of Finance and Public Credit	Decree No. 2555 of 2010 compiling and reissuing the rules on the financial, insurance and securities market sectors, and issuing other provisions
Mexico	Law to Regulate Financial Technology Institutions	Banco de México, Ministry of Finance and Public Credit and National Banking and Securities Commission	Law on Credit Institutions; Securities Market Law; General Law of Credit Organizations and Auxiliary Activities; Law for Transparency and Organization of Financial Services; Law to Regulate Credit Information Firms; Law on Protection and Defence of Financial Service Users; Law to Regulate Financial Groups; Law of the National Banking and Securities Commission; Federal Law for the Prevention and Identification of Operations Using Funds of Illegal Origin

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
[a] No specifically on fintech.

Figure V.3
Latin America and the Caribbean (11 countries): countries in which fintech has been regulated or is expected to be regulated



Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the questionnaire on the status of the normative and regulatory framework of the fintech industry.

Table V.6 shows the topics on which some type of regulation has been issued, or is expected to be issued in the near future. Thus far, regulators have mainly focused on issues related to means of payment and transfers, owing to the heavy concentration of firms providing this type of service.

Table V.6
Latin America and the Caribbean (11 countries): market segments in which fintech is regulated or is expected to be regulated

Segment	Paraguay	Uruguay	El Salvador	Honduras	Brazil	Mexico	Guatemala	Colombia	Costa Rica	Argentina	Dominican Republic
Authentication, custody and trust in value	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued	Currently undergoing legislative or regulatory processing	No new regulations issued	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued
Payments and transfers	Regulations issued in the last three years	Regulations issued in the last three years	Regulations issued in the last three years	Regulations issued in the last three years	Regulations issued in the last three years	Currently undergoing legislative or regulatory processing	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued
Exchange instruments	Currently undergoing legislative or regulatory processing	Currently undergoing legislative or regulatory processing	No new regulations issued	No new regulations issued	New regulations expected to be issued in the next three years	Currently undergoing legislative or regulatory processing	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued
Alternative or collective credit	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued	Currently undergoing legislative or regulatory processing	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued
Alternative or collective investment	Currently undergoing legislative or regulatory processing	No new regulations issued	No new regulations issued	No new regulations issued	Regulations issued in the last three years	Currently undergoing legislative or regulatory processing	New regulations expected to be issued in the next three years	Currently undergoing legislative or regulatory processing	No new regulations issued	No new regulations issued	No new regulations issued
Insurance and risk management	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued	Currently undergoing legislative or regulatory processing	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued
Audit and accounting	No new regulations issued	No new regulations issued	No new regulations issued	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	New regulations expected to be issued in the next three years	No new regulations issued	No new regulations issued	No new regulations issued	No new regulations issued

No new regulations issued
New regulations expected to be issued in the next three years
Currently undergoing legislative or regulatory processing
Regulations issued in the last three years

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the questionnaire on the status of the normative and regulatory framework of the fintech industry.
Note: In the case of Mexico, the survey was applied before the Law to Regulate Financial Technology Institutions was passed.

Another segment that also attracts attention is alternative financing or crowdfunding. The Board of Directors of the Financial Regulation Projection and Studies Unit (URF) of the Ministry of Finance of Colombia approved a draft decree to regulate electronic platforms for crowdfunding in the country, which is expected to enter into force in 2018. This project establishes the norms on investment limits and financing amounts, information disclosure, the operational standards of the required infrastructure, prevention of money laundering and management of conflicts of interest, among other issues.

In August 2017, for example, the Central Bank of Brazil also issued Public Consultation Decree No. 55 of 2017 on the regulatory proposal for firms specializing in lending through electronic platforms, which provides for the creation of direct credit firms and person-to-person loan firms. The main activity of the former will be to make loans through electronic platforms using financial resources obtained exclusively from their capital, while the latter refer to intermediation activities of between borrowers and lenders (P2P loans).

In addition to the segments considered, some countries, such as El Salvador and Guatemala, have indicated the possibility of issuing regulations on foreign-currency dealings.

3. Opportunities and risks of fintech

In terms of risk factors, the countries questioned cite cybersecurity as the main problem (see table V.7). Losses suffered by the Latin American financial sector from cybersecurity shortcomings total nearly US$ 1 billion per year (BBVA, 2017). Nonetheless, in many of the region's countries, the concept of cybercrime and combating it remain absent from national laws. The authorities consulted do not foresee major risks in terms of liquidity, insolvency or disruptions in cash flows.

Table V.7
Latin America and the Caribbean (11 countries): degree of risk in the fintech industry

Risk factor	Paraguay	Colombia	Mexico	Guatemala	Uruguay	Dominican Republic	Brazil	Costa Rica	El Salvador	Argentina	Honduras
External effects that can threaten price stability	green	light blue	pale	green	pale	pale	green	green	green	green	green
Bad macroeconomic projections	green	green	pale	green	pale	pale	green	green	pale	green	pale
Excess or insufficient liquidity in the banking sector	green	green	pale	green	pale	pale	pale	pale	pale	pale	pale
Bank insolvency	green	green	pale	green	pale	pale	pale	pale	pale	pale	green
Disruptions in the flow of funds at the interbank or retail level	light blue	green	pale	light blue	pale	pale	pale	pale	pale	pale	green
Risk assessment error	dark blue	dark blue	dark blue	light blue	pale	green	green	pale	green	green	green
Cybersecurity	dark blue	dark blue	dark blue	dark blue	dark blue	light blue	light blue	light blue	light blue	green	green
Encouragement of illicit activities and money laundering	light blue	light blue	dark blue	dark blue	light blue	light blue	light blue	green	green	pale	green

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: The colours indicate the intensity of expected effect; the darker the colour, the greater the expected effect.

In terms of opportunities, the authorities consulted have different points of view, but they agree on the high potential of digital financial technology (see table V.8). They highlight the reduction in transaction costs and the greater efficiency in payment systems, along with the improvement in universal access to financial services by individuals and SMEs, in addition to greater competition in the sector. In Mexico, about 46% of emerging fintechs are concentrated in the underbanked and unbanked consumers and SMEs market, while in Brazil the equivalent figure is 28% (IDB/Finnovista, 2017).

Table V.8
Latin America and the Caribbean (11 countries): perception of opportunities generated by fintech

Reason for opportunity	Colombia	Argentina	Dominican Republic	Honduras	Guatemala	Mexico	Uruguay	Brazil	Paraguay	El Salvador	Costa Rica
Efficiency in payment and transfer systems											
Reduction of transaction costs											
Mobilization of a larger volume of information to assess credit risk more effectively											
Improved credit risk management through a smart network of contracts and guarantees											
Improvement of universal access to financial services by consumers and SMEs											
Greater competition and less concentration in the financial sector											

Source: Economic Commission for Latin America and the Caribbean (ECLAC).
Note: The colours indicate the intensity of expected effect; the darker the colour, the greater the expected effect.

E. Conclusions

New digital financial technologies reduce transaction costs and information asymmetries, lower entry barriers and intensify competition. A set of new firms and services is thus deployed in different segments of the financial sector value chain, with the opportunity to serve unbanked sectors, such as SMEs and low-income groups. Fintech firms are fostering innovation and promoting knowledge-intensive activities and technology.

These ventures are burgeoning in Latin America and the Caribbean, with means of payment and alternative or crowdfunding solutions the segments that concentrate most of these initiatives. Brazil and Mexico are the key markets for the development of enterprises in these segments.

Although not immune to uncertainty and risks, the emergence of fintech firms can generate conditions favouring the development of a more inclusive and transparent financial system. As was the case with the development of other regulated sectors, instead of imposing restrictions on new firms, it is possible to produce a more open ecosystem that generates conditions to promote innovation. Most of these firms provide specialized services within their value chain, which allows regulators to experiment with different models, without the complexity or impact of having to supervise institutions that operate throughout the value chain and are critical for financial stability.

Promotion of the use of regulatory technologies and the improvement of the quality of information and dialogue with firms, creating incentives that facilitate interaction and monitoring, are some of the steps that can be taken in the regulatory domain for firms that use digital financial technologies. Promoting international cooperation is also important in a globally interconnected environment.

As in the rest of the world, the regulation of fintech firms is incipient in the region; and most the countries surveyed still do not have regulation in many of the segments. Mexico has progressed the furthest in this regard. The other leading countries in the region —Brazil and Colombia— are in the stages of development, approval and entry into force of new regulations. The segments to which the regulators pay most attention are means of payment and transfers. In terms of risks, the main concerns are cybersecurity and illicit activities, including money laundering.

Bibliography

Aggarwal, R. and P. Stein (2016), "The complex regulatory landscape for fintech: an uncertain future for small and medium-sized enterprise lending", *White Paper*, Geneva, World Economic Forum, August [online] http://www3.weforum.org/docs/WEF_The_Complex_Regulatory_Landscape_for_Fintech_290816.pdf.

Arner, D., J. Barberis and R. Buckley (2016), "The evolution of fintech: a new post-crisis paradigm?", *University of Hong Kong Faculty of Law Research Paper*, No. 2015/047, Kowloon Tong, University of Hong Kong, October.

BBVA (Banco Bilbao Vizcaya Argentaria) (2017), "La ciberdelincuencia, una amenaza para la banca de América Latina", 4 September [online] https://www.bbva.com/es/ciberdelincuencia-amenaza-banca-america-latina/.

Bettinger, A. (1972), "Fintech: a series of 40 time-shared models used at Manufacturers Hanover Trust Company", *Interfaces*, vol. 2, No. 4, Catonsville, Institute for Operations Research and the Management Sciences (INFORMS), August.

Burgueño, C. (2017), "Decisión definitiva: no habrá regulación del BCRA para las fintech", *Ámbito Financiero*, Buenos Aires, 20 October [online] http://www.ambito.com/900920-decision-definitiva-no-habra-regulacion-del-bcra-para-las-fintech.

CB Insights (2018), "Fintech Trends to Watch in 2018", New York [online] https://www.cbinsights.com/research/report/fintech-trends-2018/.

Christensen, C., M. Raynor and R. McDonald (2015), "What is disruptive innovation?". *Harvard Business Review*, Watertown, Harvard Business Publishing, December [online] https://hbr.org/2015/12/what-is-disruptive-innovation.

Citigroup (2017), *Digital Disruption Revisited: What Fintech VC Investments Tell us About a Changing Industry*, New York, January.

CoinMarketCap (2018), "Cryptocurrency market capitalizations", 28 February [online] https://coinmarketcap.com/.

Cordero, C. (2017), "Las Fintech reconfiguran el mapa del sector informático", *El Financiero*, San José, 9 December [online] https://www.pressreader.com/costa-rica/el-financiero-costa-rica/20171209/textview.

Deloitte (2015), "2016 Financial services M&A predictions: rising to the challenge", London [online] https://www2.deloitte.com/uk/en/pages/financial-services/articles/2016-financial-services-ma-predictions.html.

Dorfleitner, G. and others (2017), "Definition of fintech and description of the fintech industry", *Fintech in Germany*, Berlin, Springer.

ECLAC (Economic Commission for Latin America and the Caribbean) (2015), *Reinforcing production cooperation and dialogue spaces: the role of SMEs* (LC/L.4020), Hamburg, EU-LAC Foundation, May.

EY (2017), "EY Fintech Adoption Index 2017: key findings", New York [online] http://www.ey.com/Publication/vwLUAssets/ey-fintech-key-findings-2017/$FILE/ey-fintech-key-findings-2017.pdf.

Ferraro, C. (comp.) (2011). *Eliminando barreras: el financiamiento a las pymes en América Latina* (LC/R.2179), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC)/ Spanish Agency for International Development Cooperation (AECID), November.

FSB (Financial Stability Board) (2017), "Financial stability implications from fintech: supervisory and regulatory issues that merit authorities' attention", Basel, June [online] http://www.fsb.org/wp-content/uploads/R270617.pdf.

Finnovista (2017), "The Mexican fintech ecosystem grows 50% in less than a year and overtakes Brazil as the fintech leader in Latin America", Mexico City, 6 July [online] https://www.finnovista.com/update-fintech-radar-mexico/?lang=en.

Hoder, F. and others (2016), "La revolución fintech: cómo las innovaciones digitales están impulsando el financiamiento para las mipyme en América Latina y el Caribe", New York, Oliver Wyman/ Inter-American Investment Corporation (IIC), September [online] http://www.ebankingnews.com/wp-content/uploads/2017/02/La-Revoluci%C3%B3n-Fintech.pdf.

Hsieh, C. (2014), "Crowdfunding: some basics", 9 September [online] http://www.chsieh.com/uploads/4/4/7/9/4479813/crowdfunding__some_basics.pdf.

IDB/Finnovista (Inter-American Development Bank/Finnovista) (2017), *Fintech: Innovations You May Not Know Were from Latin America and the Caribbean*, Washington, D.C., May.

IIMV (Ibero-American Institute of Securities Markets) (2017), *La financiación de las micro, pequeñas y medianas empresas a través de los mercados de capitales en Iberoamérica*, Madrid.

IOSCO (International Organization of Securities Commissions) (2017), "IOSCO research report on financial technologies (fintech)", Madrid, February [online] https://www.iosco.org/library/pubdocs/pdf/IOSCOPD554.pdf.

KPMG (2017), "The Pulse of Fintech Q3 2017: Global Analysis of Investment in Fintech", Amstelveen, November [online] https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2017/11/pulse-of-Fintech-q3-17.pdf.

Magnuson, W. (2017), "Regulating fintech", *Texas A&M University School of Law Legal Studies Research Paper*, No. 17-55, Fort Worth, Texas A&M University.

Mahoney, N., A. Veiga and G. Weyl (2014), "Competition policy in selection markets", *CPI Antitrust Chronicle*, Competition Policy International (CPI), September.

McKinsey Global Institute (2015), *The Fight for the Customer: McKinsey Global Banking Annual Review 2015*, New York, September.

OECD (Organization for Economic Cooperation and Development) (2017), "Technology and innovation in the insurance sector", Paris [online] https://www.oecd.org/finance/Technology-and-innovation-in-the-insurance-sector.pdf.

OECD/ECLAC (Organization for Economic Cooperation and Development/Economic Commission for Latin America and the Caribbean) (2013), *Latin American Economic Outlook, 2013. SMEs Policies for Structural Change* (LC/G.2545), París, January.

Philippon, T. (2017), "The fintech opportunity", *BIS Working Paper*, No. 655, Basel, Bank for International Settlements (BIS), August.

Rralthatha, R. and J. Sanín (2017), "Mobile money in Latin America and the Caribbean: Five years of growth", London, GSM Association, 9 November [online] https://www.gsma.com/latinamerica/es/dinero-movil-en-latinoamerica-y-el-caribe-un-lustro-de-crecimiento.

Schueffel, P. (2016), "Taming the beast: a scientific definition of fintech", *Journal of Innovation Management*, vol. 4, No. 4, Porto, University of Porto.

Tanguy, C. and others (2017), "Insurtech: the threat that inspires", McKinsey Global Institute, March [online] https://www.mckinsey.com/industries/financial-services/our-insights/insurtech-the-threat-that-inspires#0.

Tapscott, D. and A. Tapscott (2016), *Blockchain Revolution: How the Technology behind Bitcoin Is Changing Money, Business, and the World*, New York, Penguin Random House, May.

Ventura, A. and others (2015), "The future of fintech: a paradigm shift in small business finance", Geneva, World Economic Forum, October [online] http://www3.weforum.org/docs/IP/2015/FS/GAC15_The_Future_of_FinTech_Paradigm_Shift_Small_Business_Finance_report_2015.pdf.

World Economic Forum (2017), "Beyond fintech: a pragmatic assessment of disruptive potential in financial services", Geneva, August [online] http://www3.weforum.org/docs/Beyond_Fintech_-_A_Pragmatic_Assessment_of_Disruptive_Potential_in_Financial_Services.pdf.

