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YOU SAY YOU WANT A REVOLUTION: STRATEGIC APPROACHES TO INDUSTRY 4.0 IN MIDDLE-INCOME COUNTRIES

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You say you want a revolution: strategic approaches to Industry 4.0 in middle-income countries

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Abbreviations

12-NESDP	12th National Economic and Social Development Plan (2017-2021), Thailand
20-YNS	20-Year National Strategy (2017-2036), Thailand
DST	Department of Science and Technology, South Africa
DTI	Department of Trade and Industry, South Africa
I4.0	Fourth Industrial Revolution (Industry 4.0)
INTI	National Institute of Industrial Technology
IPAP	Industrial Policy Action Plan, South Africa
MDIC	Ministry of Industry, International Trade and Services, Brazil
MSTPI	Ministry of Science, Technology and Productive Innovation
PEII	Programa Estratégico Industrias Inteligentes, Chile
MITI	Ministry of International Trade and Industry, Malaysia
MOST	Ministry of Science and Technology
RMK11	Eleventh Malaysia Plan
IMP3	Third Industrial Master Plan
STI	Science, Technology and Innovation

Abstract

The Fourth Industrial Revolution—or Industry 4.0—is expected to radically transform manufacturing as a driver of global development. Because industrialization remains a cornerstone of the long-term development aspirations of numerous developing countries, this paper addresses the following overarching questions: Are developing countries getting ready for Industry 4.0? How are they preparing? Can any lessons be gleaned from existing policy efforts around Industry 4.0? While acknowledging the buzz around Industry 4.0, the paper invites moderation in the analysis of the trends associated with it. Building on evidence from middle-income countries, this paper shows that policy responses have generally remained at the trial stage and are insufficiently articulated with long-term national development strategies. There is significant room for further research and policy experimentation, and role models have yet to emerge. The paper is intended as a reference for policymakers grappling with questions of which strategies to pursue on the path towards I4.0.

Keywords: Industry 4.0; middle-income countries; industrial policy; industrialization

JEL codes: L52, N60, O34, O38.

1. Introduction

Several technological trends are expected to transform the nature of manufacturing and, more generally, of industrialization. These trends, commonly referred to as the Fourth Industrial Revolution—or Industry 4.0 (I4.0)[1]—are characterized by disruptive processes of convergence and integration between the digital and the manufacturing realm and significant changes in the organization and operation of production and value chains (Deloitte, 2016; Manyika et al., 2012), with mass customization becoming a distinctive feature of the next stage of manufacturing development (Berger, 2016). The Fourth Industrial Revolution integrates advanced control systems with internet-based technologies to enable closer communication, interaction and collaboration between people, machines, logistics systems and products within intelligent factories. Nine technologies lie at the core of I4.0: robotics, big data, augmented (virtual) reality, additive manufacturing (3-D printing), cloud computing, cybersecurity, Internet of Things (IoT), systems integration and simulation.

López-Gómez et al. (2017) emphasize the heterogeneous priorities around advanced manufacturing (product innovation, process innovation, supply chain and customer demand) and the gamut of activities beyond R&D that shape I4.0. The extent of possible implications associated with I4.0 remains uncertain, but advocates tend to agree that inaction is the least desirable option. The Revolution is poised to modify the way firms, economic sectors and even countries integrate into global value chains, the nature of innovation and the conditions for participating in international trade and investment flows. It is expected that significant productivity gains will result from improved process flexibility, adaptability and efficiency. The increased ability to manage, process and analyse enormous amounts of data in real time will underpin customizable "intelligent" production systems. In addition to dramatic cost reductions and savings in resource utilization, machines will be able to control and adjust operations, literally in real time, in accordance with the needs of rapidly changing business environments. Novel value creation processes will accompany the adoption of new business models, novel sources of employment and so on.

Possible downsides include elimination of certain industries and jobs that have a high probability of being automatized, or a widening generation gap, with youth's extensive

[1] Terms such as "Fourth Industrial Revolution", "the next production revolution", "Industry 4.0", "industrial internet", "Internet of Things" (IoT), "internet of everything", "smart manufacturing", "digital manufacturing", "smart factories", "cloud manufacturing", "cyber-physical production systems" or "digital factory" are pervasive in the literature, in the media and among international consulting firms (PwC, 2016a; López-Gómez et al., 2017; Deloitte, 2016; OECD, 2017). The terms are frequently used interchangeably, although they have no one-to-one correlation, or are not always defined or used consistently (López-Gómez et al., 2017). Because 'Fourth Industrial Revolution' and 'I4.0' tend to be more commonly used in policy circles, we use these terms interchangeably in this paper.

exposure and openness to new technologies giving them an edge in the labour market (Indonesia Economic Forum, 2016). Hallward-Driemeier and Nayyar (2017, p. 77) question "whether new trends in technology and globalization—Industry 4.0 and the continued rollout of Industry 3.0—will weaken the industrialization prospects across a broad range of [low and middle-income countries] LMICs or whether they will create new potential to boost manufacturing output and exports and leverage them for growth." They assert that emerging technologies are changing the prospects of manufacturing export-led development in many different ways that are difficult to determine; these changes vary substantially by type of technology, type of firm and degrees of manufacturing sector development across countries. Others, on the other hand, caution that the real dangers of I4.0 do not derive from its associated technologies, but from its potential to revive protectionism across the world (The Economist, 2017a).

From a policy perspective, the notion of I4.0 already has an impact on the industrialization strategies of highly industrialized economies. The Digital Transformation Monitor (2017) documents the different approaches various European countries have adopted to develop I4.0, and the close link between individual I4.0 strategies and broader national development strategies. I4.0 as a guiding concept has also permeated strategic thinking of international organizations with a stake in manufacturing (UNIDO, 2017). By contrast, with the notable exception of China, lesser attention has been paid to documenting the efforts of middle-income countries in relation to I4.0. Are they getting ready for the Fourth Industrial Revolution? How are they preparing themselves? What are the basic tenets of strategic policy responses to I4.0? Which sectors are government strategies predominantly targeting? What concrete measures or tools are being deployed to facilitate readiness for I4.0? Is progress being measured? If so, how is it measured? Do strategic responses open opportunities for international policy coordination and collaboration? These are the questions this paper seeks to address.

This paper acknowledges the considerable buzz surrounding the technological trends that shape I4.0. It also gives a voice to moderation in reading a process that remains fluid and that we are still trying to figure out. We intend to provide some food for thought for policymakers in emerging economies, who have been tasked to design and implement roadmaps or develop full-fledged strategies to prepare their economies for I4.0. Learning from experience and identifying role models remains problematic as the Revolution unfolds in uncertain directions. Numerous questions emerge on which route to follow, what works and what does not. This paper takes stock of some of the elements underpinning the efforts to prepare for I4.0. We focus on processes rather than on actual results.

The paper proceeds as follows. Section 2 describes the research methodology used for data collection and analysis. Section 3 builds mostly on the experiences of developed countries to illustrate how I4.0 is guiding policy interventions in manufacturing and other sectors. We find that concrete policy initiatives remain at initial stages of implementation, even in advanced countries. Section 4 analyses I4.0-inspired industrial policy approaches in middle-income countries. The results of the analysis show that I4.0 policies are at very early stages of development, with various degrees of absorption into national or sectoral development strategies. Despite this novelty, it is possible to draw preliminary conclusions from the policy planning processes already in place. Section 5 concludes.

