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INDUSTRY 4.0 AS AN ANSWER TO THE PRODUCTIVITY GAP IN EUROPEAN CATCHING-UP ECONOMIES?

Industrija 4.0 kao odgovor na jaz u produktivnosti u evropskim zemljama u razvoju?

Abstract

The recent productivity growth slowdown, experienced both in developed as well as in emerging EU economies, has become a major worry for both companies and policy makers. The emerging technologies of Industry 4.0, spurring the fourth industrial revolution, are expected to slow down the decline and improve productivity trends. However, the implementation of new technologies in Europe is slower than desirable, with significant differences across countries, sectors, company sizes, and export orientation. This paper explores the effects of new technologies on productivity growth in emerging economies and proposes a comprehensive policy approach that would stimulate companies to adopt Industry 4.0 technologies. It must be built on the analytical-diagnostic approach, taking into account the already achieved levels of development and the specifics of a country. It should consider domestic and foreign experiences (i.e., have an eclectic view) as well as tit-for-tat (carrot and stick) strategies.

Keywords: *economic development, catching-up, strategy for Industry 4.0 development.*

Sažetak

Nedavno usporavanje rasta produktivnosti, kako u razvijenim, tako i u zemljama u razvoju u EU, postalo je glavna briga i za kompanije i za kreatore politike. Očekuje se da će nove tehnologije Industrije 4.0, koje označavaju četvrtu industrijsku revoluciju, usporiti pad i poboljšati trendove produktivnosti. Međutim, implementacija novih tehnologija u Evropi je sporija nego što je poželjno, sa značajnim razlikama između zemalja, sektora, veličine preduzeća i izvozne orijentacije. Ovaj rad istražuje ulogu novih tehnologija u rastu produktivnosti u ekonomijama u razvoju i predlaže sveobuhvatan pristup politika koji bi stimulisao kompanije da usvoje tehnologije Industrije 4.0. On mora da bude zasnovan na analitičko-dijagnostičkom pristupu (da uzme u obzir postignuti nivo razvoja i specifike pojedinih zemalja). Treba da uključuje iskustva svoje zemlje i iskustva drugih zemalja (tj. da bude eklektičan) i mora da se bazira na „tit-for-tat" strategijama (princip štapa i šargarepe).

Ključne reči: *ekonomski razvoj, države u razvoju, strategija razvoja Industrije 4.0.*

Introduction

European emerging economies have made a significant leap forward since 1990, especially those that were additionally hampered by the transitional decline. Despite the successful catch-up process, especially just before the crisis, when economic growth in these economies reached even beyond 10%, today, the countries in question are facing similar problems as the "old, developed" Europe, i.e., the EU15: a slowdown in productivity growth and a still wide productivity gap, not just relative to the developed EU member states but, similarly as the developed EU15, also relative to the US (Figure 1).

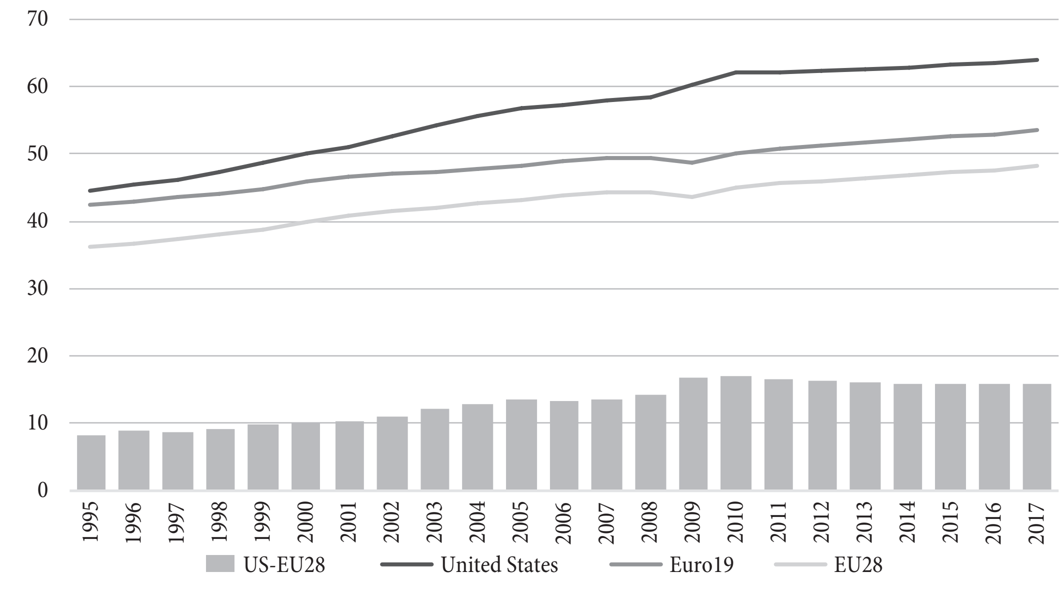
Besides the wide gap between European and the U.S. productivity, another threat to the living standards in the old continent in the long run is the continuously declining productivity growth in both the EU28 and the Euro 19 (Figure 2), which has been systematic since the mid-1990s. The post-crisis productivity growth was weak, although the recovery was job-rich according to McKinsey [52].

In general, economic growth in smaller, very open catching-up economies followed a similar pattern of export-led growth, which, besides facilitating demand and the subsequent manufacturing growth, also enabled technological transfer, knowledge spillover, and the inclusion of companies from emerging economies in strong global value chains, which supported their development and competitiveness [59], [62], [66].

Moreover, as Ribeiro et al. [62] claim, export is an important source of growth. On a sample of 26 EU economies, they show that high growth is in fact facilitated by export specialization, focusing on high value-added products, especially in manufacturing and advanced technologies, and also by export diversification across partners. It is important to concentrate on export, primarily to higher-growth countries.

Research also shows that economic growth becomes increasingly dependent on total factor productivity growth, which depends mostly on technology. For example, according to Chadha [16], about two thirds of all growth since the first industrial revolution (between 1760 and 2015) can be attributed to total factor productivity growth. According to his findings, the same is true also of the period from 1938 to 2018, with total factor productivity growth amounting to 1.48 percentage points of the 2.38 percent yearly total average growth, representing about two thirds of the total. Atkinson's [5] findings add to this discussion another important notion, namely that "The lion's share of productivity growth in most nations comes not from changing the sectoral mix to higher-productivity industries, but from all industries, even low-productivity ones, boosting their productivity". The developed economies

Figure 1: GDP per hours worked in US $ and the gap between the US and the EU28 GDP per hour in US $(grey columns) (constant 2010 prices)



Source: [56].

as well as the developing ones are currently putting a lot of hope in the impact of Industry 4.0 and digitalization on a productivity boost [60], which is expected to once again increase productivity growth and help offset the negative impacts of an ageing population and the lack of a labor force on future growth.

In this paper we discuss the potentials of Industry 4.0 in boosting productivity levels and competitive strengths in Europe in general, in some better developed European countries (which serve as a benchmark), and with particular emphasis on small European catching-up economies. A case study of Slovenia will be presented.

