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THE CHALLENGE OF DIGITALIZATION FOR FIRMS IN DEVELOPING COUNTRIES

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The challenge of digitalization for firms in developing countries

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Abstract

The challenge of digitalization and Industry 4.0 for firms in emerging countries is examined in this paper, considering technological trajectories and the degree of integration in the global economy. A conceptual framework is proposed, with a typology of emerging countries' firms based on their technological capabilities, their potential for digitalization, their presence in global markets and global value chains, and their involvement with foreign direct investment. Two empirical investigations are carried out. The first concerns the flows of FDI projects in emerging countries—based on the FDImarkets database—in digital-related industries and in high skill activities – R&D, design, ICTs. The second analysis investigates the patterns of innovation in a group of emerging economies using World Bank data on Innovation Surveys that allow identifying different groups of firms on the basis of their technological capabilities, innovative activities and their potential for digitalization.

The findings highlight the technological hierarchy among emerging countries' firms and the opportunities for upgrading and moving closer to digitalization and Industry 4.0. The rather large number of product innovating firms in emerging economies represents the base for the emergence of enterprises with greater technological competences, *potential entrants* in global markets. Highly innovative firms, which have reached the first stage of digitalization with new products, new processes, automation of production and R&D activities, are empirically identified; they tend to be *insider firms* in the global economy, active in both incoming and outgoing FDI. Leading digital firms combine the above qualities with extensive ICT use in all business activities; they are a selected group of dynamic firms in emerging countries at the top of the hierarchy, and include *global players* in technology, production and investment flows.

Keywords: Innovation, digitalization, foreign direct investment, emerging countries

1 Digitalization in global industry

1.1 The rise of Industry 4.0

Over the last few years, Industry 4.0 has been identified as a new phase of technological development, building on the previous diffusion of information and communication technologies (ICTs). A set of advanced digital technologies—including industrial robots, additive manufacturing and 3D printing, big data and cloud computing, computer aided design and computer aided manufacturing (CAD/CAM), artificial intelligence and machine learning—have emerged in advanced countries, offering opportunities for drastic changes in production activities, linking firms in global networks, integrating manufacturing and related services, shortening product cycles, increasing flexibility and variety, reducing costs and employment (Roland Berger, 2016; OECD, 2017; UNIDO, 2017). A definition of Industry 4.0 technologies is provided in Table 1. They can be perceived as a pyramid, rising against the backdrop of advanced digitalization of the economy, with industrial automation as the first step and the operation of 'smart factories' as the final outcome.

Industry 4.0, in fact, must be perceived in the context of the development of technologies that is best understood as a succession of techno-economic paradigms (Freeman and Louca, 2001). Building on the work of Kondratieff and Schumpeter, we argue that capitalist development is characterized by a succession of techno-economic paradigms based on a cluster of core technologies with a major diffusion potential across the economy and at rapidly reducing costs. Steam power and the textile machines of the first industrial revolution were the key elements of the first techno-economic paradigm; the present one emerged in the 1980s and is based on information and communication technologies (ICTs), with a current acceleration in digitalization, networks and the automation of production and Industry 4.0 technologies.

In the context of Industry 4.0, large firms and government policies invest in the acceleration of digitalization and the automation of manufacturing and services, with important measures in the areas of robotization, 'big data', the 'Internet of Things', 'cloud computing' and the 'platform economy'. This model of digitalization and automation entails major challenges for the future of economic activities in terms of business strategies and the location of production, quantity and quality of jobs, education and training, employment contracts, etc.

Table 1: Definition of technologies of the 4th Industrial Revolution

Technology	Attributes
Industrial robots	Industrial robots are automatically controlled, reprogrammable, multipurpose manipulators programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. They largely rely on algorithms driven by software, which may be enabled to communicate with other machines through the Internet of Things and to engage in self-learning and autonomous reprogramming through artificial intelligence. Industrial robots tend to substitute routine tasks in workers' occupations.
Additive manufacturing (3D printing)	3D printers build products by adding materials in layers. Using 3D modelling software (e.g. CAD), machine equipment and layering material, additive manufacturing equipment reads data from CAD files and lays downs or adds layers of liquid, powder, sheet material or other to fabricate a 3D object. This reduces the time, material use and number of workers involved in design, prototyping and product layout (all of which are created digitally) and facilitates product customization.
Big data and cloud computing	Big data analytics refers to a set of techniques that allows voluminous amounts of machine-readable data to be rapidly generated, accessed, processed and analysed. These processes are often undertaken through cloud computing that substantially increases the availability and affordability of computing services by using servers, storage, databases, networking, software, analytics, etc. over the internet (i.e. the "cloud"). Machine learning systems can employ these data and recommend product features by predicting what customers will like.
Computer aided design and computer aided manufacturing (CAD/CAM) techniques	Software used to design and manufacture prototypes, finished products and production runs. CAD systems allow an engineer to view a design from any angle with the push of a button and to zoom in or out for close ups and long distance views. In addition, the computer keeps track of design dependencies so that when the engineer changes one value, all other values that depend on it are automatically modified accordingly, first in building designs in blueprints, and then in creating or assembling physical products and parts using computer controlled equipment.
Artificial intelligence and machine learning	Algorithms allowing computers and machines embodying or linked to computers to learn from data and to mimic and predict human behaviour.

Source: Mayer (2018, p.5).

For advanced countries, the promise of Industry 4.0 is to achieve a 'leap' in the development and use of advanced digital technologies, increasing control over labour, global supply chains and markets; this is expected to increase growth, product diversity, productivity, flexibility and at the same time lowering production, transaction, communication and labour costs. Lower production and labour costs may create conditions for a 'reshoring' of production in advanced countries,

reducing the opportunities of less developed economies to be integrated in international production systems. Little connection with sustainable development has so far been made in advanced countries.

For emerging countries, the challenge of Industry 4.0 is 'leapfrogging' in their growth trajectory, using the new technologies as a way to catch up faster with technological 'leaders'. At the same time, there is a risk of losing high value added activities—including research, production and marketing—that may be further concentrated in advanced countries; in this case, emerging countries could be left in a state of 'premature deindustrialization' (Rodrik, 2016).

The concept of Industry 4.0 originated in Germany to support the digital transformation of production, challenging U.S. monopoly in digital networks and platforms. The governments of many advanced countries, particularly in Europe, have identified the specific goal of spreading advanced digital technologies such as robotics and automation, cloud computing, big data, sensors and 3D printers, and have introduced a wide range of measures. Policies generally include incentives for R&D, investment in 4IR machinery, venture capital benefits, high-tech infrastructures and university and secondary education support (European Commission, 2017).

These policies have played a positive role in bringing attention to the technological upgrading of industry and the need for an innovative leap; they have favoured a significant increase in demand for automation equipment and advanced industrial machinery, stimulating a rise in investment patterns that have generally been stagnant since the 2008 crisis (for the case of Italy, see Nascia and Pianta, 2018). 'Industry 4.0' programmes have a positive modernization effect and have provided a stimulus to business investment. It remains to be seen whether these effects reach beyond the most advanced group of manufacturing firms and foster a broader technological upgrading of industry. These concerns apply even more to emerging countries, where the group of 'leading' technology-based firms tends to be smaller and the bulk of firms have more limited technological capabilities.

The first concern is that the focus on digital technologies and advanced automation could be relevant for a rather limited number of companies, either in advanced or in emerging countries; these firms tend to be large companies, technologically advanced and may be in less need of government support. Conversely, the main challenge is to increase the number of innovative firms that may not have the internal capabilities, structures and skills—including a significant number of employees with a university education—to venture on the uncertain ground of digitalization.

A second concern is that Industry 4.0 programmes are inspired by a model of far reaching automation that might reduce the need for human labour and competences and concentrate control over complex processes within a few large companies. This trajectory of technological change may have limited coherence with national industrial structures where small and medium sized firms tend to be prevalent, including in the industrial automation sector, and where the supply of labour is abundant. There is a risk that such a policy may lead to a more polarized industrial structure, lower employment and higher inequalities (Pianta, 2018; Guellec and Paunov, 2017).

1.2 Industry 4.0, technology and emerging countries

The rise of Industry 4.0 generates new challenges for emerging countries. They must be viewed in the context of the novel attention that has recently been focussed on the role of technology in development. Over the last decades, the ability to introduce new technologies has been recognised by most emerging economies as being a crucial element in the process of industrialization.

Choices in technology adoption in emerging economies are related to the countries' development strategies, relying on particular advantages in terms of knowledge base, capital stock, absorption capabilities, institutional and infrastructural setting, low labour costs, social and environmental conditions, etc. The technological solutions, the resulting economic activities—private or public, market or non-market—the combinations required for the quantity and quality of capital and labour employed, the economic and social outcomes are the results of the decisions of key economic players and government policies.

A large number of studies and reports by international organizations have addressed the role of technology in the development of emerging countries (UNIDO, 2015). More recent studies focus on the challenges of digitalization and Industry 4.0 for emerging countries (World Bank, 2016; Lopez-Gomez et al., 2017; Sturgeon, 2017; ILO, 2018; Mayer, 2018). Other studies explore the potential impact of digitalization on employment in emerging countries (Chang and Huynh, 2016; Hallward-Driemeier and Nayyar, 2017). Industry 4.0 policies of emerging countries' governments are reviewed by Santiago (2018).

Major policy efforts in these directions have included measures to encourage firms to introduce new products and processes, to attract foreign direct investment (FDI) from multinational corporations (MNCs), to imitate frontier innovators, to adopt new capital equipment and production technologies and to diffuse the use of new goods and services. This process is highlighted by the success of some Asian countries (China and India in particular) in shifting from a paradigm of technology adoption to one of domestic knowledge generation (Altenburg et al.,

2008), although the ability of other countries to follow the same path has been questioned (Perez, 2008).

However, the question of digitalization and its impact must be set in the context of the broader role technology plays in the development and industrialization of emerging countries, which is reviewed in the next section. A conceptual framework will be developed to link a country's technological capabilities and its position in the global economy, identifying a typology of firms of emerging countries. Empirical investigations are described in Sections 3 and 4. The results of the analyses are presented in the conclusions.

2 Technological capabilities and the trajectories of firms in emerging countries

Digitalization and Industry 4.0 are quite remote from emerging countries' current capabilities, which have advanced along a more incremental path and have limited points of entry to advanced digitalization. Consideration of the various and complementary capabilities that are of relevance for firms in emerging countries will allow us to highlight the key conditions for entering the digital era.

2.1 Mapping the capabilities of firms in emerging countries

A large body of literature addresses the importance of capabilities in firms to determine their ability to operate with efficiency, increase output and employment and to upgrade their technological competences (Lall, 1992; Cimoli et al., 2009; Bogliacino et al., 2012). This approach is of particular importance for firms in emerging countries and is crucial for identifying the possibilities of moving closer to digitalization.

A firm's main capabilities can be divided between capabilities internal to the firm and capabilities provided by national innovation systems.

2.1.1 Capabilities internal to the firm

a) Capabilities for innovation in products, processes, organization, automation, ICT use and R&D

Capabilities internal to the firm encompass the core competence of firm organization and of the individuals operating in the firm at different levels of responsibility. They are dynamic in nature as they provide the learning processes required to upgrade and innovate all business activities. In emerging countries, the development of technological capabilities is a crucial factor for industrialization; this can be achieved through the acquisition and adaptation of foreign technologies; participation in global production networks organized by multinational firms; and the development of a domestic knowledge base and innovative potential. Complementarities or

trade-offs may emerge between the acquisition of foreign technology and efforts for developing internal R&D and innovative capabilities. Moreover, gaps in these capabilities often exist in emerging countries due to the lack of resources in firms, the 'brain drain' of highly skilled workers, engineers and researchers who leave the country, the lack of accumulation of internal competences and weak R&D activities. These capabilities are crucial for digitalization, as they are a necessary precondition for rethinking current production processes in the new context of digitalization and Industry 4.0.

Section 4 of this paper presents empirical documentation of such capabilities based on World Bank Innovation and Enterprise Surveys. Four groups of firms with different levels of internal capabilities are identified and their technological and economic performance is explored.

b) Capabilities in management, skilled labour, production and exports

Such capabilities are associated with the ability to manage the production process, using suitably skilled labour and finding appropriate markets, for export in particular. They are a central asset of firms, shaping the overall management, quality of labour used, the efficiency of production, the ability to export and gain market power. Firms in emerging countries—especially those active in global markets and involved in GVCs—have been able to rapidly develop such capabilities through the replication of models of advanced countries and through the effects of FDIs. Digitalization may, however, significantly influence their relevance and how they are developed and used in the Industry 4.0 context.

c) Financial capabilities

Access to and availability of financial resources is a key requirement for the operation of firms. Emerging countries encounter greater difficulties due to the smaller size of their firms, the poor relationship between finance and industry and institutional factors. Digitalization requires extensive capital resources and a long-term perspective, which is necessary for developing new knowledge and technological capabilities.

2.1.2 Capabilities external to the firm

a) Infrastructure provision

Basic infrastructure—transport, water, electricity, waste disposal, etc.—are an often disregarded necessary precondition for economic activities, which is often lacking or is unreliable in emerging countries. Over the last two decades, ICTs have become an indispensable infrastructure for economic activity, with the cabling of businesses and households, fast internet access, mobile communication systems, etc. The presence of an adequate public ICT infrastructure is now a basic

requirement for digitalization. Some of these high-tech infrastructures (such as mobile communications) have developed rapidly in emerging economies while others are still inadequate, such as cabling and internet access.

b) The national innovation system

Firms must operate within a network of diversified, complementary firms—either as suppliers, partners or customers—with the support and guidance of public actors. In addition, public creation of knowledge and education is necessary for the technological development of firms and the availability of skilled workers. Furthermore, the financial system must provide resources for long-term investment in capital and immaterial assets. These factors make up the national innovation system, providing material and immaterial inputs for the technological development of firms. The national innovation systems of emerging countries are often characterized by structural and institutional weaknesses. In the context of digitalization and Industry 4.0, these complementarities play an increasingly important role and emerging countries face major challenges in providing them.

Emerging countries' capabilities are very uneven. The firms in some large countries, specifically China and India, possess the necessary capabilities to be 'integrated' in the Industry 4.0 model, or have the capacity to develop their capabilities in a different direction (for instance, focussing less on labour replacement and more on diffusion or on sustainable development). In other emerging countries, the presence of such capabilities is limited. Firms are trying to develop them in an incremental 'localized' way, focussing on the production processes currently in place, relying on market outlets in GVCs and export markets. The pace of development of these capabilities may therefore be uneven, preventing broader access to digital technologies.

How can the presence of such capabilities, particularly *capabilities for innovation in products, processes, organization, automation, ICT use and R&D*, be documented in firms? Aside from the conventional science and technology indicators—R&D expenditure and patents—innovation surveys have emerged in recent decades as the most suitable tool for documenting the extent of these capabilities in firms. We rely on some of the evidence drawn from innovation surveys to develop the conceptual framework to conduct the empirical investigation in Section 4.

2.2 Evidence on innovation in emerging countries

A large body of empirical literature has recently addressed the contributions of technological change and innovation to economic development in emerging countries (see Zanello, 2016; Bogliacino et al., 2012). This body of work largely relied on new sources of evidence.

First, the innovation survey on firms pioneered in Europe has been extended to include emerging countries (OECD, 2018). The documentation of science and technological activities goes beyond traditional indicators, such as R&D and patents, which are unsuited for emerging countries (Archibugi and Pianta, 1996). Innovation surveys provide quantitative and qualitative information on the activities, expenditure, aims and outcomes of firms' innovative efforts, documenting the presence of innovation in products, processes and organization.

Second, the World Bank Enterprise Surveys (*www.enterprisesurveys.org*) in emerging countries includes specific innovation surveys for selected countries, providing information that is consistent with the approach of innovation surveys. In addition, the World Bank database releases firm-level data that have been used by a large number of studies on innovation and firm performance. These data are used for the empirical investigation in Section 4.

Third, data on the spread of information and communication technologies (ICTs) have been collected by several organizations—including the OECD—providing methodological tools (Calvino et al., 2018) and evidence on the progress of new technologies and digitalization. However, in spite of these important data collection efforts, including surveys on ICT usage and intangibles, no comprehensive set of indicators on digitalization with reliable information on the progress of digitalization and Industry 4.0 across countries is available.

Fourth, databases on large firms and their FDI make it possible to investigate firms' business strategies to determine their research, production and marketing activities at the global level and to identify the emergence of patterns of international production characterized by global value chains (Milberg and Winkler, 2013). These data—in aggregate terms—are used in the empirical investigation in Section 3.

Considering the extent of efforts and research that have been expended for innovation surveys in advanced and emerging countries, we begin this section by summarizing the results of these studies. The complex and multi-dimensional nature of technological change in firms and its industry specificity (Dosi, 1982; Pavitt, 1984; Bogliacino and Pianta, 2016) has been documented by innovation surveys that provide a variety of indicators on inputs, outputs, sources, objectives and obstacles.

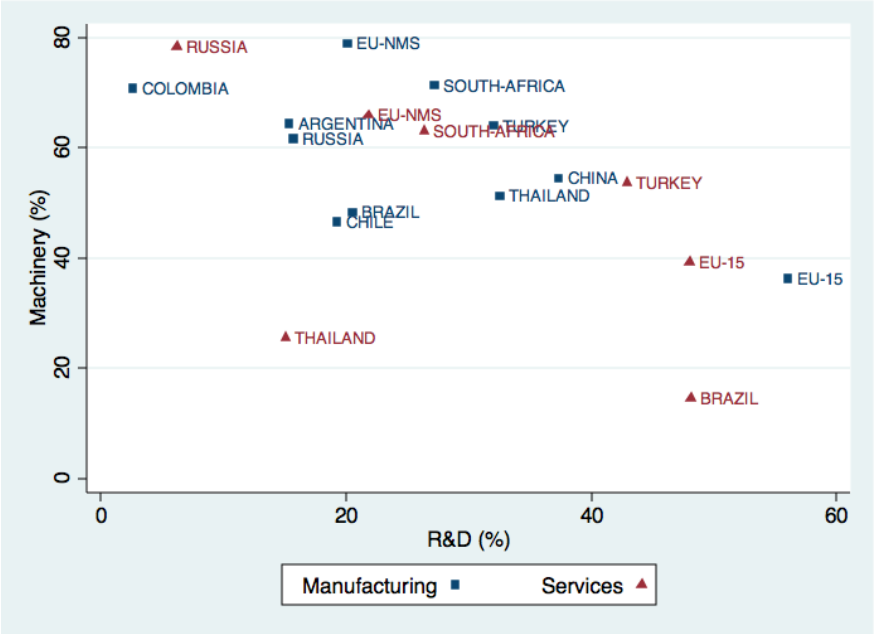
A detailed investigation has reviewed and compared the evidence from innovation surveys in emerging countries for the period 2002 to 2006 (Bogliacino et al., 2012). The EU-15 countries (no innovation survey was carried out in the U.S. during that period) outperform emerging countries in terms of innovative performance. The performance of a few Asian countries—such as the Republic of Korea—is comparable or higher than that of the EU-15. The innovative output of the majority of emerging countries and of recent EU member states lie below EU-15 levels. A few countries lag behind by a substantial margin.

One useful way of summarizing the evidence is to consider the main technological trajectories in emerging countries. We report on Figure 1 taken from the survey of innovation in emerging countries (Bogliacino et al., 2012), which illustrates the trade-off between two main trajectories of the development of technological capabilities. On the one hand are R&D activities associated with a search for new products; on the other is new machinery associated with new processes. The trajectories are based on the opposition between technological and cost competitiveness (Pianta, 2001).

These two trajectories also represent the two major priorities in terms of expenditure on innovation – on the one hand, the prevalence of R&D, characteristic of countries closer to the technological frontier and engaging in original innovation; on the other hand, the concentration of resources on the introduction of new production technologies (usually developed elsewhere) through the acquisition of new machinery and equipment. Countries that are in the process of industrializing tend to devote a large majority of their technological efforts to the latter. Based on available innovation survey results, this appears to be the case in Latin America (with the exception of Brazil), Russia, South Africa, but also of the Central and Eastern European countries that have joined the EU. On the other hand, China, other Asian countries and Turkey hold an intermediate position, devoting their efforts in roughly equal shares to R&D and new machinery; this indicates that these countries are moving closer, at least in some industries, to the EU-15's pattern of expenditure for innovation.

Innovation surveys also allow for an identification of the main objectives of innovation; strategies based on new and improved products may be linked to a search for new markets and wider product range, while efforts focussed on production processes may lead to greater capacity and flexibility or lower labour and other production costs.

Figure 1: Two trajectories of technological capabilities: R&D and acquisition of new machinery in selected countries



Note**:** Data are expressed as a share of total innovation expenditure.
Source: Bogliacino et al. (2012) based on data from countries' innovation surveys.

2.3 Stylized facts on innovation in emerging countries

Building on existing literature, in particular Lall (1992), Freeman and Louça (2001) and on our previous extensive work on innovation in emerging countries (Bogliacino et al., 2012), we can identify a number of stylized facts that can now be updated and extended, providing a conceptual foundation for understanding technological development and the conditions for the rise of digitalization.

a) A technological hierarchy can be found in emerging countries' firms

As regards technological development, leading firms in the largest and more dynamic emerging countries have moved closer to those firms in advanced countries. If well-organized national innovation systems and technology infrastructure are available, these firms can build strong R&D capabilities, thereby moving closer to digitalization.

A second group of firms in emerging countries has developed significant technological capabilities, carrying out R&D and design activities as well as product and process innovation, using patenting and other tools of protection of IPRs.