2. Methodology

2.1 Defining a sample of countries for the study

The evidence in this paper builds mostly on secondary data sources. Data collection proceeded as follows: first, we applied different criteria to select countries for our study. We sought to balance coverage across developing country regions. Evident candidates were Brazil, India and South Africa because they belong to BRICS. We excluded China because it has been covered in previous studies as an early adopter of I4.0 (Tourk and Marsh, 2016). We gave preference to less documented cases. Regional importance in terms of size, i.e. population or economy was considered as well (Table 1). Countries that contribute high-level international I4.0 initiatives were also included in our study, for example, the Global Manufacturing and Industrialization Summit (GMIS, 2017) or activities under the aegis of the World Economic Forum (World Economic Forum 2017). Few countries consistently participate in such initiatives; we explore to what extent this is translated into or reflected in corresponding I4.0-inspired policies. The literature review provided additional insights into countries worth considering.

In total, 15 developing countries or former transition economies were included in our study, distributed across different regions. Together they represent around 31.6 per cent of the world's population and approximately 12.7 per cent of global GDP (Table 1). The unweighted average income per capita in 2016 amounted to USD 7,065, somewhat below the world's average of USD 10,390.5. From a regional perspective, the relative weight of each country is likewise significant.

Table 1 Population and GDP for the countries included in this study, 2016*

	Population million	% World Population	GDP Growth Annual %	GDP per capita	% World GDP	% in Regional GPD (2016)	
Argentina	43.8	0.59	-2.3	10,148.5	0.58	7.52	**Latin America & Caribbean**
Brazil	209.6	2.82	-3.6	10,826.3	2.91	38.01	
Chile	18.1	0.24	1.6	15,019.6	0.35	4.55	
Mexico	128.6	1.73	2.3	9,707.1	1.60	20.93	
India	1326.8	17.83	7.1	1,861.5	3.19	82.54	**South Asia**
Malaysia	30.8	0.41	4.2	11,028.2	0.44	1.57	**East Asia & Pacific**
Thailand	68.1	0.92	3.2	5,901.4	0.53	1.85	
Viet Nam	94.4	1.27	6.2	1,770.3	0.21	0.75	
Ethiopia	101.9	1.37	7.6	511.2	0.07	3.0	**Sub-Saharan Africa**
Kenya	47.3	0.64	5.8	1,143.1	0.07	3.0	
South Africa	55.0	0.74	0.3	7,504.3	0.54	25.0	
Egypt	93.4	1.26	4.3	2,724.4	0.34	7.89	**Middle East & North Africa**
Morocco	34.8	0.47	1.1	3,196.0	0.15	3.47	
Kazakhstan	17.9	0.24	1	10,570.5	0.24	0.8	**Europe & Central Asia**
Turkey	79.6	1.07	2.9	14,071.2	1.45	4.9	
Total	2350	31.6			12.7		

Notes: *GDP values at constant 2010 prices in USD

Source: UNIDO Statistics Unit and World Bank Databank

As regards industrial and specifically manufacturing activities, the countries in our sample represented about 29.7 per cent of global industrial value added in 2016, and their overall share of manufacturing value added relative to individual country's GDP amounted 15.4 per cent (Table 2). While the manufacturing value added of most Latin American countries was negative in 2015/2016, the other countries in the sample reported positive rates; Ethiopia's performance, in particular, stands out, albeit starting from a very low share of manufacturing value added in total GDP.

Table 2 Industrial and manufacturing, value added (VA), 2016*

	Industrial VA, (% of GDP)	% in World Industrial VA	Manufacturing, VA (% of GDP)	Manufacturing, VA (annual % growth)
Argentina	26.7	0.47	16	-5.7
Brazil	21.2	2.20	12	-5.2
Chile	31.3	0.41	12	-0.9
Mexico	32.7	1.77	19	1.3
India	28.8	3.25	17	7.9
Malaysia	35.7	0.57	20	4.4
Thailand	35.8	0.68	27	1.4
Viet Nam	36.4	0.26	16	11.9
Ethiopia	21.3	0.04	4	18.4
Kenya	19	0.05	10	3.5
South Africa	28.9	0.49	13	0.7
Egypt	32.9	0.38	17	0.8
Morocco	29.7	0.13	18	2.1
Kazakhstan	33.5	0.30	11	0.7
Turkey	32.4	1.39	19	3.9

Notes: *At constant 2010 USD
Source: The World Bank Databank

Our introductory section highlights the internet as a key platform enabling the emergence of I4.0. Sub-Saharan African countries are still lagging behind in establishing the minimum framework conditions to facilitate the adoption of internet-based services and novel technologies associated with I4.0; electrification levels remain suboptimal and despite some recent improvements, internet penetration is low relative to most of the other countries in our sample (Table 3). By contrast, several countries included in our study report a significant internet penetration rate through mobile technologies (two or more subscriptions per person).

Concerns about cyber-security in low and middle-income countries are justified on grounds of limited availability of secured internet servers.

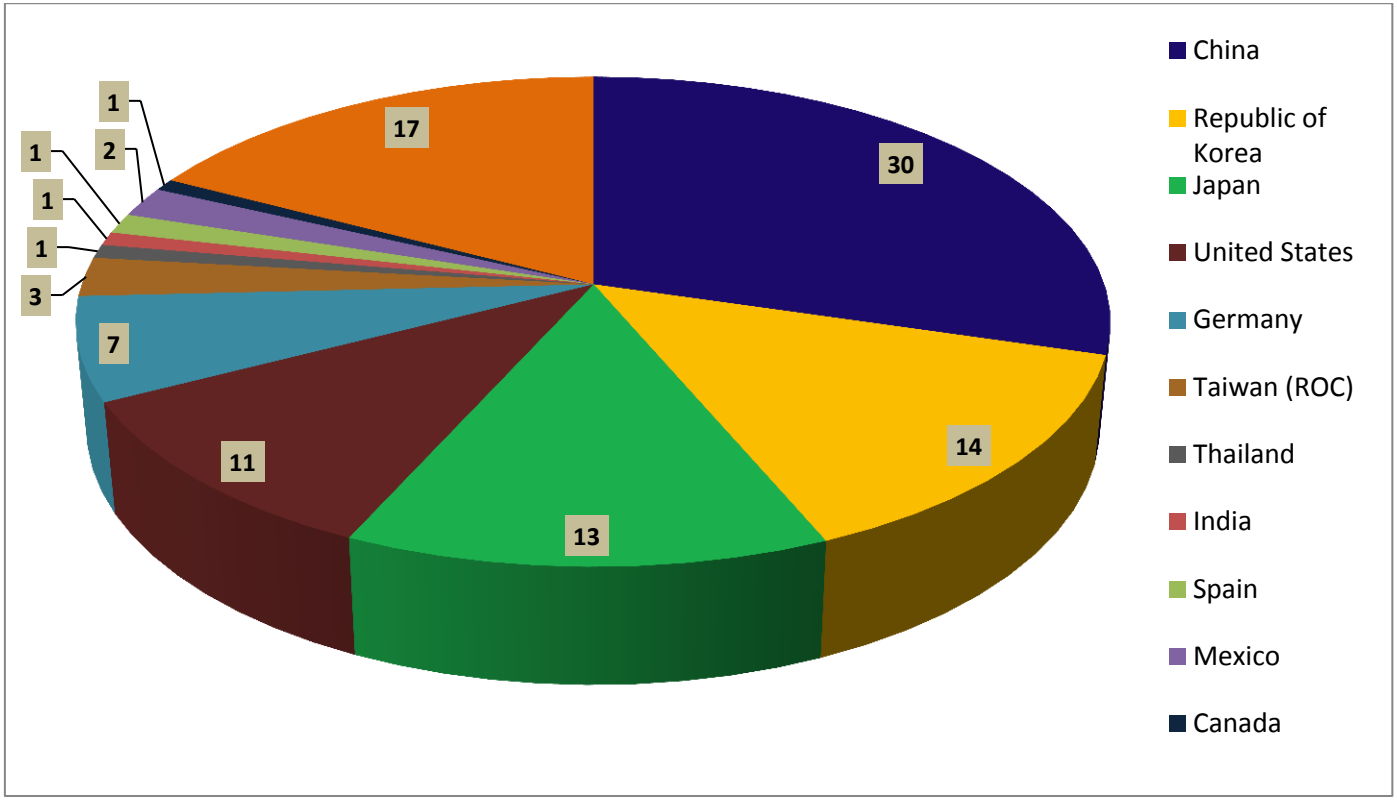
Table 3 Internet access in countries included in this study, 2016