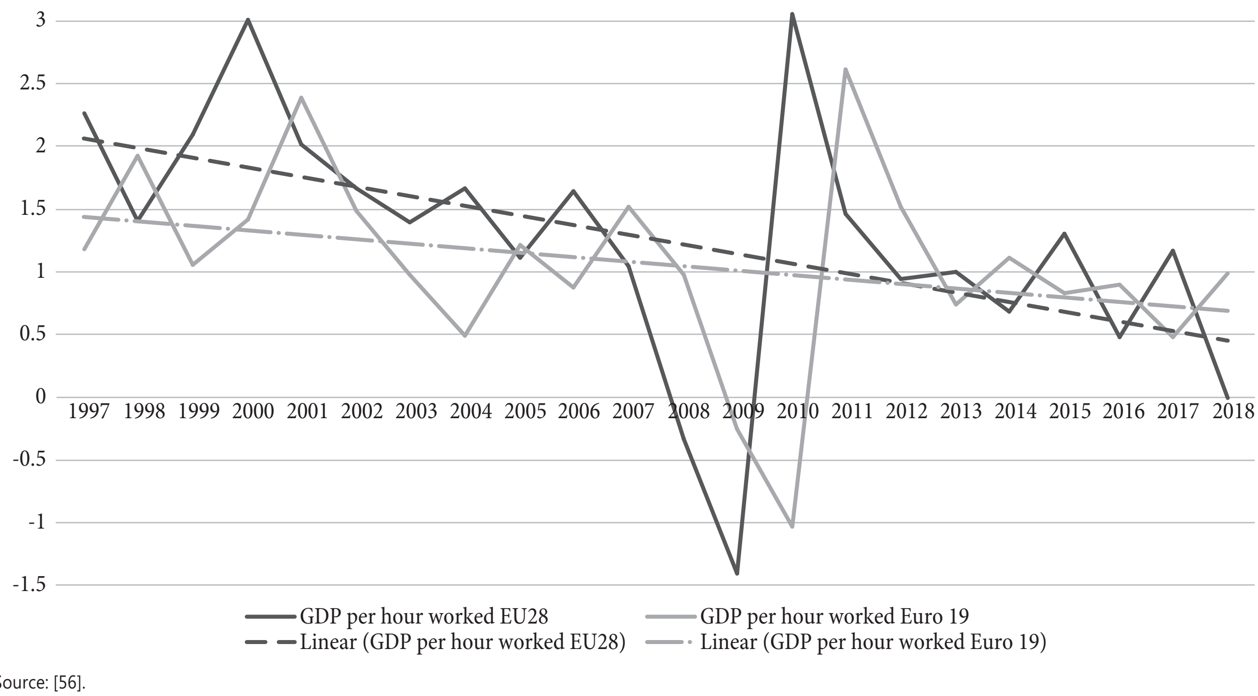
Industry 4.0: drivers and impacts

The fourth industrial revolution

Since the first industrial revolution, the nature of production has changed immensely. The first industrial revolution was marked by the invention of the first mechanical loom. Technological progress continued with the general introduction of steam power, which, among other things, transformed transportation. Industrialization led to mass urbanization and increased the need for rationalization and the division of labor due to large-scale production. In 1870, the first production line was introduced, marking the beginning of the second industrial revolution. Soon, electricity and internal combustion engines were in widespread use, and productivity continued to increase before and primarily after the Second World War, accompanied by the emergence of the consumer society. The third industrial revolution dates back to 1969, with the development of Modicon, the first programmable logistic controller [40], which further helped increase productivity in manufacturing and services, transportation, and other. In the 1990s, this third industrial revolution was accompanied by the rise of the knowledge economy [3], [4], [6], which boosted productivity growth in the US, as well as caused a more pronounced lag between the US and the EU. The knowledge-based economy also gave rise to the importance of intangible investment for growth, stressing innovation and economic competencies as well as computerized information, all closely linked to knowledge, technology, and digitalization. Again, the US and the UK were the most successful at intangible investment, which can contribute to productivity up to a third [17], [55].

The emergence of a more pronounced difference in productivity growth between the EU and the US, amplified further by the marked and prolonged impact of the crisis,

Figure 2: Productivity growth slowdown in the EU (percentage change in real GDP per hour)



Source: [56].

and a general global productivity slowdown coincided with the beginning of the most recent, the fourth industrial revolution. If the third industrial revolution was marked by computerization and automation, the fourth industrial revolution merges the technological, the physical, and the biological into cyber-physical systems. The term, coined by Klaus Schwab in 2011 [65], describes new technologies which are at the moment most evidently present in the manufacturing and service sector with robots, but include also technologies such as the Internet of Things, artificial intelligence, 3D printing, additive manufacturing, big data, customization, nanotechnology, autonomous machines, and many others [60], [65], [72].

According to Schwab [65], the drivers of the fourth industrial revolution can be classified into three large groups: physical, digital, and biological. The physical drivers comprise autonomous vehicles, 3D printing, advanced robotics, and new materials. Autonomous vehicles are most often considered to refer to cars, although they also include trucks, drones, aircraft, and boats. Accompanied by smart sensors and artificial intelligence, these technologies will markedly change production and our daily lives. 3D printing has numerous potentials for use in manufacturing and life-improvement (e.g., medical devices, implants), and is already being upgraded into 4D printing, expected to generate self-adaptable products, which will be able to adapt to changes in the environment. Robotics, one of the dominant features of Industry 4.0, is also becoming smarter, more adaptive, accompanied by artificial intelligence and being endowed with a more "biologically inspired" design. Humanoid robots or robots with smart sensors and artificial intelligence (AI) in general are expected to be able to adapt to their environment and carry out a number of tasks (instead of humans). These new technologies have been accompanied, but also largely stimulated, by the emergence of new materials. With broader use, these are becoming cheaper to produce, consequently speeding up the technological loop. There are numerous digital drivers according to Schwab [65], the most prominent among them being the Internet of Things, a bridge "between the physical and digital application." Sensors, remote monitoring, blockchain technologies, big data, and others are allowing rationalization, customization, and the emergence of the on-demand economy (e.g., the sharing economy, the Uber model, etc.). In terms of biological drivers, Schwab [65] stresses particularly the role of genetics in the recent past, while a lot is expected from synthetic biology, which should further improve healthcare. Combined with 3D manufacturing, it is expected to give rise to bioprinting to generate tissues and organs.

The expected impact of new technologies on business performance and productivity growth

Industry 4.0 is expected to both boost productivity and have wider positive impacts due to a number of reasons. Xu et al. [72] claim that these will result from: 1) lower barriers between inventors and markets, which implies a faster commercialization of innovations, 2) the stronger role of artificial intelligence, 3) the fusion of different technologies, 4) connected life through the Internet of Things (IoT), and 5) the wider use of robots, which will improve production and our lives. Schwab [65] maintains that the impact on the "economy, business, governments and countries, society and individuals" will be evident, and predicts that the extent of the "disruption that the fourth industrial revolution will have on existing political, economic and social models will therefore require (…) collaborative forms of interaction to succeed."

Generally, companies introduce new technologies for a number of reasons, classified into push and pull factors (Table 1). On the push side, companies desire to benefit from new technologies due to higher revenue and turnover growth, the increase in market shares, and the opening of new markets. Additionally, the introduction of new products and services, alongside organizational and process innovation as well as stronger integration along value chains, can reasonably be strong motivators for the implementation of a given technology due to competitiveness and productivity impacts. Something similar is true of pull factors, which encompass the productivity and efficiency increase resulting from process standardization, quality increase, better data use, etc. Rationalization and customization facilitated by new technologies are further expected to boost productivity.

In terms of economic impacts, the biggest positive impact is expected in the productivity boom of the fourth industrial revolution once technologies are used at a larger scale, offsetting the negative impacts of crisis stagnation and the waning impact of the third industrial revolution. Moreover, it is also expected to offset the problem of labor availability as the effect of an ageing population. For example, firms in Slovenia have been reporting labor shortage as one of the key reasons for the introduction of robots [60].

With regard to developed countries as well as catching-up economies, it is important to keep in mind the need to remain competitive, strive for the highest possible quality, and innovate products at a low cost also due to increasing global competition and entrants from emerging markets. For companies in emerging EU economies, the fourth industrial revolution is an opportunity to follow, learn, and increase their productivity.

Europe is lagging behind the most developed economies in the use of modern technologies

Despite the widespread discussions about the possibilities of Industry 4.0, at the moment, the data shows that its implementation is strongest in robotics, while other technologies have not been implemented fast enough and have not been used to their fullest potential. For example, the most recent data from the International Federation of Robotics for 2018 show that 2.4 million robots are in use, which is about 15% more than in 2017 and more than 20% than in 2016. By 2021, the number of robots in use is expected to reach 3.7 million [41].