Technology in a third group of firms—the largest one—primarily comes in the form of acquisition of new machinery and imitation of products and processes developed elsewhere. Both technology adoption and imitation can spread rapidly among firms in emerging countries, with benefits typical of the catching-up process.

b) Institutions and the national innovation system matter

In emerging countries, the weaknesses of institutions and of the national system of innovation can pose a problem, with a lack of integration between firms in the production system, the financial sector, research and education activities and the policies of the public sector. Evidence from innovation surveys on the sources of knowledge and obstacles to innovation points towards the importance of a coherent innovation system.

c) Industrialization and global markets drive technological development

On the supply side, innovation is closely linked to the process of industrialization, as demonstrated by the importance of technology adoption and the acquisition of new machinery in emerging countries. On the demand side, countries with strong economic growth and integration in international markets and GVCs are able to rapidly diffuse modern production competences adopting new process technologies and new machinery, and to find expanding markets for products that either imitate those of advanced countries, or are produced within the requirements of GVCs. Industrialization with technology adoption and growing markets with imitation appear as highly complementary developments in those countries that are most successful in the catching up process. The possibility of a mismatch between the supply and demand dynamics may constrain the development process.

d) Large firms are important technology drivers, with exceptions

The Schumpeterian hypothesis on the importance of large firms in innovation is generally also confirmed in emerging countries, where the polarization of the industrial structure tends to be stronger than elsewhere. On the one hand, the capital intensive nature of innovation—namely the significance of investment in new machinery—implies that large firms maintain their relevance. Digitalization, on the other hand, increases the knowledge intensity in activities with lower capital intensity, and network structures may partly compensate for size. Still, market power together with a larger size allow firms to better benefit from innovative products and services.

e) International integration stimulates technological capabilities

Firms involved in global markets, exporting products or integrated in GVCs, tend to have greater incentives to improve their technological capabilities compared to firms serving the domestic market alone, as several empirical studies indicate. Market openness on its own, however, is insufficient to further technological development, as domestic firms may simply be put out of business by more efficient foreign competitors if domestic capabilities are inadequate and dynamic scale economies have not yet been reached. National industrial policies should search for a trade-off between these opportunities and risks (see Cimoli et al., 2009).

f) FDI moves technologies

The amount of innovative activities tend to be higher in the affiliates of multinational corporations than the national average in emerging countries. This also applies in advanced countries (Castellani and Zanfei, 2006), and is linked to intra-firm knowledge flows and to the strategies of foreign firms aiming to exploit their competences and technologies in local markets. In emerging countries, however, the integration between foreign affiliates and local firms and the spillover effects may be limited, and FDI may be concentrated in production rather than on the development of novel technological capabilities.

g) The cost of technology and the lack of finance are major obstacles

The major obstacles for innovation reported by firms in emerging countries—as well as in many advanced ones—include the high costs and the lack of finance. This is attributable to the prevalence of small and medium sized enterprises in many economies, which possess modest internal financial resources. The presence of forward-looking financial systems ready to fund long-term technology projects is an important (but rare) component of national innovation systems in emerging countries.

2.4 From innovation to Industry 4.0

How have the capabilities and characteristics of firms in emerging countries discussed so far been affected by the emergence of digitalization and Industry 4.0? The literature on the analysis of capabilities and innovation has largely shifted from an understanding of the role of ICTs as the current technological paradigm, including their implications for innovation, to the rise of networks, automation, international production and global markets. Industry 4.0 can be understood as an acceleration of the technological trajectory of ICTs in one possible direction – moving from industrial automation and labour-replacing robots to the 'smart factory' using artificial intelligence and machine learning. As mentioned in Section 1, the aim of the Industry 4.0 strategy being implemented in Europe is to expand the advantage of its stronger economies,

and may not be a suitable strategy for emerging countries' industries, as many of the requirements are missing in weaker economies.

In emerging economies, there is extensive evidence of 'localized' automation, with CAD/CAM use and new processes, machinery and robots replacing human labour and assuring greater reliability and quality of output within the more technologically advanced firms, many of them owned by MNCs originating from advanced countries. There is less diffusion of 'networked' automation linking different production activities and plants with 'intelligent' learning systems; the use of big data and cloud computing is also less widespread than in advanced countries.

An empirical investigation of these developments entails major challenges, as detailed, reliable data on most attributes of Industry 4.0—from the number and impact of robots to the use of CAD/CAM, 3D printing, big data—are simply unavailable. Industry 4.0 technologies are rooted in a set of digital activities that are associated with strong innovative capabilities, automation, increase of skilled labour, ability to export, etc. In this regard, digitalization can be understood as an enabler and precondition of Industry 4.0. We can assess several dimensions of digitalization using the available information on innovation and investment performance. The empirical investigations in Sections 3 and 4 explore digital activities –using a variety of approaches and variables as a precondition and complementary technology to Industry 4.0. We identify the industries, business activities and innovation strategies in which digitalization is more important and widespread, and in which firms may be closer to adopting and developing Industry 4.0 technologies.

2.5 A typology of emerging country firms in the face of digitalization

Building on the importance of capabilities, the stylized facts and the links between innovation, digitalization and Industry 4.0, we propose a tentative typology of firms in emerging countries as a conceptual tool to understand the position and possible trajectory of the evolution of firms. Firms in emerging countries can be tentatively grouped on the basis of their position in this development as follows:

a. Global players. A selected group of firms in emerging countries has the potential to play a relevant, independent role in the development of Industry 4.0 and digital technologies as competitors or (almost) equal partners of northern multinational corporations. They may become 'leaders' in some niches of digital technologies and take advantage of the opportunity to 'leapfrog' facilitated by digitalization and Industry 4.0 technologies. They have the competences and resources to develop independent technological capabilities in a trajectory characterized by internal innovative capabilities (from R&D to design) and by the successful adaptation of foreign

know-how, leading to new products for the local and international markets, and the ability to compete with advanced countries in at least some product groups and industries.

b. Insider firms. A larger group of firms in emerging countries has some Industry 4.0 and digital capabilities and is integrated in global supply chains controlled by northern multinational corporations. They include domestic firms of large affiliates of foreign corporations, 'imitators' and 'supplier partners' of technological 'leaders' of other countries. Their integration in international technology networks is the main channel for acquiring technological capabilities. They operate in open, export-oriented economies, with close links with foreign owned domestic firms and the system of international production of multinational firms. Specific channels for acquiring new capabilities include the transfer of technologies, production capabilities and participation in innovative activities, primarily through the acquisition of new machinery. This may lead to positive innovative performance, but with limited consolidation of the domestic knowledge base. Key decisions on the types of technologies used and the mode of implementation of digitalization may remain in the hands of the multinational firms controlling international production. Conversely, the presence of a large domestic market and the ability to expand market outlets parallel to global value chains could be an asset for strengthening these insider firms.

Recent evidence includes cases, for example, Foxconn and Nike, of advanced robotization strategies that might replicate the large labour displacing effects witnessed in advanced economies in emerging countries.

c. Potential entrants. A large share of firms in emerging countries has some capabilities and a potential for investing in digital technologies, adopting either a strategy of entering global supply chains controlled by northern firms based on technology or cost advantages or adopting a domestic/regional strategy of more independent development, perhaps in particular industry niches, with a possible differentiation in terms of the direction digitalization might take. They include 'imitators' and 'adopters/adaptors' of digital technologies developed by foreign 'leading' firms.

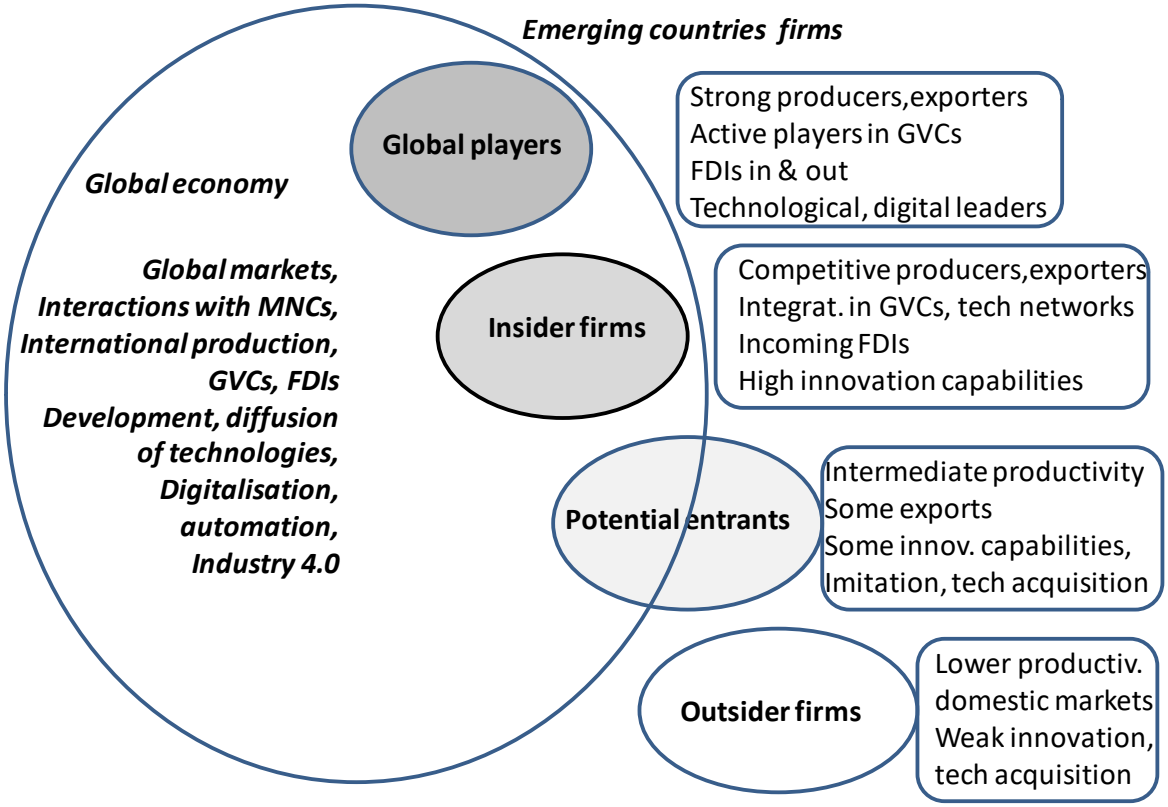
This group of firms tends to rely on imported technological capabilities through the acquisition of new machinery and learning processes, leading to new products, but with no innovative capabilities. This pattern is characteristic of economies that are resource intensive, commodity exporting or at the initial stages of offshore production; they tend to be unable to build a critical mass of domestic knowledge base. The acquisition of machinery may allow some catching up in terms of productivity levels; however, alongside machinery, they might import the same labour saving bias typical of advanced countries in very different employment contexts.

d. Outsider firms. A large number of firms in emerging countries, in particular, small and medium-sized firms, are excluded from technological upgrading and from the learning processes required by digital technologies, resulting in stagnant positions in markets and economic activities. They remain technologically dependent on foreign firms, typical of countries with a small industrial base and industries with limited technological opportunities. They may also be constrained by a weak national and local innovation and production system which does not offer adequate infrastructure and opportunities for learning, imitation and upgrading.

Figure 2 summarizes this typology of firms and their position in the global economy and in technological development.

One major challenge for this analysis—and for understanding the prospects of digitalization in firms in emerging countries—is exploring and documenting the specific patterns of production, FDI and technological activities that are characteristic of each type of firm summarized in each box in Figure 2. The above relationships are explored in Section 3 to determine how FDI patterns can shed light on the position of firms and economies in emerging countries. Section 4 examines the extent of innovative activities and digitalization in firms in emerging countries.

Figure 2: A typology of firms in emerging countries. Their position in the global economy and in technological development



Source: Author's elaboration.

3 Foreign direct investment in emerging countries

The conceptual framework developed in the previous section and the typology of firms in emerging countries is the foundation for empirical investigations that highlight some of the issues to be explored. Unfortunately, we face serious challenges, namely:

- the ability of available sources of information to document the extent of digitalization and the development of Industry 4.0 in firms in emerging countries;
- the ability of existing innovation surveys to account for firms' most sophisticated technological capabilities;
- the possibility of linking and integrating information on technology, economic performance and FDI of firms;
- the coverage and comparability of emerging countries in the available surveys.

In the remainder of this paper, we explore the potential of two new data sources for providing information on innovation and digitalization in firms in emerging countries. In this section, we use the FDImarkets database to investigate the investment environment within which emerging countries operate, considering in particular relevant industries, R&D, design and ICT activities. In Section 4, we use the World Bank Innovation Surveys for selected emerging countries to document the quality and quantity of technological capabilities of firms and their relevance for their prospects of digitalization.

3.1 Foreign direct investment projects in highly innovative and digital activities in emerging countries

This section investigates a new source of empirical evidence on technology based on foreign direct investment (FDI) projects in emerging countries and in highly innovative activities that create the conditions for digitalization. We report aggregate data from the FDImarkets database compiled by the Financial Times, summarizing the evidence of ongoing work carried out with Antonello Zanfei and Andrea Coveri of the University of Urbino who have a license to use FDImarkets data (Zanfei, Coveri and Pianta, 2019).

Data are available for MNCs based in all countries and investing in all countries. Variables include the number of projects announced and the estimated value of the capital investment. They cover the 2003-2014 period.

FDI projects are important as they map the development of new greenfield investments that change the technological competences and production capacity of emerging countries. We break down FDI data along four main dimensions.

a) Countries of FDI destination

First, we consider the destination of total FDI based on a detailed breakdown of emerging countries by region, including the following countries:

- **Advanced economies** (including North America, the European Union, Japan, the four 'Asian Tigers', Australia and New Zealand)
- **Emerging economies***: Non-EU Europe (excluding Norway and Switzerland, which are included in the EU group above), Russia, China, India, Rest of Asia, Middle East and Northern Africa, sub-Saharan Africa, Latin America*

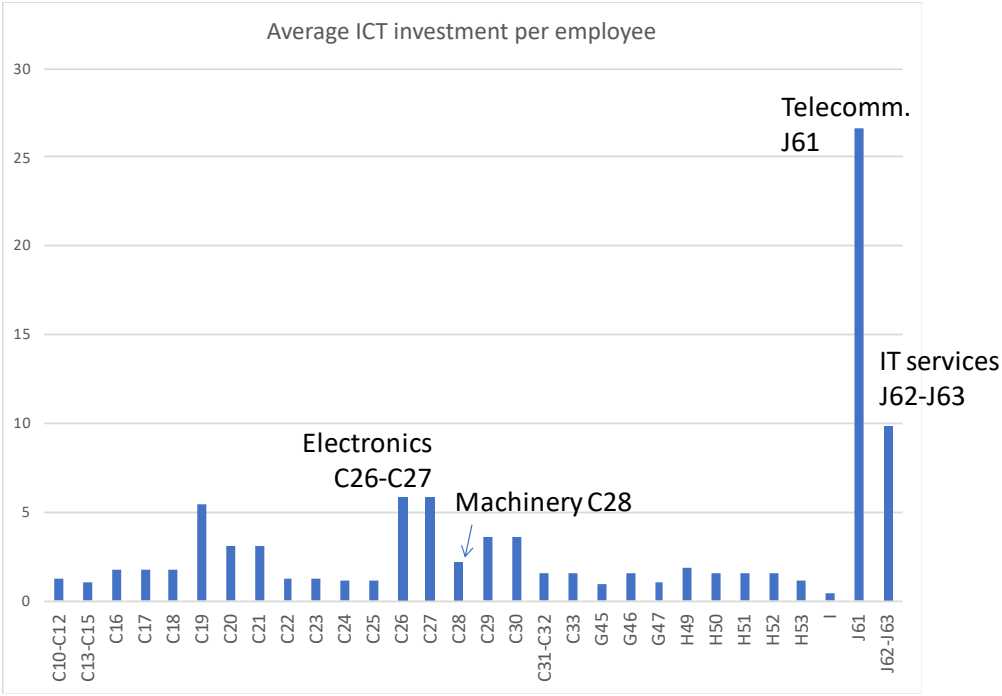
b) Industries

Second, FDI projects directed towards industries in which digital activities play a more important role indicating an expansion of firms' capabilities towards greater innovation and digitalization. As suggested in Section 2 above, this may point to a greater potential for adoption and development of Industry 4.0 technologies. We therefore focus our analysis on the manufacturing and service industries where technological activities are more intense and digitalization is more relevant. We rely on OECD studies (Calvino et al., 2018) and on the findings of innovation surveys in other countries to identify these industries; the ISIC Rev. 3.1 classification (reported in Table 2 in the Appendix), or the similar NACE classification (reported in Table 3 in the Appendix) are usually adopted for such analyses; however, the classification of FDImarkets differs in some cases from these standard industry classifications.

Figure 3 summarizes the evidence on the most relevant ICTs in industries based on the NACE classification; we use data from the Sectoral Innovation Database (SID) developed at the University of Urbino where information on a large number of economic and innovation variables is available using the NACE Rev.1 and Rev.2 classifications (data cover the six largest European economies for the period 1995-2018, see Pianta et al., 2019). Figure 3 shows the importance of ICT investment per employee for the average of the six major EU countries (Germany, France, UK, Italy, the Netherlands, Spain) for the period 2009-2014. The NACE classifications of information technology services and electronics have the highest values. The *electronics* sector includes the subsectors of office, accounting and computing machinery; electrical machinery and apparatus; radio, television and communication equipment; the *IT services* industry includes computer and related activities; *post and telecommunications* has by far the highest ICT intensity with most of its investments in ICT activities. The ranking of industries is stable across countries, in both advanced and in emerging countries.

Figure 3: ICT intensity in industries

ICT investment per employee, average 2009-2014, averages for major European countries: DE, FR, ES, IT, NL, UK



Note: Industries are based on the NACE industry classification. ICT investment is the sum of investments in computing equipment, communication equipment, software and databases, which are all part of gross fixed capital formation, divided by the number of employees, in millions of euros at current prices. Average over the period 2009-2014 for Germany, France, UK, Italy, the Netherlands, Spain.

Source: Author's elaboration based on the Sectoral Innovation Database (SID), University of Urbino.

Table 2 lists the sectors and subsectors of the FDImarkets database, with the number of total FDI projects that closely correspond to the above standard industry classifications. The NACE classification of *electronics* includes the FDImarkets classification *business machines*, *electronic components* and *semiconductors*. The *IT services* industry largely corresponds to the FDImarkets classification of *software and IT services*. The *post and telecommunications* industry includes a large part of the FDImarkets classification of communications, although some of these services are present in other industry groups. Sectors identified by the ISIC classification are very similar to those in the NACE classifications (see Tables 2 and 3 in the Appendix).

Table 2: The sectoral breakdown of FDI projects in digital-intensive industries

Sector	No. of projects
Manufacturing	
Business Machines & Equip.	1722
Commercial & service industry machinery	1
Communications equipment	1
Computer & peripheral equipment	1604
Other (Business Machines & Equipment)	116
Electronic components	4570
Aircraft engines, other parts & auxil..	4
All other electrical equipment & comp..	2909
Audio & video equipment	270
Batteries	188
Communication & energy wires & cables	279
Computer & peripheral equipment	2
Electric lighting equipment	396
Electrical equipment	344
Magnetic & optical media	48
Other (Consumer Electronics)	1
Wiring devices	129
Semiconductors	1686
Other (Semiconductors)	2
Semiconductor machinery	4
Semiconductors & other electronic compon	1680
Services	
Software & IT services	18124
All other information services	10
Business support services	1
Computer facilities management services	61
Computer systems design services	714
Custom computer programming services	3486
Internet publishing & broadcasting & ..	2604
Other (Software & IT services)	97
Other computer related services	45
Software publishers, except video games	10482
Video games, applications and digital..	624
Communications	7521
Cable & other subscription programming	37
Communications equipment	2191
Data processing, hosting, & related s..	1057
Motion picture & sound recording indu..	314
Navigational instruments	92
Other telecommunications	73
Radio & TV broadcasting	530
Satellite telecommunications	114
Wired telecommunication carriers	1295
Wireless telecommunication carriers	1818
Total	**33623**

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

On the basis of this evidence, we consider the FDImarkets classifications listed above to be digital-intensive industries and focus our analysis on their relevance in FDI flows to emerging countries.

a) Business activities

A third dimension we consider in this section is the type of business activities within each industry. The FDImarkets database breaks down FDI projects on the basis of their 'content', ranging from manufacturing to construction, to retail, etc.; the business activities that are more relevant for innovation and digitalization include the following:

- *Research & Development (R&D)*: The discovery, design, or development of a product – technical design centres.
- *Design, development & testing:* Projects that involve the design, development or testing of a product. Software companies that establish development centres are usually also involved in testing. To be included in R&D activities, the firm must carry out pure research.
- *ICT & internet infrastructure*: Providing infrastructure for the ICT industry – broadband infrastructure, internet data centres, data recovery centres, etc.

b) FDI originating from emerging countries

A fourth dimension is FDI that originates in emerging countries, in keeping with the same regional grouping listed above; this allows us to understand the relevance, content and direction of technological investments by emerging countries, highlighting their specific strategies in these sectors.

3.2 The distribution of FDI projects by region, industry, business activity

Table 3 presents the number of FDI projects by industry and region of FDI destination, with absolute numbers, percentages by row (regions) and column (industry)[1]. Table 4 presents the same FDI projects in terms of their estimated capital investment.