	Population access to electricity (%)*	Fixed broadband subscriptions[1]	Individuals using Internet[2]	Secure Internet servers[3]	Mobile cellular subscriptions[1]
Argentina	100	16.94	70	62	151
Brazil	99.7	12.97	60	79	119
Chile	100	15.97	66	152	127
Mexico	99.2	12.67	60	41	88
India	79.2	1.44	30	8	87
Malaysia	100	8.74	79	106	141
Thailand	100	10.69	48	33	173
Viet Nam	99.2	9.91	47	19	128
Ethiopia	27.2	0.55	15	0	51
Kenya	36	0.33	26	11	81
South Africa	86	2.84	54	125	142
Egypt	99.8	5.2	39	5	114
Morocco	91.6	3.65	58	7	121
Kazakhstan	100	1.68	77	31	150
Turkey	100	13.55	58	80	97

Notes: *2014,[1] per 100 people,[2]. % of population,[3] per million people.
Source: The World Bank Databank

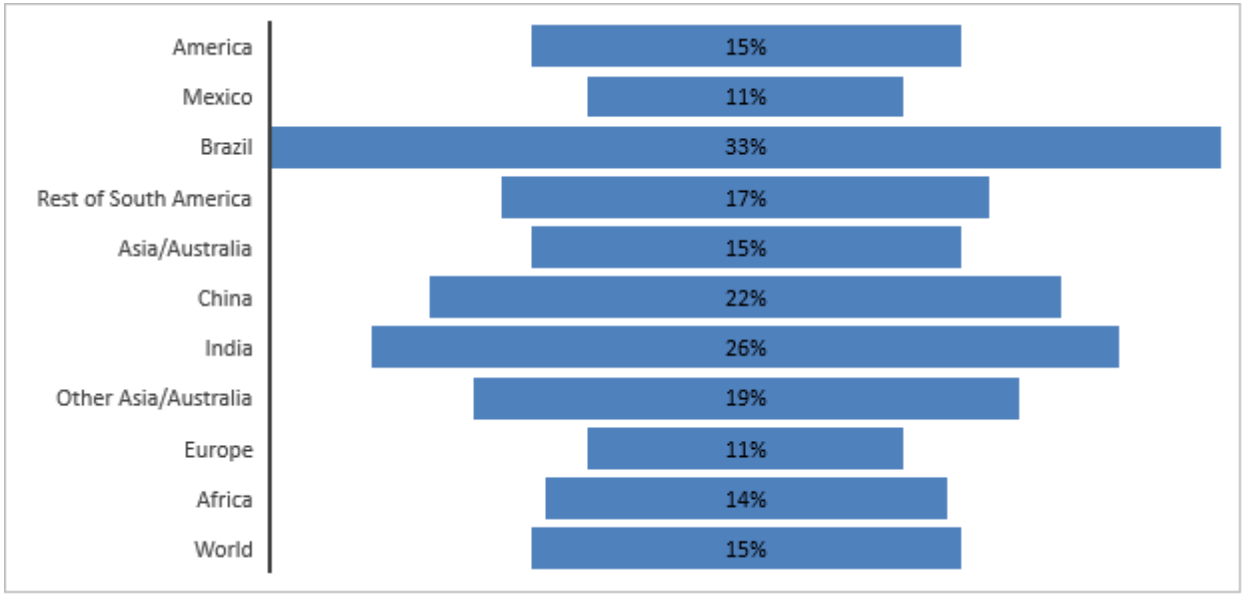
Heterogeneity in readiness for I4.0 is evident when considering the presence of the countries in our sample in global markets for industrial robots. In addition to China, countries such as Brazil, India, Mexico and Thailand have increased both their total global sales (Figure 1) and the expected dynamics in the shipment of multipurpose industrial robots between 2018 and 2020 (Figure 2). These countries have reached individual shares of nearly 1 per cent in the global sale of robots, while the growth rates are expected to sustain two-digit figures over the short term.

Figure 1 **Distributions of global robots sales by country, 2016**



Source: IFR (2017)

Figure 2 **Estimated annual shipments of multipurpose industrial robots in selected countries, CAGR 2018-2020**



Source: IFR (2017)

2.2 Approach to the analysis

Having identified countries to be included in the study, we carried out a web search to find strategic policy document(s) describing each individual country's approach to I4.0. These documents were collected from government web sites, notably from ministries of industry, economy, communications, (higher) education or science and technology. Additional material was found in grey literature, particularly specialized media. The identified materials included national or industrial development plans, industrialization strategies and road maps for comprehensive I4.0 strategies; we did not find concrete national strategies around I4.0. Additional searches included national strategies or policy documents related to specific technologies within the I4.0 bundle, namely big data, cloud computing, IoT and others.

These documents were queried for definitions of I4.0 and the extent to which this concept was contextualized to suit specific country conditions, highlighting opportunities and challenges. Next, we established timelines for implementing the strategy—if at all defined—the entities responsible to supervise strategy implementation (either a ministry or department of industry) and the extent of cross-government collaboration or coordination between different policy domains. Finally, we examined I4.0 strategies, considering the following factors:

- Strategic objective(s)
- Funding
- Instruments used to promote the adoption, development or readiness for I4.0 (for instance, sector-specific initiatives, partnerships with industry, regional initiatives, etc.)
- Correspondence or synergies with national policy(ies) in other sectors
- Monitoring and evaluation plan, including indicators proposed to measure progress
- Other interesting aspects.