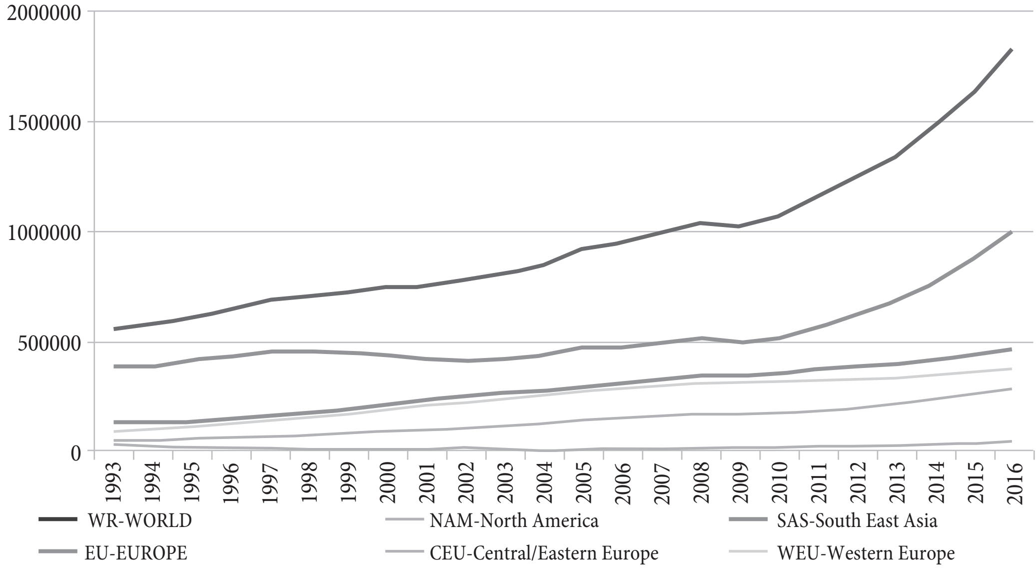
Figure 3 depicts the increase in the number of robots used. According to the data by IFR [41], the operational stock of robots has been increasing by an average of 10% per year. This growth was faster primarily in fast-growing regions with lagging robotization. Between 2011

Table 1: Push and pull factors in introducing new technologies

PUSH	OVERLAP	PULL
Revenue, turnover growth	Customer satisfaction	Productivity and efficiency increase
Market share increase	Understanding market requirements	Process standardization
New markets	Flexibility and customization	Quality increase
New products/services	Prioritization	Shorter delivery times
Compliance	Reduction of employment	Data analysis (and monitoring)
Horizontal and vertical integration		Better process insights
Improving management		Legislation adaptation
Complexity of processes and products		Consumer power
Government support		Employee satisfaction

Source: [14].

Figure 3: Operational stock of robots in manufacturing, measured in number of robots



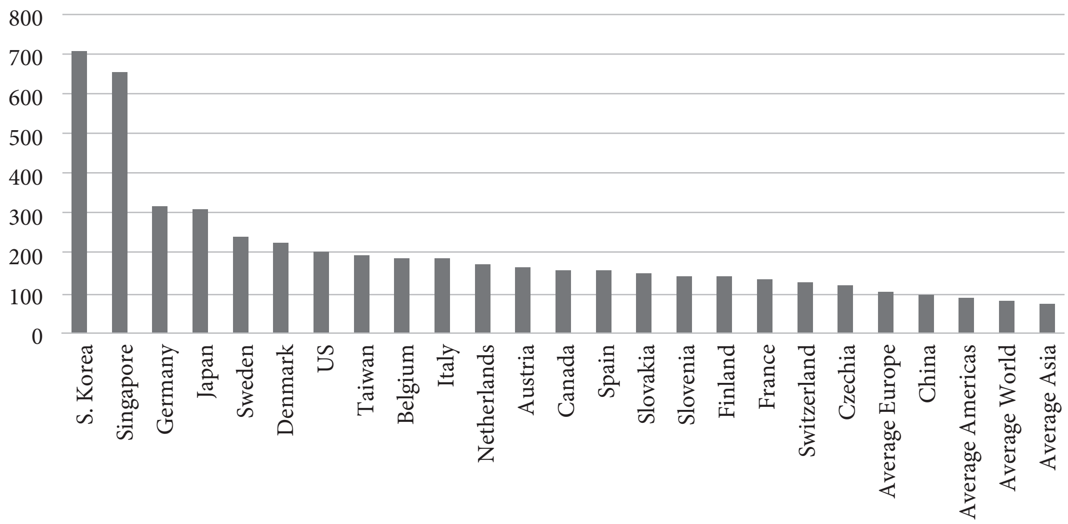
Source: [41].

and 2016, the volume of robots in China was increasing at an average rate of 36%, and in 2016 China became the country with the highest total number of robots (340 thousand). In the same period, the operational stock of robots was fast increasing also in Central and Eastern European countries, by about 19% per year. Europe in general exhibited a slower increase in the number of robots (see Figure 3 for how the gap between Europe as a whole and Western Europe has widened).

The country which has implemented robots into manufacturing most successfully is South Korea, with 710 robots per 10 thousand employees in manufacturing in 2017. It is closely followed by Singapore and less closely, behind by over 300 robots, by Germany and Japan. In general, European economies had 106 robots per 10 thousand employees in manufacturing (Figure 4).

The pace of the implementation of robots depends also on the industrial structure of an economy. Robots are predominantly used in manufacturing (Table 2) – in 2016, 86% of all robots were used there. The key driver of the increased use of robots was the automotive sector, followed by the suppliers to the automotive sector. The automotive sector itself uses around 50% of all robots, in some countries even more (e.g., the Czech Republic, 60% in 2016). However, other industries are following fast. In 2016, robot sales to the electrical/electronics industry increased by 41%, accounting for a third of the total supply in 2016. In the rubber and plastics industry, sales

Figure 4: Number of robots per 10 thousand employees in manufacturing in 2017



Source: [41].

Table 2: Structure of robot use in % in selected EU economies

	DE-Germany	CZ-Czech R.	SL-Slovenia
Total operational stock (number of robots)	**189270**	**13049**	**2452**
Structure by industry (% of total), selected industries			
D-Manufacturing	**85.2**	**91.5**	**88.9**
10-12-Food and beverages	3.6	1.3	3.8
19-22-Plastic and chemical products	10.7	14.8	14.1
22-Rubber and plastic products (nonautomotive)	9.5	14.6	13.4
24-28-Metal	13	12.2	14.2
25-Metal products (nonautomotive)	6.8	8.1	8.5
28-Industrial machinery	4.9	3.3	4.6
26-27-Electrical/Electronics	4.5	1.8	5.3
29-Automotive	**49.5**	**58.6**	**48.3**
291-Motor vehicles, engines and bodies	32.6	24.4	16.2
293-Automotive parts	16.6	34.1	31.5
2931-Metal (Auto parts)	6.4	14.3	13.1
2932-Rubber and plastic (Auto parts)	2.3	8.3	5.1

Source: [42].

increased by 9% on average per year between 2011 and 2016. Robot sales to the pharmaceutical and cosmetics industries substantially increased as well [42].

Industry 4.0 is, of course, marked by several other technologies, but their use in Europe is still weak. Table 3 presents data on the use of some of the recent technologies, which represent the process of digitalization and are further more necessary for stronger automation and rationalization. Even at the EU15 level, the use of CRM (customer relationship management) and ERP (enterprise resource planning) software, which are most widespread, is weak, with only around a third of companies using it in the EU15. The use of RFID (radio frequency identification) is even sparser, and the technology is primarily used in its simplest application, which is for identification, although it offers significantly more.