Zetzsche, D. and others (2017), "From fintech to techfin: the regulatory challenges of data-driven finance", *EBI Working Paper series*, No. 6, Frankfurt, European Banking Institute.

Annex V.A1
Main fintech business associations in Latin America

Mexican Association of Crowdfunding Platforms (AFICO)
Fondify (see [online] https://fondify.mx/)
HipGive (see [online] https://hipgive.org/)
Donadora (see [online] https://donadora.mx/)

Asociación Fintech México (México)
Afluenta (see [online] https://www.afluenta.com/)
Alibre (see [online] https://www.alibre.io/)
Axend (see [online] https://axend.co/)
Kubo Financiero (see [online] http://www.kubofinanciero.com/Kubo/Portal/index.xhtml)
Mi Cochinito (see [online] https://www.micochinito.com/)
Olympian Capital (see [online] https://ocapital.mx/)
Propeler (see [online] https://www.propeler.mx/)
Zigo Capital (see [online] https://zigocapital.com/)

Brazilian Equity Crowdfunding Association (Brasil)
Kria (see [online] https://www.kria.vc/)
EqSeed (see [online] https://eqseed.com/)
Kickante (see [online] https://www.kickante.com.br/)
URBE.ME (see [online] https://urbe.me/)
StartMeUp (see [online] https://www.startmeup.com.br/)

Brazilian Fintech Association (ABFINTECHS) (Brasil)

Colombian Association of Financial Technology and Innovation Firms (Colombia Fintech) (Colombia)
Afluenta (see [online] https://www.afluenta.com/)
ArmaTuVaca (see [online] https://armatuvaca.com/)
Broota (see [online] https://broota.com/)
HomeParte (see [online] https://www.homeparte.com/es)
Ideame (see [online] https://www.idea.me/)
Kuanto (see [online] https://www.kuanto.co/)
La Vaquinha (see [online] https://www.lavaquinha.com/)
Mesfix (see [online] https://www.mesfix.com/)
Uprop (see [online] https://www.uprop.co/)

Crowdfunding firms registered in Chile
Broota
Facturedo
Ideame
RedCapital
Becual
Let's Fand
Soho
Cumplo (sponsored by the Production Development Corporation (CORFO))

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

CHAPTER

VI

The industrial Internet for advanced manufacturing

Introduction[1]

The development of disruptive digital technologies has led to a transition from the consumer Internet to the ecosystem of advanced manufacturing, where the new frontier of applications has shifted from individual devices to integrated systems with multiple interconnected sensors. This new phase in the digital economy is the result of the coevolution of the Internet of Things (IoT) and new connectivity networks, cloud computing, big data analytics, additive manufacturing (3D printers), robotics and artificial intelligence systems.

Advanced manufacturing represents the next great wave of innovation and it is expected to bring about far-reaching changes in production models throughout the economy. Advanced manufacturing offers an opportunity to build sustainable growth on the back of more efficient, diversified and low-carbon production systems. However, the world is adopting these technologies at different rates and, consequently, a new digital gap is opening up between companies, countries and regions.

For high-tech industrial companies, the new manufacturing methods promise obvious economic benefits in terms of efficiency and productivity. However, most traditional industrial companies are up against a number of barriers —infrastructural, technological, financial and administrative— that hamper the adoption of new technologies. Removing those obstacles requires public policies that encourage technological investment by companies, access to technology suppliers, the availability of those suppliers and specialized personnel training.

This technological revolution is taking place at a time of growing debate about and disenchantment with economic globalization. On the one hand, some observers forecast a lengthy period of economic stagnation, growing inequality in the distribution of the benefits of globalization and job losses as a result of new automation technologies. From another perspective, others argue that digital innovation, through creative destruction, will continue to be a source of growth as manufacturing technologies have been since the Industrial Revolution.

International experience shows that the leading countries are taking advantage of the opportunities offered by advanced manufacturing by introducing reforms focused on transforming their production structures towards greater productivity, sophistication and diversity. To achieve that, they have been implementing mission-guided industrial policies that go beyond the approach based on market failure theory. The digital transformation of manufacturing is a complex and dynamic process that requires a combination of hardware and software technologies, networking, data storage, analytics, cognitive technologies and artificial intelligence. This complexity has led to the development of new technological platforms that demand new forms of collaboration between companies, industries and the public sector.

This chapter presents a conceptual framework for analysing the industrial Internet and its implications for advanced manufacturing, particularly as regards convergence between advanced manufacturing and services.[2]

A. Technological bases

The industrial Internet is based on three technological pillars: connectivity networks, cross-industry platforms that cover several industries, and vertical specialization, where technologies at different levels of development converge. These include connectivity networks, the Internet of Things, robotics, artificial intelligence systems, additive manufacturing, cloud computing, and big data storage and analytics (see table VI.1). This concentration in the implementation and use of new technologies poses highly complex challenges for companies and organizations in monitoring activities that take place in the industrial Internet ecosystem.

1 This chapter was prepared by Mario Castillo and Nicolo Gligo of the Production, Productivity and Management Division of ECLAC.
2 For a more detailed analysis of this topic, see Castillo (2017). Annex VI.A1 identifies the sectors covered by the concept of advanced manufacturing.

Table VI.1
The three pillars of the industrial Internet

	Mature	Advanced	Emerging
Connectivity	Fixed and mobile (3G and 4G) broadband	Short- to medium-range wireless: WiFi, Bluetooth, mesh networks, narrow-band Internet of Things (NB-IoT) and low-power wide-area networks (LPWAN)	Next generation networks (5G)
Cross-industry platforms	Data storage, cloud computing and common sensors	Internet of Things, machine-to-machine communications (M2M), big data, intelligent devices and security platforms	High-performance computing and Internet of Things platforms
Vertical specialization	Uncommon sensors and additive manufacturing (3D printing)	Cyberphysical systems, network platforms, drones and autonomous vehicles	Visualization, robots and artificial intelligence

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of the Gartner Hype Cycle methodology.

The digitization of industrial production has sped up in recent years as the result of a new convergence between industrial process operating technologies and the industrial Internet. There have been three main phases of convergence over the past five decades. The most notable of these is the most recent, in which developments related to the Internet of Things, cloud computing, big data analytics and robotization have brought about a new factory model that has changed the paradigms of production, organization and business models, primarily in the industrial sector.

Industrial automation and its convergence with information technologies is not a new phenomenon: instead, it emerged in a series of stages, facilitating progressive improvements in operating technologies. Initially, in the 1960s and 1970s, it allowed improvements within individual activities; improvements in the coordination of activities followed in the 1980s and, more recently, it has facilitated improvements throughout the entire product cycle (see table VI.2).

Table VI.2
Evolution of automation technologies

	Operations and engineering	Business processes and suppliers	Development period
Individual activities at the machine level	Computer numeric control (CNC) Computer aided design (CAD)	Manufacturing resource planning	1960s and 1970s
Coordination of activities at the factory, supplier and customer levels	Computer integrated manufacturing (CIM) Distributed manufacturing Digital simulation 3D digital modelling	Customer relationship management (CRM) Supply chain management Enterprise resource planning (ERP)	1980s and 1990s
Complete product cycle at the value chain level	Virtual manufacturing enterprise Modelling, simulation and analysis Remote high-performance computing	Cloud-based CRM Cloud-based ERP	2010 to the present

Source: Economic Commission for Latin America and the Caribbean (ECLAC).

In addition to improving process controls and increasing production scale flexibility, the emergence of this new technological model has structural implications for how the economy is organized. In this case, it is not merely a matter of connecting objects and machines to coordinate operations or of building intelligent optimization networks; instead, for the first time in history, the possibility of constructing autonomous learning systems exists. Table VI.3 depicts the evolution of digital factories in the areas of automation, connectivity and human interaction. The current situation, characterized by simple and repetitive automated processes and by isolated robotization, will evolve by way of more complex and flexible processes with collaborative robotization towards intelligent, adaptive processes and, most importantly, autonomous robots.

Table VI.3
Evolution of the digital factory

	Now	In five years' time	In ten years' time
Connectivity	Local networks	Integrated networks	Hyperconnectivity
Automation	Simple and repetitive	Complex and flexible	Intelligent and adaptive
Human interaction	Caged robot	Collaborative robots	Machines that learn

Source: ABB Group.

B. The value chain

The industrial Internet's value chain is different from that of the consumer Internet in two ways. First, it requires a high level of coordination and interoperability among its components and, second, it entails fewer barriers to learning and to market entry and development of products and services.

As new communications standards are established, the complete cycle of any product or service can be addressed: from development and engineering, through manufacturing to use, maintenance and recycling. This value chain is more fragmented and demands a higher level of coordination among the companies responsible for its components. For example, network technology and cloud computing service companies need manufacturers of objects (sensor-equipped devices) as much as the latter need service companies for the joint development of the software and hardware applications industry.

At the same time, digitization has broken down the barriers that hamper learning and the entry of new players, and it has opened markets up to new manufacturers, thanks to the lower requirements for infrastructure and human resources. The benefits associated with the new digital services models —infrastructure, hardware and software as services— have enabled the creation of companies dedicated to both software and hardware, and that has reduced the levels of investment and working capital required. In particular, pay-as-you-go models allow access to computing capacity; marketplaces for freelance professionals and specialized consultants afford access to a pool of programmers and engineers; and co-working venues provide alternative models based on shared spaces. The availability of manufacturing modules, with 3D and integrated circuit printers, has also accelerated the process of designing prototypes and small-scale manufacturing (Hagel and others, 2015).

The industrial Internet value chain comprises four segments (see diagram VI.1): devices (parts and operating systems), communications, applications platforms (administration of communications, data, identity and security), and the development, integration and distribution of products. The first segment entails the electronic manufacture of sensor-equipped devices: in other words, the production of sensors, nodes, controllers and other artefacts for the collection of data. The second involves cellular and wireless communications networks, which falls into the sphere of integrated circuits and includes microprocessors, chips and the protocols they use to communicate and process information. The third segment covers the development of software platforms for managing communications and data: this is the task of the industrial Internet, which is responsible for designing hardware and software for systems monitoring, data analytics and the use of security protocols. Finally, the fourth segment involves the integration of applications in vertical industries: in other words, the design of remote applications, services and maintenance functions, operated by means of cloud computing interfaces and application programming and the final marketing and distribution of the applications (API) (DestinHaus, 2015).

Diagram VI.1
Value chain of the industrial Internet

Specific and generic parts	Embedded operating systems and software	Communications	Device communications and administration	Data administration	Security	Identity	Product development and integration	Distribution and sales
Personalized parts, usually commodified: casings, sensors and batteries Generic parts that can be reused in numerous devices	Software, either generic or customized, for inclusion in devices	Fixed, cellular (2G/3G) Low-power wide area networks (LPWAN), satellites or other wide area networking technologies (WAN)	Administration of communications and devices Short- and medium-range wireless: WiFi, Bluetooth and mesh	Data acquisition, management, storage, processing and visualization; integration of capacities with external software and other data sources	Point-to-point security, but primarily by means of the cloud	Identity management is also important, particularly in consumer applications	Integration needed to connect industrial Internet services with the other applications	Distribution and commercialization of products and technical support

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of DestinHaus, "The Internet of Things value chain", Rancho Santa Margarita, 2015, unpublished.

In contrast to the consumer Internet, in the industrial Internet's value chain there is more balance between the forces of economic concentration and deconcentration. The forces that lead to concentration are the economies of scale and network economies associated with software platforms in a small number of companies. The forces that allow deconcentration are associated with the possibilities of localization, with the creation of niche markets in product development and with the integration of vertical industries. An intermediate level of concentration is found in the electronic manufacturing of devices, where fierce competition is forecast and a leading position is held by smart devices, communications systems and the control of objects.

Around 30% of the growth in the industrial Internet market around 2020 will come from the design, manufacture and sale of new devices (Norton, 2015). The main manufacturers are transforming their products' components to make them more intelligent, interactive and valuable through a series of innovations. Examples of this include Nest —recently acquired by Google— in the area of thermostats; Philips, in the area of Bluetooth applications, WiFi and lighting sensors; and ThinFilm Electronics ASA, in the production of labels.

The critical aspects of the value chain's evolution include the forms of communication and control that will be predominant in the industry. Considering the vast number of devices with different systems that will have to be connected, network providers will have to develop communications solutions —based on such systems as Bluetooth and WiFi— that create value in the network and further downstream in the chain.[3] Thus, the dominant networks will be those that succeed in offering systems that are simple to operate and guarantee data security and privacy. A similar situation exists among companies that develop unified control technologies for various devices.

C. Advanced manufacturing

Advanced manufacturing is defined as the series of manufacturing activities carried out by those companies that lead the production and use of digital technologies to control the physical world, by synchronizing equipment, processes and people. Advanced manufacturing leads to the installation of a new kind of factory, creates high-productivity jobs, promotes innovation and contributes to sustainable growth (Muro and others, 2015). Advanced manufacturing is associated with advanced services, which are defined as the software and

3 One example of this is provided by Cisco Systems, which uses cloud computing services to connect chain components from different sectors —transportation, infrastructure, health— and, simultaneously, uses cloud networks to create value in other components of the chain.

telecommunications activities deployed by leading companies that interact with advanced manufacturing sectors and, in particular, with activities in the area of industrial automation.

Some industry analysts, such as the McKinsey Global Institute, Gartner and the International Data Corporation (IDC), have highlighted the importance of the industrial Internet and advanced manufacturing, managed by algorithms, smart devices and robots.[4] All the forecasts offered by these analysts emphasize the radical changes in the digital ecosystem that will arise from the convergence of different digital and industrial technologies, in which people, processes and machines will establish new forms of communication and coordination (Manyika and others, 2012).

Manufacturing models evolve: from specialized automation processes at the factory level and isolated and standardized robotization to more complex and autonomous processes that cover the entire product value chain, with connected, collaborative robotization and new protocols for interactions between people and machines, and between machines and other machines (ABB Group, 2016).

The leading countries are dealing with these changes from a geopolitical perspective, supporting their main industrial conglomerates in the development of new technological platforms to promote industrial competitiveness. Examples of this include public-private partnerships and, in some cases, industrial policies that promote infrastructure, capacity-building, testing facilities and the setting of standards (EP, 2016).

The progress of advanced manufacturing accelerated in 2016. Surveys conducted that year showed that companies were beginning to make investment decisions in the field. Between 2013 and 2015, around 75% of companies were exploring the use of the industrial Internet,[5] but only 15% had taken specific steps.[6] By 2016, however, more than 30% of companies had decided to invest in those technologies over the following two years (Gates, Mayor and Gampenrieder, 2016).

However, forecasts about the take-up of these technologies must be read with caution. The main obstacles to adoption include uncertainty about how these technologies will evolve, their exclusive availability to large corporations with standardized production processes, difficulties in agreeing on interoperability standards and the shortage of critical capacities (for example, for big data analytics) and of qualified human resources.

D. Impact on manufacturing activities

The main repercussions of the industrial Internet within factories will come from the development of technologies involving virtual reality, robotics, artificial intelligence and autonomous learning. These technologies will play an essential role in the establishment of digital factories, in a context of an accelerated transition of factories' digital business functions to the architecture of the cloud.

This process faces several difficulties, including the complexity of interactions between Internet of Things applications and cloud platforms, latency problems in communications networks and the need for security in manufacturing processes. The priority development areas for manufacturing production chains include the concept of user-centric design in manufacturing plants, decentralized computing architecture models (fog computing) and the relationship between production processes and logistics (O'Brien and Avery, 2016). In the context of the digital factory, the concept of user-centric design is defined as the set of technologies associated with devising models for behaviour and contingencies in production chains. Those technologies include tools for simulations, modelling and calculations for assessing system capacities when production is increased, together with those systems' responses to unexpected situations or operational changes (Schneider Electric).