Policy documents were supplemented with additional material, where possible, from consulting firms or firms specialized in the development of I4.0 technologies and applications, presentations by academics and industrial experts, or policy-oriented organizations such as OECD, UNIDO, the World Bank and others (UNIDO, 2017; OECD, 2017; Hallward-Driemeier and Nayyar, 2017). Where possible, we interacted with researchers and government officials in our case countries to identify policy documents or policy initiatives and to validate the information collected through the literature review and web searches.

3. Behold the Fourth Industrial Revolution!

Advocates of I4.0 point out its inevitability: embrace it and you'll be better off; if you fail to do so, you will run the risk of falling behind (Deloitte, 2016, 2016; PwC, 2016a; Schwab, 2016). The development of cyber-physical systems and other I4.0-related technologies is driving convergence beyond common process automation.[2] The interconnection and integration of the digital and manufacturing realms is set to transform industrial firms into digital platforms where the creation of physical products will be enhanced by digital interfaces and data-based innovative services (PwC, 2016b).

Considerable efforts are being geared towards developing diagnostics, toolkits and tailor-made blueprints to assess readiness for I4.0 and, based on these, to produce industry or country profiles showcasing their potential to participate in and benefit from I4.0 (Deloitte, 2016; PwC, 2016b; Deloitte, 2016; World Economic Forum, 2017). Emphasis is placed on the extent of digitalization of productive processes, particularly in flagship sectors, and on the steps to follow to successfully integrate to I4.0. One example of such an index is the Networked Readiness Index (NRI) calculated by the World Economic Forum to assess the performance of 139 economies in leveraging ICTs to boost competitiveness, innovation and well-being. Table 4 presents the ranking of our sampled countries according to the NRI's 2016 edition. When relevant, the Index reviews what different actors in society—both private and public—can do to contribute to the country's I.4.0 readiness.

Policy recommendations inspired by such indexes seem intuitive: organizations should develop a long-term vision, re-invent themselves around digital power, increase their capacity to tap into external knowledge, combine assets and improve knowledge about markets, industries and customer preferences (Deloitte, 2016). The level of aggregation and diversity of the index's individual components often muddle the line between recommendations policymakers can act upon and those they cannot control.

[2] Unlike traditional automation of single machines and processes to enhance the end-to-end digitization of multiple physical assets; systems integration resulting from I4.0 seek to transform value chains into truly digital ecosystems (PwC, 2016a).

Table 4 Country classifications according to the Networked Readiness Index, ranking 2016*

	Overall	Environment sub-index	Readiness sub-index	Usage sub-index	Impact sub-index	Rank
Argentina	3.79	3.3	4.69	3.84	3.36	89th
Brazil	4.01	3.41	5.07	4.04	3.54	72nd
Chile	4.62	4.72	4.89	4.48	4.37	38th
Mexico	3.99	3.88	4.61	3.81	3.68	76th
India	3.75	3.69	4.44	3.25	3.62	91st
Malaysia	4.91	5.15	4.77	5.09	4.64	31st
Thailand	4.2	4.15	4.94	3.97	3.73	62nd
Viet Nam	3.93	3.82	4.65	3.68	3.56	79th
Ethiopia	3.11	3.63	3.15	2.79	2.87	120th
Kenya	3.83	3.85	3.88	3.63	3.95	86th
South Africa	4.16	4.66	4.82	3.8	3.35	65th
Egypt	3.66	3.49	4.2	3.53	3.42	96th
Morocco	3.95	3.9	4.35	4.01	3.52	78th
Kazakhstan	4.59	4.27	5.47	4.41	4.2	39th
Turkey	4.39	4.23	5.47	4.04	3.81	48th

Notes: The NRI measures a country's performance on a scale from 1 (worst) to 7 (best) over four categories of indicators: (1) the overall environment for technology use and creation (political, regulatory, business, and innovation); (2) networked readiness in terms of ICT infrastructure, affordability and skills; (3) technology adoption/usage by the three groups of stakeholders (government, the private sector and private individuals); and (4) the economic and social impact of the novel technologies. The framework translates into a composite indicator made up of four main categories or sub-indexes, ten subcategories or pillars, and 53 individual indicators distributed across the different pillars.

Source: Word Economic Forum. Networked Readiness Index 2016

The OECD (2017) does not dispute the inevitability of I4.0, but calls for moderation to avoid a "hype"[3] about the changing processes and technologies associated with it. It points out that the majority of efforts undertaken to facilitate the diffusion and uptake of I4.0 technologies tend to be concentrated on a small sample of firms, namely large multinationals in specific industries. The experiences of other types of firms, notably medium- and small-sized enterprises, which are lagging behind a rapidly changing technological frontier should be considered. Finally, the OECD recommends developing foresight capabilities to anticipate technological changes relevant for the future of manufacturing and its associated changes in skills requirements, investment in infrastructure and so on.

[3] Emphasis in the original.

The Digital Transformation Monitor (2017b) also calls for moderation in its reflection of the likely changes that European countries will experience in relation to I4.0. Changes will mostly be incremental, "[r]ather than creating new industries, the greatest digital opportunity for Europe lies in the transformation of existing industry and enterprises" (p. 2); moreover, one of the most significant challenges for European I4.0 strategies is the inclusion of SMEs. Public funding, capability building, enhanced planning and monitoring mechanisms, alignment of policy governance and industry co-financing need to be addressed to facilitate SMEs' participation in I4.0 (Digital Transformation Monitor, 2017b).

Berger (2016) and Gates and Bremicker (2017) subscribe to the same view. Building on firm-level data, they conclude that despite significant investments in I4.0 capabilities and technologies across the globe, progress is quite heterogeneous. The majority of initiatives are at pilot stages, largely driven by global multinational firms, despite positive prospects for companies already embedded in global value chains to follow suit (UNIDO, 2017). Only few companies have achieved a scale and level of integration sufficient to capitalize and draw value from I4.0 (PwC, 2016b). Gates and Bremicker (2017, p. 5) decry the gap between "executive ambition and transformative action"; the 'factory of the future' or the "digital enterprise" largely remain long-term aspirations (Roland Berger GMBH, 2016).[4]

Moving forward, increasing adoption rates of digital technologies in both developed and developing countries would continue to remain a key barrier for I4.0 (Digital Transformation Monitor, 2017b; PwC, 2016a). Moreover, understanding the drivers of I4.0 and its expected impacts on efficiency, productivity and profitability will continue to attract attention. Policymakers, private firms and other interested actors need to stimulate their constituencies to develop learning and other capabilities required to catch up. There is no one size fits all approach to I4.0. Small steps need to be taken, technological options based on desired end goals need to be tested before committing to full I4.0 implementation (MITI, 2017).

Areas in which I4.0 is expected to challenge established conventions include employment and minimum skill requirements across a range of professions and trades and the imposition of additional demands on education systems. The evolution in scientific and technological systems will bring about changes to government-citizen relationships and other socio-cultural and environmental areas (Schwab, 2016). Novel policy approaches should address those challenges to maximize potential benefits while minimizing risks.