E-commerce, another feature of digitalization, is still developing, but is not yet widely used (Table 4). Although the vast majority of enterprises do have internet access (97%), only 77% have a website. The use of websites is often limited to providing product information (56% of companies), while only 42% use social networks or

Table 3: Software and technologies used in European companies, % of all companies in 2017

	Enterprises using RFID technologies (as of 2014)	Enterprises with ERP to share information between different functions	Enterprises using software solutions such as CRM	Enterprises using CRM to analyze information about clients for marketing purposes	Enterprises using CRM to capture, store, make available client information to other business functions
EU15	13	36	37	23	35
EU28	12	34	33	21	32
Euro area	14	39	37	23	36
Austria	19	40	43	27	43
Croatia	14	26	20	12	19
Czech R.	8	28	19	16	18
Denmark	9	40	36	23	36
Estonia	12	28	24	15	23
Finland	23	39	39	23	37
Germany	16	38	47	26	46
Lithuania	10	47	33	24	33
Luxembourg	18	41	39	23	39
Poland	9	26	23	16	23
Slovakia	18	31	24	17	22
Slovenia	15	30	25	13	25
Sweden	12	31	35	20	34
UK	8	19	32	21	31

Source: [38].

Table 4: Infrastructural characteristics in the EU in 2016 and 2017 (where stated)

	EU28
Enterprises with Internet access	97
Enterprises with a website	77
Enterprises with a website providing product catalogs or price lists	56
Enterprises with a website providing online ordering, reservation or booking, e.g., a shopping cart	18
Enterprises with a website providing online order tracking	8
Use of the enterprise's blog or microblogs (e.g. Twitter, Present.ly, etc.)	14
Use of multimedia content sharing websites (e.g., YouTube, Flickr, Picasa, SlideShare, etc.)	15
Enterprises using the Internet and web pages to:	
Develop the enterprise's image or market products (2017)	40
Obtain or respond to customer opinions, reviews, questions (2017)	27
Involve customers in the development or innovation of goods or services (2017)	12
Collaborate with business partners or others (2017)	12
Recruit employees (2017)	23
Exchange views, opinions, or knowledge within the enterprise online (2017)	13
Use social media for any purpose (2017)	45

Source: [38].

multimedia websites (YouTube) to promote their products. Online ordering is provided by 18% of companies.

The digital environment in many countries remains deficient and does not translate the benefits of new technologies into tangible and inclusive trade and growth opportunities. Moreover, poor infrastructure and a lack of economies of scale, due to fragmented cross-border markets, substantially affect the ability of micro, small and medium-sized enterprises to participate in digital marketplaces and global value chains. The European Union monitors the digital readiness and the state of development of its economies using the DESI indicator[1] [19]. DESI summarizes the countries' digital performance and monitors progress in digital competitiveness. The index studies the following aspects: connectivity development, human capital development, the use of Internet services, and digital public services. The data (Figure 5) show that digital readiness and the use of new technologies are most intense in Northern Europe, while the Mediterranean economies and the new EU members are mostly ranked below the EU average, with some exceptions, such as Estonia, Spain, Malta, and Lithuania.

1 The DESI indicator monitors the following: 1) connectivity development, i.e., fixed broadband, mobile broadband, broadband speed and prices; 2) human capital development and the presence of skills, i.e., Internet use, basic and advanced digital skills; 3) the use of Internet services in the country, i.e., the citizens' use of content, communication, and online transactions; 4) the integration of digital technology, i.e., business digitization and e-commerce; 5) digital public services, i.e., e-Government.

Based on the data, there are two trends that are currently observable regarding Industry 4.0 in Europe: 1) the overall decline in the growth of productivity is associated with weak adoption of new technologies; 2) the gap between core European countries and Europe's catching-up economies is large.

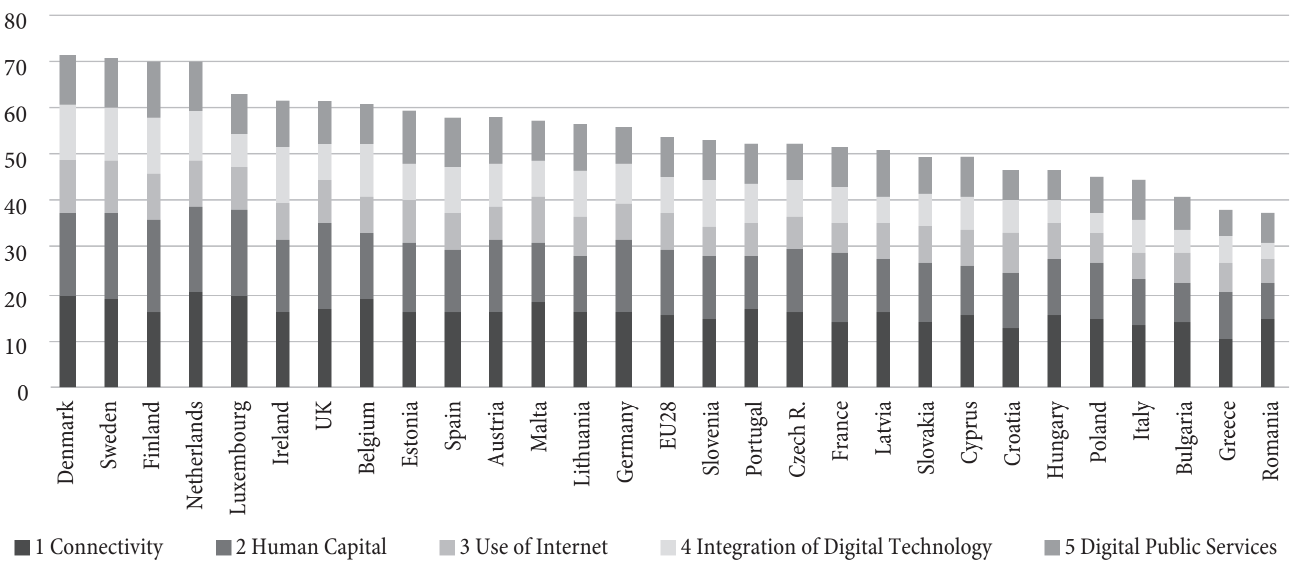
Policies to speed up the development of Industry 4.0 in Europe

A general perspective

To boost the productivity of the European economy, the European Commission (EC) initiated different policies in order to speed up the development of Industry 4.0 and digitalization. Table 5 summarizes the central policies related to digitalization and Industry 4.0 in the European Union.

The first major area is the area of "skills for industry" [35], where two major goals are set. The first is the goal of increasing the talent pool, and the second is to reskill and upskill individuals to fit the needs of the advancing industries. Within this context, several initiatives have been developed. Upskilling and reskilling are also important due to technology-induced unemployment and the consequent change of needs and skills [35]. In addition to upskilling and reskilling, it is very important that the EU promotes sectoral cooperation in the field of

Figure 5: DESI Index in European Union countries, 2017



Source: [19].

skills development [25]. Moreover, special attention is placed on the development of digital skills and e-skills, which are promoted via several mechanisms [20], [68]. Special attention is also given to IT professionals and KETS skills (key enabling technologies related skills[2]) as well as leadership skills, where both standardization and strategies on how to promote skill development, including new curricula, are being developed [35].

The second major policy area is digital transformation. Here, the European Commission stresses that European businesses are not yet taking full advantage of technologies, especially those that rely on the collaborative economy [33]. As previously mentioned, significant focus is placed on the development of digital skills, upskilling, and the development of smart cities, which will facilitate the achievement of sustainable development goals [33]. To promote digital development, several initiatives have been launched, and a number of projects are being financed promoting the development and adoption of new technologies. These are primarily H2020 projects, the COSME program, and programs such as the European Innovation Partnership on Smart Cities and Communities, fostering SMEs' growth through digital transformation.

ICT standardization across European economies is crucial for faster adoption, better cross-country collaboration, and internal market efficiency as it will lower transaction costs [31]. To promote standardization, the EU supports the work of three European standardization organizations, with a view to achieving standardization in five priority areas, essential for wider EU competitiveness: 5G, the Internet of Things, cloud computing, cyber security, and data technologies [31]. Several other initiatives have been launched, from the Digital Transformation Monitor to the Strategic Policy Forum on Digital Entrepreneurship [32].