Table 5 shows the number of FDI projects by type of activity—R&D, ICT, design and development—and region of FDI destination. Table 6 reports the same breakdown for their estimated capital investment. The evidence reveals the following:

[1] The minor differences in the totals compared to Table 2 are due to projects where not all of the required information was available.

For the period 2003-2014, a large number of total FDI projects was recorded—nearly 150,000—with a very large planned investment of USD10 trillion. There is broad coherence between the distribution by region and industry of data on the number of projects and data on the estimated capital investment. The total number of global FDI projects in digital-related industries is 34,000, with an investment of USD 1,200 billion; the share of total FDI is 23 per cent for the number of projects and 12 per cent for capital investment. Technology intensive projects tend to entail a smaller average investment than the rest of the industries where large production projects in capital intensive industries play a major role.

The largest recipients of FDI are advanced countries themselves, with 74,000 projects, 20,000 of which target digital industries, with a total investment of USD 3,300 billion. Several emerging countries, however, are becoming major players. The number of FDI projects to China was 14,000, 2,900 of which targeted digital industries, with a total investment of USD 1,200 billion. India has been the destination of 8,400 FDI projects, 2,500 of which targeted digital industries, with a total investment of USD 445 billion. The number of FDI projects to Latin America was 12,000, 2,600 of which targeted digital industries, with a total investment of USD 1,100 billion. There were close to 12,000 FDI projects to the rest of Asia, but only 1,800 targeted digital industries, with a total investment of USD 1,100 billion. Data for the Middle East and Northern Africa are included as well. Other regions have much smaller FDI activities.

Table 3: Number of FDI projects by industry and region of FDI destination

		Destination industry							
Destination regions		**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies	Frequency	894	2522	868	11734	3934	19952	53882	73834
	% per country	1,2	3,4	1,2	15,9	5,3	27,0	73,0	100
	% per industry	52,0	55,2	51,5	64,8	52,4	59,4	48,9	51,3
Emerging economies									
Non-EU Europe	Frequency	26	77	14	403	168	688	3178	3866
	% per country	0,7	2,0	0,4	10,4	4,4	17,8	82,2	100
	% per industry	1,5	1,7	0,8	2,2	2,2	2,0	2,9	2,7
Russia	Frequency	31	61	19	193	195	499	3463	3962
	% per country	0,8	1,5	0,5	4,9	4,9	12,6	87,4	100
	% per industry	1,8	1,3	1,1	1,1	2,6	1,5	3,1	2,8
China	Frequency	178	780	418	1026	481	2883	11549	14432
	% per country	1,2	5,4	2,9	7,1	3,3	20,0	80,0	100
	% per industry	10,4	17,1	24,8	5,7	6,4	8,6	10,5	10,0
India	Frequency	110	248	157	1523	459	2497	5876	8373
	% per country	1,3	3,0	1,9	18,2	5,5	29,8	70,2	100
	% per industry	6,4	5,4	9,3	8,4	6,1	7,4	5,3	5,8
Rest of Asia	Frequency	178	316	119	693	513	1819	10040	11859
	% per country	1,5	2,7	1,0	5,8	4,3	15,3	84,7	100
	% per industry	10,4	6,9	7,1	3,8	6,8	5,4	9,1	8,2
Middle East & N.Afr.	Frequency	126	203	43	910	531	1813	8884	10697
	% per country	1,2	1,9	0,4	8,5	5,0	17,0	83,1	100
	% per industry	7,3	4,4	2,6	5,0	7,1	5,4	8,1	7,4
Sub-Saharan Africa	Frequency	44	62	1	289	420	816	3961	4777
	% per country	0,9	1,3	0,0	6,1	8,8	17,1	82,9	100
	% per industry	2,6	1,4	0,1	1,6	5,6	2,4	3,6	3,3
Latin America	Frequency	133	300	47	1350	806	2636	9404	12040
	% per country	1,1	2,5	0,4	11,2	6,7	21,9	78,1	100
	% per industry	7,7	6,6	2,8	7,5	10,7	7,8	8,5	8,4
Total	Frequency	1720	4569	1686	18121	7507	33603	110237	143840
	% per country	1,2	3,2	1,2	12,6	5,2	23,4	76,6	100
	% per industry	100	100	100	100	100	100	100	100

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

Table 4: Capital investment of FDI projects by industry and region of FDI destination, in USD million

		Destination industry							
Destination regions		**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies	USD million	22.165	95.854	94.319	156.998	165.406	534.742	2.731.260	3.266.002
	% per country	0,7	2,9	2,9	4,8	5,1	16,4	83,6	100
	% per industry	38,7	44,5	47,3	65,0	37,2	46,2	33,3	34,9
Emerging economies									
Non-EU Europe	USD million	516	1.255	554	5.408	7.887	15.620	147.116	162.736
	% per country	0,3	0,8	0,3	3,3	4,8	9,6	90,4	100
	% per industry	0,9	0,6	0,3	2,2	1,8	1,3	1,8	1,7
Russia	USD million	433	2.665	480	3.354	4.058	10.990	282.497	293.487
	% per country	0,1	0,9	0,2	1,1	1,4	3,7	96,3	100
	% per industry	0,8	1,2	0,2	1,4	0,9	0,9	3,4	3,1
China	USD million	14.143	56.287	62.189	16.702	22.237	171.559	987.538	1.159.097
	% per country	1,2	4,9	5,4	1,4	1,9	14,8	85,2	100
	% per industry	24,7	26,2	31,2	6,9	5,0	14,8	12,0	12,4
India	USD million	2.115	16.051	15.594	27.109	21.801	82.670	362.300	444.970
	% per country	0,5	3,6	3,5	6,1	4,9	18,6	81,4	100
	% per industry	3,7	7,5	7,8	11,2	4,9	7,1	4,4	4,8
Rest of Asia	USD million	13.504	24.727	13.594	7.811	32.943	92.578	1.012.955	1.105.533
	% per country	1,2	2,2	1,2	0,7	3,0	8,4	91,6	100
	% per industry	23,6	11,5	6,8	3,2	7,4	8,0	12,3	11,8
Middle East & North Africa	USD million	1.664	5.149	9.785	11.308	20.711	48.617	1.160.367	1.208.984
	% per country	0,1	0,4	0,8	0,9	1,7	4,0	96,0	100
	% per industry	2,9	2,4	4,9	4,7	4,7	4,2	14,1	12,9
Sub-Saharan Africa	USD million	576	453	3	4.143	42.673	47.848	536.582	584.430
	% per country	0,1	0,1	0,0	0,7	7,3	8,2	91,8	100
	% per industry	1,0	0,2	0,0	1,7	9,6	4,1	6,5	6,2
Latin America	USD million	2.128	12.728	2.955	8.597	126.729	153.137	982.469	1.135.606
	% per country	0,2	1,1	0,3	0,8	11,2	13,5	86,5	100
	% per industry	3,7	5,9	1,5	3,6	28,5	13,2	12,0	12,1
Total	USD million	57.244	215.167	199.473	241.430	444.446	1.157.760	8.203.085	9.360.845
	% per country	0,6	2,3	2,1	2,6	4,7	12,4	87,6	100
	% per industry	100	100	100	100	100	100	100	100

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

Table 5: Number of FDI projects by type of activity and region of FDI destination

		Type of activity					
Destination regions		**R&D**	**Design & Development**	**ICTs**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Advanced economies	Frequency	1465	3387	1515	6367	67467	73834
	% per country	2,0	4,6	2,1	8,6	91,4	100
	% per activity	56,0	51,7	56,7	53,8	51,1	51,3
Emerging economies							
Non-EU Europe	Frequency	26	84	90	200	3666	3866
	% per country	0,7	2,2	2,3	5,2	94,8	100
	% per activity	1,0	1,3	3,4	1,7	2,8	2,7
Russia	Frequency	42	82	59	183	3779	3962
	% per country	1,1	2,1	1,5	4,6	95,4	100
	% per activity	1,6	1,3	2,2	1,5	2,9	2,8
China	Frequency	421	842	90	1353	13079	14432
	% per country	2,9	5,8	0,6	9,4	90,6	100
	% per activity	16,1	12,9	3,4	11,4	9,9	10,0
India	Frequency	327	1128	96	1551	6822	8373
	% per country	3,9	13,5	1,2	18,5	81,5	100
	% per activity	12,5	17,2	3,6	13,1	5,2	5,8
Rest of Asia	Frequency	100	301	166	567	11292	11859
	% per country	0,8	2,5	1,4	4,8	95,2	100
	% per activity	3,8	4,6	6,2	4,8	8,6	8,2
Middle East & N.Afr.	Frequency	103	258	100	461	10236	10697
	% per country	1,0	2,4	0,9	4,3	95,7	100
	% per activity	3,9	3,9	3,7	3,9	7,8	7,4
Sub-Saharan Africa	Frequency	19	73	185	277	4500	4777
	% per country	0,4	1,5	3,9	5,8	94,2	100
	% per activity	0,7	1,1	6,9	2,3	3,4	3,3
Latin America	Frequency	111	394	370	875	11165	12040
	% per country	0,9	3,3	3,1	7,3	92,7	100
	% per activity	4,3	6,0	13,9	7,4	8,5	8,4
Total	Frequency	2614	6549	2671	11834	132006	143840
	% per country	1,8	4,6	1,9	8,2	91,8	100
	% per activity	100	100	100	100	100	100

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

Table 6: Capital investment of FDI projects by type of activity and region of FDI destination

		Type of activity					
Destination regions		**R&D**	**ICTs**	**Design & Development**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Advanced economies	Millions of US dollars	49.289	162.546	92.861	304.696	2.961.306	3.266.002
	% per country	1,5	5,0	2,8	9,3	90,7	100
	% per industry	50,0	41,5	50,8	45,2	34,1	34,9
Emerging economies							
Non-EU Europe	Millions of US dollars	1.086	8.567	1.091	10.745	151.991	162.736
	% per country	0,7	5,3	0,7	6,6	93,4	100
	% per industry	1,1	2,2	0,6	1,6	1,7	1,7
Russia	Millions of US dollars	965	3.004	1.116	5.085	288.402	293.487
	% per country	0,3	1,0	0,4	1,7	98,3	100
	% per industry	1,0	0,8	0,6	0,8	3,3	3,1
China	Millions of US dollars	23.036	7.828	28.854	59.718	1.099.379	1.159.097
	% per country	2,0	0,7	2,5	5,2	94,8	100
	% per industry	23,4	2,0	15,8	8,9	12,7	12,4
India	Millions of US dollars	12.965	14.760	27.880	55.605	389.366	444.970
	% per country	2,9	3,3	6,3	12,5	87,5	100
	% per industry	13,1	3,8	15,2	8,3	4,5	4,8
Rest of Asia	Millions of US dollars	3.043	20.128	7.486	30.656	1.074.877	1.105.533
	% per country	0,3	1,8	0,7	2,8	97,2	100
	% per industry	3,1	5,1	4,1	4,6	12,4	11,8
Middle East & North Africa	Millions of US dollars	2.621	15.729	8.301	26.651	1.182.333	1.208.984
	% per country	0,2	1,3	0,7	2,2	97,8	100
	% per industry	2,7	4,0	4,5	4,0	13,6	12,9
Sub-Saharan Africa	Millions of US dollars	537	41.573	1.436	43.546	540.884	584.430
	% per country	0,1	7,1	0,2	7,5	92,5	100
	% per industry	0,5	10,6	0,8	6,5	6,2	6,2
Latin America	Millions of US dollars	5.092	117.867	13.950	136.909	998.697	1.135.606
	% per country	0,4	10,4	1,2	12,1	87,9	100
	% per industry	5,2	30,1	7,6	20,3	11,5	12,1
Total	Millions of US dollars	98.634	392.003	182.974	673.611	8.687.234	9.360.845
	% per country	1,1	4,2	2,0	7,2	92,8	100
	% per industry	100	100	100	100	100	100

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

When we consider the business activities in Tables 5 and 6 that are relevant for advanced technology and digitalization, namely R&D, design and development and ICTs, we found 6,300 FDI projects in advanced countries, with a total investment of USD 305 billion. China had 1,400 FDI projects, with an investment of USD 60 billion. India reported 1,500 FDI projects, with an investment of USD 57 billion. Latin America had close to 900 FDI projects with an investment of USD 137 billion. Other regions had a much smaller number of FDI projects; sub-Saharan Africa, for example, reported USD 40 billion in investments in ICT activities, mainly in the telecommunications industry.

3.3 The specialization of regions in highly innovative and digital activities

One effective way of summarizing these patterns is to calculate the indexes of specialization of emerging countries in digital-related industries and in business activities associated with high-technology industries. The index of specialization is a standard tool used in the analysis of trade patterns, and has been extended to technology (see Archibugi and Pianta (1992) for a detailed analysis of the theory, methods and results). Countries with a high relative concentration of trade in a given industry (as a share of their total trade) are 'specialized' in that particular industry if the share of the industry lies above the share recorded for total world trade. The same index can be calculated for production, patenting and FDI attraction.

We calculate the index as the ratio between the share of a region's FDI projects in a given industry (or activity) and the share of the industry (or activity) in world FDI in all activities. The index is 0 when no FDI is present; it is equal to 1 when the relevance of the industry (or activity) is equal to the world's total, and greater than 1 if a relative specialization of the region in these industries (or activities) is evident. Table 7 presents the specialization indexes of all regions for the industries included in our study. A breakdown of the years before and after the 2008 crisis is also provided to determine whether the patterns of FDI were affected by the financial crisis and any ensuing instability. Table 8 shows the specialization indexes of all regions based on the business activities identified above. The results can be summarized as follows: the rankings of the region's specialization indexes in industries and business activities are similar when we consider capital investment instead of the number of FDI projects.

The specialization patterns of FDI projects show the strong advantage advanced countries have in digital-related industries. Japan and the four Asian Tigers are the most specialized economies in these activities, dominating FDI in all relevant sectors. North America and the EU have limited positive specialization, attributable to their strength in software and IT services. Among the emerging countries, India is the only economy with an overall positive digital specialization, with strengths in software, office machines and communications. China has extensive FDI activity in other manufacturing sectors, and emerges with a positive specialization in high-tech manufacturing, namely semiconductors, electronic components and office machinery. In the communication industry, a strong relative specialization of FDI has moved to Latin America and sub-Saharan Africa. The rest of Asia is specialized in office machinery. The flows of FDI appear to be consistent with the production specialization of emerging countries; China and India show an important diversification in most industries related to digitalization.

If we break down the FDI projects into two periods 2003-2008 and 2009-2014 to reflect FDI before the financial crisis and after 2008, we find that the relevance of digital technologies in emerging countries weakened in the majority of cases. In terms of FDI destination, most emerging economies record a reduction in their specialization indexes, including China and India, while their activities in other industries become relatively more important. Conversely, North America and Europe have increased the concentration of FDI in digital technologies. The crisis of 2008 may have reinforced the technological hierarchy in FDI and slowed down the catching up process of emerging countries.

This finding has important policy implications. Market-oriented approaches—inspired by Ricardo's trade theory—have long argued that the 'efficient' operation of market processes leads countries to become more specialized in the activities in which they are (relatively) 'better' than others. In this case, we can expect that countries with already existing production and trade specialization in the relevant industries and activities will attract FDI.

Table 7: Number of FDI projects by industry. Specialization indexes of regions of FDI destination

Entire period 2003-2014

	Destination industry							
Destination regions	**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies								
North America	0,77	0,99	0,67	1,19	0,94	1,06	0,98	1
EU28+Norw+Swiz	1,03	1,07	0,67	1,20	0,96	1,10	0,97	1
Japan	1,50	1,46	3,71	1,88	1,33	1,77	0,77	1
Four Asian Tigers	1,28	1,45	3,46	1,35	1,27	1,45	0,86	1
Australia & New Zealand	1,07	0,47	0,21	1,90	1,55	1,50	0,85	1
Emerging economies								
Non-EU Europe	0,56	0,63	0,31	0,83	0,83	0,76	1,07	1
Russia	0,65	0,49	0,41	0,39	0,95	0,54	1,14	1
China	1,03	1,70	2,47	0,56	0,64	0,86	1,04	1
India	1,10	0,93	1,60	1,44	1,05	1,28	0,92	1
Rest of Asia	1,26	0,84	0,86	0,46	0,83	0,66	1,11	1
Middle East & North Africa	0,99	0,60	0,34	0,67	0,95	0,73	1,08	1
Sub-Saharan Africa	0,77	0,41	0,02	0,48	1,68	0,73	1,08	1
Latin America	0,92	0,78	0,33	0,89	1,28	0,94	1,02	1

Pre-crisis period 2003-2008

Specialization indeces of regions of destination (based on number of FDIs from the World by industry), 2003-2008 (pre-crisis period)								
	Destination industry							
Destination regions	**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies								
North America	0,71	0,83	0,79	1,10	0,98	0,99	1,00	1
EU28+Norw+Swiz	0,92	1,06	0,59	1,16	0,90	1,03	0,99	1
of which from outside Europe:	*1,59*	*1,17*	*0,91*	*1,64*	*1,13*	*1,41*	*0,88*	*1*
Japan	1,61	1,03	3,35	1,87	1,45	1,77	0,77	1
Four Asian Tigers	1,42	1,92	3,98	1,34	1,43	1,64	0,81	1
Australia & New Zealand	0,84	0,24	0,16	1,97	1,58	1,45	0,87	1
Emerging economies								
Non-EU Europe	0,63	0,59	0,08	0,41	0,93	0,54	1,14	1
Russia	0,68	0,40	0,20	0,37	0,75	0,46	1,16	1
China	0,97	1,73	2,13	0,64	0,74	0,94	1,02	1
India	1,10	0,92	1,69	1,87	1,25	1,55	0,83	1
Rest of Asia	1,44	0,84	0,84	0,48	0,90	0,70	1,09	1
Middle East & North Africa	1,20	0,48	0,37	0,69	1,01	0,74	1,08	1
Sub-Saharan Africa	0,74	0,22	0,04	0,47	1,34	0,61	1,12	1
Latin America	1,01	0,64	0,34	0,89	1,36	0,92	1,02	1

Post-crisis period 2009-2014

Specialization indeces of regions of destination (based on number of FDIs from the World by industry), 2009-2014 (post-crisis period)								
	Destination industry							
Destination regions	**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies								
North America	0,88	1,07	0,68	1,21	0,90	1,09	0,97	1
EU28+Norw+Swiz	1,12	1,05	0,79	1,27	1,01	1,16	0,95	1
of which from outside Europe:	*1,63*	*1,16*	*1,16*	*1,69*	*1,08*	*1,46*	*0,86*	*1*
Japan	1,33	1,82	4,29	1,89	1,23	1,77	0,76	1
Four Asian Tigers	1,18	1,15	2,90	1,35	1,18	1,32	0,90	1
Australia & New Zealand	1,32	0,59	0,35	1,84	1,53	1,53	0,84	1
Emerging economies								
Non-EU Europe	0,38	0,63	0,45	0,51	0,68	0,56	1,14	1
Russia	0,53	0,60	0,97	0,42	1,21	0,65	1,11	1
China	1,04	1,71	2,70	0,50	0,53	0,76	1,07	1
India	1,02	0,95	1,13	1,08	0,86	1,01	1,00	1
Rest of Asia	1,06	0,83	0,92	0,45	0,78	0,62	1,12	1
Middle East & North Africa	0,78	0,68	0,32	0,66	0,91	0,71	1,09	1
Sub-Saharan Africa	0,90	0,49	0,00	0,47	1,86	0,80	1,06	1
Latin America	0,90	0,86	0,39	0,88	1,23	0,95	1,02	1

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

However, not all industries are equal in terms of learning processes, technological intensity, digital potential, and the emerging countries specializing in less dynamic, low-technology industries are likely to end up with slower overall performances and more difficulties catching up.

Conversely, policies that emphasize the need for a long-term national development strategy based on backward and forward linkages and diversification (Cimoli et al., 2009; Hausman et al. 2007) highlight the importance of entering—and specializing—in high-technology, high growth industries. Given the significance of digitalization, this analysis sheds light on the ability of some emerging countries to move out of traditional specialization and develop capabilities and economic activities in digital-intensive activities.

Table 8: Number of FDI projects by type of activity, Specialization indexes of regions of FDI destination

	Type of activity					
Destination regions	**R&D**	**Design & Development**	**ICTs**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Advanced economies						
North America	1,03	1,05	0,68	0,96	1,00	1
EU28+Norw+Swiz	1,01	0,94	1,07	0,98	1,00	1
Japan	1,43	1,20	1,88	1,40	0,97	1
Four Asian Tigers	1,83	1,36	1,64	1,53	0,95	1
Australia & New Zealand	0,71	0,81	2,08	1,07	0,99	1
Emerging economies						
Non-EU Europe	0,37	0,48	1,25	0,63	1,03	1
Russia	0,59	0,45	0,80	0,56	1,04	1
China	1,61	1,28	0,34	1,14	0,99	1
India	2,15	2,96	0,62	2,25	0,89	1
Rest of Asia	0,46	0,56	0,75	0,58	1,04	1
Middle East & North Africa	0,53	0,53	0,50	0,52	1,04	1
Sub-Saharan Africa	0,22	0,33	2,09	0,71	1,03	1
Latin America	0,51	0,72	1,65	0,88	1,01	1

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

In terms of business activities (R&D, design and development, ICTs), the same relative patterns of specialization generally emerge, with a few novelties. In advanced countries, surprisingly, North America and the EU have values just below 1, suggesting a weakening of FDI flows in the most advanced technological activities. Japan and the Asian Tigers again show a strong positive specialization in all these activities. India shows very high specialization, driven by FDI in design and R&D, a pattern that is followed at a distance by China. There is a relative concentration of FDI in ICTs in sub-Saharan Africa and Latin America, associated with the telecommunication infrastructure and services industry, a pattern non-EU Europe follows as well. The rest of Asia and Latin America have much lower FDI values in these activities in comparison with the previous industry-based picture; these countries appear to concentrate on production activities, with fewer capabilities in R&D and design.