[4] The call for moderation when interpreting observed trends related to I4.0 remind of Cassidy's (2002) account of events leading to the burst of the technological bubble in the 1990s, and the ensuing crisis of the dot.com industry – a phenomenon that the author described as an example of Mackay's (1995) notion of the "madness of crowds" (emphasis in the original).

Questions about how governments can facilitate a smooth transition towards I4.0 remain unaddressed. These include questions such as: how can the diffusion and public acceptance of new technologies be ensured without falling into the trap of concentrating resources and policy efforts in the search for silver bullets How can strategies underpinning enterprise creation, productivity and growth be reinvigorated? Who will be the winners and losers across industries and nations? (OECD, 2017; López-Gómez et al., 2017)

3.1 Emerging policy issues

I4.0 as a policy-guiding concept is quite novel. It was first introduced to denote one of the ten Future Projects expected to underpin the German government's approach to industrial modernization—High Tech 2020 Strategy and subsequently the High Tech 2020 Action Plan—was launched in the early 2000s (Digital Transformation Monitor, 2017a). The platform that provides form and structure to I4.0 (Plattform Industrie 4.0) was only officially launched at the Hanover Fair 2013 (Federal Ministry for Economic Affairs and Energy, 2017). Plattform Industrie 4.0 is Germany's response to the challenges the country faces to secure and develop international leadership in industrial manufacturing (Federal Ministry for Economic Affairs and Energy, 2017). Sustained leadership demands a consistent and reliable framework to facilitate the digital structural transformation of the German economy. The implementation process has acknowledged the emergence of an increasingly networked economy characterized by enhanced cooperation, participation and coordination of multiple stakeholders. Multi-stakeholder dialogues are necessary to create a consistent understanding of I4.0 as the foundation for the achievement of intended objectives. In essence, Plattform Industrie 4.0 is an extremely sophisticated learning exercise "To draw up relevant recommendations for action and demonstrate with example applications how industrial manufacturing can be digitised successfully in practice" (Federal Ministry for Economic Affairs and Energy, 2017).

Despite its novelty, I4.0 has rapidly spread across Europe—Austria, Finland, France, Spain, the United Kingdom and other countries have adopted strategies starting in 2012 (Infosepp, 2015; Digital Transformation Monitor, 2017b)—as well as the United States (US) and China (Deloitte, 2016).[5] Differences in design, funding mechanisms and implementation strategies are often more substantial than the terminologies used. Indeed, I4.0 is used to identify emerging research agendas, efforts to enhance policymaking capabilities, the building of novel concepts

[5] López-Gómez et al. (2017) and Digital Transformation Monitor (2017b) document the diversity of interpretations or designations of I4.0 and related processes across the world: "Alliance pour l'Industrie du Futur" in France, "Smart Industry" in the Netherlands, "Produktion 2030" in Sweden, "Connected Industry 4.0" in Spain, "Smart Manufacturing" in the US; "Made in China 2025" in China; "Manufacturing Innovation 3.0" in South Korea; "Industrial Value Chain Initiative" in Japan; and "Smart Nation Programme" in Singapore (MITI, 2017).

and metrics linked to broader evolutionary social and economic processes beyond the initial convergence of manufacturing, digital technologies and human beings within the smart plant. These differences notwithstanding, the goal of sustaining or regaining industrial leadership, the pursuit of economic, social and environmental goals, and the direct connection of I4.0 strategies into broader development aspirations—as recorded in national development plans—is common in highly industrialized countries (Digital Transformation Monitor, 2017b).

López-Gómez et al. (2017) suggest that because technological convergence is blurring the boundaries of innovation across manufacturing activities, traditional industrial classifications based on well-defined industries or technological characteristics will become insufficient to capture the complex processes underpinning I4.0. Policymakers need alternative tools and frameworks to characterize increasingly complex manufacturing systems, intricate interdependencies across industries, firms, technologies, subsystems and ever-expanding components systems.

At the same time, a growing number of players, including emerging economies, are adopting advanced manufacturing processes, even in areas traditionally reserved for highly industrialized countries (Daudt and Willcox, 2016; López-Gómez et al., 2017). One example is aerospace where several middle-income countries have endeavoured to gain presence in specific segments of the global market (López-Gómez et al., 2017). Increased competition requires more decisive efforts for building capabilities to endorse I4.0. Policymakers must enhance their understanding of the geographical distribution of innovation and industrial leadership and about the spaces available to foster knowledge exchange and collaboration between existing and emerging partners in both developed and developing countries.

As regards policy coordination, I4.0 brings industrial and innovation policy together, touching on issues related to employment and employability, radical changes in productive processes and a redefinition of intellectual property rights, among other domains (OECD, 2017). However, there is no guarantee that supporting industrial innovation, particularly through enhanced R&D funding, improves readiness for I4.0 (López-Gómez et al., 2017; OECD, 2017). The scope for policymaking extends to "supporting the scale-up of disruptive/emerging technologies, promoting commercialisation by business and adoption by SMEs, while fostering balanced regional development" (López-Gómez et al. 2017, p. 9).

The rationale for strategic policy choices around I4.0 is highly contextual, it largely reflects a country's economic, industrial and innovation structures, penetration of digital infrastructure and national priorities and capacities to mobilize public-private partnerships. Examples of

drivers for I4.0-related policy strategies in select developed countries are presented in Box 1. Section 4 documents that I4.0 strategies also remain challenging for middle-income countries.

Box 1 Conditions for adoption of I.4.0 in highly-industrialized countries

According to Berger (2016), the transformations associated with I4.0 go beyond microeconomic impacts on firm performance; they imply macroeconomic challenges for highly-industrialized economies. Individual industrial policy positions towards I4.0 reflect the differences in the size of the economy and of the domestic market, the strength of domestic manufacturing industries, degrees of automation and differences in the means to achieve intended objectives. The strategic directions leading I4.0 adopters should follow are characterized as follows (Berger, 2016):

Germany is a pioneer, emerging from a period of challenges associated with rising labour and energy costs, demands for the renewal of infrastructure and skill shortages. The country has rapidly become a lead producer of I4.0 solutions, hosting major players in the field, such as Siemens and Bosch. The country's I4.0 strategy is *simultaneously defensive*—seeking to maintain home-based production and increasing flexibility to respond to crises in international markets—*and offensive*, seeking to retain skills and know-how to support an export-led model.

France should implement a strategy of *resurgence* of an aging and decreasing industrial base. Enhanced digitalization and virtualization and a growing start-up ecosystem underpins the renewal of the domestic manufacturing base, repositioning France as an industry leader, provided it can offset heightened labour costs and related social constraints. Leadership in I4.0 could help improve public perception of the manufacturing sector and foster some degree of relocation to industries such as textiles, parts and others, while creating skilled jobs.

In stark contrast with the recent discourse of the US Federal government, Berger (2016) recommends that the US should implement an *industrial relocation strategy* to respond to two parallel processes. First, manufacturing activities should be relocated abroad, which will be accompanied by a loss of manufacturing jobs; second, it should pursue heavy investments in the industrial sector including substantial modernization, automation, robotization, high labour productivity and significant corporate profit gains. Arguably, however, the generation of value added has failed to keep up with the pace of capital investments. That is, I4.0 policies are expected to enable a relocation of industrial activities, to fuel high-quality skilled jobs, increase value addition and enhance the use of a modernized industrial base.