Future development in the field of digitalization depends largely on how successful the EU will be at developing new technologies. The Commission identified six key enabling technologies or KETs: micro- and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies [34]. These technologies can be used in a number of industries, they can support solving major social challenges, and help create "advanced and sustainable economies". These technologies are also key to innovation, which is why the EU additionally promotes their development directly through smart specialization platforms and Horizon 2020 projects, which stimulate cross-cutting KETs in particular, and European structural and investment funds (EISF), allows state aid to be granted to important projects of common European interest (IPCEIs), and helps improve the accessibility of loans to KET projects in cooperation with the European Investment Bank [30].

2 These are considered to be "strong technical background, strong business sense and strategic vision" [35].

Table 5: Summary of the main policies related to digitalization and promoting Industry 4.0

Policy area	Purpose/goal	Measures and documents
Skills for industry	Ensure workforce is properly educated and skilled to meet the needs of technologically advanced industries	New Skills Agenda for Europe (2016, upskilling), Blueprint for Sectoral Cooperation on Skills (2018, high-tech sectors), Digital Skills and Jobs Coalition (2016), IT skills development and development of the e-competence framework, KETs and STEM competence development and leadership skills;
Digital transformation	Digital B2B platforms and data-driven business models	Digital Single Market Strategy, Big Data public-private partnership, H2020 projects, COSME, European Innovation Partnership on Smart Cities and Communities, fostering SMEs' growth through digital transformation;
	Digital cities and smart cities	
	Smart use of ICT for SMEs	
ICT standardization	Unified ICT standards for achieving the interoperability of new technologies	Communication on ICT Standardization Priorities, European Multi Stakeholder Platform on ICT Standardization, 2018 Rolling Plan for ICT Standardization;
Key enabling technologies*	Applications in multiple industries address economic and societal challenges, stimulate growth and competitiveness	2012 Communication on KETs, supporting investments in KETs, KETs Observatory, helping SMEs get KET technology platforms, activities on trade, skills, facilitation of large industrial projects.
Clusters	Promote cluster development as the core of industrial development	The European Cluster Observatory, Cluster Excellence; Cluster Internationalization, Clusters in Emerging Industries.

KETs: micro- and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies.
Source: adapted from text and [33], [34], [35], [36], [37]

The European Commission is also well aware of the importance of clusters. In the EU, there are about 2000 clusters, 150 of them world leaders stimulating development and job growth [29]. Clusters are being recognized as particularly important for promoting not only the growth of SMEs and innovation but also collaboration among sectors and across borders, which is crucial for small EU members, especially those with a granulated enterprise structure (e.g., Slovenian firms with less than 10 employees generate over 10% of export). The clusters are being directly supported through H2020 projects, small business acts, entrepreneurship action plans, promoting also cluster internationalization and focusing on clusters in emerging sectors.

To achieve the stated development goals, the European Commission has numerous policy instruments at its disposal, from financial instruments and direct funding to several major development funds. These are: the European Regional Development Fund, the European Social Fund, both available to all countries, the Cohesion Fund, which is available only to less developed countries, the European Agricultural Fund for Rural Development (EAFRD), and the European Maritime and Fisheries Fund (EMFF). Besides these major funds, the EU also has an EU Solidarity Fund, which offers support in major disasters, and the Instrument for Pre-Accession Assistance (IPA) [36]. It should be mentioned, however, that none of the funds currently focuses on the acceleration of first technological lines of enterprises, but rather on the catching-up of technologically least developed lines. In the future (2021–2027), the main goals will be developing (1) a smarter Europe, (2) a greener and carbon-free Europe, (3) a better connected Europe, and (4) a more social Europe, which will be (5) closer to its citizens by promoting locally-led development strategies [37].

An assessment of European policies

The ambitious European Union program of Industry 4.0 development does not yet deliver the expected results (as shown in the previous section). The fact is that the program is activist in nature, and is based on some of the EU's fundamental principles: 1) the EU functions mainly as a facilitator of the Industry 4.0 platform, where the main responsibility (including major investments) lies with the member states and companies (i.e., to become more productive and competitive); 2) the formation of a digital single market is an aspiration which goes hand in hand with the principles of the European single market, proclaimed as the main engine of the European economy. "Competition is not the curse but the cure to European falling competitiveness", maintained Gunea and Erixon [46] after a failing merger of Alstom and Siemens, advocated by French and German governments in order to defend incumbent firms against Chinese competition in Europe. The EU does not support the champions building industrial policy (picking the winner), and even in the case of sectoral industrial policies it prefers horizontal measures and not subsidies targeted to particular firms [22]; 3) concerning the divide between the core and the (super) periphery, Table 5 does not validate specific policies favoring catching-up economies. It confirms the dominant European doctrine of economic convergence, i.e., the strategy of reducing income disparities between the developed European countries and the catching-up countries, where the main role belongs to the free movement of capital from the more developed to the catching-up countries based on the claim of the higher marginal productivity of capital in catching-up countries. Accordingly, in the view of its advocates, knocking down regulatory barriers between EU countries represents the main challenge in achieving a digital single market in the EU [27].[3]

However, many factors that hold back Europe's digital transformation or Industry 4.0 are not solely specific to this industry. They are about the general conditions to do business across borders in Europe. Moreover, in small, open catching-up economies, they have an even more

3 The last two principles are questionable. This was shown before the recent financial crisis as the foreign capital in catching-up economies was not focused on activities with high marginal product of capital, but on activities with low marginal product of capital (banking, retail, real estate, [58]). The financial crisis was therefore transmitted from core to (super) periphery countries (external factor of amplification) which together with strong internal factors of amplification due to the less developed financial systems (which are typical bank-based) brought to enormous social costs of the crisis in "catching-up" economies [8], [9]. On the other hand, due to the EU strict policy on state aids (not allowing subsidies), EU state spending measures during the crisis were almost five times lower than in the US and more than six times lower than in Australia [7].

important role because of the development gap. Let us elaborate a few of them: 1) financing, 2) human capital development, and 3) government capacities.

First, the European model is focused on bank financing, although data show that the share of bank vs. non-bank financing has shifted to a smaller emphasis on bank financing – from 70% of financing from banks in 2008 to 55% now [23]. This is still high compared to the USA, where the share is unchanged at 1/3 of total financing. On the other hand, the role of market finance in the euro area is growing, particularly through the reduction of the share of the banking system and the increase of non-regulated finance (investment funds). Enhancing market-based finance, including financing SMEs and the delivery of the early-stage finance, is an open issue in the entirety of Europe, and in particular in catching-up economies. Meanwhile, capital inflows into catching-up economies have started to recover, and there is a question whether the next Minsky moment could happen if the bank financing of Industry 4.0 investments based on excessive external (wholesale) borrowing prevailed again [9].

Second, labor market restrictions represent another limitation factor which is not related solely to the development of Industry 4.0 and is of particularly high importance in catching-up economies. The key element of adopting advanced Industry 4.0 technologies is, namely, complementarity. Improving labor market functioning through mobility and recruitment practices to upgrade managerial and skill capabilities represents one part of the solution. While there is considerable uncertainty about what skills exactly will be needed in the future, an adaptable education system, on-the-job training, and flexible labor markets represent ways to facilitate adjustment. The critical role, here, belongs to the tertiary education system. To help those entering the market, higher cooperation between businesses and higher education institutions is required, adapting higher education programs to follow technological trends and their applications is a necessity, teaching life-long learning as a value and a skill is needed, and creating an education-to-employment system integrator to coordinate and integrate activities, as well as monitor outcomes, becomes a target. In addition, to help those already working, reskilling opportunities must be made available. The lack of adequate institutional and organizational settings in the labor market presents, therefore, a real challenge.