4 Advances with and falling costs for microprocessors, WiFi networks, radio-frequency identification technology (RFID), broadband and sensors open up new possibilities for connecting every machine, process and product to the Internet, in what is called the Internet of Things or industrial Internet. This technology is useful for all kinds of activities, both in vertical industries —manufacturing and other sectors— and in the management of complex ecosystems, such as cities and the environment.

5 Survey conducted by the Economist Intelligence Unit (EIU) among 779 corporate executives from across the world.

6 Based on 433 survey responses from corporate executives in China, France, Germany, the United Kingdom and the United States.

Fog computing applied to manufacturing is another innovative concept related to the use of systems for mass processing and analytics that demand increasingly rapid response times. It is difficult to meet those requirements with existing Internet of Things models, which are equipped with centralized circuits supported by cloud-based management models. Nevertheless, the decentralized architecture models offered by fog computing can take computing resources and services to the extremes of infrastructure, allowing effective links of continuity to be forged between data sources and the cloud (OpenFog Consortium).

In addition to the challenges of factory automation and robotization, the new intelligent factories will need to establish relationships between logistics processes and machines, through the creation of new internal communications models and protocols and, in addition, through the connection and provision of value information in the supply chain to the supplier and to the customer. In this case, there must be a machine-to-machine (M2M) dialogue between all the components that make up the production chain.

Estimates of the market value of advanced manufacturing and its economic impact are still unclear, and so the following figures must be read with caution. Predictions about the quantities of devices that will be connected by 2020 vary greatly, but in each case the numbers are high: Gartner calculates 20 billion devices; IDC, 30 billion; Cisco Systems, 50 billion; and Morgan Stanley, 75 billion (Evans, 2011). The most important regions for the industrial Internet, measured in terms of income generation, are the following: the Asia-Pacific region, accounting for more than 50%; North America, with 26%; and Western Europe, with more than 15% (Lund and others, 2014).

In 2016, the number of connected objects ("things")[7] was estimated at around 6.4 billion (Gartner, 2015), 30% more than in 2015.[8] The sectors with most connected devices are automobiles, smart homes, fitness devices and consumer goods. However, the highest levels of spending on this technology are recorded in industrial applications: advanced manufacturing. Spending on consumer applications is estimated to have reached US$ 546 billion in 2016, while in industry —both cross-industry and vertical specialization— the total was US$ 868 billion (see table VI.4).

Table VI.4
Connected devices and industrial Internet spending, 2016 and 2020

	Connected devices *(millions)*		Industrial Internet spending *(billions of dollars)*	
	2016	2020	2016	2020
Consumer goods	4 024	13 509	546	1 534
Cross-industry	1 092	4 408	201	566
Vertical specialization	1 276	2 880	667	911
Total	6 392	20 797	1 414	3 010

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Gartner, "Gartner says 6.4 billion connected 'things' will be in use in 2016, up 30 percent from 2015", Stamford, 10 November 2015 [online] https://www.gartner.com/newsroom/id/3165317.

Investment in this area has remained dynamic, even during the years when the global economy slumped. In 2015, investment levels rose over the previous year's figure to stand at US$ 1.5 trillion in telecommunications infrastructure, US$ 700 billion in the Internet of Things and US$ 100 billion in data centres (Huawei Technologies, 2016)[9]. That year, according to Gartner and the International Federation of Robotics, shipments of 3D printers totalled 200,000 units, twice the previous year's figure, while sales of robots totalled more than 180,000 units, for a rate of growth in excess of 10%. The main industries placing orders for that equipment were automobiles, semiconductors, electronics and agriculture.

It is estimated that the potential annual impact of the industrial Internet by 2025 will be at least US$ 4 trillion. The leading applications include advanced manufacturing (US$ 1.2 trillion), city management (US$ 900 billion),

7 "Thing" here means any physical object that has a device with its own IP address and that can connect to the network and send and receive information over it.
8 Manyika and others (2015) estimate that there are more than 9 billion connected devices, including computers and smartphones.
9 That means annual growth rates of 1.3% in telecommunications infrastructure, of 14.3% in the Internet of Things and 1.9% in data centres.

transportation and logistics (US$ 500 billion), retail trade (US$ 400 billion) and industry based on natural resources (US$ 200 billion). The lion's share (62%) of these applications' economic value will be located in advanced countries; however, there are areas with greater potential in developing economies, such as natural resource processing, transportation and logistics, and manufacturing industry (Manyika and others, 2015).

Nevertheless, the current situation within companies indicates that the scope of advanced manufacturing applications is still limited and that its implementation suffers from weaknesses, particularly as regards human resources. A 2017 survey conducted by Strategy Analytics among nine industries in France, Germany, the United Kingdom and the United States revealed that 35% of companies had fewer than 100 devices connected in their applications and that, in the United States, more than 70% of installations involved fewer than 500 devices. In addition, 66% of companies spent less than US$ 100,000 on projects in this area (Strategy Analytics, 2017).

A survey of 500 international companies revealed deficiencies in their human resources at the corporate and technical levels: 76% of the respondents said that their companies had a deficit of corporate personnel with technological skills; 72% detected a shortage of managerial staff with experience in implementing technology; and 80% were short of solution development skills. The critical areas of specialization were security and big data analytics.

Increasing the impact of these changes demands improvements in communications networks and investment in vertical platforms and applications. The technical areas where progress is needed are the implementation of Internet Protocol version 6 (IPv6), the sustainability of sensors, agreements on interconnection standards and the security of those applications. Interoperability, in particular, is a critical factor, and the most plausible alternative is the adoption of open standards and the existence of platforms that allow Internet of Things systems to communicate among themselves. According to the McKinsey Global Institute, the absence of interoperability systems reduces the potential benefit of those applications by at least 40%.

Further reductions are needed in the production costs of data communications, storage and processing hardware and services: specifically, annual reductions of between 5% and 15% are needed, depending on the technology or service in question. The hardware components include low-consumption sensors, microelectromechanical sensors, radio-frequency identification devices and low-cost batteries. Among services, the critical elements are software for analytics and visualization, low-cost data communications links and data processing and storage services.

Several estimates exist of the microeconomic impact that these technologies will have on companies. Gerbert and others (2015) estimated that over the coming ten years, productivity in Germany would increase by between 5% and 8%, and that as many as 390,000 jobs could be created, as a result of improvements in flexibility, speed, productivity and quality. Similarly, Manyika and others (2015), based on their research among 300 companies in Germany, Japan and the United States, calculated that the boost to productivity could reach 26%. PwC (2014) also analysed Germany's situation and estimated that, in five years, it would achieve an 18% increase in productivity and that lower costs would yield annual savings of 2.65%.

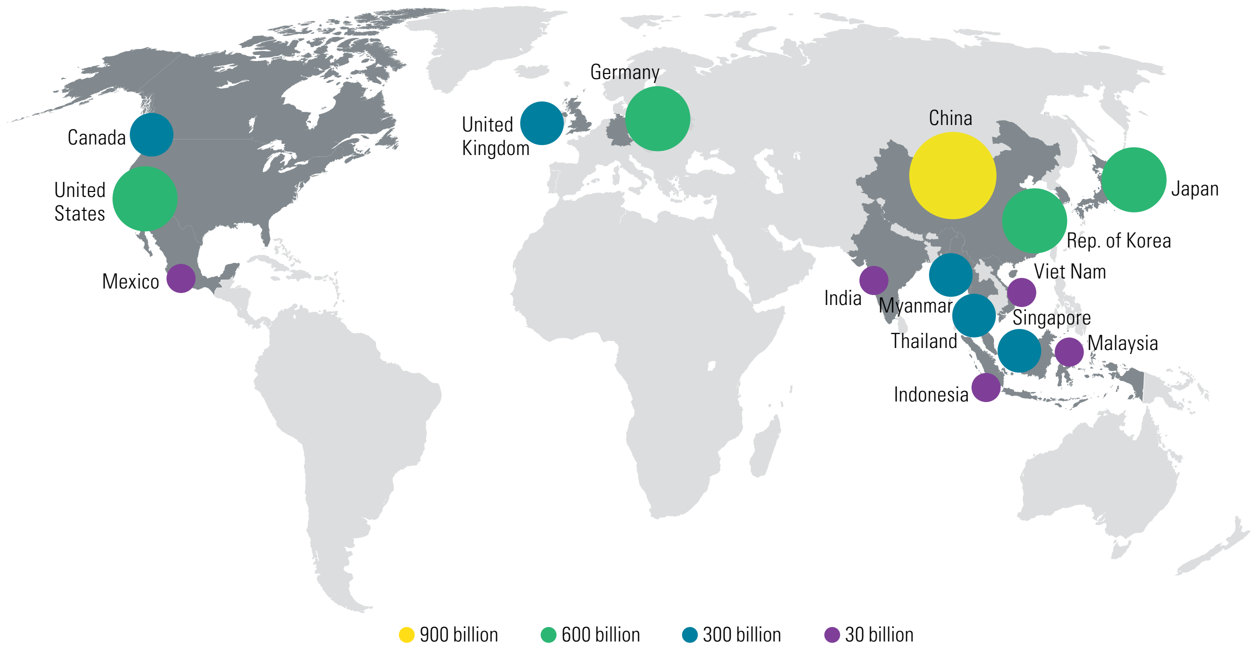
Roland Berger (2016) simulated the impact that the implementation of these technologies would have on a typical autoparts factory, taking five factors of technological change into account.[10] It was estimated that their implementation would simultaneously raise returns on capital investments (from 15% to 40%), plant usage (from 65% to 90%) and profitability (from 6% to 13.1%).

Around 2020 three regions of the world with advanced manufacturing are expected to exist —Asia, Europe and North America— led, respectively, by China, Germany and the United States. According to Deloitte's Global Manufacturing Competitiveness Index, China was the most competitive country in this area in 2010, 2013 and 2016; meanwhile, the United States has been improving its competitiveness index and has risen

[10] The factors of technological change are the following: (i) virtual factories that allow processes to be digitally simulated before manufacturing begins, thus reducing the lead time needed to develop and launch new products; (ii) automated flows (using autonomous vehicles or cobots) to make the overall system more flexible and sensitive, and to provide answers that traditional human capacities cannot; (iii) intelligent machines, which need fewer operators than their traditional equivalents and can self-correct and operate either separately or in connection with others; (iv) predictive maintenance, which allows improved planning of and efficiency in machine time use by predicting the machines' down time; and (v) the cyberproduction system, which is the senior command system for the factory and its suppliers and which allows customized mass production and the adjustment of output according to demand.

from fourth position in 2010 to third place in 2013 and to second place in 2016. It is predicted that by 2020, the United States will assume the leadership position in competitiveness, followed by China and Germany (Deloitte, 2016). These changes in manufacturing competitiveness between the countries are creating three dominant clusters that will compete for supremacy in advanced manufacturing and where cost arbitrage is beginning to be replaced by the arbitrage of digital automation arising from the adoption of the industrial Internet (see diagram VI.2).

Diagram VI.2
Main new manufacturing clusters and exporting countries around 2020



Source: Deloitte.

E. Convergence of manufacturing and services

One of the characteristics of the transformation in the digital technologies ecosystem since the 1990s has been the convergence between the hardware, software, telecommunications and services industries, with services for the financial sector and the media playing a leading role. Convergence is defined as a competitive dynamic where the borders or boundaries of industries are blurred and technologies come together as companies permanently seek new ways of creating value (Basole, Park and Barnet, 2014). Recently, a similar process of transformation has been under way among the various segments of the advanced manufacturing ecosystem, which are converging as a result of the reconfiguration of value chains through the addition or elimination of activities, and of consolidation through mergers and acquisitions or the expansion of actors throughout the entire ecosystem. Some industrial segments that were traditionally separate —such as machinery, electronics, semiconductors, software, data processing and telecommunications— are now closely interconnected, and they offer cyberphysical, integrated and packaged products and services.

It is increasingly difficult to distinguish between manufacturing and advanced services. The advantages associated with economies of scale have been bolstered by economies of scope, in that companies create greater value by combining a variety of products and services and offering end-to-end integrated solutions. The most common manifestation of this phenomenon is the interface between the hardware components, software and communications networks that must work in coordination in complex processes (Tassey, 2014). Another dimension of this phenomenon is the new "anything as a service" business models that are intended to raise the profitability of machinery, equipment and capital-intensive infrastructure: in other words, machinery as a service (for example, Rolls-Royce aircraft engines), computer processing as a service (cloud high-performance computing) or infrastructure as a service (data centre services).

One of the most important phenomena in the software industry has been the emergence of platform companies —Apple, Alphabet, Microsoft and Amazon, for example— that have brought about disruptive changes not only in the realm of digital services, but also in manufacturing, transportation, banking, health and energy. Of the 25 leading platform companies, 15 are from the United States, 4 are Chinese, 3 are Japanese and the remainder are from Germany, the Republic of Korea and South Africa. Those companies have helped improve productivity, create new venues for commerce through the share economy and promote innovation. These new business models, however, have also fuelled concerns and regulatory controversies on account of their capacity for dominating markets, weakening competition and avoiding taxes and labour obligations (Evans and Gawer, 2016).

Convergence has been measured in different ways, using such variables as corporate diversification, technological relations, patent cooperation, macroeconomic analyses of inputs and products, and analytical network metrics. This chapter uses the latter approach and estimates analytical network metrics of mergers and acquisitions in the advanced manufacturing ecosystem, echoing the methodology used by Basole, Park and Barnett (2014). In addition to calculating network metrics for mergers and acquisitions, visualization tools have been used to depict the competitive dynamics of convergence over time.

The data source used is the Bloomberg mergers and acquisitions database, which contains information on firms carrying out operations of this kind and minority investments in other firms.[11] From that data, around 102,000 cases were identified, covering agreements announced between 1 January 1990 and 31 December 2016 in which one of the entities involved —either as the purchaser or the object of the acquisition— belonged to advanced industry or advanced services. The sample was then filtered and selected for relevant attributes, keeping only those cases involving a merger or an acquisition in which both firms belonged to the sectors of interest. The result of this process was a sample of around 40,000 cases of mergers and acquisitions involving 53,000 firms from the advanced manufacturing ecosystem.

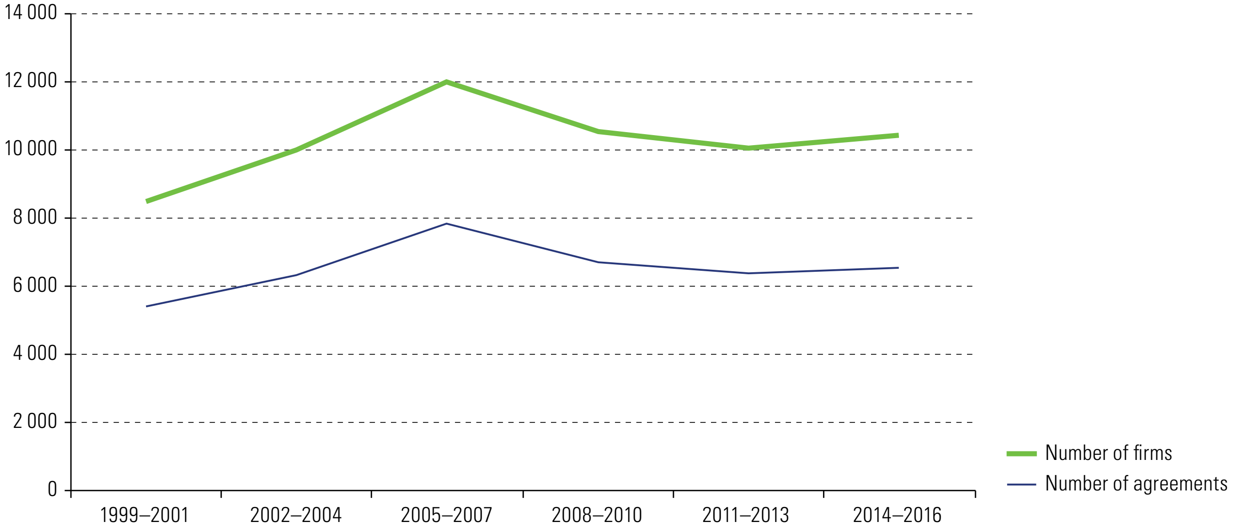
In consideration of the characteristics of both the phenomenon under study and the available data —which are both relational— a directed graph model strategy was chosen, which agrees with the way in which economic network exercises are normally tackled. The main advantage of graph models is the existence of a theoretical framework for studying their structures. More details on the conceptual framework used to address the process of convergence can be found in Castillo (2017).