This breakdown of FDI provides new insights on the ability of emerging countries to move into production in highly innovative industries and to move up in the type of business activities necessary for expanding technological capabilities. It appears that for firms in emerging countries, the barriers to entry are higher for knowledge intensive business functions, namely R&D and design, than for high-technology industries as such, where emerging country firms could be integrated in GVCs or engage in subcontracting activities, even in a context of low investments in advanced technological activities.

Table 9: FDI projects in emerging countries by type of activity and by industry

FDI projects in Emerging countries by type of activity						
Percentages by industry						
(percentage values, %)						
	Type of activity					
Destination industry	**R&D**	**Design & Development**	**ICTs**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Business Machines & Equipment	1,7	1,1	0,1	1,0	1,2	1,2
Electronic Components	3,6	2,9	0,1	2,5	3,0	2,9
Semiconductors	5,0	6,9	0,2	5,1	0,8	1,2
Software & IT services	17,8	40,6	14,5	30,3	7,3	9,1
Communications	9,3	9,9	82,8	25,3	3,4	5,1
Other sectors	62,6	38,6	2,4	35,9	84,3	80,5
Total	**100**	**100**	**100**	**100**	**100**	**100**
FDI projects in Emerging countries by industry						
Percentages by type of activity						
(percentage values, %)						
	Type of activity					
Destination industry	**R&D**	**Design & Development**	**ICTs**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Business Machines & Equipment	2,3	4,2	0,1	6,6	93,4	**100**
Electronic Components	2,0	4,5	0,0	6,6	93,4	**100**
Semiconductors	7,1	26,5	0,2	33,9	66,1	**100**
Software & IT services	3,2	20,1	2,6	26,0	74,0	**100**
Communications	3,0	8,7	27,0	38,6	61,4	**100**
Other sectors	1,3	2,2	0,0	3,5	96,5	**100**
Total	1,6	4,5	1,7	7,8	92,2	**100**

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

Table 9 provides additional insights into the activities at the technological edge in emerging countries. FDI projects in digital-related industries are matched with the high-tech business activities discussed above (R&D, ICT and design and development). These data allow us to better understand how FDI moves into industries and business functions, mapping the technological trajectories affecting firms in emerging countries. The first part of the table shows that two-thirds of FDI in emerging countries go to non-high-tech industries, as they are more likely to upgrade large production capabilities in more traditional or medium-technology manufacturing industries. Software and IT services is the only industry that has attracted a substantial amount of FDI in R&D (one-sixth of total FDI in R&D). Investments in ICT are mostly concentrated in telecommunication infrastructure and services as well as software. Design and development occurs primarily in software and IT services, and in non-high-tech industries.

The second part of the table presents the same data but with a focus on the relative importance of business activities in each industry. Ninety per cent of FDI projects went to production, distribution, marketing and other business activities in office machines, electronic components and other industries, disregarding high-tech activities in emerging country firms. Conversely, semiconductors and software attracted significant shares of FDI for design and development activities, and—following at a distance—for R&D. The significance of ICT activities in the telecommunications industry is again confirmed.

3.4 FDI originating from emerging countries

Finally, Tables 10 and 11 presents data of FDI originating from emerging countries, and look at their distribution by region, industry and business activity. The first part of Table 10 shows that 25 per cent of total FDI projects went to Europe, and around 13 per cent went to the Middle East, North Africa and to the rest of Asia. Latin America's share of 9 per cent of total FDI is similar to that of the U.S. and Canada. India and China did not attract large shares of FDI projects from other emerging countries.

Looking at industry composition, the second part of Table 10 reveals that a high amount of FDI from emerging countries went to digital activities in Latin America (25 per cent of total FDI, mainly for IT and software), while other emerging countries accounted for between 8 per cent and 16 per cent of total FDI projects. The share of FDI in digitally intensive industries in advanced countries ranges from 25 per cent to 33 per cent, mainly targeting IT and software.

Table 11 presents the same data with a breakdown by business activity. Europe attracted the majority of FDI in R&D, followed by North America; the share of FDI in China and India amounted to 10 per cent, while the other regions were of little relevance. The findings for FDI

projects in design and development are broadly similar. In the case of ICT, the FDI targets are mainly sub-Saharan Africa, Latin America and the rest of Asia, with cross-border investments of regional telecom companies aiming to enter fast growing markets rather than developing novel technological capabilities abroad.

Table 10: FDI projects from emerging countries by industry and region of FDI destination

FDI projects from Emerging countries by industry percentage distribution by region of destination

(percentage values, %)

	Destination industry							
Destination regions	**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies								
North America	8,2	12,9	13,3	17,5	8,1	13,8	8,7	9,6
EU28+Norw+Swiz	32,7	41,1	24,2	29,0	19,7	27,8	23,9	24,6
Japan	0,0	2,2	6,3	1,8	0,7	1,6	0,7	0,9
Four Asian Tigers	6,4	6,6	10,9	6,3	5,7	6,3	4,6	4,9
Australia & New Zealand	0,0	1,9	0,8	3,0	1,8	2,4	1,6	1,7
Emerging economies								
Non-EU Europe	1,8	2,6	0,0	1,9	4,1	2,6	2,8	2,8
Russia	0,0	1,9	0,0	0,8	1,8	1,2	3,0	2,6
China	1,8	5,8	24,2	3,9	2,0	4,1	5,3	5,1
India	5,5	4,6	9,4	3,4	4,1	4,0	4,3	4,3
Rest of Asia	5,5	4,4	5,5	6,1	10,7	7,2	13,7	12,5
Middle East & North Africa	9,1	7,0	3,1	7,5	11,1	8,4	15,0	13,8
Sub-Saharan Africa	10,9	4,3	0,0	3,5	16,1	7,3	8,2	8,1
Latin America	18,2	4,8	2,3	15,3	14,2	13,3	8,1	9,1
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

FDI projects from Emerging countries by region of destination percentage distribution by industry

(percentage values, %)

	Destination industry							
Destination regions	**Business Machines & Equip.**	**Electronic Components**	**Semiconductors**	**Software & IT services**	**Communications**	**Tot. FDIs in digital tech.**	**Tot. FDIs in other ind.**	**Total**
Advanced economies								
North America	0,4	3,2	0,7	17,7	4,5	26,5	73,5	**100**
EU28+Norw+Swiz	0,6	4,0	0,5	11,4	4,3	20,8	79,2	**100**
Japan	0,0	6,0	3,7	19,9	4,2	33,8	66,2	**100**
Four Asian Tigers	0,6	3,3	1,2	12,6	6,2	23,8	76,2	**100**
Australia & New Zealand	0,0	2,6	0,2	17,1	5,7	25,6	74,4	**100**
Emerging economies								
Non-EU Europe	0,3	2,2	0,0	6,7	7,8	17,0	83,0	**100**
Russia	0,0	1,7	0,0	2,8	3,6	8,1	91,9	**100**
China	0,2	2,7	2,5	7,5	2,1	15,0	85,0	**100**
India	0,6	2,6	1,1	7,7	5,2	17,1	82,9	**100**
Rest of Asia	0,2	0,9	0,2	4,7	4,5	10,5	89,5	**100**
Middle East & North Africa	0,3	1,2	0,1	5,3	4,3	11,2	88,8	**100**
Sub-Saharan Africa	0,6	1,3	0,0	4,2	10,6	16,7	83,3	**100**
Latin America	0,9	1,3	0,1	16,4	8,4	27,0	73,0	**100**
Total	0,5	2,4	0,5	9,7	5,3	18,4	81,6	**100**

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

Table 11: FDI projects from emerging countries by type of activity and region of FDI destination

FDI projects from Emerging countries by type of activity, percentage distribution by region of destination						
(percentage values, %)						
	Type of activity					
Destination regions	**R&D**	**Design & Development**	**ICTs**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Advanced economies						
North America	16,6	17,9	4,9	13,7	9,3	9,6
EU28+Norw+Swiz	37,6	31,6	10,2	26,3	24,5	24,6
Japan	2,4	1,6	0,4	1,4	0,9	0,9
Four Asian Tigers	6,2	7,3	7,3	7,1	4,7	4,9
Australia & New Zealand	0,7	1,9	0,9	1,3	1,8	1,7
Emerging economies						
Non-EU Europe	1,7	1,6	7,5	3,4	2,8	2,8
Russia	0,3	1,1	2,0	1,2	2,7	2,6
China	10,3	7,5	0,7	6,0	5,0	5,1
India	9,7	8,8	1,3	6,7	4,1	4,3
Rest of Asia	5,9	5,2	12,4	7,5	12,8	12,5
Middle East & North Africa	4,1	4,8	7,7	5,6	14,3	13,8
Sub-Saharan Africa	0,7	1,7	25,0	8,6	8,0	8,1
Latin America	3,8	8,9	19,7	11,2	8,9	9,1
Total	**100**	**100**	**100**	**100**	**100**	**100**

FDI projects from Emerging countries by region of destination percentage distribution by type of activity						
(percentage values, %)						
	Type of activity					
Destination regions	**R&D**	**Design & Development**	**ICTs**	**Tot. FDIs in tech. act.**	**Tot. FDIs in other act.**	**Total**
Advanced economies						
North America	2,0	5,7	0,9	8,7	91,3	**100**
EU28+Norw+Swiz	1,8	3,9	0,8	6,5	93,5	**100**
Japan	3,2	5,6	0,9	9,7	90,3	**100**
Four Asian Tigers	1,5	4,6	2,8	8,9	91,1	**100**
Australia & New Zealand	0,5	3,3	0,9	4,7	95,3	**100**
Emerging economies						
Non-EU Europe	0,7	1,8	5,0	7,5	92,5	**100**
Russia	0,2	1,2	1,4	2,8	97,2	**100**
China	2,4	4,5	0,2	7,2	92,8	**100**
India	2,7	6,3	0,6	9,6	90,4	**100**
Rest of Asia	0,6	1,3	1,8	3,7	96,3	**100**
Middle East & North Africa	0,4	1,1	1,0	2,5	97,5	**100**
Sub-Saharan Africa	0,1	0,7	5,7	6,5	93,5	**100**
Latin America	0,5	3,0	4,0	7,5	92,5	**100**
Total	1,2	3,1	1,9	6,1	93,9	**100**

Source: Zanfei, Coveri and Pianta (2019) based on the FDImarkets database.

The lower part of the table presents the same data organized by region of destination. Ninety per cent to 97 per cent of FDI from emerging countries went to production, distribution and marketing that lie outside the knowledge intensive business activities (R&D, ICT and design and development). The largest technology-based FDI projects went to Asia—India, Japan, China, the Asian Tigers—for design, and to the U.S. and Canada. The FDI directed at Latin America and non-EU Europe targeted ICT activities. Japan, India and China attracted some FDI in R&D as well.

3.5 Summary of the evidence

The evidence highlights the environment within which emerging country firms find themselves in in terms of FDI flows to industries and activities that are relevant for advanced technological capabilities and digitalization. The overall picture for emerging countries has different shades. The positive factors are the large number of FDI projects and investments their economies have attracted, in innovative manufacturing and services industries as well, which are relevant for digitalization. Firms from emerging countries have surfaced as new players in FDI.

The findings that are more problematic for the prospects of emerging countries include the prevalence of production-oriented FDI in both incoming as well as outgoing investments from emerging countries, with less attention being paid to R&D, design and ICT activities. A country's production capabilities must be built up before it can move into learning processes and high innovation activities; emerging countries appear to follow a well-established technological trajectory in this regard.

The speed of their expansion in manufacturing production is much higher than their current capability to 'move up' and enter high-tech business functions.

China and India represent special cases of success in terms of attracting FDI flows in technological activities as well, building a diversified industrial system and important innovative capabilities. Many of their firms have become global technological players. Studies on China have explored the rise of its knowledge economy (Rodriguez-Pose and Wilkie, 2016), and the country's policies for industry modernization, automation and digitalization are outlined in its plan for manufacturing 2025 (Li, 2018; European Union Chamber of Commerce in China, 2017). In the case of India, more detailed evidence is provided in Section 4.

Conversely, the evidence on FDI flows to other emerging countries suggests that the technological gap is likely to remain substantial; the economies of the rest of Asia experienced strong growth in industrial production, but they lag behind with regard to digital industries and business

activities; in Latin America, modernization has mainly taken place in the telecom industry, and a similar prevalence of the telecom industry is also evident in the Middle East and North Africa, as well as in sub-Saharan Africa, Russia and non-EU Europe.

The patterns of technological flows, the opportunities for learning and catching up, the potential of digital technologies and Industry 4.0 are therefore likely to be highly differentiated within emerging countries, with a significant number of firms becoming global players in FDI as well as in GVCs and in technology networks, but with persisting hierarchies in high-tech activities that are closer to the digital frontier.

To explore the developments at firm level in more detail, we turn our focus on innovation patterns in the firms of selected emerging countries.

4 Innovation and digitalization in emerging country firms

This section presents a firm-level analysis, and investigates the range of innovative activities of firms, the presence and impact of ICT use, the distribution across industries and firm size groups, and the impact on firms' technological and employment dynamics.

This analysis helps identify the capabilities of firms in emerging countries, their position in the hierarchy of technological competences, the extent of their digital activities and the potential for becoming full players in the development of Industry 4.0. The findings are then related to the typology of business strategies identified in Section 2.

The empirical analysis uses the World Bank Innovation Follow-up 2013-2014. This is a well-established source of microdata on emerging countries, based on a common questionnaire, which has been used by a large number of empirical studies (Seker, 2011; Saliola and Seker, 2011; Cirera and Sabetti, 2016; Cirera et al., 2016).

Countries with an innovation survey for the years 2013-2014 include Bangladesh, Congo, Ghana, India, Kenya, Malawi, Namibia, Nepal, Nigeria, Pakistan, South Sudan, Sudan, Tanzania, Uganda and Zambia. All countries have been considered in a preliminary analysis on the importance of firms with innovative and digital activities (see Table 12).

Questions addressed in the survey include basic data on the firm (size, industry, etc.) and a wide range of information on their activities. The data that are more consistently present across firms and countries include the following key variables: the presence of innovation in products; the presence of innovation in processes (broken down into production, distribution and logistics, support and management); whether the new process has led to automation of production; the

presence of internal or external R&D activities; the extent of ICT use with a detailed set of questions; the presence of patent applications on new products; and the impact of the innovation on skilled and unskilled employment. An extension of the analysis links these variables with economic characteristics and performances.

The evidence from innovation surveys allows us to identify a set of specific capabilities that are associated with technological activities, the potential for digitalization and Industry 4.0, and for higher economic performance. The key dimensions explored in this section include the capabilities that were discussed in Section 2, namely:

a) Capabilities for innovation in products, processes, organization, automation, ICT use and R&D

Innovation surveys provide information on these activities, including the type of innovation introduced, the presence of R&D activities and the impact on automation. These variables document a range of sophisticated capabilities leading to successful innovation and digitalization. They are combined below to identify four groups of firms that exhibit different degrees of capabilities in this regard.

b) Technological capabilities from external and internal sources

One important specification of such capabilities is whether innovative activities are the result of external or internal sources of know-how. This can be documented using the available surveys. Enterprise surveys provide information on the presence of technology licensing agreements with a foreign firm; this *external* technology acquisition is often the first step for firms in emerging countries to improve their know-how and technological capabilities.

Innovation surveys provide information on the presence of patent applications in firms, which is a key indicator of significant *internal* capabilities in the development, use and protection of technological inventions. This, in turn, requires substantial capabilities in R&D, engineering and product development. These two variables effectively summarize the trajectories of technological development—based on either external or internal sources—of firms in emerging countries.

c) Capabilities in management, skilled labour, production and exports

For this set of capabilities discussed in Section 2, we can provide empirical documentation on the following two types of capabilities:

Export capabilities

A firm's ability to enter and grow in international markets is an important factor that is often based on specific technological capabilities and, in turn, stimulates greater innovative activities to improve the firm's competitiveness. Operating in international markets requires specific managerial and marketing capabilities. Enterprise surveys provide information on the presence and amount of exports that can be related to the number of the firm's employees. This is an important performance indicator that highlights the success of innovative efforts and the relevance of capabilities to enter international markets.

a) Skilled labour capabilities

Capabilities and knowledge are embodied in people and organizations; therefore, the presence and growth of skilled workers in firms is a necessary condition for success in all of the above activities. Innovation surveys provide information on the impact of new products on the employment of skilled and unskilled workers. Enterprise surveys provide information on the level of employment. This sheds light on the presence of skilled labour capabilities in firms that complement the presence of capabilities in technology, innovation and export. This also allows us to identify the trajectory of technological change and its impact on labour; a large body of literature finds that innovation can either be associated with a strategy of technological competitiveness based on new products and leading to growth and higher skill jobs, or it can be used to achieve cost competitiveness by reducing unskilled employment and wages (Pianta, 2018).

The presence of such capabilities in firms can be associated with a 'virtuous circle' of growth and better performance. This mechanism is at the root of the rise of emerging countries' firms which may bring them closer to automation and digitalization.

To operationalize these concepts, we develop groups of firms based on their innovation and digital activities, which is then empirically investigated for several emerging countries.

4.1 Grouping of firms based on their innovation and digital activities

A preliminary analysis of the survey data for the countries considered reviews descriptive statistics and the general consistency of responses. Building on our extensive experience in the analysis of innovation survey data and on the trajectories typical of firms and industries (see Bogliacino et al., 2012; Crespi and Pianta, 2008; Bogliacino and Pianta, 2016; Pianta, 2018), we focus on the extent of innovation and digital activities in firms, identifying a set of characteristics that best allow us to identify capabilities and performance relevant for digitalization in emerging country firms. We identify the following four groups of firms on this basis.

a) Firms not engaged in product innovation

These are firms that answered "no" to the question whether they had introduced a new product or service in the previous three years. The firm may have introduced a new process or new organizational arrangement, but this was achieved with limited efforts and does not qualify the firm as being technologically dynamic. These firms have the lowest level of technological activity, are likely to be over-represented among small firms and in traditional and low-technology industries, generally playing the role of 'outsiders' in global production systems.

b) Firms engaged in product innovation

These firms answered "yes" to the question whether they had introduced a new product or service in the previous three years. The innovation literature and evidence from innovation surveys (see Section 2) have long shown that the ability to introduce a new product is a key factor that allows differentiating between firms with real innovative capabilities and firms with modest technological activities. The introduction of a new process is clearly a relevant complementary factor, but firms that only introduce new processes may in fact just be acquiring new machinery or a computer, with a limited impact on their overall technological capabilities. A large share of product innovators has also introduced new processes. This group is therefore a good proxy for firms with relevant technological capabilities. The introduction of a new product is a significant outcome of the innovative process, which requires the presence of several factors – adequate knowledge, capital, production systems, qualified personnel as well as some market power. Product innovators tend to have better performance in terms of productivity levels, growth of output, exports and employment. We can therefore assume that the group of product innovators is a group of firms with significant capabilities and dynamism, which—using the typology introduced in Section 2—have moved from being 'outsider firms' to becoming 'potential entrants' or even 'insiders' in efficient production systems and in global value chains.

c) Highly innovative firms

A set of demanding conditions applies to firms defined as highly innovative. The necessary conditions for belonging to this group are the following:

- introduction of a new product or service
- introduction of a new process – either in production, distribution or support activities
- the innovative process must have led to automated manual processes, partially or fully
- either internal or external R&D has been conducted.

This set of requirements identifies firms that have strong, systematic technological capabilities in all major dimensions of innovation. Besides the ability to launch new products and services, they

have the structures and resources to carry out R&D, a fundamental activity that is required for learning processes, the accumulation of competences and the interaction with technological leaders, either domestic or foreign. They also have the ability to innovate in processes—in different business activities—demonstrating that the necessary complementarities in innovative efforts exist. Moreover, the new processes have allowed automation to be introduced with the replacement of manual processes of production. These demanding characteristics imply that highly innovative firms much stronger technological capabilities than product innovators, and that they are likely to be 'insiders' in global value chains, playing a dynamic role in terms of learning, investment and innovation. In short, these firms are active at the first 'level' of the 'digitalization pyramid' with automation and technological competences.

a) Digital leaders

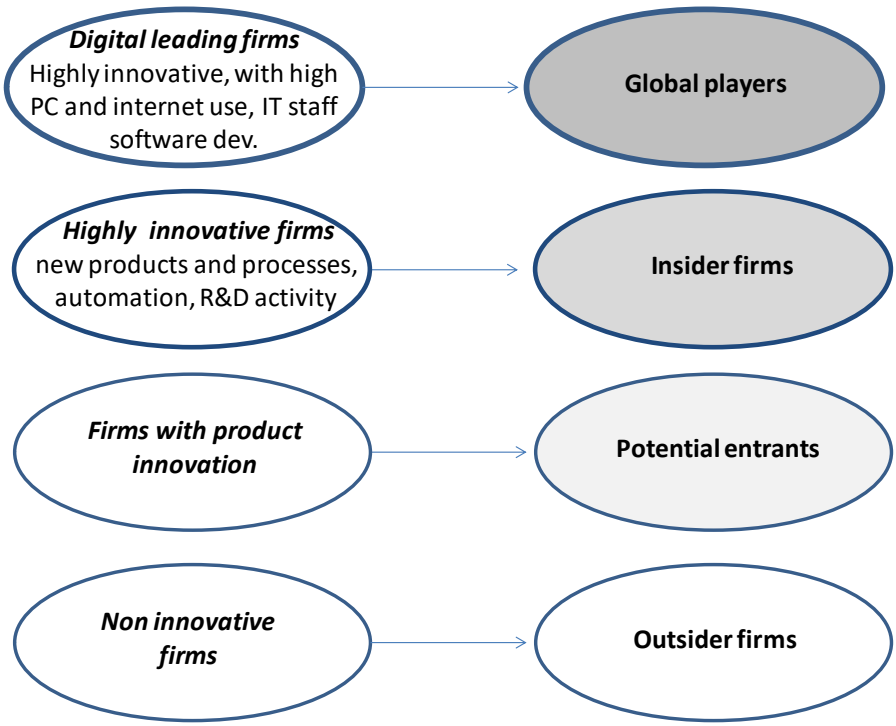
To identify firms with stronger digital capabilities, we review the responses of firms to the question on use of ICTs in addition to the criteria for highly innovative firms. Firms that meet the conditions of highly innovative firms and, in addition, have the following characteristics belong to an 'elite' group of digital leaders:

- large share of employees who use computers
- purchase or in-house development of software
- presence of employees working with IT
- use of computer consultants
- use of the internet for all business activities, including emails with clients and suppliers, communication between employees, online purchases of inputs, online sales, inventory management, marketing and R&D activities.