Third, the government has an important role in developing the Industry 4.0 society. As a response to the Great Recession, Australian total fiscal expenditures reached as high as 5.2% of GDP in the 2008–2010 period, cumulatively (in Europe, this share amounted to 3.0%). Out of this, around 60% (3% of GDP, cumulatively) was invested in Industry 4.0 infrastructure, whilst in Europe this was true of only 0.01% of GDP [7]. Catching-up economies are even more affected due to the severe financial crisis and the post-crisis amplification. Much more investment is currently needed in broadband coverage, which is still lacking in many areas. High-speed internet connections and educational training are lacking in many countries as well. Next, many governments in catching-up economies need to ensure an increase in the basic factors of productivity (facilitate trade, encourage FDI and the mobility of skilled labor, knowledge sharing, improved access to human and financial capital, etc.). Additionally, a transformation into Industry 4.0 requires investment in the education system, the health system, culture, etc. If learning spillovers are to occur, regional collaboration and lower income inequalities are important as well. Furthermore, Industry 4.0 can cause the obsolescence of certain industries and completely reshape others. However, the room for maneuver regarding fiscal expenditures in individual European catching-up economies differs significantly. Besides, what works in one country may not work in the other. For example, government subsidies to accelerate digital collaboration among firms in the automotive cluster in Slovenia may not lead to the expected results as there are missing firms on top of the value chain. The majority of existing firms are suppliers, positioned lower in the value chain, often competing with each other in the same market. Their willingness to collaborate is not very high [49]. In some economies, an additional problem lies in the shallow understanding of the meaning of state subsidies. The receivers of subsidies are often not interested in the effect of externalities. Also, the state is frequently incapable of monitoring its investments due to severe operational inefficiencies, and corruption could be a severe problem.

It is also true that European countries started their Industry 4.0 transformations at different stages of development. For example, robotization in Denmark has progressed in line with the bottom-up approach through organic development in the Odense cluster. The success of the Odense-based robotics cluster, which was a failing start-up in 2008, inspired the development of an entire robotics society consisting of several strong robotics clusters, robotics manufacturers, and innovation networks supported by educational programs [70]. Denmark is currently one of the most developed European countries in terms of digitalization (see Figure 5) and automation [49]. However, the development of the next generation of digital infrastructure in Denmark may require a more top-down approach in the future [51].

In Austria, the major incentives for automation and robotization used to come from the corporate sector, especially in the automotive industry [49]. In contrast to Denmark, they were more fragmented, and the government decided to run a big campaign for Industry 4.0. Austria is a front runner in the implementation of Industry 4.0 according to an assessment based on a report by Roland Berger [63]. Austria's approach can be characterized as much more top-down than Denmark's and is similar to Germany with the government assuming an active role in the promotion of Industry 4.0 [63].

The German federal government sees Industry 4.0 as a major opportunity for Germany to establish itself as an integrated industry lead market and provider. This strategy is based on two goals: (1) Germany to become one of the world's most competitive and innovative manufacturers, and (2) Germany as a technological leader in industrial production research and development [44]. However, despite investments made by Germany's largest companies, other businesses have not responded to the challenge, with SMEs (the so-called "Mittelstand") proving particularly problematic in terms of awareness and readiness [48].

Alternatively, the government of the Netherlands tried to define the country's key economy sectors and the specific needs to be addressed in the future.[4] The sector-driven approach is based on the identification of sectors in which the Netherlands has existing well-established competitive advantages, which can be developed further. The main emphasis fell on digitalization, entrepreneurship, and entrepreneurial initiatives. Dedicated funds are provided by the government to address specific problems in key sectors. The state is seen as a moderator between external knowledge carriers (education, training, and research) and internal knowledge carriers to address the key sectors' needs. The usage of state funds should create positive externalities for the society as whole.

A pragmatic Slovenian solution

Slovenia in the past experienced a few attempts to build an industrial policy as the core of its strategic development. In the first period after independence (1990–1999), industrial policy was mainly aimed at stabilizing the economy and bank rehabilitation in the new market environment. In 1999, the Ministry of the Economy formulated a new concept of industrial policy [12]. The goal was to encourage entrepreneurship and corporate growth in an improved business environment. Policies focused on developing social capital by promoting partnerships between companies, universities, and research institutions. Between 2004 and 2009, Slovenia supported the emergence of competency centers and centers of excellence. Regardless of the fact that Slovenia established strong "basic research" units, there was an obvious lack of transfer to practical use by applying their findings in practice [11], [47].

Next, Slovenia's industrial policy is shaped by the Smart Specialization Strategy (S4).[5] It is structured into two pillars: 1) the business and innovation ecosystem, 2) chain and value networks. The first relates to the promotion of entrepreneurship and innovation. It calls for a consistent (i.e., at all stages of company growth) and integrated support (i.e., including finance, content, promotion, and infrastructure) of the business and innovation ecosystem, which is based on a systematic collection of actions under the programs Dynamic Slovenia (with the subprograms (1) Start-up Slovenia and (2) Knowledge and technology transfer) and Creative Slovenia (with the subprograms

4 Ministry of Economic Affairs, Agriculture and Innovation, Government of the Netherlands [53].

5 It was initiated by the Slovenian government office for development and European cohesion policy in 2014.

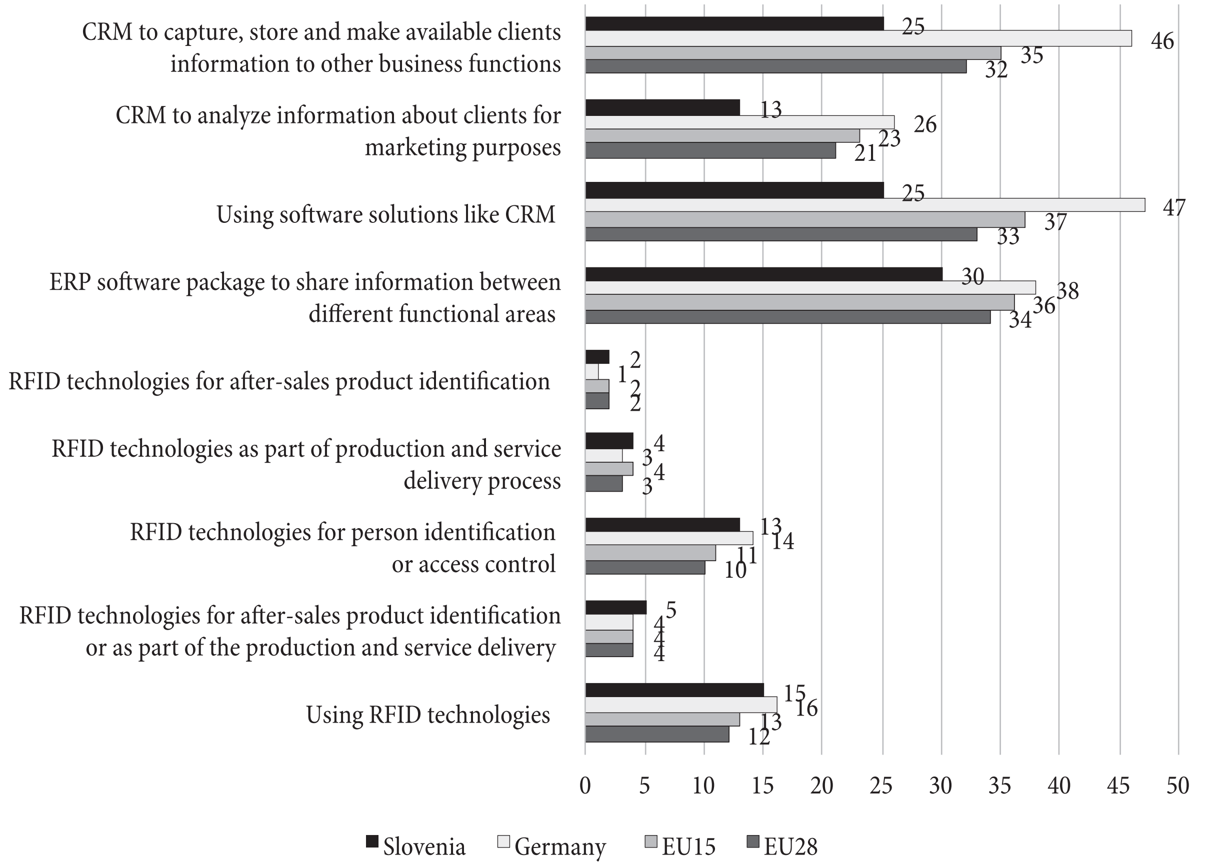
(1) Young Slovenia and (2) Design Slovenia). The second highlights the comparative advantages of Slovenia in some industries (the chemical industry, pharmaceuticals and medical devices, the manufacturing of metal and metal products, the electronics and electric power industries, ICT, engineering, and the automotive and marine industries),[6] and the need for the networking of companies to create five priority areas (smart specialization): 1) smart factories, 2) smart buildings and homes, 3) smart cities and communities, 4) the rational use of resources, 5) and health. For each area a package of measures is presented, which are to be implemented in particular through the system of development centers (the centers of excellence and competency centers), funded primarily through the European structural funds.