Based on the analysis of the results of the mergers and acquisitions in the advanced manufacturing ecosystem, figure VI.1 presents the number of firms and accumulative merger and acquisition agreements in each of the following periods: 1999 to 2001, 2002 to 2004, 2005 to 2007, 2008 to 2010, 2011 to 2013 and 2014 to 2016. The evolution of these variables indicates that the number of companies involved and the number of merger and acquisition agreements rose at a steady rate between 1999 and 2007, after which they decreased until around 2013 and then recovered slightly over the 2014–2016 period. The number of companies and agreements reached their maximums prior to the financial crisis (2005 to 2007), with 12,000 firms and 8,000 agreements. During the entire period examined, the number of agreements per company remained relatively stable at around 1.5.

Figure VI.2 portrays convergence metrics in the advanced manufacturing ecosystem in terms of merger and acquisition agreements. In this case, it shows the evolution of the natural logarithm of the multiplicative inverse of the assortativity of the industrial sectors. The assortativity of the sectors is a metric that indicates that the merger and acquisition agreements are carried out by firms from different sectors. The convergence process intensifies slightly between 2002 and 2007, speeds up between 2008 and 2013, and then accelerates even more after 2014.

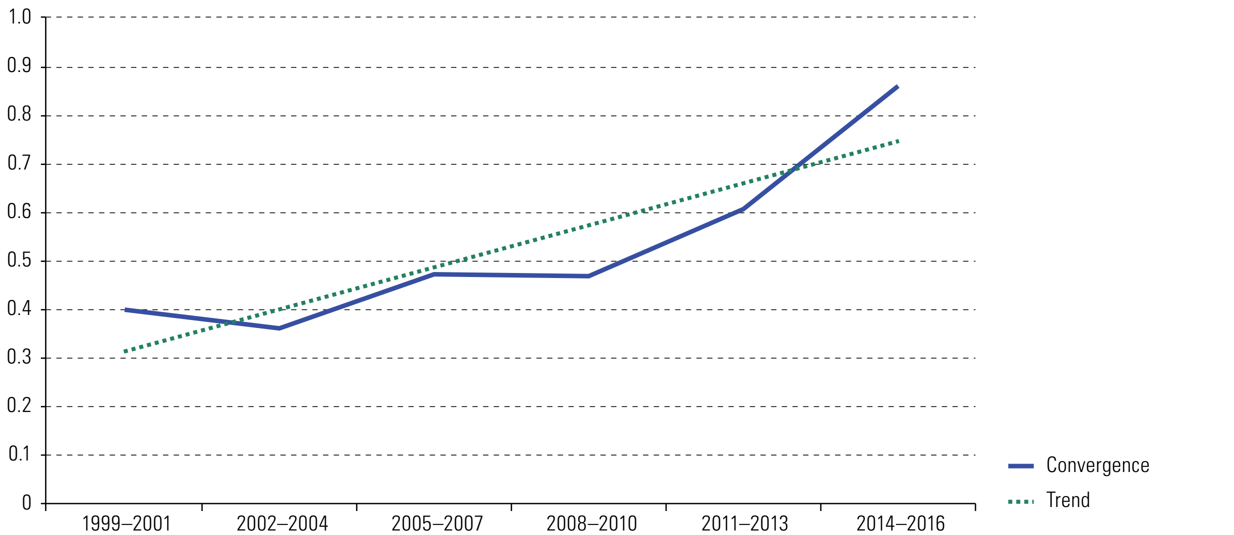
[11] Minority investment means investment in the assets of another company without necessarily entailing the transfer of corporate control.

Figure VI.1
Evolution of companies and merger and acquisition agreements, 1999–2016
(*Number of cases*)



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Figure VI.2
Convergence of the advanced manufacturing ecosystem, 1999–2016

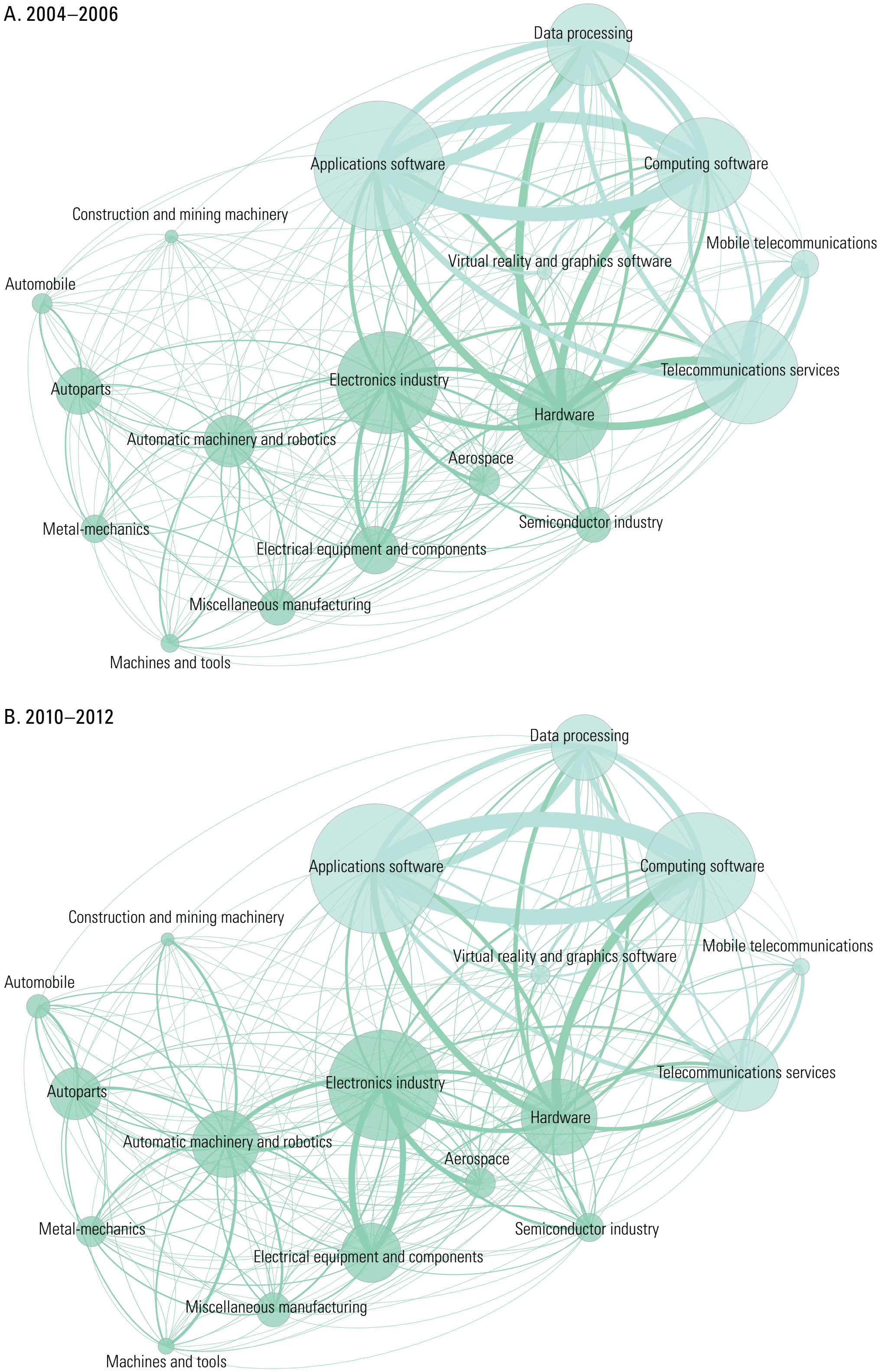


Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Diagram VI.3 shows the structural evolution of the convergence process in the advanced manufacturing ecosystem at the sector level during the periods 2004 to 2006 and 2010 to 2012. The figures show that following the first decade of the century, all sectors in the advanced manufacturing ecosystem reported a process of convergence, the intensity of which began to rise in 2010 following an earlier upward trend between 2004 and 2006. There are several interesting features in the growing interdependence between the ecosystem's different sectors, including the central role played by the software industry, which serves to bind the ecosystem together, along with the electronics, hardware, telecommunications, machinery, automation and robotics industries. The machinery and equipment sectors are beginning to interconnect more intensely and also to connect with the electronics and automobile industries.

Diagram VI.3

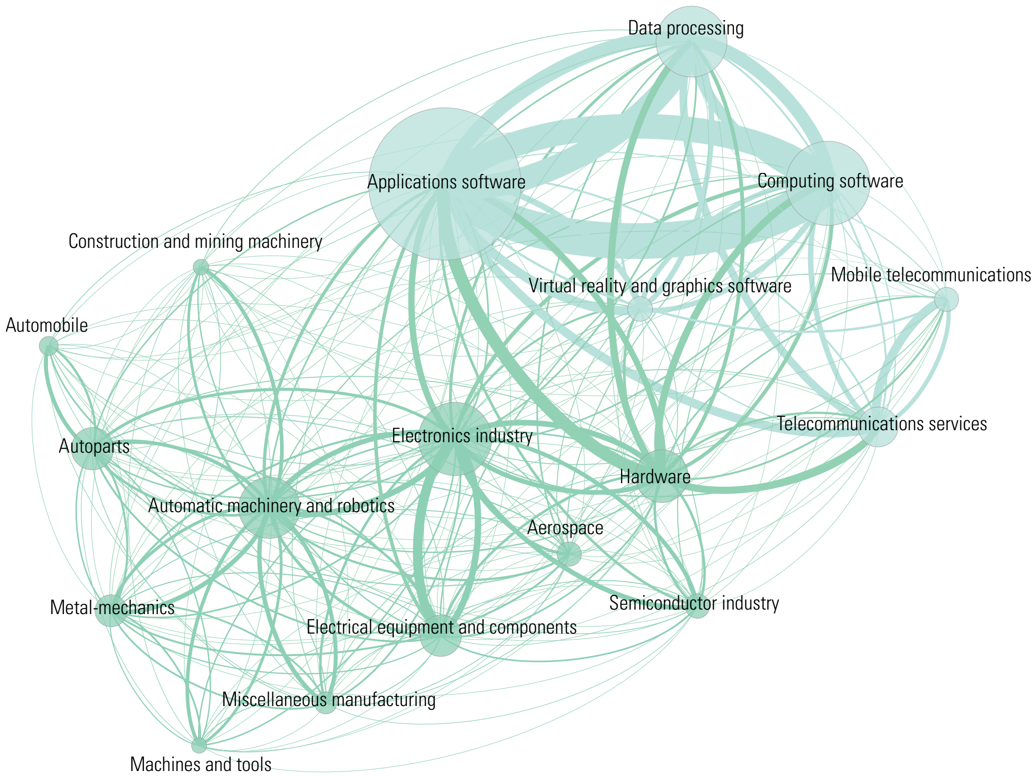
Increased convergence in the advanced manufacturing ecosystem



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

Diagram VI.4 shows how the ecosystem's convergence advanced between 2014 and 2016. The main characteristics are the increasing density of links among all the ecosystem's sectors, the reduced number of agreements between firms from the same sector and the central place in the convergence networks of four main core technologies: software and data processing, electronics and hardware, telecommunications, and machinery and equipment. These results show that, within the ecosystem, consolidation has occurred in the advanced services convergence process, chiefly as regards software, whereas advanced manufacturing still has some way to go to reach maturity.

Diagram VI.4
Accelerated convergence of the advanced manufacturing ecosystem, 2014–2016



Source: Economic Commission for Latin America and the Caribbean (ECLAC).

F. Conclusions

The evolution of the international advanced manufacturing sector is characterized by technological convergence, the consolidation of the leading companies and the emergence of new industrial Internet platforms. A new manufacturing ecosystem is emerging as the result of convergence between the industrial automation industry and the digital technologies sector. The main characteristics of this ecosystem include the blurring of boundaries between manufacturing and digital services, shortened product life cycles and increased geographical proximity between production and innovation activities. However, the reach and scale of this process is limited, since most traditional industrial companies face barriers —infrastructural, technological, financial and administrative— that hamper the adoption and adaptation of these new technologies.

At the same time, an elite of technological companies is emerging, its members coming from the largest industrial automation and digital technology groups and leading and concentrating the process of new manufacturing. Through various corporate strategies based on cooperation and acquisitions among companies from manufacturing sectors and from the digital technologies sector, manufacturing and coordination models are being transformed across entire product value chains. However, unlike the high levels of integration and concentration in the consumer Internet value chain, the industrial Internet value chain offers greater possibilities for locating and creating niche markets associated with vertical industries.

In addition, new technological platforms made possible by the technologies of the industrial Internet are being created and are flexibly and securely connecting advanced manufacturing producers and consumers. The consolidation of a reduced number of specialized vertical industry platforms can be expected, given that industrial automation increases both the complexity and the vulnerability of systems and processes. Accordingly, there is a need for secure, robust platforms that, when faced with contingencies, can minimize the risk of large-scale failures. As occurred with the concentration of digital platforms, regulatory controversies will arise on account of the capacity for market domination and for endangering competition.

Finally, although the industrial and technological sector will lead this transformation, industrial policies will also play a critical role in facilitating the adoption and spread of advanced manufacturing (Cimoli and others, 2017). In addition to new requirements in the areas of regulation, security and environmental impact, the workforce will need to be equipped with the necessary skills and small manufacturers and broader supply chains will have to be in position to adopt the new technologies.

Bibliography

ABB Group (2016), *Annual Report 2016: Committed to Unlocking Value*, Zurich.

Basole, R., H. Park and B. Barnett (2014), "Coopetition and convergence in the ICT ecosystem", *Telecommunications Policy*, vol. 39, No. 7, Amsterdam, Elsevier, August.

Castillo, M. (2017), "El estado de la manufactura avanzada: competencia entre las plataformas de la Internet industrial", *Production Development series*, No. 217 (LC/TS.2017/123), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), December.

Cimoli, M. and others (eds.) (2017), "Políticas industriales y tecnológicas en América Latina", *Project Documents* (LC/TS.2017/91), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), November.

Costa, L. and others (2007), "Characterization of complex networks: a survey of measurements", *Advances in Physics*, vol. 56, No. 1, Routledge, Taylor and Francis, February.

Deloitte (2016), *2016 Global Manufacturing Competitiveness Index*, London.

DestinHaus (2015), "The Internet of Things value chain", Rancho Santa Margarita, December, unpublished.

EP (European Parliament) (2016), *Industry 4.0*, Brussels.

Evans, D. (2011), "The Internet of Things: how the next evolution of the Internet is changing everything", *White Paper*, San Jose, Cisco Systems, April [online] https://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf.

Evans, P. and A. Gawer (2016), "The rise of the platform enterprise: a global survey", *The Emerging Platform Economy series*, No. 1, New York, Center for Global Enterprise (CGE), January.

Gartner (2015), "Gartner says 6.4 billion connected 'things' will be in use in 2016, up 30 percent from 2015", Stamford, 10 November [online] https://www.gartner.com/newsroom/id/3165317.