This set of requirements identifies firms that are strong digital players, building on a solid foundation of advanced technological capabilities. Their ability to introduce new products and processes, to automate and carry out R&D is supported by widespread digital activities that promote interaction with foreign technological leaders. Meeting these very demanding characteristics, digital leaders are firms with the strongest technological capabilities, likely to be 'global players' not only in global value chains, but also in the global process of digitalization and the development of Industry 4.0; they are moving higher in the 'digitalization pyramid' with automation, digital competences and broad technological activities.

A summary of the definition of these three groups of firms in emerging countries is provided in Figure 4, indicating the possible links with the typology of emerging country firms discussed in Section 2.

Figure 4: Grouping of firms with innovative and digital activities



Source: Author's elaboration.

The firms in the four groups of innovative and digital enterprises can be empirically identified using the World Bank Innovation Surveys. While each group may have firms with a high internal heterogeneity of characteristics and performance; the distance between groups in terms of technological and economic performance is expected to be high due to the rigorous innovative and digital requirements we have included as discriminating criteria for the definition of this group. The distribution of emerging country firms among the four groups is a preliminary, effective indicator of technological capabilities.

Table 12 documents the presence of firms in the four groups defined above in all countries included in the World Bank Innovation Surveys. The share of product innovators ranges between 50 per cent in India and Bangladesh to 32 per cent in Kenya, 26 per cent in Nigeria and 21 per cent in Pakistan, while high shares are also found in some African countries. These data reflect the differences among emerging countries in terms of economic size, diversification of production, reliance on raw material extraction and institutional factors, and are broadly in line with the findings from innovation surveys in emerging countries (see Bogliacino et al., 2012) and from studies on other regions.

Table 12: Grouping of firms with innovative and digital activities in emerging countries

	India		Kenya		Nigeria		Pakistan		Bangladesh	
TYPE	No.	%	No.	%	No.	%	No.	%	No.	%
Digital leaders	52	1.49	4	0.73	4	0.45	1	0.14	7	0.71
Highly innovative	485	13.90	55	10.07	91	10.17	13	1.88	143	14.44
Product innovators	1,738	49.80	174	31.87	231	25.81	144	20.84	478	48.28
Non-innovators	1,215	34.81	313	57.33	569	63.58	533	77.13	362	36.57
Total	3490	100.00	546	100.00	895	100.00	691	100.00	990	100.00

	DR Congo		Ghana		Nepal		Malawi		Namibia	
TYPE	No.	%	No.	%	No.	%	No.	%	No.	%
Digital leaders	2	0.52	2	0.37	1	0.21	3	1.21	3	0.79
Highly innovative	36	9.40	30	5.51	7	1.49	32	12.96	40	10.58
Product innovators	109	28.46	122	22.43	73	15.53	74	29.96	97	25.66
Non-innovators	236	61.62	390	71.69	389	82.77	138	55.87	238	62.96
Total	383	100.00	544	100.00	470	100.00	247	100.00	378	100.00

	South Sudan		Sudan		Tanzania		Uganda		Zambia	
TYPE	No.	%	No.	%	No.	%	No.	%	No.	%
Digital leaders	6	1.11	2	0.49	1	0.18	6	1.34	2	0.37
Highly innovative	27	4.99	11	2.72	5	0.92	29	6.47	69	12.78
Product innovators	287	53.05	123	30.37	83	15.34	203	45.31	256	47.41
Non-innovators	221	40.85	269	66.42	452	83.55	210	46.88	213	39.44
Total	541	100.00	405	100.00	541	100.00	448	100.00	540	100.00

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

There is a significant share of highly innovative firms based on the very demanding requirements defined above in several emerging countries: 14 per cent in India and Bangladesh, 10 per cent in

Kenya, 10 per cent in Nigeria and 2 per cent in Pakistan; some African countries also have relatively high shares of highly innovative firms. The presence of a sizeable group of firms from emerging countries among those positioned at the first 'level' of the global 'digitalization pyramid' is an important finding. Their numbers are higher in economies with the most diversified industrial base; in some smaller countries, this result may be affected by an over-representation of dynamic firms in the survey sample.

Between 0.14 per cent and 1.5 per cent of firms in emerging countries are digital leaders, belonging to the 'elite' of technological players. A significant number of firms (52) from the largest country, India, are included in this group of global digital players. Some emerging countries are now moving from being top performers in industrial production capabilities to entering the club of firms with top technological and digital capabilities. This requires substantial efforts by individual firms as well as a national system of production and innovation capable of supporting the technological upgrading of enterprises. A large country size, a diversified industrial base with strong manufacturing capabilities, well-functioning institutions, educational and public policy systems are important conditions in this regard.

One further insight into these patterns is provided in Table 13, which focusses on manufacturing firms only. The picture is not much different from that for all firms, with a similar distribution of firms across the four groups.

Table 13: Grouping of firms with innovative and digital activities in manufacturing only

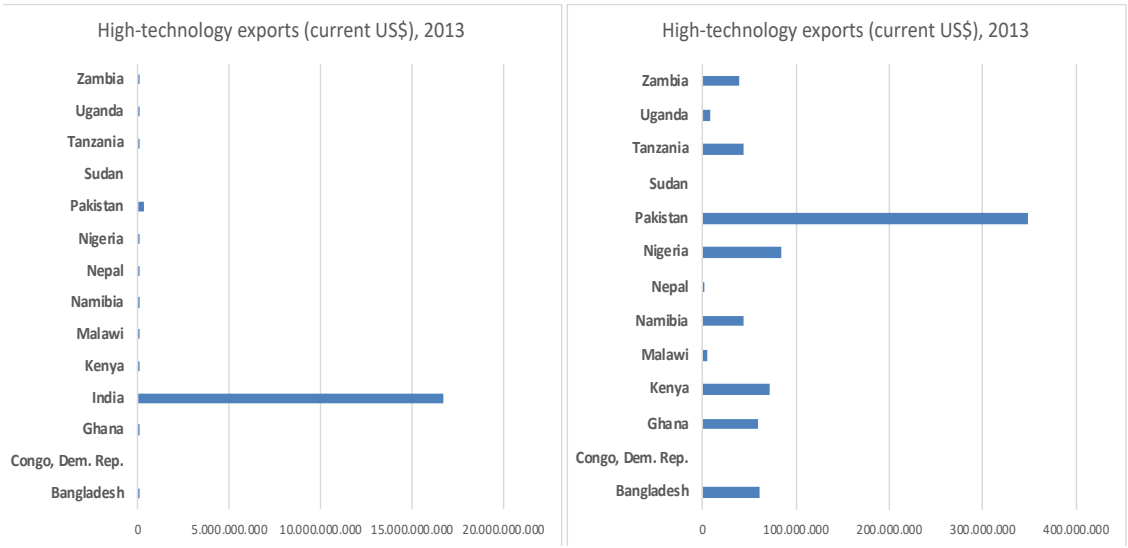
Percentages of total manufacturing firms

Country	Digital leaders	Highly innovative	Product innovators	Non-innovators
Bangladesh	0.70	15.91	46.32	37.08
DR Congo	0.55	10.38	30.60	58.47
Ghana	0.35	7.80	18.79	73.05
India	1.69	16.81	50.33	31.17
Kenya	0.71	11.39	33.45	54.45
Malawi	2.99	20.90	35.82	40.30
Namibia	0.00	15.87	31.75	52.38
Nepal	0.43	2.13	14.47	82.98
Nigeria	0.75	9.95	27.36	61.94
Pakistan	0.00	2.07	22.63	75.30
South Sudan	1.22	6.10	63.41	29.27
Sudan	1.06	5.32	32.98	60.64
Tanzania	0.00	0.74	17.65	81.62
Uganda	2.88	9.13	44.71	43.27
Zambia	0.00	15.30	45.15	39.55

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

Figure 5: High-technology exports for selected countries

Graph with India *Graph excluding India*



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

The distribution of firms among these technological groups shows the firms' trajectory, upgrading from the basic innovation capabilities of product innovators to the fully integrated technological capabilities of highly innovative firms, to the digital qualifications of digital leaders.

Among these countries, an in-depth investigation should focus on a selected number of countries that are more relevant in terms of economic size, relevance of high-technology activities and the potential for digitalization. It should also address the number of firms in the innovation survey, the presence of missing values and data strength. The most important countries in terms of high-technology exports are presented in Figure 5; India, Pakistan, Nigeria and Kenya are the top exporters with large economies.

As regards innovation survey results, only countries with robust data should be considered; specifically, countries with less than 400 respondent firms or with too many missing responses to key questions on sector, size, innovation, automation and ICT use are excluded from further investigation. Countries with the most extensive data from innovation surveys include India, Kenya, Nigeria and Pakistan, i.e. the same countries that have greater high-technology relevance; the in-depth analysis in the rest of this section therefore focusses on these four countries.

The main dimensions addressed by the in-depth analysis for these four countries include size, industries, patterns of specialization, technological performance and impact on employment.

4.2 Size and industry characteristics of the group of firms

Table 14 presents the firm size of the groups of firms in the four countries we have included (no data are available for Kenya).

Table 14: Firms in the innovation and digital group by size

	INDIA		**KENYA**		**NIGERIA**		**PAKISTAN**	
	No.	%	No.	%	No.	%	No.	%
All firms by size groups								
Large (>100)	932	26.69	Not available		74	8.18	138	19.83
Medium (20-99)	1,589	45.50			243	26.85	226	32.47
Small (5-19)	971	27.81			450	49.72	287	41.24
Micro (<5)	0	0.00			138	15.25	45	6.47
Total	3,492	100.00			905	100.00	696	100.00
Non-innovative firms								
Large (>100)	268	22.06	Not available		39	6.85	100	18.76
Medium (20-99)	590	48.56			160	28.12	162	30.39
Small (5-19)	357	29.38			287	50.44	233	43.71
Micro (<5)	0	0.00			83	14.59	38	7.13
Total	1,215	100.00			569	100.00	533	100.00
Firms with product innovations								
Large (>100)	443	25.49	Not available		25	10.82	28	19.44
Medium (20-99)	771	44.36			51	22.08	57	39.58
Small (5-19)	524	30.15			117	50.65	52	36.11
Micro (<5)	0	0.00			38	16.45	7	4.86
Total	1,738	100.00			231	100.00	144	100.00

Highly innovative firms							
Large (>100)	190	39.18	Not available	9	9.89	8	61.54
Medium (20-99)	212	43.71		29	31.87	5	38.46
Small (5-19)	83	17.11		41	45.05	0	0.00
Micro (<5)	0	0.00		12	13.19	0	0.00
Total	485	100.00		91	100.00	13	100.00
Digital leaders							
Large (>100)	31	59.62	Not available	1	25.00	0	0.00
Medium (20-99)	16	30.77		2	50.00	1	100.00
Small (5-19)	5	9.62		1	25.00	0	0.00
Micro (<5)	0	0.00		0	0.00	0	0.00
Total	52	100.00		4	100.00	1	100.00

Note: The size of the firm was defined on the basis of the number of permanent full-time workers: micro (less than 5 employees), small (5 to 19 employees), medium (20 to 99 employees), and large (more than 99 employees).
Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

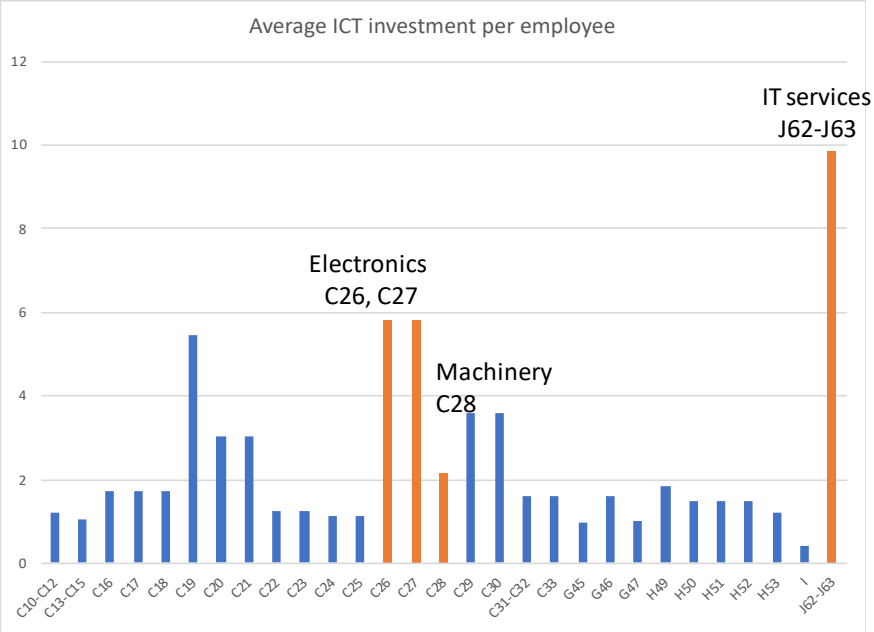
Large firms show strong differences across countries, but their share in total firms and in product innovators is largely the same. In India, large firms account for 27 per cent of all firms and 25 per cent of product innovators; in Nigeria, the shares are 8 per cent and 11 per cent, respectively; in Pakistan, 20 per cent are large firms and 19 per cent of all firms are product innovators. Medium-sized firms account for about 40 per cent of product innovators in both India and Pakistan, and 22 per cent in Nigeria. Micro firms (under 5 employees) were included in the surveys of Nigeria and Pakistan; in Nigeria, the share of small and micro firms that are product innovators is 16 per cent, and 5 per cent in Pakistan. Moving to highly innovative firms, we again find that large firms are not the only relevant technological players. In India, large and medium sized firms have similar shares of highly innovative firms at around 40 per cent; in Pakistan, large firms account for 62 per cent of highly innovative firms, while in Nigeria, smaller firms dominate in the group of highly innovative firms.

Digital leaders in India tend to be large enterprises, but there are also niches of digital success among some medium and small firms (60 per cent are large firms, 31 per cent are medium sized and 10 per cent are small firms). If we consider manufacturing firms only, the shares are very similar: 57 per cent, 33 per cent and 11 per cent, respectively. The same applies to other countries; as global digital activities expand, integration in value chains and advanced digitalization may also take place in (relatively few) smaller, specialized firms of emerging countries.

National industrial structures are a crucial factor, and the innovative dynamism of small firms as well is clearly a positive finding of the surveys. Evidence on innovation in firms reveals the importance of size for creating the conditions for strong, diversified technological capabilities, and the limitation that small firms encounter when seeking to enter international markets. Some growth in firm size could effectively lead to a rise in innovative and digital capabilities of emerging countries firms.

Figure 6: ICT intensity in industries

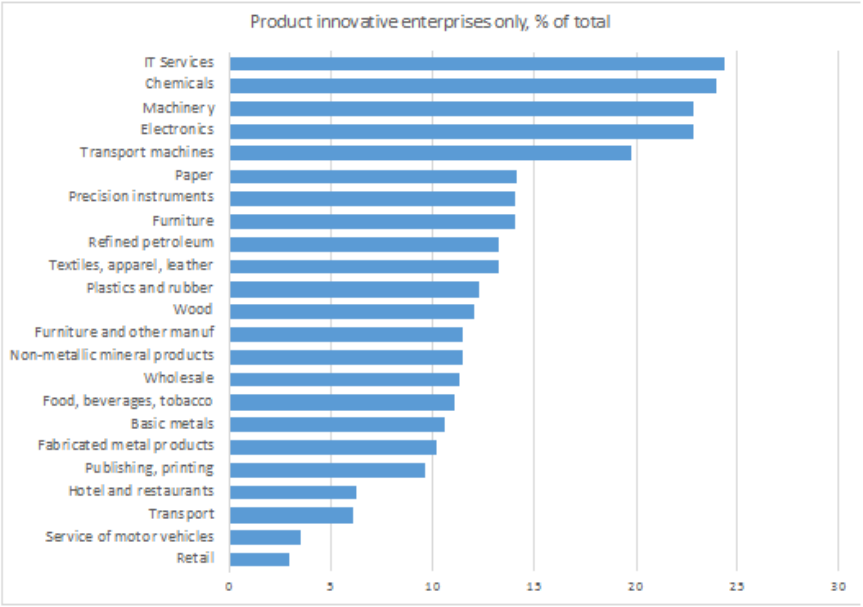
ICT investment per employee, average for 2009-2014, averages for major European countries: DE, FR, ES, IT, NL, UK



Note: Industries are based on the NACE 2-digit industry classification. Average over the period 2009-2014, average for Germany, France, UK, Italy, the Netherlands, Spain

Source: Author's elaboration based on the Sectoral Innovation Database (SID), University of Urbino.

Figure 7: Share of firms introducing product innovations in Europe, ranking of industries



Note: Industries are based on the NACE 2-digit industry classification.
Source: Author's elaboration based on the Sectoral Innovation Database (SID), University of Urbino.

The industrial structure of emerging countries is crucial for understanding their potential for innovation and digitalization. The relevance of manufacturing vs. services is one first important distinction. Industries with greater potential for innovation and digitalization must also be identified. We rely on the extensive evidence from ICT diffusion (see OECD, 2018) and innovation surveys in Europe and look at industries with the highest indicators of digitalization and innovation. The ranking of industries based on these indicators tend to be stable across both advanced and emerging countries. To identify the sectors of manufacturing and services with the greatest potential for digitalization, we first consider the importance of ICT investment per employee in all industries. We use the NACE classification (listed in Table 3 in the Appendix) adopted by the Sectoral Innovation Database (SID) developed at the University of Urbino (see Pianta et al., 2019). Figure 6 presents data for the average of six major EU countries (Germany, France, UK, Italy, the Netherlands, Spain) for the period 2009-2014. Information technology services and electronics have the highest values.

The second indicator is the share of firms introducing product innovations only, a good proxy for the potential for high innovation; Figure 7 shows the ranking of industries based on the NACE classification and on data from the Sectoral Innovation Database (SID) for the average of those countries, considering the innovation survey of 2014 (the ranking of industries is very similar when we look at firms that have introduced product, process and organizational innovations).

Information technology services, chemicals, machinery and electronics are industries with a greater dynamism in new products.

Moreover, IT services, machinery and electronics are crucial activities for digitalization as they provide the software and hardware for automation and digital activities. Chemicals is an industry that is of little relevance for digitalization, in spite of its ability to introduce a large number of new chemical and pharmaceutical entities (telecommunication is not considered here because this industry is not available in the World Bank Innovation Survey, as it is included in the transport industry). In the rest of this analysis, we therefore focus on IT services, machinery and electronics as 'digital industries'. Evidence from business and technology studies confirms the key relevance of these three industries for the prospects of digitalization. The industry analysis addresses the importance of these industries in detail.

Table 15 presents data for the sectoral composition of firms—again grouped by their innovative and digital potential—in the four emerging countries included in our study; we consider the manufacturing/service divide and the relevance of IT services, machinery and electronics.

Manufacturing is important for India and Pakistan (78 per cent and 84 per cent, respectively; no detailed data is available for Pakistan). India has a more diversified economy and a stronger presence in high-technology manufacturing and services. Nigeria has a concentration in oil and natural resources, which are grouped in 'other industries'. One significant result in India is the relatively diversified distribution in all firm groups across industries with the highest innovative performance.

Electronics accounts for 6.5 per cent of all firms, 6.2 per cent of product innovators, 10.5 per cent of highly innovative firms, 12 per cent of digital leaders. Machinery accounts for 8.6 per cent of all firms and for 9.3 per cent, 11.1 per cent and 13.4 per cent of firm groups, respectively. Information technology services represent a small share of all firms; the remaining manufacturing and service firms, including some traditional industries, account for 82 per cent of all firms; product innovators and highly innovative firms account for similar shares. The range of industries with technologically dynamic firms appears to be a factor of strength of India's industry, broadening the base from which digital players could emerge. Conversely, in the case of Nigeria, high-technology manufacturing and services appear to be of modest relevance for the country's innovative performance.