This structural approach now faces severe criticism. Some proponents claim that its practical validity is poor. Others are striving for a bigger role of the basic sciences. Building a new government strategy is therefore already on the horizon. However, what really matters in small, open catching-up economies is how productive the economy is, and whether the new productive Industry 4.0 methods are used to improve its position among the global competition. In addition, being at the top may not be the most important aspect – it may be surpassed by a focus on the distribution of firms and reasonable productivity increases (Figure 6).

Slovenia has made significant progress in the implementation of new technologies in the past two decades, especially in the past decade. In 2004, Slovenian companies employed a total of 391 robots, whereas in 2008

6 The idea of preferred sectors can be "vague", especially in small catching-up economies. Take, for example, the ICT industry in Slovenia. The contribution draft for the Smart Specialization Strategy by the Chamber of Commerce of Slovenia [45], which is the basis for the sectoral approach presented in the Smart Specialization Strategy, describes the ICT industry as promising, with a large number of innovative small businesses conquering the global niche markets and entering the international global chain. However, the analysis of value added reveals that the IT services sector accounts for only 56% of the average value added in the EU27 [50].

Figure 6: The share of enterprises using new technologies in Slovenia and the EU in 2017 (% of all companies that use a specific technology)*



*RFID: Radio Frequency identification, CRM: Customer Relationship Management, ERP: Electronic Resource Planning
Source: [38]

Table 6: The use of new technologies in Slovenia in 2017 (% of all companies that use a specific technology, financial sector excluded)

	All enterprises, (10 persons or more)	Small enterprises (10–49 persons)	Medium enterprises (50–249 persons)	Large enterprises (250 persons employed or more)
Enterprises using RFID technologies (as of 2014)	15	10	33	54
Enterprises using RFID technologies for after-sales product identification or as part of the production and service delivery	5	3	11	17
Enterprises using RFID technologies for person identification or access control (as of 2014)	13	8	30	50
Enterprises using RFID technologies as part of the production and service delivery process (as of 2014)	4	3	9	12
Enterprises using RFID technologies for after-sales product identification (as of 2014)	2	1	6	9
Enterprises which have an ERP software package to share information among different functional areas	30	22	58	93
Enterprises using software solutions such as CRM	25	21	39	68
Enterprises using CRM to analyze information about clients for marketing purposes	13	11	21	40
Enterprises using CRM to capture, store and make available client information to other business functions	25	21	39	68

Source: [38].

this number was already 852 robots, and in 2016 it reached 2500 robots. While in the past decade robotization and new technologies were implemented mainly in the automotive sector, today the electrical, chemical, and pharmaceutical industries are following suit very quickly [41].

Slovenia is also quickly implementing other new technologies. Recent data [61] show that around 40% of companies are using cloud computing and smart mobile devices, around 30% have systems such as CRM, ERP, and RFID, 20–30% also have linked processes and some automation in production, and around 20% of companies reported using the Internet of Things. In using some of the more complex technologies, especially considering technologies used in manufacturing in larger companies (RFID), Slovenia could be compared to European averages (Figure 6).

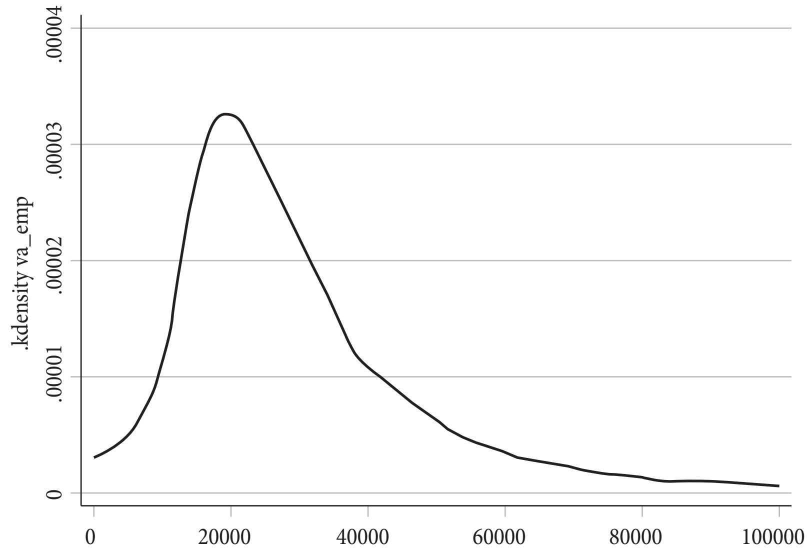
However, big disparities can be identified by company size. Large enterprises are much more advanced in the use of new technologies (Table 6). While, for example, radio frequency identification (RFID) is used by 15% of all companies on average, more than a half of the large companies use it. Over 90% of large companies use enterprise resource planning (ERP) software, but only a third of small ones. Similarly, big differences can be identified in the use of other technologies (Table 6).

A very strong influence on the implementation of new technologies comes from exporting markets, where primarily larger Slovenian companies represent important parts. An investigation into the behavior of large Slovenian companies [59] showed that Slovenian companies can be divided into four sub-groups by two dimensions: final market orientation (exports vs. domestic) and sector (manufacturing and services). The results showed that those companies that are strongly oriented towards the most demanding global markets and are primarily from higher value-added sectors (these are primarily B2B companies, many in the automotive, metal, electrical, and plastics industries) are strongly investing into the continuous development of their competencies (including technological); innovation and R&D are an important source of competitive advantage and are thus strategically important for these companies. As a consequence, the vast majority of them invest more than 3% into R&D and are very innovative – more than half of the companies introduced globally new products. They are also driven by the competition as well as their partners to remain competitive, and new technologies (as was shown in recent research) are very important in this context. For example, Slovenian partners in automotive chains, such as the companies TPV and Kolektor, are also some of the most robotized, to the point that they even built a smart factory [60]. The other three groups are less propulsive, but also operate in more traditional industries, or in industries producing for the final consumer (B2C). In these sectors, the focus on R&D and innovation is weaker, and the companies lag behind in the implementation of new technologies [41], [61]. As opposed to the first, most export-oriented group, they do not perceive innovation and R&D to be strategically as important, and they also invest less in human capital development (training). With companies that are oriented mostly towards the domestic market, again, the drive toward innovation is weaker, they invest less in R&D [59], and they have fewer new technologies in production if, for example, measured by the number of robots [41]. The literature also confirms the importance of presence in exports as one of the key determinants of corporate behavior, learning, innovation, technological change, R&D, and productivity growth [1], [54], [57].

From the perspective of economic development, technology, knowledge, innovation, and related concepts are important primarily because technologically more advanced products or production processes increase the value added, which is the primary goal of economic development as it allows for the improvement of the standard of living. The distribution of value added in Slovenia shows that the firms are asymmetrically distributed. To raise the standard of living, the distribution should shift right.