Gates, D., T. Mayor and E. Gampenrieder (2016), *Global Manufacturing Outlook 2016*, Amstelveen, KPMG International, May.

Gerbert, P. and others (2015), "Industry 4.0: the future of productivity and growth in manufacturing industries", Boston, Boston Consulting Group (BCG), 9 April [online] https://www.bcg.com/en-cl/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx.

Hagel, J. and others (2015), *The future of manufacturing: making things in a changing world*, London, Deloitte University Press.

Huawei Technologies (2016), "Connect where it counts: mapping your transformation into a digital economy with GCI 2016", *WinWin*, No. 25, Shenzhen, July.

Kallstrom, H. (2015), "Suppliers' power is increasing in the automobile industry", *Investing in the automotive industry: what you need to know*, New York, Market Realist, February [online] https://marketrealist.com/2015/02/suppliers-power-increasing-automobile-industry.

Lund, D. and others (2014), "Worldwide and regional Internet of Things (IoT) 2014–2020 forecast: a virtuous circle of proven value and demand", Framingham, International Data Corporation (IDC) [online] https://www.business.att.com/content/article/IoT-worldwide_regional_2014-2020-forecast.pdf.

Manyika, J. and others (2015), *The Internet of Things: Mapping the Value Beyond the Hype*, San Francisco, McKinsey Global Institute (MGI), June.

___(2012), *Manufacturing the Future: The Next Era of Growth and Innovation*, San Francisco, McKinsey Global Institute (MGI), November.

Muro, M. and others (2015), *America's Advanced Industries: What They Are, Where They Are*, Washington, D.C., Brookings Institution, February.

Newman, M. (2003), "The structure and function of complex networks", *SIAM Review*, vol. 45, No. 2, January.

Norton, S. (2015), "Internet of Things market to reach $1.7 trillion by 2020: IDC", *The Wall Street Journal*, New York, 2 June [online] https://blogs.wsj.com/cio/2015/06/02/internet-of-things-market-to-reach-1-7-trillion-by-2020-idc/.

O'Brien, L. and A. Avery (2016), "Positioned for recovery: top 50 automation companies of 2015", *Control*, Schaumburg, 17 October [online] https://www.controlglobal.com/articles/2016/positioned-for-recovery-top-50-automation-companies-of-2015/.

PwC (2014), *Industry 4.0: Opportunities and Challenges of the Industrial Internet*, London, December.

Roland Berger (2016), *The Industrie 4.0 Transition Quantified: How the Fourth Industrial Revolution is Reshuffling the Economic, Social and Industrial Model*, Munich.

Strategy Analytics (2017), "IoT reality: market value less than $ 0.5T globally by 2025", New York, PR Newswire, 5 April [online] https://www.prnewswire.com/news-releases/iot-reality-market-value-less-than-05t-globally-by-2025-300435200.html.

Tassey, G. (2014), "Competing in advanced manufacturing: the need for improved growth models and policies", *Journal of Economic Perspectives*, vol. 28, No. 1, Nashville, American Economic Association.

Annex VI.A1

The advanced manufacturing and advanced services sectors

In this chapter, ten advanced manufacturing macrosectors have been identified, based on the industrial sectors in the United States with the highest levels of technological innovation and of qualified human resources. Table VI.A1.1 shows the advanced manufacturing sectors with the highest rates of spending on research and development per worker and the highest proportions of employees with a background in science, technology, engineering and mathematics (STEM).[12]

Table VI.A1.1
Main advanced manufacturing sectors

Macrosectors	Research and development spending per worker, 2009 *(US$ per worker)*	Proportion of workers with a science, technology, engineering or mathematics background, 2012 *(percentages)*
Automobile industry	48 461	27
Autoparts and automobile equipment	6 791	36
Aeronautics	20 501	59
Electrical equipment and components	820	37
Electronics industry	60 338	71
Machines and tools	23 671	50
Construction and mining machinery	11 709	39
Industrial automation services	13 330	42
Hardware	91 428	57
Semiconductor industry	49 612	50

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Brookings Institution, European Commission and Bloomberg.

The industrial organization of advanced manufacturing has changed significantly over the past decade, particularly in the area of corporate strategy, operating models, new markets and strategic alliances. Faced by technological change and competition, companies have been forced to modernize their production chains, to increase the sophistication of their products and to develop new high-technology market segments. This has been possible thanks to the convergence between manufacturing, electronics, software and communications networks, in a context that, following the 2008 financial crisis, saw a sharp upswing in mergers and acquisitions. Table VI.A1.2 identifies the world's leading advanced manufacturing companies.

[12] The advanced manufacturing sectors were identified by using three criteria: (i) they had to be sectors involved in the manufacturing sector, (ii) their spending on research and development per worker had to be in the 80th percentile for the industry and higher than US$ 450, and (iii) the proportion of the sector's workers in STEM-specialized positions had to be higher than the national average, that is, more than 21% of the workforce.

Table VI.A1.2
Main advanced manufacturing companies

Macrosectors	Main companies
Automobile industry	Toyota Motor Corporation, Volkswagen Group, General Motors, Ford Motor Company, Fiat Chrysler Automobiles, SAIC Motor Corporation Limited, Daimler AG, Honda Motor Company, Nissan Motor Company
Autoparts and automobile equipment	Robert Bosch, Denso Corporation, China South Industries Group, Continental AG, ZF Friedrichshafen AG, Magna International, Hyundai, Aisin Seiki, Johnson Controls
Aeronautics	Boeing Company, Airbus SE, China North Industries Corporation, Lockheed Martin, Aviation I of China, China Aerospace, United Technologies, Northrop Grumman, General Electric
Electrical equipment and components	Siemens, General Electric, Hitachi, ABB, United Technologies, Schneider Electric, Mitsubishi, Honeywell, Toshiba, Daikin Industries
Electronics industry	Samsung, LG, China Electronic, Boe Technology, Au Optronics, Innolux, Japan Display, Sharp, Byd Co., Delta Electronics
Machines and tools	Caterpillar, John Deere, China National Machinery Import and Export Corporation, Hitachi, Komatsu, Fiat, CNH, Atlas Copco, Kubota, Shaanxi
Construction and mining machinery	Caterpillar, John Deere, China National Machinery Import and Export Corporation, Hitachi, Komatsu, Fiat, CNH, Atlas Copco, Kubota, Shaanxi
Machinery, automation and robotics	Siemens, Panasonic, Hanwha, Yaskawa Electric, Kuka, Sensata Technologies, Yokogawa Electric, Omron Corp., Rockwell Automation
Hardware	Apple, Samsung, HP, Legend Holdings, Lenovo, Cisco, Panasonic, Sony, LG, Huawei
Semiconductor industry	INTEL, Samsung, TSMC, Qualcomm, Sk Hynix, Texas Instruments, Broadcom, Toshiba, Micron Technology, Applied Materials

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Bloomberg.

This chapter has identified six advanced services macrosectors, based on the software and telecommunications services in the United States that most frequently interact with manufacturing and have high levels of technological innovation and specialized human resources. Table VI.A1.3 shows the advanced services sectors with the highest research and development spending per worker and the highest proportions of employees with STEM training.[13]

Table VI.A1.3
Main advanced services sectors

Macrosectors	Research and development spending per worker, 2009 *(US$ per worker)*	Proportion of workers with a science, technology, engineering or mathematics background, 2012 *(percentages)*
Applications software	27 476	40
Data processing	1 020	56
Computing software	722	74
Graphics software and virtual reality	80 977	70
Mobile telecommunications	454	40
Telecommunications services	1 998	57

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Brookings Institution, European Commission and Bloomberg.

The importance of the software industry to advanced services in particular and to technology in general lies in the contributions it makes to the digitization of manufacturing. As with advanced manufacturing, the software industry is subject to Kaldorian economies of scale, has spillover effects for the remaining sectors of the economy, generates increases in productivity and contributes to the diversification of the export mix and, as such, it represents an engine for economic growth. In the context of the convergence of communications networks, hardware and services, software has assumed a position at the heart of the industrial Internet

13 The advanced services sectors were identified using the information and communications technology (ICT) services that meet the same criteria as the advanced manufacturing sectors in terms of research and development spending per worker and the proportion of the sectors' workers in specialized positions.

and advanced manufacturing. Table VI.A1.4 identifies the world's leading software and telecommunications services companies.

Table VI.A1.4
Main advanced services companies

Macrosectors	Main companies
Applications software	Microsoft, SAP SE, Alphabet Inc., Tencent Holdings, Sony, Salesforce, Activision Blizzard, Adobe Systems, Intuit, Electronic Arts
Data processing	Huawei Technologies, IBM, Accenture PLC, Hewlett-Packard, Fujitsu, NEC Corporation, Tata Group, NTT Data
Computing software	Microsoft, Oracle, IBM, Amazon, VMware, Symantec, Atea, CA Technologies, Citrix Systems, ITOCHU Techno-Solutions Corporation (CTC)
Graphics software and virtual reality	Microsoft, SAP SE, Alphabet Inc., Tencent Holdings, Sony, Salesforce, Activision Blizzard, Adobe Systems, Intuit, Electronic Arts
Mobile telecommunications	AT&T, Verizon Communications, China Mobile, Nippon Telegraph and Telephone Corporation, Deutsche Telekom, SoftBank Group, Vodafone Group, Telefónica, Orange
Telecommunications services	AT&T, Verizon Communications, China Mobile, Nippon Telegraph and Telephone Corporation, Deutsche Telekom, SoftBank Group, Vodafone Group, Telefónica, Orange

Source: Economic Commission for Latin America and the Caribbean (ECLAC), on the basis of Bloomberg.

CHAPTER

VII

Artificial intelligence for development

A. The theory

1. Current status and outlook[1]

The volume of information that is being produced in the world today is expanding at the dizzying pace of nearly 30% per year. This means that, every three years, more new information is being generated than had been produced in humankind's entire history up to that time. The only way to manage that volume of information is with digital technologies.

Given this explosive growth of digitized information, it simply cannot be managed by human beings alone. People cannot filter the approximately 500 million tweets sent per day or the million or so hours of video uploaded to YouTube. This is why, some time ago, the tasks of interpreting and filtering content began to be delegated to intelligent algorithms. The fact that the world's total computational capacity has been growing three times faster than its information storage and transmission capacity has opened the way for the use of increasingly complex, powerful and flexible algorithms.

The availability of so much data has given rise to rapid advances in the field of artificial intelligence (AI). For example, the use of deep neural networks has made it possible to lower the word-error rate (WER) in voice recognition systems from 26% to 4% in just four years (between 2012 and 2016) (Lee, 2016), which is far better than human transcribers' error rate (Xiong and others, 2016). When these systems are applied to visual elements, they can seek out images using such abstract concepts as "a warm embrace". This interpretive power has given rise to omnipresent online recommendation algorithms, which have come to play a crucial role in communications management (Ricci and others, 2011). People spend two thirds of their waking hours communicating through channels that are mediated in one way or another by artificial intelligence (Center for the Digital Future, 2016). Among other examples, what are known as "recommender algorithms" have come to play such an important role that they are regarded as being responsible for the creation of many of the filter bubbles and echo chambers that are now clouding the communications landscape in ways that have influenced a wide range of processes, including democratic elections (Bakshy, Messing and Adamic, 2015; Colleoni, Rozza and Arvidsson, 2014; Pariser, 2011).[2]

Today, many people trust AI in their day-to-day activities, as in the case of the anti-lock braking systems (ABS) used in motor vehicles and aeroplane autopilots. The most heavily used power source (the electrical grid) is controlled by AI systems (Ramchurn and others, 2012); three out of every four trades on stock exchanges in the United States are conducted by automated negotiation algorithms (Hendershott, Jones and Menkveld, 2011); and one out of every three marriages in that country is the outcome of what began as an online date (Cacioppo and others, 2013). Digital algorithms have also begun to play a part in mating and genetic inheritance patterns. Life in a society that delegates nearly all of its decisions regarding energy distribution, three fourths of its decisions about resource distribution and one third of its decisions regarding procreation to machines demonstrates just how much our economies and societies have come to rely on artificial intelligence.

(a) Artificial intelligence: history and outlook

The history of AI is crucial to an understanding of how it can be used to further the development process. This involves looking at two different concepts or terms —"artificial" and "intelligence"— whose definitions have evolved as technology has progressed.

1 This chapter was authored by Martin Hilbert and Supreet Mann of the University of California at Davis.
2 The terms "filter bubbles" and "echo chambers" refer to situations in which a person is exposed to ideas, people, events or news that are all associated with a given political or social ideology.

Historically, human beings have actually been using intelligent machines for the last 2,000 or 3,000 years. Representations of robotic creations have been found in the Talmud and the Iliad, in Hobbes' visions of the Leviathan and in Da Vinci's machines. Most analysts place the birth of modern AI in the 1950s and associate it with the development of the Turing test (used to distinguish between human behaviour and that of machines) and with the Dartmouth Summer Research Project, held at Dartmouth College in 1956, which was an extended brainstorming session that plotted out many of the main directions that AI development was to take in the following decades. The participants in that workshop, such as the AI pioneer Herbert Simon, predicted that, within 20 years, machines would be capable of doing any kind of work that humans could do. Marvin Minsky, who worked with Simon, agreed and wrote that the problem of how to create artificial intelligence would be solved for all intents and purposes in a generation (Schreuder, 2014).

Following a typical deployment curve for technological paradigms (Pérez, 2009), this initial enthusiasm gave way to broken promises and a shortage of funding. The 1970s are known as the "AI winter" (Russell and Norvig, 1995). In the 1980s and 1990s, some commercial successes were achieved with so-called "expert systems", which are a form of AI that simulates the knowledge and analytical abilities of human experts. By 1985, the world market for AI had already grown to over US$ 1 billion.

In the 1990s and 2000s, technological progress mainly involved the spread of information via Internet connections, databases and mobile telephones. By the 2010s, this had given rise to an information overload that prompted experts to embark on a search for computational solutions that would help people make sense of this avalanche of data. The current wave of advances in AI began in 2012, when Geoffrey Hinton and his team surprised the academic world by showing how powerful deep convolutional neural networks could be in classifying images (Allen, 2015). These networks are not based on expert systems that are fed set patterns (knowledge, grammar, decision-making rules and so forth) but instead use machine learning algorithms that are capable of discerning patterns on their own.

(b) Artificial intelligence today: machine learning

One of the main objectives of modern AI systems is to discern patterns in unprocessed data and then to use those patterns to build their own knowledge. This path in the development of these systems has been taken in order to overcome the difficulties associated with the knowledge-based approach to machine learning. The traditional approach, using expert systems, focused on codifying or "hard-coding" knowledge about the world in formal languages in which computers could then use rules of inference to reason in a logical way (Goodfellow, Bengio and Courville, 2016). This approach has its limitations, however, because people cannot establish formal rules for detecting and accurately representing the subtleties of language. Therefore, the solution currently being explored does not involve working with a knowledge base but rather "learning knowledge". The ability of AI systems to acquire knowledge on their own (i.e. machine learning) enables computers to devise solutions for problems that require some understanding of the real world and to take what appear to be subjective, situational decisions.

In other words, in contrast to the knowledge-based expert systems of the 1980s, the new systems learn based on examples rather than rules, which is much more like the way that children learn. Expert systems were focused on automating knowledge acquired by human beings and incorporating the resulting rules into code. For example, in order to recognize an automobile, the machines were taught rules about how to define an automobile (four wheels, a certain size, etc.). However, small children do not learn by using these types of rules but rather by assimilating the characteristics of different objects that are all categorized as automobiles. The resulting classification criteria are more flexible and natural than predefined rules (Halevy, Norvig and Pereira, 2009).