Table 1 in the Appendix provides an overview of the relevance of each industry in the firm groups in the case of India. The relevance of the three industries we have focussed on is confirmed. Machinery and electronics account for 13 per cent and 12 per cent of all digital leaders—by far the most important industries—and for 11 per cent of all highly innovative firms. Other manufacturing industries with large shares of highly innovative firms are chemicals and plastics, which are far from automation and digitalization activities. IT services tend to be provided by a few large firms, therefore, their relevance in the total number of firms is low.

Table 15: Firms in the innovation and digital groupings by industry

	INDIA		**KENYA**		**NIGERIA**		**PAKISTAN**	
	No.	%	No.	%	No.	%	No.	%
All firms								
Manufacturing	2,724	78.01	282	51.37	410	45.30	83.76	83.76
Services	768	21.99	267	48.63	495	54.70	113	16.24
Total	3,492	100.00	549	100.00	905	100.00	696	100.00
Machinery	301	8.62			3	0.33		
Electronics	227	6.50	not available		3	0.33	not available	
IT services	102	2.92			17	1.88		
Other	2,862	81.96			882	97.46		
Total	3,492	100.00			905	100.00		
Non-innovative firms								
Manufacturing	849	69.88	153	48.88	249	43.76	436	81.80
Services	366	30.12	160	51.12	320	56.24	97	18.20
Total	1,215	100.00	313	100.00	569	100.00	533	100.00
Machinery	78	6.42			3	0.53		
Electronics	62	5.10	not available		1	0.18	not available	
IT Services	40	3.29			10	1.76		
Other	1,035	85.19			555	97.54		
Total	1,215	100.00			569	100.00		
Firms with product innovations								
Manufacturing	1,371	78.88	94	54.02	110	47.62	131	90.97
Services	367	21.12	80	45.98	121	52.38	13	9.03

Total	1,738	100.00	174	100.00	231	100.00	144	100.00
Machinery	162	9.32			0	0.00		
Electronics	108	6.21	not available		2	0.87	not available	
IT services	57	3.28			6	2.60		
Other	1,411	81.19			223	96.54		
Total	1,738	100.00			231	100.00		
Highly innovative firms								
Manufacturing	458	94.43	32	58.18	40	43.96	12	92.31
Services	27	5.57	23	41.82	51	56.04	1	7.69
Total	485	100.00	55	100.00	91	100.00	13	100.00
Machinery	54	11.13			0	0.00		
Electronics	51	10.52	not available		0	0.00	not available	
IT services	4	0.82			1	1.10		
Other	376	77.53			90	98.90		
Total	485	100.00			91	100.00		
Digital leaders								
Manufacturing	46	88.46	2	50.00	3	75.00	0	0.00
Services	6	11.54	2	50.00	1	25.00	1	100.00
Total	52	100.00	4	100.00	4	100.00	1	100.00
Machinery	7	13.46			0	0.00		
Electronics	6	11.54	not available		0	0.00	not available	
IT Services	1	1.92			0	0.00		
Other	38	73.08			4	100.00		
Total	52	100.00			4	100.00		

Note: Machinery (29-30), electronics (30-31) and IT services (72) are industries with high ICT and innovative characteristics. ISIC Rev. 3.1 industry classification code in parenthesis.

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

4.3 Technological and employment performance of firm grouping

Table 16 presents a key indicator of technological performance, i.e. the ability of firms to apply for a patent for a new product they have developed. Patents are an output indicator for the success and originality of a firm's invention (see Archibugi and Pianta, 1996). Moreover, in global technology markets, they indicate the international relevance of a firm's technology.

In India, 21 per cent of product innovators, 16 per cent of highly innovative firms and 29 per cent of digital leaders applied for a patent. In Kenya, the shares were 3 per cent for product innovators and 9 per cent of highly innovative firms. In Nigeria, 16 per cent of product innovators and 13 per cent of highly innovative firms applied for a patent. In Pakistan, these shares were 11 per cent and 38 per cent, respectively. The absolute number of firms that are actively patenting new products are significant, and confirm many emerging countries' technological potential. In the case of digital leaders in India, with its substantial number of players, 29 per cent of such firms submit patents on new products; considering that many firms in this group are in the services sector, other forms of protection of intellectual property rights may be adopted.

Tables 17 and 18 look at the impact of new products on skilled and unskilled jobs. Table 17 reflects the answers of product innovators that the employment of skilled workers has increased, decreased or remained the same as a result of the new product. New skilled jobs have been added by 34 per cent of firms among the group of product innovators, by 53 per cent of highly innovative firms and 60 per cent of digital leaders. Remarkably, 63 per cent of product innovators did not increase their skilled workforce. Job losses have only been recorded by a few firms. In Kenya, the results show that the shares among firms that are expanding and maintaining skilled employment are much closer. In Pakistan, highly innovative firms had a more positive impact on new skilled jobs.

Table 18 shows that new products in India did not have an impact on unskilled jobs in 70 per cent of product innovators, 57 per cent of highly innovative firms and 40 per cent of digital leaders, with very few firms reporting any job losses. Nigeria and Pakistan also reveal unchanged levels of unskilled employment.

Table 16: Patents for new products by firms in the innovation and digital firm groups

	INDIA		**KENYA**		**NIGERIA**		**PAKISTAN**	
	No.	%	No.	%	No.	%	No.	%
Non-innovative firms								

Yes	83	6.83	5	1.60	12	2.11	17	3.19
No	1,105	90.95	305	97.44	545	95.78	499	93.62
Do not know	27	2.22	3	0.96	12	2.11	17	3.19
Total	1,215	100.00	313	100.00	569	100.00	533	100.00
Firms with product innovations								
Yes	372	21.40	6	3.45	36	15.58	16	11.11
No	1,357	78.08	165	94.83	189	81.82	121	84.03
Do not know	9	0.52	3	1.72	6	2.60	7	4.86
Total	1,738	100.00	174	100.00	231	100.00	144	100.00
Highly innovative firms								
Yes	76	15.67	5	9.09	12	13.19	5	38.46
No	405	83.51	50	90.91	78	85.71	7	53.85
Do not know	4	0.82			1	1.10	1	7.69
Total	485	100.00	55	100.00	91	100.00	13	100.00
Digital leaders								
Yes	15	28.85	0	0.00	2	50.00	0	0.00
No	36	69.23	4	100.00	2	50.00	1	100.00
Do not know	1	1.92	0	0.00			0	0.00
Total	52	100.00	4	100.00	4	100.00	1	100.00

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

Table 17: Impact on skilled employment among firms as a consequence of product innovation

	INDIA		KENYA		NIGERIA		PAKISTAN	
	No.	%	No.	%	No.	%	No.	%
Firms with product innovations								
Increased	596	34.29	80	45.98	Not available		49	34.03
Remained the same	1,103	63.46	90	51.72			80	55.56
Decreased	35	2.01	4	2.30			7	4.86
Do not know	4	0.23	0	0.00			8	5.56
Total	1,738	100.00	174	100.00			144	100.00
Highly innovative firms								
Increased	256	52.78	33	60.00			10	76.92
Remained the same	228	47.01	19	34.55			3	23.08
Decreased	1	0.21	3	5.45			0	0.00
Total	485	100.00	55	100.00			13	100.00
Digital leaders								
Increased	31	59.62	2	50.00			1	100.00
Remained the same	20	38.46	2	50.00			0	0.00
Decreased	1	1.92	0	0.00			0	0.00
Total	52	100.00	4	100.00			1	100.00

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

Table 18: Impact on unskilled employment among firms as a consequence of product innovation

	INDIA		KENYA		NIGERIA		PAKISTAN	
	No.	%	No.	%	No.	%	No.	%
Firms with product innovations								
Increased	472	27.16	29	16.67	Not available		36	25.00
Remained the same	1,224	70.43	101	58.05			91	63.19
Decreased	39	2.24	27	15.52			9	6.25
Do not know	3	0.17	17	9.77			8	5.56
Total	1,738	100.00	174	100.00			136	100.00
Highly innovative firms								
Increased	195	40.21	15	27.27			3	23.08
Remained the same	278	57.32	26	47.27			8	61.54
Decreased	10	2.06	8	14.55			2	15.38
Do not know	2	0.41	6	10.91			0	0.00
Total	485	100.00	55	100.00			13	100.00
Digital leaders								
Increased	30	57.69	2	50.00			1	100.00
Remained the same	21	40.38	0	0.00			0	0.00
Decreased	1	1.92	1	25.00			0	0.00
Do not know			1	25.00			0	0.00
Total	52	100.00	4	100.00			1	100.00

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up 2013-2014.

The literature on technology and employment (Pianta, 2018) has long pointed out that at the firm level, new products generally have positive employment effect, as they allow for an expansion of output – sometimes at the expense of competitors. Conversely, new processes tend to have negative employment effects. Skilled jobs are complementary to more sophisticated products and services as the knowledge of qualified workers is generally required for product novelties. Unskilled jobs are expanded, as the success of new products may require more production workers for higher output. At the same time, learning processes may allow new product and output growth in some firms, even without hiring new skilled employees. This may explain the large share of firms that show no change in employment as a result of product innovation and the fairly small differences between the results for skilled and unskilled workers.

4.4 Innovation and digitalization in India

The relationships between digitalization and overall innovative capabilities in firms are complex. In this section, we carry out a more detailed investigation of India by matching different degrees of digital activities in firms and overall innovative performance. Based on the World Bank questionnaire, we identify five indicators of digitalization: 1) Share of employees who regularly use computers is above 50 per cent; 2) Purchase or in-house development of software; 3) Presence of IT employees; 4) Presence of external computer/software consultants; and 5) Use of ICTs across the entire range of business activities listed in the questionnaire. We construct dummy variables for each indicator and based on their sum, define four groups: 1) No digital activities: sum of dummies equal to 0; 2) Low digital activities: sum of dummies equal to 1 or 2; 3) Medium digital activities: sum of dummies equal to 3 or 4; 4) High digital activities: sum of dummies equal to 5. Data on India, reported in Table 19, reveal the following highlights:

Thirty per cent of firms have a **medium or high level of digitalization** (scores 3, 4, 5), with a significant or systematic use of ICTs in business activities. These are mainly large firms. About two-thirds are in manufacturing, are innovators in products and in processes and carry out R&D. They are highly innovative and digital, and lie at the forefront of technological change and digitalization.

Seventy per cent of firms have no or low digitalization (scores 0, 1, 2), with a lack or very modest use of ICTs in business activities. They are mostly small and medium firms. Three-quarters of these firms are engaged in manufacturing. About two-thirds are capable of introducing innovations in products or processes; half of the firms carry out R&D. They combine some innovative capabilities with no or low digitalization. They appear to be engaged in manufacturing niches where digitalization is secondary to the diffusion and adoption of production technologies, with the acquisition of new machinery and product imitation.

Table 19: India, digitalization and innovative activities

Absolute values

	Number of firms	Large Firms	Product innovators	Process innovators	R&D performers	Highly innov. Firms
No. digital activities						
Manufacturing	527	66	356	350	217	45
Total	666	76	441	425	242	48
Low digital activities						
Manufacturing	1290	385	905	961	752	278
Total	1627	453	1079	1178	848	292
Medium digital activities						
Manufacturing	603	255	431	437	417	161
Total	825	337	535	577	508	171
High digital activities						
Manufacturing	12	11	11	8	8	3
Total	52	38	44	24	27	8
Tot. Manuf.	**2432**	**717**	**1703**	**1756**	**1394**	**487**
Total all firms	**3170**	**904**	**2099**	**2204**	**1625**	**519**

Percentages of total firms

	Number of firms	Large firms	Product innovators	Process innovators	R&D performers	Highly innov. firms
No digital activities						
Manufacturing	22%	3%	15%	14%	9%	2%
Total	21%	2%	14%	13%	8%	2%
Low digital activities						
Manufacturing	53%	16%	37%	40%	31%	11%
Total	51%	14%	34%	37%	27%	9%

Medium digital activities						
Manufacturing	25%	10%	18%	18%	17%	7%
Total	26%	11%	17%	18%	16%	5%
High digital activities						
Manufacturing	0%	0%	0%	0%	0%	0%
Total	2%	1%	1%	1%	1%	0%
Tot. Manuf.	100%	29%	70%	72%	57%	20%
Total all firms	**100%**	**29%**	**66%**	**70%**	**51%**	**16%**

Note: Groups of firms are defined in a list of five digital activities in the World Bank questionnaire, which are turned into dummy variables:
a) Share of employees who regularly use computers is above 50 per cent
b) Purchase or in-house development of software
c) Presence of IT employees
d) Presence of external computer/software consultants
e) Use of ICTs in the entire range of business activities listed in the questionnaire
No digital activities: sum of dummies equal to 0; Low digital activity: sum equal to 1 or 2; Medium digital activity: sum equal to 3 or 4; High digital activity: sum equal to 5
Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

When we focus on **highly digital firms (score 5)** only, we find that only 2 per cent of all firms (52 firms, 22 of which are engaged in IT services) systematically use ICTs in business activities; three-quarters of them are large, 90 per cent of them are product innovators, and half of them are process innovators and carry out R&D activities. They emerge as highly digital firms, with innovative capabilities focussed on new products and (mostly) services.

4.4.1 Summary of the evidence of innovation surveys

Evidence from the World Bank Innovation Surveys on firms has offered some preliminary answers on the extent of innovative capabilities and digital activities of firms in emerging countries. The four groups of firms we consider can be effectively used to differentiate between firms with different technological capabilities. Their distribution among firm size groups and industries in manufacturing and services has shown that more innovative firms tend to be larger and more present in high-technology and digital industries, albeit with significant differences among the countries. They also claim more patents and show better employment outcomes, especially for skilled workers, as a result of innovation.

The four groups of firms appear to provide a solid documentation of the technological and production 'hierarchy' of firms, revealing how many firms have taken a 'first step' towards developing innovative capabilities for introducing new products and have thus entered the group of product innovators; how many have moved to the next level (highly innovative group), building strong technological competences across a spectrum of activities; and how many (or few) have successfully engaged in digital activities, becoming digital leaders. The results of this preliminary analysis appear to be consistent with the findings of the literature in this field and provide a picture of the countries investigated here that is broadly consistent with our knowledge of their industrial structure.

4.5 Matching innovation and enterprise surveys

In a next step in the analysis, we integrate the information collected from innovation surveys with more general information about firms' characteristics and performance from the World Bank Enterprise Survey. The two surveys can be matched by using the global unique identifier code assigned to each firm. Considering the importance of the inclusion of a large number of firms and the lack of missing responses, we focus this part of the analysis on India only, where high quality data are available; the findings for India could provide insights that are of general relevance for emerging countries, by assessing the significance and robustness of the typology of firms discussed so far to understand the capabilities and trajectories of emerging country firms.

To carry out the analysis, we match the World Bank India Innovation 2013-2014 follow up survey and the India 2013-2014 Enterprise Survey. The analysis includes 27 sectors of the ISIC Rev 3.1 classification, including manufacturing industries (15 to 37) and some services (45, 50, 51, 52, 55, 60-64, 72); the full list of industries is provided in Table 2 in the Appendix.

The technological variables from the innovation survey can thus be associated with a set of data that allows us to shed new light on several firm characteristics: firm size (number of employees); *technological capabilities*, with the share of firms patenting new products and the share of firms licensing foreign technology; *export capability*, with the share of exporting firms and the level of exports per employee; and *skilled labour capabilities*, with the share of firms in which product innovation has led to an increase in skilled or unskilled employees. The full list of variables used in this part of the analysis is provided in Table 20.

Table 21 presents the average values of the variables for the four innovation and digital groupings we have identified. The ranking of the four groups is substantiated in all indicators; digital leaders (DL) have the highest values in all variables, followed by highly innovative firms (HI), and at some distance by product innovators (PI), while non-innovating firms (NI) trail behind in all

indicators. The groups we have identified appear robust and relevant for understanding the diversity of firms in terms of their innovation capabilities and ability to move towards digitalization.

We now consider the different sets of capabilities discussed at the beginning of this section and examine the position of each group to assess the extent to which greater innovation and digital capabilities are associated with higher capabilities in technology, export and skilled labour.

Table 20: List of variables for enterprise analysis, India, 2013-2014

List of variables	Label
QDIGIND	Share of firms in digital industries (electronics, machinery and IT services)
SIZE	Size of the firm (average number of employees)
QEXPFIRM	Share of exporting firms (condition: export>0)
QPAT	Share of firms patenting new products
QTECH	Share of firms licensing foreign technology
QISKIL	Share of firms increasing the number of skilled workers as a consequence of product innovation
QIUNSK	Share of firms increasing the number of unskilled workers as a consequence of product innovation
EXPEMP	Export per employee
DL	Digital leaders
HI	Highly innovative firms
PI	Product innovators
NI	Firms that are not product innovators

Source: Authors' elaboration

Table 21: Innovation and digital groupings, average values of selected variables, India, 2013-2014

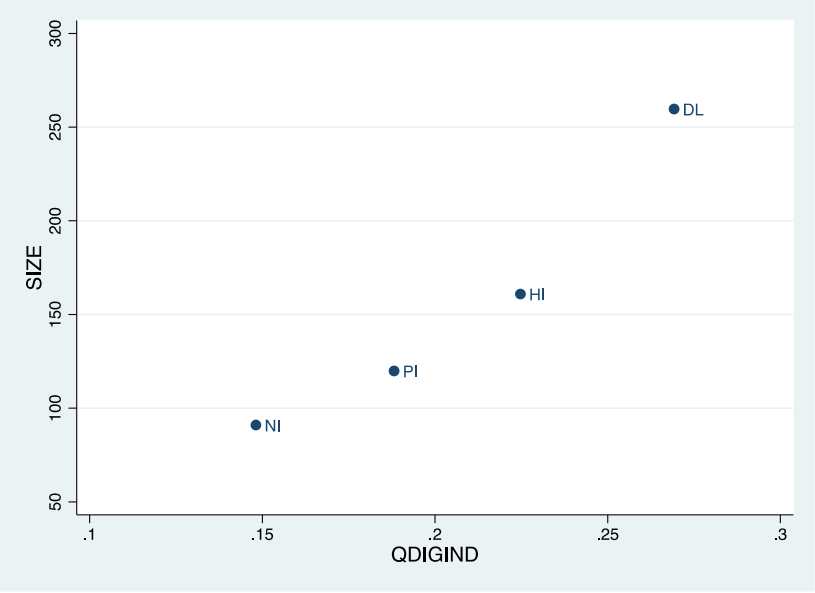
TYPE	QDIGIND	SIZE	QEXPFIRM	QPAT	QTECH	QISKIL	QIUNSK
Digital Leaders	.269	260	.346	.294	.311	.596	.577
Highly innovative	.225	161	.309	.158	.158	.528	.404
Product innovators	.188	120	.187	.215	.114	.344	.272
Non-innovators	.148	91	.131	.0699	.0618	.	.
Total	.208	158	.243	.184	.161	.489	.418

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

a) Firm size and industries

Firm size is a basic characteristic that is associated with a variety of capabilities and competences of the firm. At the same time, industry characteristics shape firms' opportunities for growth. Figure 8 combines these two dimensions, illustrating where the four groups of firms are located in terms of their share in digital industries (machinery, electronics and IT services) and average firm size. Digital leaders include firms that are more active in such industries and have the largest size; the other groups follow at a distance, with a clear linear relationship. The four groups we identified effectively summarize the importance of size and the technological and growth opportunities offered by digital industries.

Figure 8: Innovation groupings by share of firms in digital industries and size in India



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

b) External and internal technological capabilities of firms

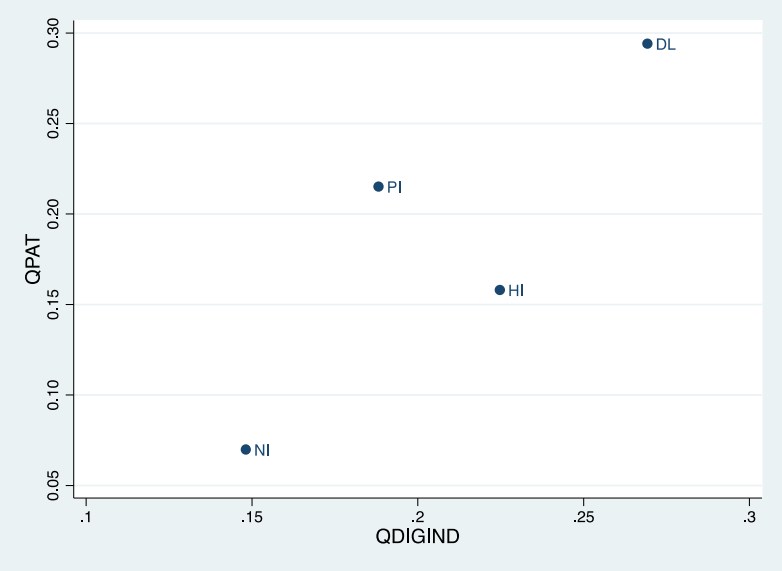
How can we assess firms' technological capabilities? And what are the sources of the technological capabilities of firms in the four groups? In particular, is there a complementarity or trade-off between the acquisition of foreign technology and the ability to develop inventions and innovations internally? Figures 9 and 10 address these questions.

Figure 9 combines industry characteristics with the importance of patenting. Digital leaders are more active in digital industries and have the highest share of firms with patents. Highly innovative firms are also more active in digital industries but claim fewer patents than product innovators. Non-innovators are only modestly active in digital industries with very few firms claiming patents.

Figure 10 combines the two alternative sources of technological capabilities, namely the acquisition of foreign licenses and the internal ability to claim patents. The same linear relationship appears again for the four groups, with greater external acquisitions being associated with greater patenting activity; highly innovative firms appear to be relatively more active in foreign acquisition—associated with the variety of efforts they undertake to produce new products, processes and automation—while product innovators are more active in the patenting of new products.