Two important conclusions should be made based on the above figures: 1) Industry 4.0 has already touched Slovenian firms to a certain degree; 2) the frontier/laggard divide in Slovenia is huge as most firms are concentrated around the lower values of value added (the median in 2016 was 23.3 thousand, while the mean was 34.1 thousand), and consequently the distribution is skewed to the right. This means that the majority of firms need to be reshaped towards the right by following the direction of the more advanced and productive firms. Praet [58], for example, claims that in such circumstances, it is possible to boost productivity by reallocating resources both across sectors and within sectors towards the most productive firms. However, Slovenia does not possess world class companies such as Amazon, Facebook, Google, and Alibaba. It does have, as mentioned, some large firms, in foreign and domestic ownership, in manufacturing and in services, which are internationally competitive and quite advanced in using new technologies. Robotics and automation, for example, have a long tradition in Slovenia. The Slovenian robotics industry is mainly developed from the bottom-up, especially through collaborations between educational institutions, the Jožef Stefan Institute, and companies. Similar to the Austrian experience, the automotive industry can be considered a key driver. Besides the firms in the automotive industry (e.g., Revoz Novo mesto, Kolektor Idrija, TPV Novo mesto, Hidria Idrija, Mahle Letrika

Figure 7: Distribution of firm-level value added per employee (va_emp) in euros (axis x) in Slovenia, 2016



Source: [2].

Šempeter pri Novi Gorici, KTL Ljubno, Magna-Steyr Maribor, etc.), other progressive companies in the field of robotics and automation, such as Knauf Insulation Škofja Loka, Danfoss Ljubljana, BSH Hausgeräte GmbH Nazarje, Eti Izlake, Instrumentation Technologies Solkan, Gorenje Velenje, Unior Zreče, Domel Železniki, Krka Novo mesto, Lek-Novartis Ljubljana, Lama automation Dekani, Akrapovič Ivančna Gorica, Pipistrel Ajdovščina, and others can be found in Slovenia. There are also a number of enterprises that specialize in the production of components used in robots, robot work-cells, as well as automated production lines for the domestic industry and exports (i.e., Zarja Elektronika) – some of them are global players. In addition, Yaskawa, a global robot producer is located in Slovenia. It built a new plant in Kočevje, and it also opened its own robotics R&D center in Slovenia. One of the main aims of Yaskawa is to help customers adopt new technologies. Whenever a customer comes to Yaskawa for help, the R&D department develops new or improves older products, which makes them more competitive. Such an investment represents the potential for further local development and new jobs. The Ministry of Education, Science and Sport has already confirmed that there will be an additional mechanical engineering program at the local education center in Kočevje to meet the demand for trained professionals in that area. Knowledge spillovers are therefore expected to appear in the region and beyond. Work on the railway line has begun, with trains set to run to Kočevje again after a gap of 46 years [13]. Next, the Jožef Stefan Institute (IJS) in Ljubljana, the leading Slovenian research organization, has also been intensively involved in promoting technological and economic development in Slovenia, both by educating personnel as well as supporting R&D activities. In order to foster knowledge transfer, which is necessary to reduce the technology gap, the IJS Technology Park has been established. By bringing together research-oriented companies, the Institute aims to create such conditions as to enable young research talent and innovators to contribute to the transfer of knowledge and modern technology into the economy [49].

The aforementioned companies, including some companies from the service sector (i.e., Petrol Ljubljana, BTC Ljubljana, etc.), are a good presentation of foreign and domestic-owned organizations with their own R&D departments, representing potential hubs for regional cluster developments involving small and medium-sized companies. However, three observations should be made regarding SME development in Slovenia: 1) Even in normal times, the banks' lending to SMEs is limited due to information asymmetry. Banks are limited in assessing new entrepreneurs, which is one of the reasons that governments in many countries (including the United States) have government-funded programs to encourage lending to small and medium-sized enterprises [67]. After the crisis, the Slovenian government reacted to this issue by activating the SID bank (SID – Slovenska izvozna in razvojna banka), which is 100% owned by the Republic of Slovenia, to provide loans to micro companies and SMEs. At the time, some complaints on the limited sizes of credits and operational (in)efficiency of the SID Bank appeared [71]. Now, there is a new policy oriented towards providing commercial banks (selected by tender) with a bigger role in providing credits for R&D activities to SMEs and other firms, by using European cohesion funds, whilst the SID bank is managing these processes; 2) As previously mentioned, a special problem in European countries is the delivery of early stage finance to technologically innovative firms. Many questions on how to achieve a Silicon Valley type of technological start-up development are currently debated in Slovenia (as in many other countries), and many different actions are being undertaken (including attempts at state (co) financing, venture capital financing by some domestic and a larger number of foreign capitalists, angel financing, Kickstarter, crowdsourcing and crowdfunding, etc.). However, investments in technological start-ups in Slovenia are low, and most of them are registered abroad, as is the ownership of innovations. It is therefore too early to evaluate the real potential of technological start-ups in Slovenia as their success depends on many factors, including the development of financial systems as discussed in the section on the assessment of European policies; 3) Since spontaneous SME development represents an important factor of the robust growth of the Slovenian economy in recent years [10], and since, as our data show, there is a huge gap between large, advanced companies and SMEs using advanced technology, one possible addition in stimulating the use of new Industry 4.0 technologies is to develop an advanced voucher system, with the aim to (co)finance the early development of the Industry 4.0 transformation of SMEs in connection with advanced, large companies at home and abroad. Many times, a possible Industry 4.0 transformation of an SME is stopped already at the initial stage, in the preparation of a feasibility study. By utilizing a voucher, an advanced and licensed large company could provide an SME with a plan of future development with calculations and influences on future cash flows, as well as the involved risks. It could also be involved in the SME's talks with possible external investors. Government officials should be present from the beginning by accurately evaluating both the receiver of the voucher (the SME) and the receiver of government money (the advanced organization). If they do not act according to the rules, the first loses the right to any further subsidy, and the second does not receive the payment or even loses its license ("the carrot and stick method").

All in all, there are many players of Industry 4.0 transformation in catching-up economies. For Slovenia, as shown in the paper, the most important ones are: 1) the government – we put the government first since its tasks are numerous, and because the government is probably faced with the most difficult task: how to shift from a proclaimed and ideological value system towards analytical-diagnostic value system; factors elaborated in the section discussing the assessment of European policies (i.e., financing, human capital development, and government capacities) are also of crucial importance for digital transformation in Slovenia; 2) advanced larger firms – an interesting occurrence in Slovenia is that they represent a good mix of foreign-owned and domestic-owned firms, and that they are regionally well distributed, which is why they can eventually be built as centers of Industry 4.0 regional cluster development with profound knowledge spillovers; 3) small and medium-sized companies –an advanced voucher system, developed on a tit-for-tat (carrot and stick) principle, between advanced large companies, SMEs, and the government can help to make steps forward.

Conclusion

Successful economic development, which results in increasing the standard of living, requires continuous productivity growth. This can be stimulated, taking into account that productivity is value added per employee, by increasing sales, lowering costs, or lowering employment. New technologies of Industry 4.0 can support the growth of sales (i.e., improved quality, innovation, increase prices…), lower costs (due to better efficiency, speed, accuracy, etc.), and boost productivity growth. Very importantly, implementing new technologies allows companies to maintain their competitive position in global value chains, which spurs learning, competence building, and technology transfer, building into a positive growth loop. However, boosting Industry 4.0 technologies is not an easy task that would tolerate copy-paste strategies. It must be built on the analytical-diagnostic approach (taking into account the already achieved levels of development and the specifics of a country). It should consider its own experiences and the experiences of others (i.e., have an eclectic view; see, for example, [39] and tit-for-tat (carrot and stick) strategies between the government and its main providers (firms).

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