The terms "machine learning" and "artificial intelligence" have now become virtually synonymous. Machine translation is the epitome of this development path. As far back as the 1950s, institutions such as IBM, the Massachusetts Institute of Technology (MIT) and the Defense Advanced Research Projects Agency (DARPA) began working on coding grammatical and terminological rules into expert systems for use in machine translation in order to produce machine-translated texts in different natural languages. In the best of cases, the results could be used to help, but not substitute for, human experts. Then, in 2006, Google Translate launched a statistical translation engine that used machine learning; it does not apply grammatical rules like an expert system would but instead draws on a corpus of bitexts (parallel texts in two different languages) containing somewhere between 150 million and 200 million words or more and two monolingual corpora of over 1 billion words each (Och, 2005). The engine then learns about the relationships between words on its own. Google Translate now handles over 100 languages at different levels of sophistication and is consulted by more than 500 million users each day.

The discernment of relationships between different concepts also enables machine learning systems to interpret meaning: insofar as linguistic meaning is derived from the relationships between different concepts, it can be learned by a machine. Vector space models are one example. These models have been used for a long time in natural language processing and represent entities in a continuous vector space, where semantically similar entities are represented at nearby points. Their similarity is demonstrated statistically, for example, by the prediction of the words or phrases that are likely to come next based on the preceding phrases or sentences.[3]

Machine-learning algorithms can be supervised or unsupervised. An AI system is said to be engaged in supervised learning if the desired result is known ahead of time. Just as a child learns to associate certain words with certain concepts, the machine is taught to convert certain inputs into certain results. The details of the input-output process depend on the machine. For example, images of a given individual are provided to an AI system, it then associates the person's facial features with that individual. Unsupervised machine learning does not have pre-determined results. The machine is asked to select indefinite patterns within a defined theoretical framework. For example, different images may be fed into an AI system and the system may then discover that many of those images are of the same person.

(c) The prospects for artificial intelligence

With machine learning, the assumption is that these systems can find patterns other than those generally assimilated by the human brain. Modern AI is therefore basically a black box that outperforms human brains, and people therefore cannot fully understand how the system obtains its results. The reverse engineering of the contents of these black boxes may yield some discoveries, however: for example, Google's AlphaGo program defeated the world's best Go players in 2015 and 2016 by using data on more plays than there are atoms in the universe (Silver and others, 2017). The Go champion Fan Hui has said in no uncertain terms that at least one of AlphaGo's decisive moves was "not a human move. I've never seen a human play this move" (Metz, 2016). When AlphaGo made that move, the champion was so confused that he had to leave the room; he came back 15 minutes later, only to lose the game. Thus, thanks to an intelligent machine, the high-powered community of Go players gained a new take on a game that is over 2,500 years old.

The proliferation of AI solutions also makes us aware that there are other types of intelligence besides human intelligence. To use an analogy, human intelligence is the result of natural selection, as is a bird's ability to fly. Historically, only birds could fly. With the advent of the technological revolution in aviation, people began to gain a better understanding of aerodynamics and discovered numerous other ways that flight could be achieved, such as with helicopters, jet aeroplanes and spacecraft. In nature, there is no way to fly to the Moon, yet, by 1969, technological advances had enabled the National Aeronautics and Space Administration (NASA) to put humans on the Moon – a scant 60 years after the Wright brothers' first flights.

It should come as no surprise that the way in which evolutionary forces have shaped human intelligence is just one of many possible manifestations of a much broader concept. Machines are finding other ways of being intelligent and of carrying forward the increasing complementarity of human and artificial intelligence.

[3] Mikolov and others (2013) have presented a Word2Vec representation algorithm implemented using the TensorFlow library for machine learning developed by Google. As an example, the 60 words that are located the closest to the word "Colombia" refer to other (primarily Latin American) countries. The names of some Asian and European countries are also found, along with the words "Andes", "Caribbean" and "republic". The algorithm learned the contextual meaning of the word "Colombia" and the relationships between words on its own and is thus one example of a self-supervised learning algorithm.

2. Deep learning architectures

One of the main theoretical aspects of the current implementation of AI is deep learning or deep neural networks. One way of looking at deep learning is to view it as an artificial neural network. This view is based on two ideas. The first suggests that the brain provides a model for artificial networks and that it is possible to reproduce the brain's functions so as to create intelligence. The second is that machine learning models that shed light on basic scientific questions not only are useful for engineering applications but can also clarify deeper theoretical constructs about what intelligence is (Goodfellow, Bengio and Courville, 2016).

Although brain modelling is useful as a way of thinking about deep learning, it may have a limited role in contemporary research because the brain is too complex a system for humans to be able to draw major insights or conclusions from it. Therefore, rather than sticking to biological analogies, it is more useful to understand several fundamental concepts that have been developed in the field of machine learning. These ideas can be described as "the four Rs" of deep learning: representation, reuse, robustness and regularization. The goal is to identify technological features that can be used to tackle economic and social development challenges.

(a) Representation: deep layers

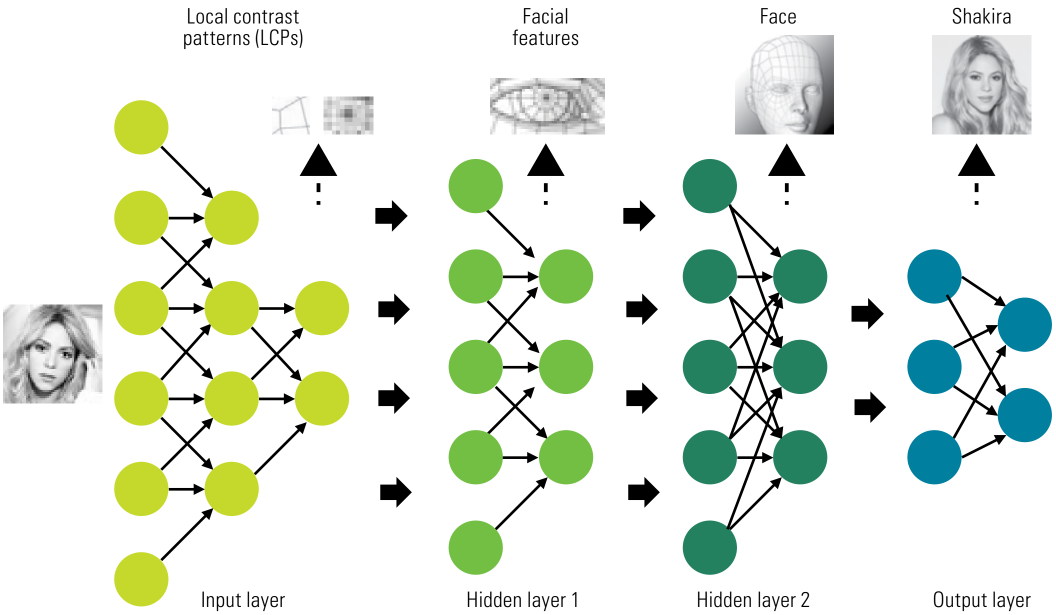
One of the main ways in which AI machines can grasp the subjective and situational nature of data is through what is called "representational learning". This type of learning uses a set of methods that allows a machine with unprocessed inputs to use those data to discover the representations that are needed to develop classifications (LeCun, Bengio y Hinton, 2015). Deep learning methods are essentially multilayered representation-learning methods that progressively generate increasingly abstract representations.

Traditional machine learning algorithms, such as logistic regressions, draw on elements representing unprocessed data. For example, a doctor interprets a scanned image and inputs the features that he or she has observed into a machine learning system (the machine receives a representation of the image, not the image itself), which then suggests courses of action (e.g. it calculates the probability of surgery being required). This process calls for the involvement of doctors who are specialists in medical imaging technology; that kind of expertise is costly, and a doctor's interpretation of those images may be subjective. One solution is to use machine learning to determine not only how the representations are mapped on the results but also to uncover the representations themselves. In deep learning, the layers of features are learned from the data rather than being explicitly designed by human engineers. In other words, the machine not only learns the data structure (traditional learning) but also a part of its own high-level architecture.

Representational learning relies on particular factors of variation in order to separate out each unique factor of the representation. One of the main problems with this approach is that some of the factors of variation often influence multiple data, so factors of variation have to be separated out so that the non-significant ones can then be ignored. Deep learning resolves the problem posed by the need to separate out factors of variation by introducing representations that are expressed in terms of other, simpler representations (Goodfellow, Bengio and Courville, 2016). By way of example, diagram VII.1 illustrates an image recognition operation of the type that is run millions of times each day in social media such as Facebook or Instagram.

A deep learning architecture is essentially a multilayered stack of simple modules that are subject to learning (LeCun, Bengio and Hinton, 2015). The classic example of a deep learning model is the feedforward deep network, or multilayer perceptron (an artificial neural network). A multilayer perceptron is a function that associates a set of input values with output values using a series of hidden layers to extract abstract features from the input, or visible, layer (Goodfellow, Bengio and Courville, 2016). As shown in diagram VII.1, the different layers learn different aspects of the whole, which introduces a flexible and robust form of modularity. To move from one layer to the next, a group of units calculates a weighted sum of their inputs from the previous layer and passes on the result via a non-linear function (LeCun, Bengio and Hinton, 2015). To achieve an optimum goodness of fit, backpropagation can be used to endow the network with the ability to form and modify its own interconnections.

Diagram VII.1
Representation of facial recognition using deep neural networks



Source: M. Hilbert and S. Mann, "Artificial intelligence for development: AI4D", Rochester, 2018, unpublished.

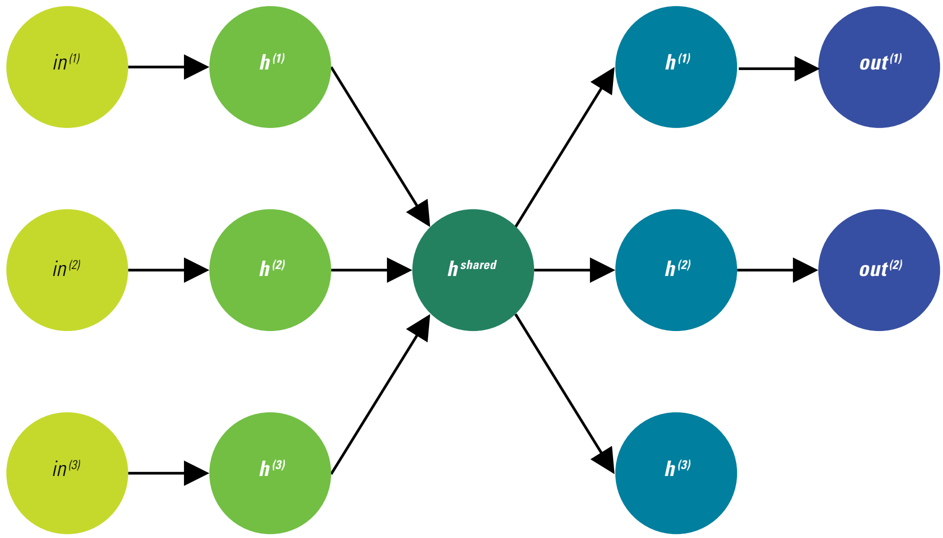
(b) Multitask and transfer learning: reuse

The most important aspect of the multilayer, modular representation of knowledge is that it allows for better generalizations by, inter alia, including a scheme for minimizing the generalization error of the prediction functions and reducing the biases associated with the training set (Yu and others, 2015). Layer-by-layer training can also be used, with the knowledge acquired at one layer then being employed to improve task performance in another. The result is essentially a transfer of knowledge: the modular nature of the system permits context-dependent adjustments to be made without having to start from zero.

One element that is shared by the vast array of methods of multitask learning is the part of the model which detects or captures a common structural set. The underlying assumption is that some of the factors that explain the variations observed in the data associated with different tasks are shared in different contexts. For example, image recognition using deep neural networks shares learned features about lines, eyes and faces at lower levels. Online recommendation systems learn to transfer customer preferences about books to music and consumer electronics. The idea of reutilization is at the core of the theoretical advantages underlying deep learning, i.e. the construction of multiple levels of representation or the learning of a hierarchy of features (Bengio, Courville and Vincent, 2013).

When this idea is implemented in a semi-supervised setting, it is often referred to as multitask learning, while it takes the name of transfer learning when implemented through supervised learning (Goodfellow, Bengio and Courville, 2016). Technically, this can be implemented top-down or bottom-up by summing up the shared structures of different inputs and providing a shared base or platform for evaluating different outputs (see diagram VII.2).

Diagram VII.2
Illustration of the architecture of multi-task or transfer learning



Source: M. Hilbert and S. Mann, "Artificial intelligence for development: AI4D", Rochester, 2018, unpublished.

In the architecture of multitask or transfer learning, a hidden variable in the intermediate levels has a shared semantics, whereas the task-specific input and output variables have different meanings. In this case, factor $h^{(3)}$ in diagram VII.2 explains some of the input variations, but it is not relevant to the current task.

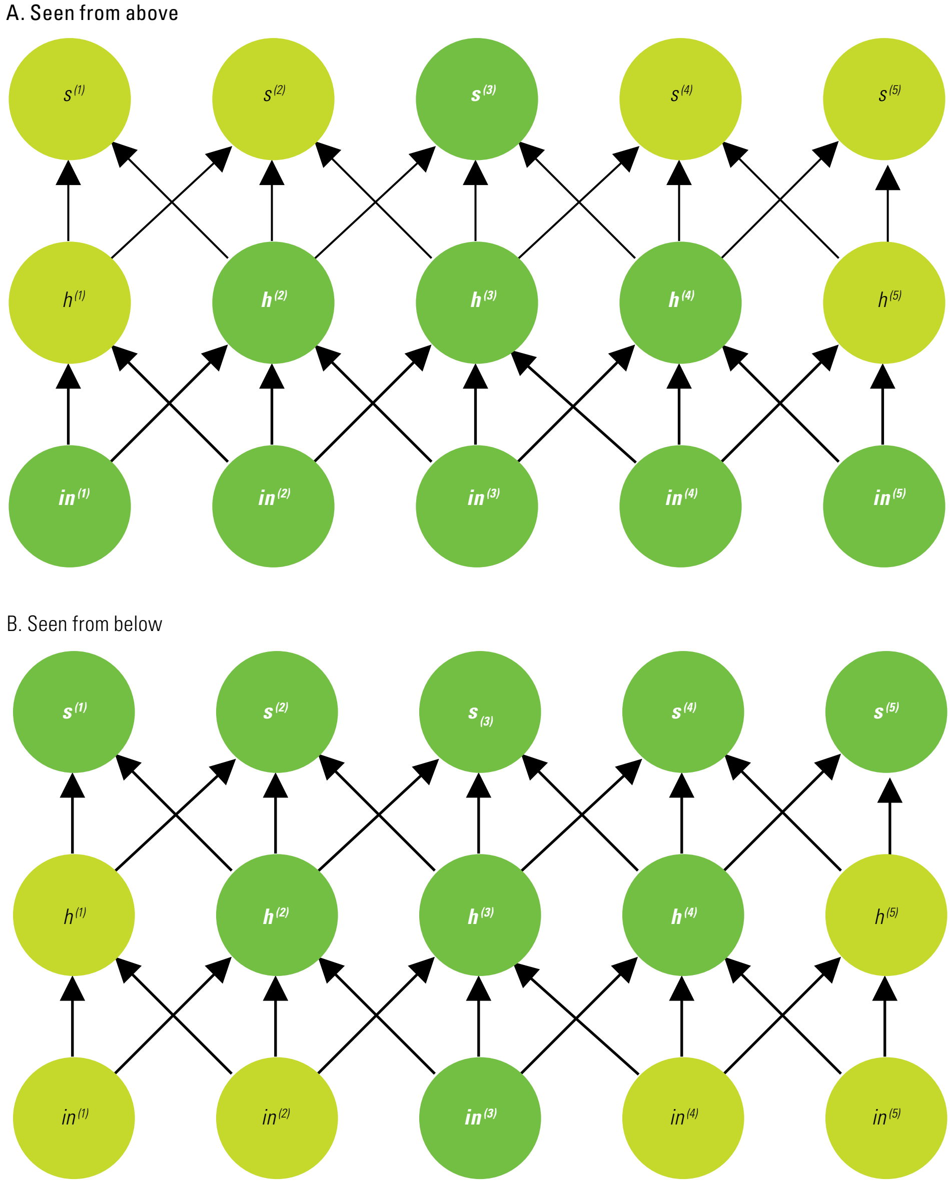
In a supervised setting, this technique is extremely useful if there are significantly more data in one setting than in another. For example, computer vision could be trained using images of house cats and then use the extracted features to identify a rarely seen wild snow leopard (Yosinski and others, 2014). It could even be used to approximate unprecedented scenarios for which no label examples are available (known as "zero-shot learning") (Goodfellow, Bengio and Courville, 2016). This can usefully be applied to the analysis of international development issues, which are rife with information asymmetries.