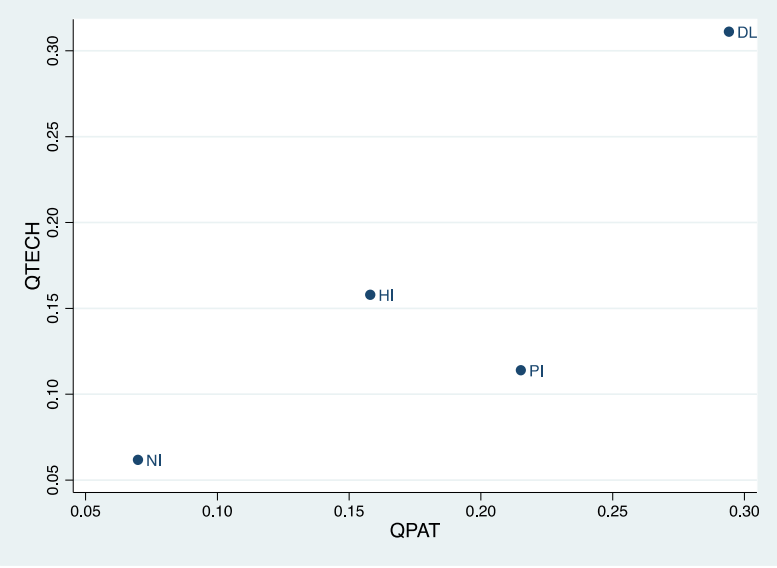
This finding shows that technological capabilities for the aggregate of firms included in the four groups, are the result of the complementarities between external acquisition of know-how, which is necessary when firms want to enter new technology fields, and the accumulation of internal capabilities, which eventually results in the successful patenting of new products. It is noteworthy that digital leaders are the largest users of licenses of foreign technologies; the diversity of knowledge required by high-tech firms means that the requirements of know-how are greater; moreover, digital leaders are more integrated in global technology networks and therefore more capable of acquiring the necessary know-how that cannot be developed internally. This also has important implications for policies on the protection of IPRs and on incentives to license and patent.

Figure 9: Innovation groupings by share of firms in digital industries and share of firms with patents in India



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

Figure 10: Innovation groupings by share of firms with patents and share of firms with foreign technology licensing in India



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

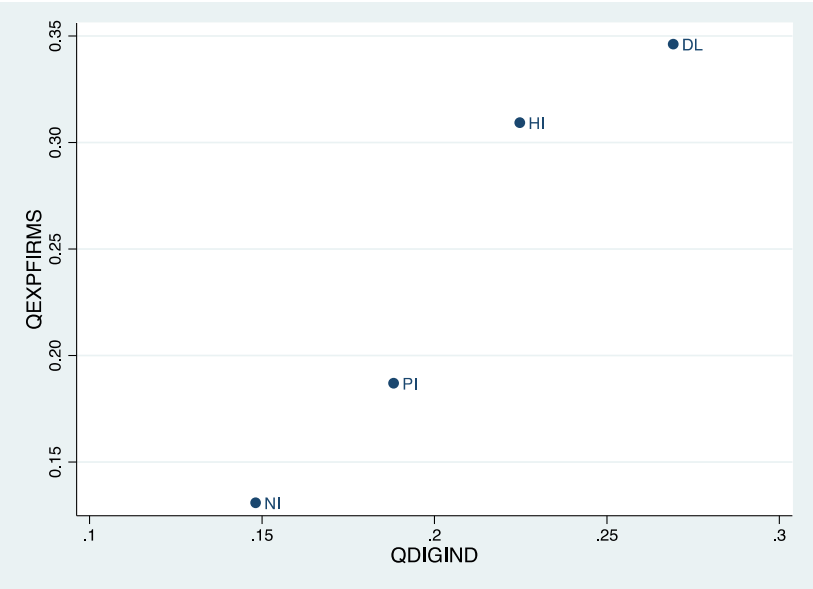
c) Export capabilities

Greater technological capabilities are expected to lead to better economic performance and, specifically, to greater export success in international markets. In the following figures, we explore the relevance of digital industries and the acquisition of foreign technologies for contributing to export dynamism. Figure 11 shows that for the four groups included in our analysis, the share of exporting firms is closely associated with the share of firms in digital industries. The greater technological and growth opportunities of digital industries open up greater possibilities for firm to enter export markets. The share of exporters among digital leaders is one-third, followed closely by highly innovative firms; values are about three times greater than for non-innovators. Product innovators tend to mainly operate in the domestic market.

Figure 12 illustrates that opening up to foreign activities works both ways, combining acquisition of foreign technology with greater presence in export markets. It appears that accessing foreign know-how is a contributing factor to the ability to develop production capabilities that are relevant in international markets, opening up export possibilities for firms.

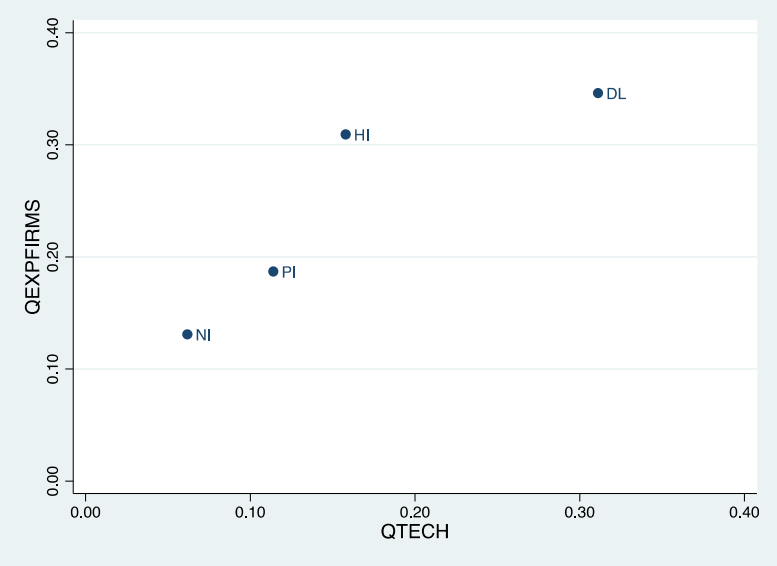
The groups we have identified can account for the development of firms' export capabilities. Export capabilities appear to be influenced by industry composition, by the acquisition of external technology and by the innovation and digital activities summarized in the grouping of firms we have identified.

Figure 11: Innovation groupings by share of firms in digital industries and share of exporting firms in India



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

Figure 12: Innovation groupings by share of firms with foreign technology licensing and share of exporting firms in India



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

d) Labour capabilities

The relationship between innovation, digitalization and employment is complex, with opportunities for expanding higher skill jobs and the risk of labour-replacing automation (Pianta, 2018). The available data allow us to assess the impact new products introduced by firms have had on the amount of high and low skill employees; non-innovators that did not introduce new products are excluded from this analysis. Figure 13 shows the relationship between firms with a presence in digital industries and employment growth of both high and low skill workers; first, for total firms, then, for manufacturing firms only. We find a positive general relationship between the presence in digital industries and positive employment effects. Among digital leaders, close to 60 per cent have expanded high skill jobs, and slightly less have increased low skilled jobs as well; the impact of demand expansion in fast growing industries is a clear driver of such employment growth. Highly innovative firms show greater differentiation, with over 50 per cent of firms expanding high skill and 40 per cent expanding low skill jobs. Product innovators have lower employment dynamism and there is a gap between high and low skill jobs. This gap is smaller in the case of manufacturing firms only.

Figure 14 shows that the acquisition of foreign technology is positively associated with greater increases of high skill employment, with the same result for product innovators and digital leaders.

This evidence is consistent with the results of the large body of literature on this issue. Fast growing industries witnessed extensive job creation associated with the role of demand; an orientation towards product innovation favours employment growth; in high-technology firms, there is a complementarity between high skills and advanced innovation that favours high skill jobs. Some of the employment gains documented here—especially for lower skill jobs—may not be *net* gains for the economy as a whole, but may result from 'job poaching' by innovative firms (illustrated in the figure) from non-innovative ones (not included in the figure), which may register large job losses.

The results show that the expansion of high skilled labour is clearly associated with higher innovative and digital activities in firms as summarized by the four groups we have identified, confirming the complementarities between human knowledge, technologies acquired from external sources and the relevance of digital activities.

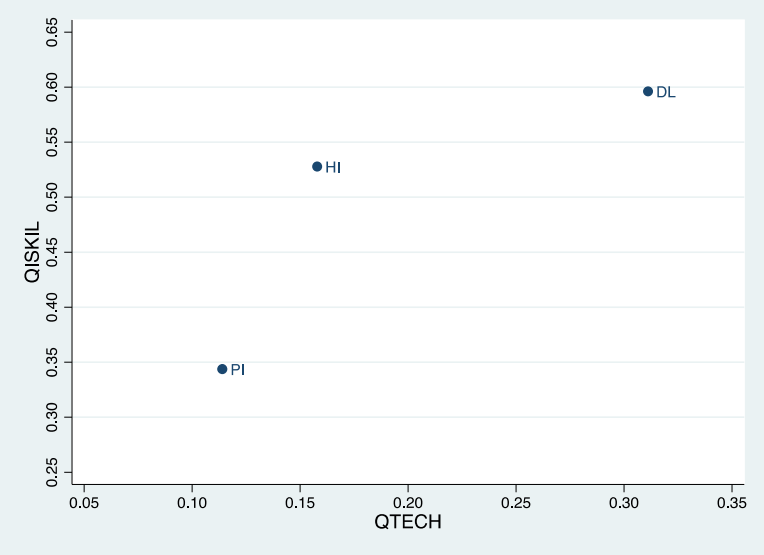
Figure 13: Innovation groupings by share of firms in digital industries and share of firms where product innovation has led to an increase in high and low skill employees in India

All firms

Manufacturing firms only

Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

Figure 14: Innovation groupings by share of firms with foreign technology licensing and share of firms in which product innovation has led to an increase in high skilled labour in India



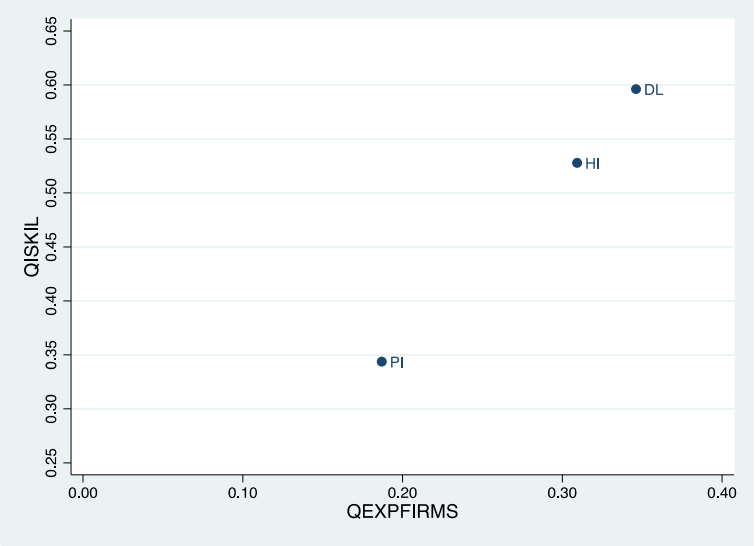
Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

Figure 15 illustrates the job performance of skilled workers and the share of exporting firms for digital leaders, highly innovative firms and product innovators, for all firms and for manufacturing firms only. We find a close relationship; greater export activity is closely linked to better employment performance, for both all firms and for manufacturing firms only.

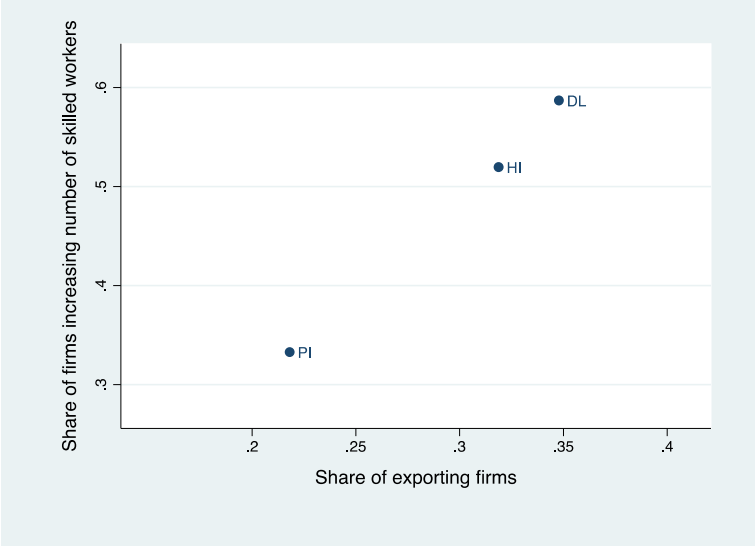
An additional performance variable is considered here, namely the level of exports per employee, which is an important indicator of productivity and success in international markets. The monetary value of this variable, however, included a number of outliers that could be the result of either a measurement error or extreme outcomes. Using the blocked adaptive computationally efficient outlier nominators (BACON) algorithm by Billor, Hadi and Velleman (2000), we find 21 outliers. These firms lie at a considerable distance from the population of firms in terms of exports and sales per employee, and we excluded them from the analysis. The electronics and machinery industries account for 30 per cent of these outliers; to ensure more robust findings, we merge the groups of digital leaders and highly innovative firms.

Figure 15: Innovation groupings by share of exporting firms and share of firms in which product innovation has led to an increase in skilled employees in India

All firms



Manufacturing firms only



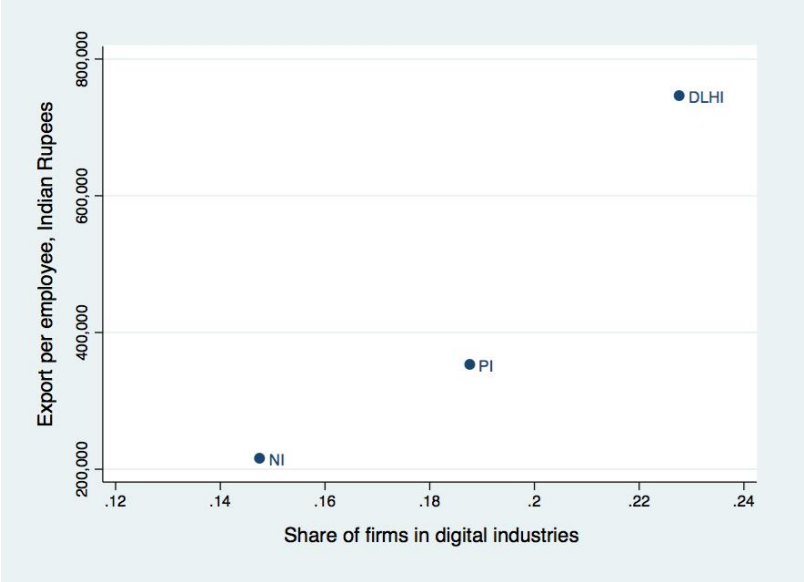
Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

Figure 16 shows that the share of firms in digital industries is positively associated with higher exports per employee. The exports per employee of digital leaders and highly innovative firms are almost four times higher than those of non-innovating firms, with product innovators that have an intermediate position. The previous analysis has relied on the share of exporting firms as the main variable to assess export capabilities, Figure 17 illustrates the close relationship between this indicator and the level of export per employee. Measures of performance are therefore

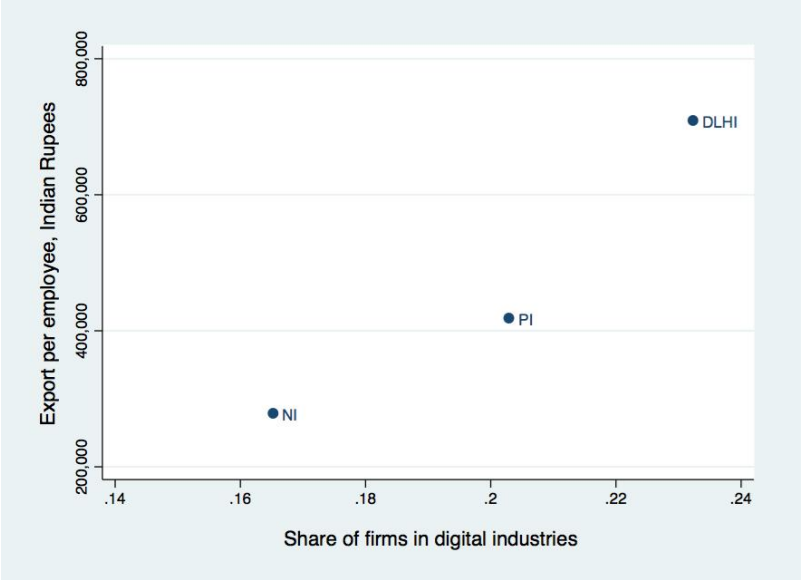
consistently associated with the innovative and digital activities of firms summarized in the four groups we identified and with the range of capabilities documented above.

Figure 16: Innovation groupings by share of firms in digital industries and level of exports per employee in India

All firms



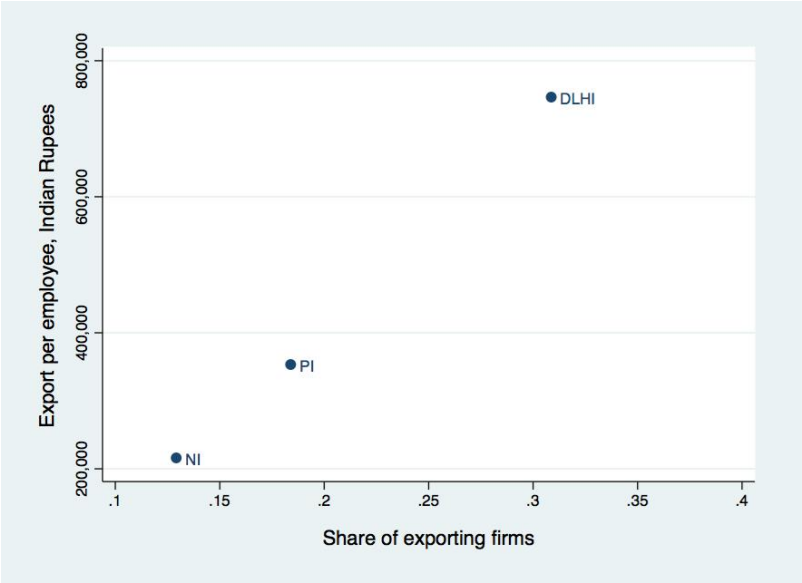
Manufacturing only



Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

Figure 17: Innovation groupings by share of exporting firms and level of exports per employee in India

All firms



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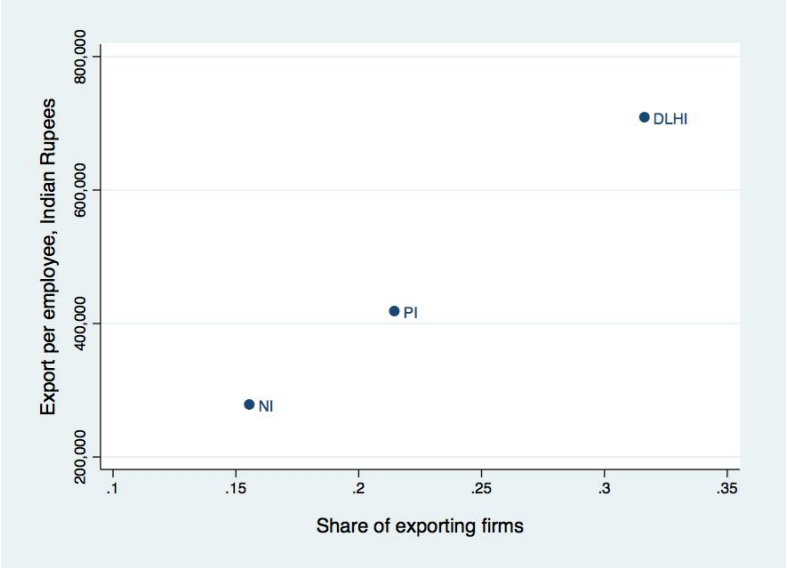


Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

4.6 Summing up the evidence

The range of analyses carried out in this section using the World Bank Innovation Surveys sheds new light on how firms in a large number of emerging countries are active in innovation and digitalization. Grouping firms as digital leaders, highly innovative firms, product innovators and non-innovators is an effective and robust way to summarize the diversity of technological capabilities and the ability to move towards digitalization.

More detailed investigations on four major emerging economies—India, Kenya, Nigeria and Pakistan—have been possible, confirming the stability of the findings on the grouping of firms and the differences associated with the structure of economies. Additional details have been provided in the case of India by matching innovation with enterprise surveys.

The grouping of firms we have identified is an important tool for understanding and linking four types of capabilities that are crucial for the development of firms in emerging countries: 1) capabilities in innovation and digitalization, 2) capabilities in external and internal technological development; 3) capabilities in export; and 4) capabilities in skilled labour. We have shown their relationship and complementarities, as well as the persisting relevance of firm size and industry characteristics in shaping the opportunities for growth. In the concluding section, we bring together these results with those of the other sections.

5 Conclusions

Building on the empirical evidence provided so far, we now integrate our findings on FDI flows and innovation surveys and link them to the typology of emerging country firms proposed in Section 2.