Japan should *relaunch industrial growth* after a period of sustained reduction in value addition, job losses and falling profits in the industrial sector. Challenges stemming from disinvestment, off-shoring, an overall drop in competitiveness and an aging population remain significant. As a relative late adopter of I4.0 among the group of highly industrialized countries, Japan is expected to build on current advanced levels of automation to regain competitiveness and flexibility. I4.0 should also renew the interest in industry among younger Japanese, while reviving investment in the quality of work in factories.

Source: Berger (2016)

4. The middle-income country perspective

UNIDO (2017) asserts that the adoption of I4.0 technologies is largely explained by market dynamics, as firms operating in developing economies seek to comply with regulations or requirements of major commercial customers. Middle-income countries acknowledge that I4.0 represents a potential technological window of opportunity to foster presence in global manufacturing[6]. The challenges associated with the massification of digital technologies and the difficulty of determining the impact of I4.0 on industry and society at large with any degree of certainty remain (Box 2).

Despite the generalized interest in I4.0, readiness to endorse the revolution remains uneven across middle-income countries, many of which are still unable to catch up with previous stages of industrialization. According to Roland Berger GMBH (2016), unlike the significant progress made by China, other BRICS countries record "low levels of industrial automation (robot density), low numbers of Industry 4.0-related patent applications, low numbers of machine-to-machine connections and limited activities in robotics and additive manufacturing by companies, which is an indication of low levels of Industry 4.0 readiness" (Roland Berger GMBH, 2016, p. 2). In Africa, despite promising signs from countries such as South Africa, the adoption of I4.0 remains low (Deloitte, 2016; PwC, 2016b). Tansan et al. (2016) share this view for Turkish firms; while awareness of I4.0 seems high, the ability to identify impacts and opportunities associated with I4.0 varies across industries and companies. Differences between multinationals and SMEs are evident; while the former tend to drive I4.0, the latter tend to be disconnected from it.

[6] Windows of opportunity identify discontinuities linked to the dynamics of a sector or system; they take the form of scientific or technological breakthroughs (technological windows), significant, often unforeseen, changes in demand conditions for certain products (demand windows), or institutional reforms that significantly modify the environment around products, sectors or systems (institutional windows) (Lee and Malerba, 2017; Perez and Soete, 1988).

Box 2 What I4.0 means for middle-income countries

In Chile, the Strategic Programme Smart Industries [Programa Estratégico Industrias Inteligentes, (PEII)] 2015-2025 acknowledges international trends towards massification of digital technologies which are becoming increasingly specialized across industries, and offer tremendous opportunities for enhancing efficiency and value addition. Big data, cloud computing, cybersecurity and robotics belong to the technologies driving I4.0 and its associated impacts on industrial activities – competitiveness, value addition and exports (CORFO, 2016).

The Government of Malaysia views I4.0 as an overarching industrial transformation that broadly influences industry, economic activities and everyday life. The potential results from rapid innovation and the convergence of physical, digital and biological systems may be disruptive. Connected digital and manufacturing technologies will drive I4.0, introducing new concepts such as smart factories where cyber-physical systems will be monitored in real time and will blend in with physical processes, with enhanced ability to make decentralized decisions independently of human interventions (MITI, 2017).

Mexico's roadmap: "Crafting the Future. A Roadmap for Industry 4.0 in Mexico" defines I4.0 as a technological revolution with direct implications for productive systems. The emergence of the smart factory will bring about enhanced flexibility in productive processes, more efficient resource allocation and process integration through monitoring in real time across productive processes. I4.0 defines converging technologies as IoT and cyber physical systems, among others, which allow real time interactions between humans, hardware and software systems (Ministry of Economy, 2016).

In South Africa, the Industrial Policy Action Plan (IPAP) 2017/18 - 2019/20 recognises that the emergence of I4.0 brings both challenges and opportunities for developed and middle-income countries. It asserts that the exact nature of the impacts remains uncertain, but that I.4.0 will cause disruptions that are not only capable of changing ""how things are done"* in the economy, but the whole future of manufacturing" (Department of Trade and Industry 2017, pp. 1-3). Spill-over effects could reach other sectors or activities, including value chains, e-commerce, employment and innovation. The Department of Trade and Industry (DTI) acknowledges nine technologies that sustain I4.0: (1) Big data and analytics, (2) Autonomous robots, (3) Simulation, (4) Horizontal System Integration, (5) Vertical System Integration, (6) IoT, (7) Cybersecurity, (8) Cloud, and (9) Additive Manufacturing (Department of Trade and Industry 2017, pp. 1-3)

In Viet Nam, Directive (16/CT-TTg) on "Strengthening the country's capacity to address I4.0", issued in May 2017, acknowledges that I4.0 is driven by the development of highly integrated platforms connecting digital, physical and biological systems facilitated by the surge in internet and artificial intelligence, digitalization and information technologies. These trends permeate countries at different speeds, but have tremendous potential to impact all aspects of socio-economic life (Nguyễn Xuân Phúc, 2017). The government views I4.0 as an opportunity to upgrade technologically, improve production capacity and compete in value chains, thus generating opportunities for creative entrepreneurship, making significant leaps in business services and so on. The Directive also highlights attractive investment opportunities in digital and internet technologies and underscores that industrial production will be brought closer to advanced science and technology (Nguyễn Xuân Phúc 2017).

Notes: *Emphasis in the original.
Source: Author compilation

Differences in readiness for I4.0 across countries reflect distinct degrees of development in domestic industrial bases, human capital, infrastructure and regulatory environments, together with differences in levels of electrification and digitalization (Table 3), which affects connectivity and broadband access at levels sufficient to support I4.0 applications, particularly of manufacturing, shortages in investment finance and low expenditure in R&D and innovation (Deloitte, 2016; PwC, 2016b; OECD, 2017).[7]

Just as I4.0 can help latecomer firms leapfrog, it can also exacerbate challenges resulting from heterogeneous economic systems. Heavily globalized, highly competitive and productive industries, often composed of large firms ready and eager to endorse I4.0, coexist with a huge segment of firms—mainly domestic-owned SMEs—which are stuck in subsistence strategies and dated productive models with limited incentives to undertake innovation and technological upgrading. Countries emerging from recent economic transition may still find domestic firms locked in pre-competitive market practices (The Prime Minister of Kazakhstan, 2017). That I4.0 is still very much a game involving large firms is illustrated by Kazakhstan, where the government has identified a set of system-forming enterprises[8]—including ERG, Kazzinc, ArcelorMittal, Kazakhmys and others—with the potential of rapidly endorsing I4.0; modernizing these companies in the next five to six years is a priority, given their role as pillars of "single-industry cities" in the country (The Prime Minister of Kazakhstan, 2017).