(c) Robustness: convolutional neuronal networks

Convolutional neural networks (CNN) are one type of deep, feedforward network that is considered easy to train and generalize and is one of the most common realizations of deep neural networks (LeCun, Bengio y Hinton, 2015). CNNs are designed to process data in multiple matrices as a colour image made up of multiple two-dimensional grids containing pixels of varying intensities. They have been very successful in practical applications.

Convolutional networks are the greatest triumph of biologically inspired AI. The developers of the underlying concept, who found that some neurons respond to highly specific patterns but are largely unresponsive to others while, at the same time, being very robust and functionally invariant, were awarded the Nobel Prize for their work (Hubel and Wiesel, 1968). In convolutional networks, these developments are implemented through the systematic use of shared parameters and involve at least two types of layers: convolutional layers and pooling layers. The convolutional layer detects groups of functions or features of the preceding layer, while the pooling layer groups similar functions or features together. Thus, even if an input image has millions of pixels, the eye can detect small but significant features, such as borders, using nuclei that use only a few dozen pixels and share those parameters. It does so by sliding overlapping windows of shared representations upward and downward over the grid structure (see diagram VII.3).

Diagram VII.3
Shared connectivity in a convolutional network



Source: M. Hilbert and S. Mann, "Artificial intelligence for development: AI4D", Rochester, 2018, unpublished.

Despite the scant (incomplete) degree of connectivity ((3) in the diagram), the configuration's deep stratification can indirectly connect all inputs and outputs (depending on their width and depth). This can be done from the top down (see diagram VII.3A), which defines receptive fields, and from the bottom up (see diagram VII.3B), when the output is formed by convolution with a nucleus of a specified width and depth.

The important result here is that this particular form of parameter-sharing in convolutional networks causes the layer to be equivariant to translation. This means that, if the input changes, the output changes in the same way. This ensures that the order does not matter under equivariance: f (g (x)) = g (f (x)). The same representation of the input is obtained even if it occurs before or after or is shifted to one side or the other. This makes it possible, for example, to discern a face in an image without it being obscured by other details such as direction, the exact location, the background or context, or other elements. It also makes it possible to take advantage of the fact that some features that are useful in learning about one part of the data may also be useful for learning about other parts. This heightens the efficiency, coherence and temporal stability of the entire system while the diversity and dynamics of the inputs are being processed. In terms of human development, the concept of equivalence makes it possible to ensure that different inputs will be represented efficiently and can be detected even if they reappear in a heavily context-dependent, volatile configuration, which is the norm in the case of the dynamics of economic and social development.

(d) Regularization: overfitting

The need for machine learning to be solid and yet flexible points up its main performance challenge, which is how to decide when to stop learning. The algorithm may learn particular details from the specific data set that are not generalizable. This problem is known as "overfitting", which means that the algorithm has learned more details than it should have.

Overfitting entails fitting the data more than is warranted (Abu-Mostafa, Magdon-Ismail y Lin, 2012). This occurs automatically when a machine is learning regularities and patterns, and it is often subjective. In many cases, the ultimate purpose of the algorithm's application is what defines which aspects are necessary and which are just noise.

The way in which the machine learning community usually deals with overfitting is known as "regularization". This term denotes any modification of a learning algorithm designed to reduce its generalization error without affecting its training error (Goodfellow, Bengio and Courville, 2016). Regularization is thus a quite broad concept that encompasses various methods, most of which are approximate heuristics, and is therefore as much an art as it is a science (Abu-Mostafa, Magdon-Ismail and Lin, 2012).

B. The practice: artificial intelligence for development

Drawing on this improved understanding of some of the achievements, concepts and architectures of modern AI (and specifically the "four Rs"), the discussion will now turn to the ways in which AI can be used to further the economic and social development process as viewed in terms of the Sustainable Development Goals adopted by the United Nations.[4] Based on a compilation of 24 case studies, four elements were identified that can be used to encapsulate the ways in which AI may influence development dynamics. The first two relate to the location of AI information processing, while the last two refer to the inputs and outputs of that process as they relate to the real world (Hilbert and Mann, 2018).

Transfer of intelligence

(i) Remote intelligence: Modern telecommunications networks make it possible to use highly trained AI systems remotely;

(ii) Local intelligence: The local application of AI systems that are capable of adapting to local contexts and requirements can be performed autonomously;

Manipulation of reality

(iii) Augmented, virtual and replicated reality: AI systems can be employed to create digital twins that can then be used to improve our understanding of reality or to replicate certain aspects of it;

(iv) Fine-grained reality: Digital footprints are generating increasingly detailed maps of the real world, and machine learning provides a way of harnessing that information to drive progress towards the achievement of development goals.

Table VII.1 depicts the applications of the four above-mentioned features of artificial intelligence for development as they relate to the Sustainable Development Goals.

4 AI technologies that can be used to address 9 out of the 17 Sustainable Development Goals were examined, and 24 case studies were compiled and analysed. Case studies were selected using principles of the random path and snowball methods on a fairly destructured basis, since the researchers did not initially expect to find so many interesting examples. Given the unstructured way in which the case studies were compiled, the list of features that was drawn up may not be exhaustive.

Table VII.1

Features of artificial intelligence for development as they relate to the Sustainable Development Goals

Sustainable Development Goals / Features of AI	Remote intelligence	Local intelligence	Augmented, virtual and replicated reality	Fine-grained reality
Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture		Smart agriculture and climate change analysis	Plants that replicate foods of animal origin	
Goal 3: Ensure healthy lives and promote well-being for all at all ages	Diagnostic support Interpretation of X-rays to detect tuberculosis Automated diagnosis Early detection of congenital cataracts	Streamlining of medical paperwork Drivers for pharmaceutical and medical research Elimination of unnecessary surgical operations Use of mobile phones to detect malaria	Improved motor vehicle safety through the use of tridimensional maps and self-driving vehicles	Research on chemical compounds Prediction of the development of cardiovascular diseases
Goal 4: Ensure inclusive and quality education for all and promote lifelong learning	Automation of individualized instruction and special education	Detection of hidden patterns in the school environment		Identification of troubled students
Goal 5: Achieve gender equality and empower all women and girls		Simulations for use in educating people about gender equality	Information (simulations) and a virtual handbook on pregnancy and girls' rights	
Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all		Local IA applications for boosting productivity in all sectors		
Goal 11: Make cities inclusive, safe, resilient and sustainable		Safer and more s ustainable cities Smarter cities	Automated driver guidance for increased safety	Road repair maps
Goal 12: Ensure sustainable consumption and production patterns	Just-in-time water supply	Detection of pipes in need of repair On-demand irrigation systems	Land-use profitability analyses	
Goal 14: Conserve and sustainably use the oceans, seas and marine resources			Ecosystem modelling and definition of sustainable alternatives	Use of drones to protect endangered species Digital mapping of the oceans
Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss		Conservation of timber	Tridimensional, interactive modelling of the Earth by EarthCube	

Source: M. Hilbert and S. Mann, "Artificial intelligence for development: AI4D", Rochester, 2018, unpublished.

Note: This schematic corresponds to the overview of AI-based solutions formulated on the basis of the findings of 24 case studies which were then used to construct an analytical framework for the use of artificial intelligence for development.

1. Remote intelligence

The term "remote intelligence" refers to the ability of AI technologies, in combination with telecommunications technologies, to make up for the shortage of resources in fields that lack sufficient personnel or that have not been adequately researched. This is especially important in view of the fact that multitask and transfer learning can make it possible to reuse intelligence generated or obtained in another location. Some of the pioneering applications of remote intelligence have been in the fields of education and health and include automated distance education and remote diagnoses of such diseases as congenital cataracts, tuberculosis and breast cancer.

AI solutions in education have automated teaching and tutoring systems that can be used on a large scale at a low cost. Structured activities such as foreign-language learning, instruction in software programming or the development of quantitative analytical techniques can be automated as well. AI learning systems can thus be used to offer structured, individualized instruction to large segments of the population.

Remote intelligence can revolutionize the health-care industry by making it more efficient and expanding its coverage. For example, Enlitic is a medical start-up that is combining deep learning with large volumes of medical data to improve doctors' diagnostic capabilities and, hence, patient outcomes. Its deep learning networks examine millions of images in order to learn to identify diseases automatically and can thus provide rich insights into such areas as early detection, treatment planning and disease monitoring. Google's DeepMind Health project is working in the same field. This technology can be used to interpret test results and determine the most effective types of treatments for different patients. DeepMind was founded in London for the purpose of boosting the efficiency of the United Kingdom's National Health System, but the technology that it is developing to support existing health-care systems and turn them into self-sustaining initiatives can benefit communities around the world.

One of the greatest potential benefits of remote intelligence is that it can offer more equal access to diagnostic resources by placing medical knowledge within the reach of remote and underserved regions at the national and international levels.

Zebra Medical Vision has developed a service called Zebra AI1 that uses algorithms to examine medical scans for just US$ 1 per scan. With the new capabilities that it is developing, its deep-learning engine can read magnetic resonance images (MRIs), CAT scans and other images and can automatically detect diseases of the lungs, liver, heart and bones. The results are transmitted to radiologists, who can then make a diagnosis or order more tests much more quickly. At present, the system can detect nearly 20 different diseases. GE Healthcare has brought out a similar technology in partnership with NVIDIA Corporation and Intel Corporation and is planning to update 500,000 of its imaging devices around the world with the new NVIDIA-powered Revolution Frontier CT. This technology will be used in GE Healthcare's advanced ultrasound imaging equipment for data visualization and quantification. GE Healthcare has also teamed up with Intel Corporation to use the scalable Intel Xeon to transmit radiological images much faster than before. Together with the GE Healthcare imaging solutions, the scalable Intel Xeon platform is designed to help the current generation of radiologists to become more productive by reducing the time needed to visualize and upload medical images.

The use of AI for diagnostic purposes and for processing medical images is intended to support the work of medical professionals by helping them to save time and to avoid costly misdiagnoses.

Remote intelligence is also being used to find new ways to diagnose malaria. Of the 300 million to 500 million cases recorded each year, between 1.1 million and 2.7 million malaria sufferers (most of them children) die. In developing countries, the lack of access to facilities capable of making accurate diagnoses is largely attributable to shortages of trained personnel and equipment. The results of a recent survey conducted in Uganda indicate that only half of the health-care centres in rural areas have microscopes and, of those centres, only 17% have people who are trained to use them to diagnose malaria. Even when a person trained for this purpose is available, the demand for these services is so great that he or she is unable to spend enough time to analyse each sample properly, and diagnoses may therefore not be as reliable as they should be.

This situation has prompted researchers to seek a technological solution for diagnosing malaria. A prototype developed by BMC Bioinformatics uses artificial vision and image processing techniques to identify parasites in images of blood films captured using a standard microscope. With sufficient training data, the algorithms used for analysing other types of medical images or performing other types of artificial vision tasks (such as face detection) can be used to detect and identify malaria plasmodia. A mobile telephone application based on morphological image processing algorithms is being used to set up a fully equipped diagnostic unit that employs mobile phones that are connected up to a portable microscope.

A commercially available system called Parasight has been developed to assist with the diagnosis of this disease. This platform analyses blood samples which are then processed by a machine learning algorithm that performs feature extraction using a computer vision support vector machine (SVM) classifier. The algorithm examines unique morphological features to reach a final diagnosis that detects, enumerates and identifies the malaria species. The objective is for this system to produce a reliable, automated diagnostic platform that functions without expert intervention.

2. Local intelligence

Another feature that was identified in the case studies is the possibility of adapting intelligence to local conditions and needs. One particularly interesting case having to do with the analysis of the effects of climate change involves the local use of a machine learning algorithm (borrowed from the neurosciences) to analyse large volumes of climate data and data on local rice crops in Colombia. The results are highly localized and provide recommendations for different cities. These forecasts helped 170 Colombian farmers to avert heavy direct economic losses and enabled them to boost their crop yields from one to three tons of rice per hectare.

Other machine learning technologies are being used to promote gender equality in the workplace and the schoolroom. Doberman Tech has used machine learning and voice recognition to create an application that helps to promote gender equality in the conference room. This application registers and analyses what is said during a meeting and provides a visualization of the contributions of different speakers, disaggregated by gender, as the meeting progresses as a means of raising awareness of gender equality.

A great deal has been written about smart cities, both internationally and in Latin America. The use of leading-edge AI to address the safety issues, traffic problems and sustainability challenges faced by cities clearly falls into the category of local intelligence. As one instance of the use of smart infrastructure in cities, HiBot Corporation is using an AI system designed to algorithmically figure out which water mains and pipes are more at risk of breakage or leakage based on the inspection of pipes that have already been replaced and an evaluation of soil dynamics, as well as other factors such as the electromagnetic forces emanating from power lines. In the United States, this system has detected a large number of water leaks each year throughout the country, thereby helping to conserve water resources.

Clearly, the health sector can also benefit from the adaptation of AI to local conditions. For example, in many developing countries, the ability to arrive at accurate, low-cost, real-time diagnoses of diseases such as malaria is vital: false negatives can be deadly, and false positives promote the proliferation of medicine-resistant strains, higher costs and a failure to treat other diseases that have similar symptoms (such as meningitis or typhoid fever).

3. Augmented, virtual and replicated reality

Many practical applications are increasingly combining remote and local intelligence with the use of virtual and augmented reality. Self-driving vehicles, for example, can use tridimensional maps to reach decisions in real time. By mapping real scenarios, self-driving vehicles can choose among an array of different options in determining the best course to take. These applications require a robust and flexible capacity to process concepts using equivalent translation methods. The principle being applied here is similar to the one being used by EarthCube, a company that is investing in real-time hologram projection technology to create an augmented tridimensional model. EarthCube has developed a tridimensional living model of the Earth that represents each of the layers of the atmosphere (in its solid, gaseous and liquid states) and is using machine learning to explore the effects of the interactions between these different layers.

AI-guided virtual realities are also used to further education and gender equality. For example, in the game Worm Attack!, designed for children 7 years of age and older, the number of healthy players has to keep growing in order to defeat the parasites in their stomachs; the game thus teaches the children about intestinal parasites and about an anti-parasitic treatment that can have a positive impact on their health and education. The Half the Sky Movement develops simulation games that can be played on mobile telephones and help to raise public awareness of the problems faced by women and girls. For example, the Movement's 9 Minutes game teaches women and girls about how to have a healthy pregnancy by taking them through each of the nine months of gestation (one month per minute).

In addition to its application in augmented and virtual realities, AI is also being used to replicate the design of atoms in the real world and molecular objects such as food. The idea is to duplicate the structure of a given object so that a more sustainable version of it can then be developed. This type of replication could be used to fight hunger. The Not Company (NotCo) has developed an AI program called Giuseppe that tries to use and replicate the molecular composition of foods of animal origin in order to determine what vegetables could be combined to create a food with a similar taste, texture and smell. "Not Mayo", like regular mayonnaise, contains canola oil, but it replaces eggs with basil, peas and potatoes.