5.1 Insights from the analysis of FDI projects and innovation surveys

The evidence provided in Sections 3 and 4 describes the environment firms in emerging countries find themselves in in terms of FDI flows and innovation activities. In terms of FDI, there are significant flows towards industries and activities that are relevant for the development of advanced technological capabilities and for digitalization. At the same time, the prevalence of production-oriented FDI in both incoming and outgoing investments from emerging countries leaves modest room for FDI that focusses on high skill activities, namely R&D, design and ICT. In parallel, the evidence from innovation surveys documented in Section 4 demonstrates the relevance of the ‘hierarchy’ between digital leaders, highly innovative firms, product innovators and non-innovators.

In the case of India, for which we have detailed information on both dimensions, FDI and innovation surveys, we match the results to identify the relevance of digital industries and of high-technology/high innovation activities. Figure 4 combines two sets of the basic results we obtained from the empirical investigation:

the first result addresses the relevance of *digital industries*; in the analysis of the innovation surveys, we defined digital industries as the aggregate of machinery, electronics and IT services; in the FDI analysis, we identified the electronics, IT services and communications services (the latter was not available in the innovation survey industry breakdown) as digital industries. We documented how important digital industries are in shaping countries' technological capabilities and growth. We can now relate the share of firms participating in the innovation surveys that belong to the digital industries group and the share of FDI projects targeted at the country's digital industries. The importance of digital industries in the structure of the economy is the common driver of both the relevance of firms and of the attraction of FDI in these fields.

The second result focusses on high-technology/high innovation industries in the economy. The analysis of innovation surveys documents the relevance and dynamisms of digital leaders and highly innovative firms that can be combined. The FDI analysis documents the investment projects targeted at R&D, design and ICT. We can now relate the share of firms that belong to the groups of digital leaders and highly innovative firms to the share of FDI with the highest technological content to determine R&D activities, design efforts and ICT systems; we expect that the firms created by such FDI will be highly innovative.

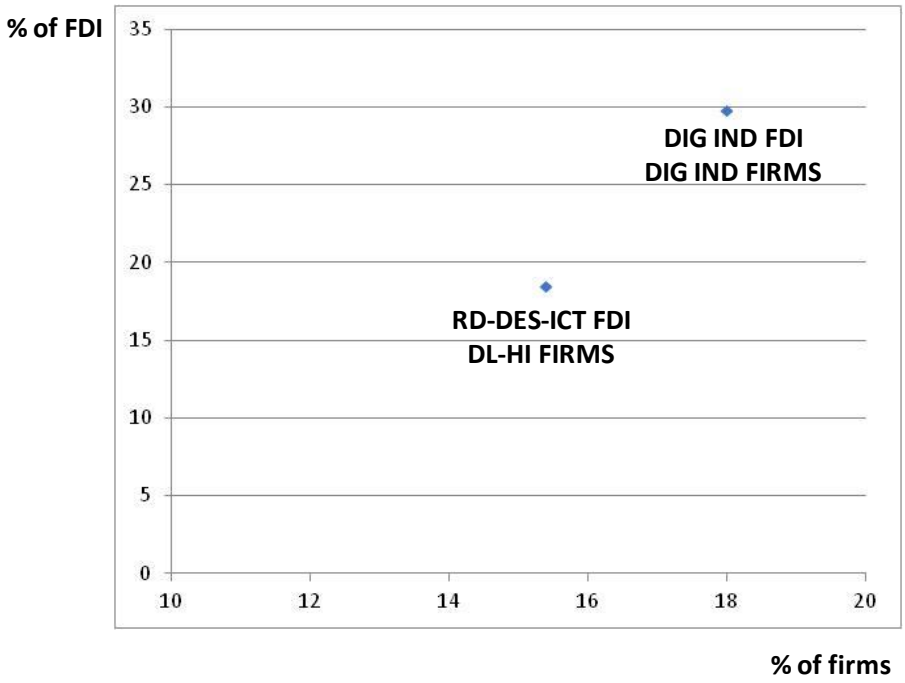
In Figure 18, we find that digital industries have a significant parallel relevance in FDI (about 30 per cent of all FDI projects) and in all firm types (close to 20 per cent). The share of high-technology/high innovation industries in the economy is lower, with 18 per cent of FDI targeting R&D, design and ICT, and 15 per cent of firms belonging to the group of digital leaders and highly innovative firms.

These simple associations could be further explored with more detailed analyses, but they already indicate a coherence between the developments in firm dynamics and FDI flows. First, the importance of digital industries in the structure of the economy affects the characteristics of firms and the flow of FDI towards the given country. Second, the relevance of the most innovative and digitally intensive firms is paralleled by the flow of FDI with a strong technological and research content. The structure of the economy and the technological capabilities are therefore two dimensions that must be investigated in parallel, combining information on firms and FDI flows. The two dimensions do not always go hand in hand, as some FDI in digital-related industries is

production or marketing oriented and may involve firms with lower technological capabilities. Conversely, FDI in high skill activities may be carried out in traditional manufacturing or services, as the expansion of production in such industries often requires an upgrading of R&D and design capabilities or of the ICT infrastructure and services.

While this exploration in the matching of FDI and innovation survey results focusses on the case of India, the consistency of the findings for other emerging countries may suggest that more general lessons can be drawn on how innovation and digital activities are developing in emerging economies. Some large countries, such as China and India, show positive performances in attracting technological FDI in the context of a diversified industrial system, with a strong presence of digital industries. The picture for other smaller emerging countries may be more fragmented; the combination of high innovative capabilities and participation in digital-related FDI flows may be more difficult to achieve, while some technological niches could be established within particular industries and activities. In general, the patterns of specialization—in FDI flows as well as in technological activities—are likely to be heavily shaped by current production activities, where non-digital industries maintain a larger presence in emerging countries compared to advanced ones.

Figure 18: Innovation and FDI performance in India



Note: Share of firms in digital industries and share of incoming FDI projects in digital industries. Share of digital leaders and highly innovative firms (DL-HI) and share of incoming FDI projects in the activities R&D, design and ICT.

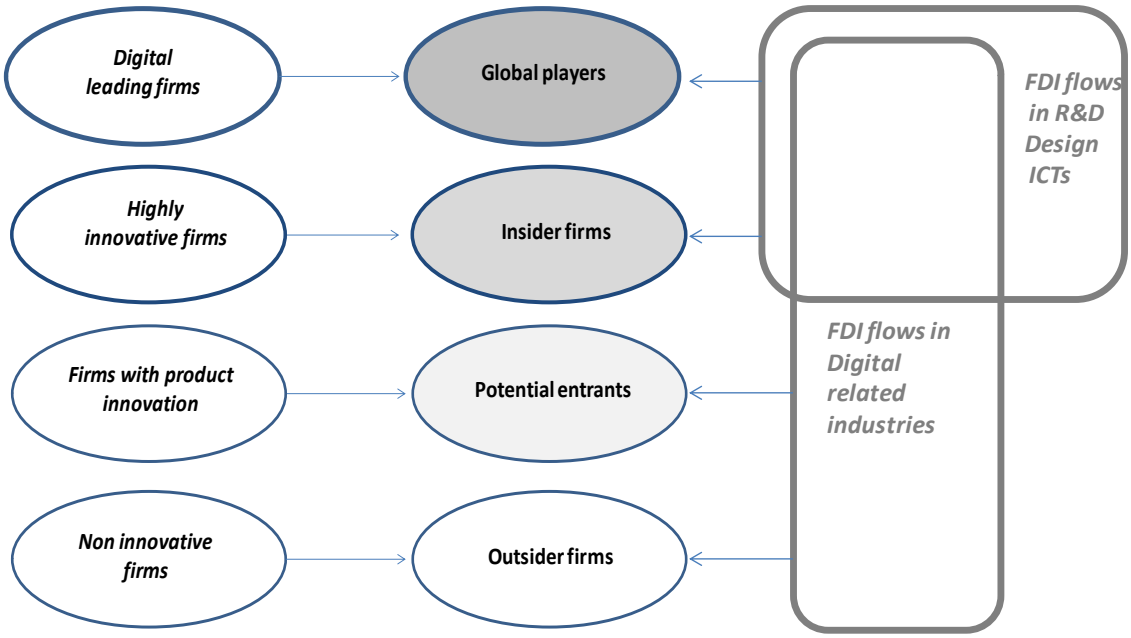
Source: Author's elaboration based on the World Bank Enterprise Survey Innovation Follow-up for India (2014).

5.2 The prospects for emerging country firms in the face of digitalization

Figure 19 summarizes the links between the typology of firms proposed in Section 2 and the results of the analysis of FDI and innovation surveys. Building on the discussion of the firm characteristics and on their position in the global economy, we can propose some stylized facts on the situation and trajectories of groups of emerging country firms.

Product innovators are firms that show significant innovation capabilities, based primarily on strategies of imitation and acquisition of foreign technologies; they are to some extent (20 per cent of Indian firms) in the position to patent their new products; they often report an increase in employment as a result of the innovation (on average, in close to 40 per cent of cases, there is a rise in high skill jobs; in 30 per cent of firms, low skill jobs increase as well). Product innovators can be associated with **potential entrants** discussed in Section 2. Their product innovation capability suggests that they may have intermediate productivity levels; their degree of integration in global markets and GVCs may vary, but this group of firms clearly has the potential for growth in production, employment, technological capabilities and international performance. From the evidence on FDI flows, the patterns of global investment in industries more closely related to digitalization, in which high skill activities are more important—R&D, design and ICT—appear to leave this type of firm at the margin of investment flows. The prospects for digitalization of such firms are difficult to evaluate; they will first need to expand their technological activities in a broader range of capabilities, including R&D efforts, new processes, automation and patenting. This expansion of capabilities appears to be a necessary precondition to fully enter the digitalization and global economy scene.

Figure 19: Relationship between typology of emerging country firms and the analysis of FDI and innovative activities



Source: Author's elaboration.

Highly innovative firms have a range of technological capabilities that suggest they tend to be competitive in international markets, with a relevance in exports and integration in GVCs. They may include foreign-owned firms and be affected by incoming FDI from advanced countries. Their high innovation capabilities include both internal strengths (R&D activities, some patenting activities) and access to foreign know-how; they are active in automation efforts using a range of new processes alongside their ability to introduce new products. They therefore have the characteristics of **insider firms,** operating in global markets and international technology networks. The technological and employment performance of this group of firms is dynamic and has the potential to move from automation of manual processes of production towards a more extensive and advanced level of digital activities. This group of firms is likely to be part of the environment of FDI flows, both incoming and outgoing, in industries that are related to digitalization and in the business activities of R&D, design and ICT. They may include foreign affiliates in high-technology industries where FDI—also in knowledge intensive activities—have been introduced. They may as well include dynamic firms from emerging countries that are now investing abroad, even though such FDI is largely outside the R&D, design and ICT activities.

These firms from emerging countries are well established at the first level of digitalization: industrial automation as well as R&D efforts and the ability to introduce new products and processes. All these activities are carried out by a substantial number of firms in emerging

countries. FDI—both incoming and outgoing—also appear to be relevant in digitally relevant industries and business activities. China and India have the strongest performance both in innovation and in FDI in high-tech industries, with a presence across a large number of manufacturing industries, and increasingly in IT-based services. For these insider firms, there is evidence that it is easier to enter digitally relevant industries with global markets—usually, with production activities or production-oriented FDI—than to 'move up' into FDI in knowledge-based activities—R&D, design and ICT—both when emerging countries are destinations or origins of FDI. The prospects for digitalization of this type of firms are likely to depend on the speed at which they are able to consolidate their capabilities across the wide range of technological activities they already carry out, to use them as the base for production growth and as a source of technological competitiveness in global markets and, at the same time, to move their efforts towards the creation of knowledge and capabilities for digitalization. The specific institutional conditions, the prospects of growth of domestic markets, the growth of capabilities in knowledge accumulation and technological development will be critical factors shaping their role in the rise of digitalization and Industry 4.0 in emerging countries.

Digital leaders belong to a group of global firms in emerging countries that appear to be strong ICT users as well as highly innovative and good performers. They are likely to be efficient producers, exporters and active players in GVCs. They are likely to be affected by both incoming and outgoing FDI. This 'elite' group of emerging country firms appears to be part of digitalization, building on its wide range of innovative activities, automation efforts, extensive involvement in ICT usage and development. These firms appear to be **global players** in both production and technology, with a potential for full involvement in the emergence of digital industries. This group of firms is fully part of the FDI dynamics, with a strong presence in digital related industries and in high skill activities (R&D, design and ICT). They may equally include foreign affiliates in higher-technology fields and domestic firms of emerging countries that have been engaged in foreign direct investment, and have therefore also become global players in FDI.

These firms in emerging countries are full players in the process of digitalization and Industry 4.0. They are not many, but they appear to be active in a whole range of advanced technological activities, including automation and widespread ICT usage, and they are likely to use FDI—both incoming and outgoing—as an additional tool for integration in global technology markets. China and India are the countries in which these developments have emerged with greater strength and with an important diversification across industries and business activities. In other emerging countries, this gap may be higher, and few firms may enter this 'elite' group of digitalization. An additional question is whether the patterns and direction of digitalization pursued by these

emerging country firms are the same as those found in the firms of advanced countries. The different institutional conditions, knowledge accumulation, degrees of market development and relative prices may lead to digitalization and Industry 4.0 possibly taking a different direction from that found in advanced countries. But the extent of this process, its content and impact in emerging countries remain to be seen.

In this paper, we provide a new conceptual framework on the typology of emerging country firms, identifying the technological and production characteristics that shape their 'hierarchy' and trajectory of development in the context of the global economy and digitalization of industry. Different sources of empirical evidence have been used to document the dynamics of technologies, the innovation in firms and their impact. We have combined these insights in a typology of firms, providing some preliminary answers to the question on the position of emerging country firms in the global economy, in current technological developments and in the rise of digitalization.

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Appendix

Table 22: Innovation and digital groupings, number and share of firms in each industry in India

ISIC Rev 3.1	INDUSTRY	Typology of firms DL	HI	PI	NI	Total
15	Food	3	19	96	93	211
		5.77	3.92	5.52	7.65	6.05
16	Tobacco	0	0	13	21	34
		0.00	0.00	0.75	1.73	0.97
17	Textiles	2	30	103	52	187
		3.85	6.19	5.93	4.28	5.36
18	Garments	3	18	54	24	99
		5.77	3.71	3.11	1.98	2.84
19	Leather	0	6	23	10	39
		0.00	1.24	1.32	0.82	1.12
20	Wood	0	8	26	19	53
		0.00	1.65	1.50	1.56	1.52
21	Paper	0	8	33	19	60
		0.00	1.65	1.90	1.56	1.72
22	Publishing	2	8	26	19	55
		3.85	1.65	1.50	1.56	1.58
23	Refined petroleum products	2	0	4	2	8
		3.85	0.00	0.23	0.16	0.23
24	Chemicals	4	52	101	88	245
		7.69	10.72	5.81	7.24	7.02
25	Plastics	2	66	139	72	279
		3.85	13.61	8.00	5.93	7.99
26	Non-metal mineral products	1	8	86	50	145
		1.92	1.65	4.95	4.12	4.15
27	Basic metals	1	43	104	79	227
		1.92	8.87	5.98	6.50	6.50
28	Fabricated metal products	7	41	130	70	248
		13.46	8.45	7.48	5.76	7.11
29-30	Machinery	7	54	162	78	301
		13.46	11.13	9.32	6.42	8.62

31 -32	Electronics	6	51	108	62	227
		11.54	10.52	6.21	5.10	6.50
33	Precision instruments	1	4	14	5	24
		1.92	0.82	0.81	0.41	0.69
34-35	Transport machines	5	39	102	65	211
		9.62	8.04	5.87	5.35	6.05
36	Furniture	0	3	18	7	28
		0.00	0.62	1.04	0.58	0.80
37	Recycling	0	0	3	7	10
		0.00	0.00	0.17	0.58	0.29
F	Construction	0	6	55	50	111
		0.00	1.24	3.16	4.12	3.18
50	Services of motor vehicles	1	1	33	68	103
		1.92	0.21	1.90	5.60	2.95
51	Wholesale	1	1	51	44	97
		1.92	0.21	2.93	3.62	2.78
52	Retail	0	9	91	42	142
		0.00	1.86	5.24	3.46	4.07
55	Hotel and restaurants	1	3	71	77	152
		1.92	0.62	4.09	6.34	4.36
60-64	Transport	5	39	102	65	211
		9.62	8.04	5.87	5.35	6.05
72	IT Services	1	4	57	40	102
		1.92	0.82	3.28	3.29	2.92
	Total	52	485	1,738	1,215	3,490
		100.00	100.00	100.00	100.00	100.00

Note: Industries were coded using the ISIC Rev 3.1 classification. The survey includes most manufacturing industries (15 to 37), and some services (45, 50, 51, 52, 55, 60-64, 72). The typology of firms corresponds to: DL – Digital leaders; HI – Highly innovative firms; PI – Product innovating; NI – Non-innovative.

Source: Author's elaboration.

Table 23: Industry classification ISIC Rev. 3.1

List of the 27 industries covered by the World Bank Enterprise Surveys

WB DATA (27 sectors)	ISIC Rev.3.1
Food	15 - Manufacture of food products and beverages
Tobacco	16 - Manufacture of tobacco products
Textiles	17 - Manufacture of textiles
Garments	18 - Manufacture of wearing apparel; dressing and dyeing of fur
Leather	19 - Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
Wood	20 - Manufacture of wood and of products of wood and cork, except furniture;
Paper	21 - Manufacture of paper and paper products
Publishing, printing, and recorded media	22 - Publishing, printing and reproduction of recorded media
Refined petroleum	23 - Manufacture of coke, refined petroleum products and nuclear fuel
Chemicals	24 - Manufacture of chemicals and chemical products
Plastics & rubber	25 - Manufacture of rubber and plastics products
Non-metallic mineral products	26 - Manufacture of other non-metallic mineral products
Basic metals	27 - Manufacture of basic metals
Fabricated metal products	28 - Manufacture of fabricated metal products, except machinery and equipment
Machinery (29-30)	29- Manufacture of machinery and equipment n.e.c.
	30 - Manufacture of office, accounting and computing machinery
Electronics (30-31)	31 - Manufacture of electrical machinery and apparatus n.e.c.
	32 - Manufacture of radio, television and communication equipment and apparatus
Precision instruments	33 - Manufacture of medical, precision and optical instruments, watches and clocks
Transport machines (34-35)	34 - Manufacture of motor vehicles, trailers and semi-trailers
	35 - Manufacture of other transport equipment
Furniture	36 - Manufacture of furniture; manufacturing n.e.c.
Recycling	37 - Recycling

Construction	F - Construction
Services of motor vehicles	50 - Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
Wholesale	51 - Wholesale trade and commission trade, except of motor vehicles and motorcycles
Retail	52 - Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
Hotel and restaurants	H - Hotels and restaurants
Transport (60-64)	I - Transport, storage and communications
	60 - Land transport; transport via pipelines
	61 - Water transport
	62 - Air transport
	63 - Supporting and auxiliary transport activities; activities of travel agencies
	64 - Post and telecommunications
IT Services	72 - Computer and related activities

Table 24: The NACE classification of economic activities, Rev.2, 2-digit level

C	**MANUFACTURING**
10	Manufacture of food products
11	Manufacture of beverages
12	Manufacture of tobacco products
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
16	Manufacture of wood and of products of wood and cork, except furniture
17	Manufacture of paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment

28 Manufacture of machinery and equipment n.e.c.

29 Manufacture of motor vehicles, trailers and semi-trailers

30 Manufacture of other transport equipment

31 Manufacture of furniture

32 Other manufacturing

33 Repair and installation of machinery and equipment

D ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY

35 Electricity, gas, steam and air conditioning supply

E WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION ACTIVITIES

36 Water collection, treatment and supply

37 Sewerage

38 Waste collection, treatment and disposal activities; materials recovery

39 Remediation activities and other waste management services

F CONSTRUCTION

41 Construction of buildings

42 Civil engineering

43 Specialised construction activities

G WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES

45 Wholesale and retail trade and repair of motor vehicles and motorcycles

46 Wholesale trade, except of motor vehicles and motorcycles

47 Retail trade, except of motor vehicles and motorcycles

H TRANSPORTATION AND STORAGE

49 Land transport and transport via pipelines

50 Water transport

51 Air transport

52 Warehousing and support activities for transportation

53 Postal and courier activities

I **ACCOMMODATION AND FOOD SERVICE ACTIVITIES**

55 Accommodation

56 Food and beverage service activities

J INFORMATION AND COMMUNICATION

58 Publishing activities

59 Motion picture, video and television programme production, recording and music publishing

60 Programming and broadcasting activities

61 Telecommunications

62 Computer programming, consultancy and related activities

63 Information service activities

K FINANCIAL AND INSURANCE ACTIVITIES

64 Financial service activities, except insurance and pension funding

65 Insurance, reinsurance and pension funding, except compulsory social security

66 Activities auxiliary to financial services and insurance activities

L REAL ESTATE ACTIVITIES

68 Real estate activities

M PROFESSIONAL, SCIENTIFIC AND TECHNICAL ACTIVITIES

69 Legal and accounting activities

70 Activities of head offices; management consultancy activities

71 Architectural and engineering activities; technical testing and analysis

72 Scientific research and development

73 Advertising and market research

74 Other professional, scientific and technical activities

75 Veterinary activities

N ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES

77 Rental and leasing activities

78 Employment activities

79 Travel agency, tour operator and other reservation service and related activities

80 Security and investigation activities

81 Services to buildings and landscape activities

82 Office administrative, office support and other business support activities

Source:
https://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2

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