At the firm level, understanding and awareness of I4.0 and its benefits is generally low (Deloitte, 2016), while the push for comprehensive policy coordination accentuates human capital gaps, the limited availability of qualified solution partners, insufficient productive scales and missing standards to facilitate technological integration and reliability (MITI, 2017; Tansan et al., 2016).

[7] A more optimistic interpretation is that African countries offer tremendous prospects for investments in infrastructure without the burden of having to replace existing legacies that constrain the adoption of modern digital technologies (Deloitte, 2016).

[8] These large system-forming companies have already developed digital modernization plans—"smart mine"—which will use I4.0 technologies such as big data analysis, advanced sensors and monitors, integrated information systems and robotics (Government of the Republic of Kazakhstan, 2017).

4.1 Responding to I4.0

4.1.1 Establishing a strategy and identifying a responsible entity is part of a country's readiness for I4.0

These elements signal awareness of the need to develop new business models and a drive for openness and interaction, together with the adoption of performance indicators to measure progress towards I4.0 – R&D, investment, technology and innovation management and others (Grant Thornton, 2017). Middle-income countries have for the most part yet to define strategic policy agendas around I4.0. National plans or concrete policy strategies are either non-existent, or at initial stages of discussion, consultation and planning. Even the few advanced cases identified show that the strategies are insufficiently articulated regarding milestones, resources and pathways towards desired outcomes.

Early adopters of an I4.0 strategy are also found in Latin America, Asia and Africa. In 2016, Chile announced the Strategic Programme Smart Industries [Programa Estratégico Industrias Inteligentes, (PEII)] 2015-2025 (CORFO, 2016)[9]. In Thailand, the basic elements of the national strategy around I4.0—"Thailand 4.0"[10]—are included in the 20-Year National Strategy (2017-2036)[11] and the 12th National Economic and Social Development Plan (2017-2021) (Thailand's Government Public Relations Department, 2016a; Baxter, 2017). In South Africa, the Industrial Policy Action Plan (IPAP) 2017/18-2019/20 devotes a full chapter specifically to enhancing the country's readiness for I4.0.[12]

A second tier of countries includes those in which a roadmap or general guidelines for the development of a national I4.0 strategy are either already in place or nearing completion. In 2016, Mexico adopted a roadmap to pave the way towards a comprehensive national I4.0 strategy[13], but the process to accomplish this has yet to be articulated. In 2017, the Government of Viet Nam issued a special directive allocating roles and responsibilities to different agents

[9] PEII aspires to become an enabling platform that drives domestic industry's digitalization. It introduces a vertical approach to looking into the problems, needs and possible solutions of individual industries (CORFO, 2016).

[10] Thailand 4.0 describes the country's long-term development path as follows: "Thailand 1.0," focused on the agricultural sector; "Thailand 2.0" on light industries tapping into cheap labour costs, import substitution and natural resources, with an emphasis on domestic production. Finally, "Thailand 3.0" has centred on more complex industries and an aggressive strategy to attract foreign investment to make Thailand a production and export hub (Board of Investment, 2017; Harnhirun, n.d.).

[11] The strategy is referred to as the "6-6-4 plan" because it consists of six target areas (including competitiveness enhancement, social equality and green growth), six primary strategies (including strengthening the economy and enhancing competitiveness on a sustainable basis; promoting green growth for sustainable development; prosperity and sustainability; enhancing the efficiency of public sector management among others) and four support strategies (development of infrastructure and logistics systems; improving science, technology, research and innovation; development of urban, regional and economic zones; and promoting international cooperation towards sustainable development) (Baxter, 2017; ThailandToday, 2017).

[12] "Seismic change ahead: preparing for the Fourth Industrial Revolution". pp. 42-47. Vol 1.

[13] The roadmap should lay the foundations for a "national value added strategy for the manufacturing industry through the implementation of Industry 4.0 strategies and technologies" (Ministry of Economy, 2016, p. 15).

with a view to fast-forwarding the adoption of I4.0 (Box 3). In Kazakhstan, the completion of a technical analysis of industry preparedness for transitioning to I4.0 was expected to be issued by the third quarter of 2017; this report will represent the foundation of a government decree to be adopted by the end of that same year, containing a step-by-step plan for the implementation of I4.0 elements until 2025 (Government of the Republic of Kazakhstan, 2017).

Box 3 The task of advancing towards I4.0 is shared by different government entities in Viet Nam

Ministry of Information and Communications: it is mandated to focus on promoting the development of ICT infrastructure, including the improvement of the institutional environment around private investment in technology adoption, diffusion and development. In addition to fostering the development of human resources for ICT and key ICT technologies and products, particularly those directly relevant for the development of I4.0, the Ministry should raise awareness of I4.0 among the population.

Ministry of Science and Technology: it is mandated to improve the overall readiness of the national system of innovation to accommodate the development of I4.0 up to 2020. Emphasis is placed on the establishment of start-ups, R&D and technology diffusion, the creation of a "Digital Literacy Knowledge System"*, fostering the implementation of National Science and Technology Programmes in mathematics, physics and basic sciences, production quality and intellectual property, among other areas.

Ministry of Education and Training: it shall foster basic skills, knowledge, creative thinking and adaptability according to I4.0; enhance education in science, technology, engineering and mathematics (STEM) in the national curriculum, with pilot high schools starting in 2017, and strengthen the research and teaching capacities at tertiary institutions.

Ministry of Labour, Invalids and Social Affairs: it shall revamp and align training and education to meet the requirements of I4.0.

Ministry of Finance: it shall promote tax and financial mechanisms and policies aimed at encouraging investments in R&D, technological upgrading and ICTs.

Viet Nam Academy of Science and Technology: it shall be responsible for spearheading scientific and technological research directions around I4.0, including in ICTs, physics, biology, artificial intelligence, materials and others.

*Emphasis in the original.
Source: Adapted from Nguyễn Xuân Phúc (2017)

Countries such as India are leveraging on efforts already in place. For instance, the government seeks to combine industry and IoT technologies through the Make in India initiative,; similarly, the 'Smart Cities Mission' projects aim to help build 100 smart cities as forerunners of I4.0 across the country (Make In India, 2017). Through the Digital India programme, the government intends to promote manufacturing and the use of infrastructure for information and communication technologies (ICTs) (Roland Berger GMBH, 2016).

Several other countries have recently initiated consultative processes with a view to developing roadmaps or national I4.0 strategies through special task forces in Malaysia, for example, or through working or consultative groups in Brazil, Turkey and Argentina (Box 4). Finally, a group of countries is still struggling with developing national ICT policies to improve their framework conditions for digitalization and related infrastructure (Egypt, Ethiopia, Kenya and Morocco) (Table 3). Finally, although they do not always explicitly mention I.40, some national digitalization strategies stress the importance of deregulation, the opening of the ICT sector to foreign investors, infrastructure to enhance access to high-speed internet and the development of big data applications, IoT, visualizations and related technologies.

4.1.2 Building I4.0 strategies requires coordinated efforts from multiple stakeholders

The collaborative multi-stakeholder approach to develop national I4.0 strategies or roadmaps in middle-income countries is consistent with the experience of advanced European countries where the preferred approach remains top-down, through working groups, stakeholder consultations and even calls for proposals (Digital Transformation Monitor, 2017b).