4. Fine-grained reality

One of the way in which AI can provide humans with more detailed information in specific areas having to do with economic and social development is by finding a new way to compile data with greater granularity that can be used to hone our understanding of reality. Automated representational learning can convert recently obtained data into useful features.

The compilation of granular data has been shown to be useful in responding to global needs or crises. By gathering data from plots of farmland that humans would be unable to obtain, AI can help to fight hunger. In education, computer vision and feelings analysis are being used to identify students that are having difficulties. This use of AI could help to achieve the goal of providing a quality education to all students, everywhere in the world, regardless of how great or limited their physical or mental capabilities are. Granular analysis can also contribute to the development of sustainable cities and communities as new technologies are used to determine how road design influences drivers' behaviour and how given modifications in the design of communities may encourage or help people to drive more safely.

Finally, detailed analyses can be used to map the impact of social dependence on access to resources. This makes it possible to map the collapse of given ecosystems in order to determine their existing degree of dependence. Subsistence fishing grounds, for example, could be mapped in order to find ways to promote sustainable development.

C. Economic and social development and artificial intelligence

A review of some of the theoretical aspects of AI and its uses can point up some of the opportunities, tensions and challenges posed by this technology for development.

1. An opportunity: reuse of artificial intelligence for remote intelligence applications

Development dynamics and goals share a number of factors that provide fertile ground for the application of different types of multitask and transfer learning. At the most fundamental level, there are common precepts such as those of human rights, which are presumed to be universal, inherent and inalienable (United Nations, 1948). The process of learning those shared, intrinsic precepts of our culture promotes the spread of common values and facilitates the use of remote intelligence. This does not preclude the possibility of placing emphasis on other more specific values in other cultural or geographical settings at more local levels.

In the coming years, smart machines will gain an understanding of the hierarchical architecture of the complex structures of multidimensional preferences that we call "global norms" or "universal standards". With proper guidance, the outcome may well be greater moral and ethical coherence, with a certain level of shared beliefs and values being coupled with diversity and multiculturalism. The hierarchical layers of deep learning are a natural way of encapsulating the representation of generic human values and specific preferences and customs. Modern AI deep learning offers a tangible means of incorporating this naturally occurring hierarchy into the socially integrated structures of human preferences.

2. Opportunity: representation of artificial intelligence for the application of local intelligence

The capacity of modern AI to robustly learn new representations rapidly in different contexts is perhaps one of the greatest promises that it holds out (Goodfellow, Bengio and Courville, 2016). Local intelligence can be used for the ad hoc training of autonomous agents that can take into account the particularities of local conditions in remote areas. Thanks to their increasing granularity and automaticity, these observations provide a steady stream of inputs that open the way for new discoveries by tapping into regional variations, particularities and dynamics that will lead to steady gains in productivity grounded in local conditions. The ever more precise digital footprint of big data will enable local agents to find more solutions that are tailored to unique local conditions, with the aggregate effect being greater economic and social efficiency at the national level.

Just as AlphaGo discovered innovative ways of solving complex problems, when AI is applied to local conditions it can offer unique solutions for local problems. The application of virtual and augmented realities makes it possible to add new layers of information to local conditions that will give rise to new discoveries and novel solutions, along with a context-dependent form of automation. This will encourage national authorities to trade in their one-size-fits-all policies for policies tailored to each set of local conditions based on global intelligence capabilities.

3. Tension: global efficiency and local diversity

Seen in isolation from one another, the two opportunities discussed above make the future look bright. In combination with one another, however, they generate tension between global efficiency and local needs. In theory, modern AI, by its very nature, embodies the ideals of reliance on the local context and global coherence. In practice, economic and social pressures may collide with one another in the form of economies of scale, cultural and political transaction costs and issues of social cohesion.

Most AI training is being conducted in the industrialized world because it can be very costly. This fact shapes the way in which AI learns the patterns to be found in the data used to train it. Since centralized solutions have an economic advantage over local training, the solutions that will be devised and the recommendations that will be made will obviously be more in tune with the historical and cultural backgrounds of the developed countries in which AI training is being performed. In the best of cases, the application of those solutions to developed countries' problems will be less useful that it would otherwise be and, in the worst of cases, will actually be harmful.

History provides a wealth of examples of situations in which the economic and cultural hegemony of one country led to the extinction of the values, culture, customs and local development goals of another. While it is true that, theoretically, modern AI offers an opportunity for preserving and celebrating diversity, this is not brought about automatically by the application of AI. Economic incentives and social pressures tend to replicate the constructs of developed countries, since it is cheaper to reuse a unique solution. Offsetting the incentive offered by the economic efficiency of reutilizing AI code will thus be an uphill battle, since AI systems will have learned concepts that are clearly overfitted to developed-world conditions. The danger of this lies in the threat of the global indoctrination of first-world intelligence.

4. Challenge: artificial intelligence for development

Meeting the challenge of designing global AI systems that can strike a balance between global efficiencies and local contexts boils down to finding the dividing line between outputs that can be generalized and those that cannot. Taking an AI system that works well in a given context and trying to apply it to a different one without considering the inherent differences and constraints is a clear-cut case of overfitting. Regularization is the machine learning community's main tool for countering overfitting (Abu-Mostafa, Magdon-Ismail and Lin, 2012, p. 126). The term also alludes to the need to regulate a process in a way that will safeguard diversity in a world where AI systems are taking more and more of the decisions.

Since regularization is more of an art than a science, the world has a vast array of poorly defined options at this juncture. The process of choosing among those options will take the form of an implicit or explicit negotiation similar to the negotiations that the machine learning community engages in when dealing with regularization issues. In both cases, it is a matter of learning differently configured generalizable perceptions and non-generalizable particularities. In this case, the different configurations in question are those of different countries' development processes and stages.

One possibility is to focus on the development of solutions that produce shared parameters (e.g. Hinton and others, 2012) that regularize each unit in such a way that it is not simply a positive feature but one that is positive in many different contexts (Goodfellow, Bengio and Courville, 2016). That being said, it must be recognized that a solution that works for all cases is often no more useful than one that does not work in any.

As the developing countries enter into these negotiations concerning the governance of AI, the only variable that they can control is their level of proactivity. The question at issue is how much weight their views will carry when they come to the bargaining table. Developing countries will need to begin to invest heavily in building their AI capacity if they are to avoid being overwhelmed or overawed by solutions that, in the best of cases, will not be suited to their needs and, in the worst of cases, will be detrimental to their interests.

AI is still an infant technology, and the forces that will drive it forward are not yet totally defined or known. Surprisingly, one of the leading countries in this area at present is China, and some small countries are also playing an important part. In terms of the number of AI papers published between 2011 and 2015, China leads the pack with 41,000, followed by the United States (25,000), Japan (around 11,700) and the United Kingdom (approximately 10,100). In terms of weighted citations per field of research (with the weightings differentiating citations by subject and year), the three top positions are held by Switzerland, Singapore and the Hong Kong Special Administrative Region of China (Baker, 2017). Both these rankings show that there are still opportunities in this area for newcomers who want to stay in the race.

Bibliography

Abu-Mostafa, Y., M. Magdon-Ismail and H. Lin (2012), *Learning from Data: A Short Course,* AMLBook.

Allen, K. (2015), "How a Toronto professor's research revolutionized artificial intelligence", *The Star,* Toronto, 17 April [online] https://www.thestar.com/news/world/2015/04/17/how-a-toronto-professors-research-revolutionized-artificial-intelligence.html.

Baker, S. (2017), "Which countries and universities are leading on AI research?", *Times Higher Education,* London, 22 May [online] https://www.timeshighereducation.com/data-bites/which-countries-and-universities-are-leading-ai-research.

Bakshy, E., S. Messing and L. Adamic (2015), "Exposure to ideologically diverse news and opinion on Facebook", *Science,* vol. 348, No. 6239, Washington, D.C., American Association for the Advancement of Science (AAAS), June [online] https://doi.org/10.1126/science.aaa1160.

Bengio, Y., A. Courville and P. Vincent (2013), "Representation learning: a review and new perspectives", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 35, No. 8, Piscataway, Institute of Electrical and Electronics Engineers (IEEE), August.

Boureau, Y. L., J. Ponce and Y. LeCun (2010), "A theoretical analysis of feature pooling in visual recognition", document presented at the 27th International Conference on Machine Learning (ICML), Haifa, 21-24 June [online] http://www.di.ens.fr/willow/pdfs/icml2010b.pdf.

Cacioppo, J. and others (2013), "Marital satisfaction and break-ups differ across on-line and off-line meeting venues", *Proceedings of the National Academy of Sciences (PNAS),* vol. 110, No. 25, Washington, D.C., National Academy of Sciences (NAS) [online] https://doi.org/10.1073/pnas.1222447110.

Caliskan, A., J. Bryson and A. Narayanan, (2017), "Semantics derived automatically from language corpora contain human-like biases", *Science*, vol. 356, No. 6334, Washington, D.C., American Association for the Advancement of Science (AAAS), April [online] https://doi.org/10.1126/science.aal4230.

Center for the Digital Future (2016), *The 2016 Digital Future Report: Surveying the Digital Future, Year Fourteen,* Los Angeles [online] http://www.digitalcenter.org/wp-content/uploads/2013/06/2016-Digital-Future-Report.pdf.

Colleoni, E., A. Rozza and A. Arvidsson (2014), "Echo chamber or public sphere? Predicting political orientation and measuring political homophily in Twitter using big data", *Journal of Communication,* vol. 64, No. 2, Oxford, Oxford University Press, April.

Goodfellow, I., Y. Bengio and A. Courville (2016), *Deep Learning,* Cambridge, MIT Press.

Halevy, A., P. Norvig and F. Pereira (2009), "The unreasonable effectiveness of data", *IEEE Intelligent Systems,* vol. 24, No. 2, Piscataway, Institute of Electrical and Electronics Engineers (IEEE), March-April.

Hendershott, T., C. Jones and A. Menkveld (2011), "Does algorithmic trading improve liquidity?", *The Journal of Finance,* vol. 66, No. 1, Hoboken, Wiley, February.

Hilbert, M. and S. Mann (2018), "Artificial intelligence for development: AI4D", Rochester, unpublished.

Hilbert, M., and P. López (2011), "The world's technological capacity to store, communicate, and compute information", *Science,* vol. 332, No. 6025, Washington, D.C., American Association for the Advancement of Science (AAAS), April [online] https://doi.org/10.1126/science.1200970.

Hinton, G. and others (2012), "Improving neural networks by preventing co-adaptation of feature detectors", Toronto, University of Toronto [online] https://arxiv.org/abs/1207.0580.

Hubel, D. and T. Wiesel (1968), "Receptive fields and functional architecture of monkey striate cortex", *The Journal of Physiology,* vol. 195, No. 1, Hoboken, Wiley.

Jia, Y., C. Huang and T. Darrell (2012), "Beyond spatial pyramids: receptive field learning for pooled image features", *2012 IEEE Conference on Computer Vision and Pattern Recognition,* Providence, Institute of Electrical and Electronics Engineers (IEEE).

LeCun, Y., Y. Bengio and G. Hinton (2015), "Deep learning", *Nature,* vol. 521, No. 7553, Washington, D.C., American Association for the Advancement of Science (AAAS), May [online] https://doi.org/10.1038/nature14539.

Lee, A. (2016), "The meaning of AlphaGo, the AI program that beat a Go champ", *Maclean*'s, Toronto, Rogers Media, 18 March [online] http://www.macleans.ca/society/science/the-meaning-of-alphago-the-ai-program-that-beat-a-go-champ/.

Metz, C. (2016), "How Google's AI Viewed the move no human could understand", *WIRED*, Boone, 14 March [online] https://www.wired.com/2016/03/googles-ai-viewed-move-no-human-understand/.

Mikolov, T. and others (2013), "Distributed Representations of Words and Phrases and their Compositionality", *Advances in Neural Information Processing Systems 26*, C. Burges and others (eds.), San Diego, University of California [online] http://papers.nips.cc/paper/5021-distributed-representations-of-words-and-phrases-and-their-compositionality.pdf.

Och, F. (2005), "Statistical machine translation: foundations and recent advances", document presented at the Tenth Machine Translation Summit, Phuket, 12-16 September [online] http://www.mt-archive.info/MTS-2005-Och.pdf.

Pariser, E. (2011), *The Filter Bubble: What the Internet Is Hiding from You*, London, Penguin Books.

Pearson, K. (1901), "LIII. On lines and planes of closest fit to systems of points in space", *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science. Series 6*, vol. 2, No. 11, Routledge, Taylor & Francis [online] https://doi.org/10.1080/14786440109462720.

Pérez, C. (2007), "Great surges of development and alternative forms of globalization", *Working Papers in Technology Governance and Economic Dynamics*, No. 15, Tallinn, The Other Canon Foundation/Tallinn University of Technology, July [online] http://www.carlotaperez.org/pubs?s=tf&l=en&a=greatsurgesofdevelopment.

Ramchurn, S. and others (2012), "Putting the 'smarts' into the smart grid: a grand challenge for artificial intelligence", *Communications of the ACM*, vol. 55, No. 4, New York, Association for Computing Machinery (ACM), April [online] https://doi.org/10.1145/2133806.2133825.

Ricci, F. and others (eds.) (2011), *Recommender Systems Handbook,* Boston, Springer.

Russell, S. and P. Norvig (1995), *Artificial Intelligence: A Modern Approach,* Upper Saddle River, Prentice Hall.

Schreuder, D. (2014), *Vision and Visual Perception: The Conscious Base of Seeing,* Bloomington, Archway Publishing.

Silver, D. and others (2017), "Mastering the game of Go without human knowledge", *Nature,* vol. 550, No. 7676, Washington, D.C., American Association for the Advancement of Science (AAAS), October [online] https://doi.org/10.1038/nature24270.

Stiglitz, J. (2002), *Globalization and Its Discontents,* New York, W. W. Norton & Company.

United Nations (1948), *Universal Declaration of Human Rights* (A/RES/217(III)), Paris, December.

Xiong, W. and others (2016), "Achieving human parity in conversational speech recognition", *Microsoft Research Technical Report,* No. MSR-TR-2016-71, Redmond, Microsoft Research Publications [online] http://arxiv.org/abs/1610.05256.

Yosinski, J. and others (2014), "How transferable are features in deep neural networks?", *Advances in Neural Information Processing Systems 27,* Z. Ghahramani and others (eds.), San Diego, University of California [online] http://papers.nips.cc/paper/5347-how-transferable-are-features-in-deep-neural-networks.pdf.

Yu, W. and others (2015), "Learning deep representations via extreme learning machines", *Neurocomputing,* vol. 149, No. A, Amsterdam, Elsevier, February.

The convergence of the physical and digital worlds is shaping an ecosystem whose dynamics are redefining the economic and social development model. This document analyses the Internet of Things, blockchain and artificial intelligence, and their transformative potential. It studies two enablers of these technologies: global digital platforms and training for upgrading human resources, and analyses the impact of these and other digital technologies on manufacturing and advanced services, and on digital financial technology (fintech) firms. It concludes with a reflection on the implications of artificial intelligence for achieving the Sustainable Development Goals.

Given the accelerating pace of technological change, Latin America and the Caribbean will have to redouble its efforts in a world in which competition among the digital technology leaders is ever fiercer. The region must increase its commitment to technological development and engage in the technical and political debate on the new regulatory and fiscal models, data security and privacy, standards and business models that are reshaping development patterns. In short, the world and the region are living through a time of decisions on the governance not only of the network but also across the entire economic and social system permeated by digitalization.

The strategy of the region must be clear: to strengthen policies to promote innovation, diffusion and appropriation of the new technologies in order to move towards a new economic, social and environmental model aligned with the 2030 Agenda for Sustainable Development.

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