In the case of middle-income countries, efforts at designing national I4.0 strategies involve shared leadership and a search for enhanced policy coordination across government organizations and between government and an entire host of private and academic organizations (Box 4). Ministries of industry or economy or science and technology (S&T) tend to take the lead; collaboration between industry and S&T authorities is common. In Brazil for instance, the development of the new National Plan for I4.0 was driven by the Ministry of Science, Technology, Innovation and Communications (MCTIC), and the Ministry of Industry, International Trade and Services (MDIC) (Portal Brasil, n.d.). Similarly, collaboration between DTI and the Department of Science and Technology (DST) in South Africa includes the development of policy and technological scenarios for the future of I4.0 and the corresponding responses required by the country (Department of Trade and Industry, 2017).

Box 4 National I4.0 strategies build on multi-stakeholder participatory processes

In Argentina, the Ministry of Science, Technology and Productive Innovation (MSTPI) and the National Institute of Industrial Technology (INTI) introduced a consultative process on I.4.0 in 2016 under a series of *Mesas Ejecutivas*, with participation from the government and the private sector (Infosepp, 2015). The Mesas will produce diagnostic studies for individual sectors, identifying their current position—including in relation to I4.0—and defining instruments and long-term development policies. Based on the results from the Mesas, the national I4.0 strategy will be geared towards facilitating innovation and the adoption of novel technologies, identify training and skill needs for employment in I4.0 industries, and encourage interactions between industry and science and technology organizations (Infosepp, 2015).

In Brazil, a working group for I4.0 (GTI 4.0) was established in 2017, under coordination of the Ministry of Industry, International Trade and Services (MDIC). Other participating organizations include the Ministry of Education; the Ministry of Science, Technology, Innovation and Communications (MCTIC); the Ministry of Finance; the Ministry of Labour, the Special Secretariat for Strategic Affairs (SEAE); the Brazilian Development Bank (BNDES); the Funding Authority for Studies and Projects (FINEP); the Brazilian Agency for Industrial Research and Innovation (EMBRAPII); the National Council for Scientific and Technological Development (CNPq) and the Ministry of Education through CAPES. Private sector associations and academia are also presented (Portal Brasil, n.d.). A national I4.0 strategy document was expected by the end of 2017.

In 2017, the Malaysian government designated a High Level Task Force (HLTF) led by the Ministry of International Trade and Industry (MITI), with representatives from other relevant ministries and agencies (MITI, 2017). The HLTF will guide the development of the government's entire I4.0 strategy, with industry as the core stakeholder. According to MITI (2017), concerted efforts are carried out by MITI, the Ministry of Science, Technology and Innovation (MOSTI) and the Ministry of Higher Education (MOHE) as the entities responsible for promoting I4.0. Additional inputs will be provided by five Technical Working Groups (TWGs) operating under the HLTF (MITI, 2017):

- Digital infrastructure and eco-system led by the Ministry of Communications and Multimedia Malaysia (KKMM);
- Funding and incentives headed by the Ministry of Finance (MOF);
- Talent and human capital led by the Ministry of Human Resources (MOHR) and MOHE;
- Technology and standards led by MOSTI;
- SMEs led by SME Corp.

In May 2017, the Prime Minister of Viet Nam, Nguyễn Xuân Phúc, issued Directive (16/CT-TTg) on strengthening the country's capacity to deal with I4.0 (Nguyễn Xuân Phúc, 2017). In addition to identifying shortcomings related to technological, human resources, policy and infrastructure required for I4.0 (MOST, 2017), the Directive mandates different ministries, heads of ministerial-level agencies, the presidents of the People's Committees of provinces and centrally-run cities and other pertinent authorities, to review and evaluate their current situation as inputs to their corresponding plans and strategies (see Box 3). These entities are authorized to arrange for and lead concrete actions and solutions geared towards the implementation of I4.0 in the country.

Source: Author compilation

A second tier of ministries involved in I4.0 is drawn from considerations of a sectorial angle of national strategies; relevant ministries include higher education, health, mining, labour and those responsible for ICTs. In addition, countries such as Chile, Mexico (Box 5) or Viet Nam have recognized and explicitly pledged support to regional initiatives converging and contributing towards national objectives, thereby opening the space for collaboration between central and provincial governments. The adoption of regional perspectives, particularly through smart specialization initiatives, is also a common element in I4.0 strategies in developed countries (Digital Transformation Monitor, 2017b).

Box 5 Development of an I4.0 strategy for the Nuevo Leon province, Mexico

The provincial government announced the initiative "Nuevo León 4.0" in May 2017, which aims to support the modernization of production systems and the introduction of new models for business and advanced manufacturing. The government plans a seed investment of MEX 150 million (~USD 8.0 million) to foster innovation projects by industries located in the province. Tax incentives will be offered to those firms that repatriate and employ highly qualified staff. The management of the initiative will be vested in the local private sector through a Governing Council, while it is expected that up to ten projects around I4.0 will be carried out in a first stage in industries including automobiles, food, aerospace, health, energy, electro-domestics, education and ICTs.

Source: Gobierno Nuevo León (2017)

4.1.3 The private sector plays a key role as a driver and partner in the development of I4.0

Because the development of I4.0 is largely the result of a technological and business dynamics driven by the private sector, fostering its direct and active involvement in policymaking is critical. In Chile, for example, although CORFO is responsible for implementing the PEII 2015-2025, a Directive Council composed of representatives from public and private sector organizations supervises its implementation (CORFO, 2016). Mexico's Roadmap was drafted through a collaboration between the Ministry of Economy, ProSoft 3.0—an official programme for the promotion of the domestic software industry—and the Mexican Association of Information Technologies (Asociación Mexicana de Tecnologías de Información), among other organizations. The private sector is also a key player in ongoing planning processes in Brazil and Malaysia (Box 4).

Private sector associations actively promote I4.0 initiatives to raise awareness through public events, conferences, workshops or by sponsoring or directly conducting sectoral diagnostics. The Confederation for Indian Industry prepared the document "Readiness for Industry 4.0", with a focus on the domestic automotive industry (Grant Thornton, 2017). Similarly, the Chamber of Business for Software and Information Services (CESSI) in Argentina has

conducted several events on the State of Digital Transformation where, among other issues, the Chamber presents the findings of an annual survey on the extent of digitalization of Argentinian firms (CESSI Argentina, n.d.). CESSI has proposed a Map for Digital Transformation to help determine the extent of digitalization by type of technology and economic sector, and the stakeholders who would be involved and benefit from the development of digital technologies (CESSI Argentina, n.d.).

4.1.4 Strategies around I4.0 call for synergies across different policy areas

Various countries are introducing I4.0-oriented programmes or specific interventions as part of their innovation strategies, seeking to develop specific technologies within the I4.0 suite. The objective is to foster innovation-driven economies, moving away from commodities and traditional industrial products into higher value added sectors (GTCC, 2017). In Argentina, Chile, Egypt, Malaysia, Thailand and South Africa, for example, science, technology and innovation (STI) authorities have assumed direct responsibility for I4.0 development through dedicated funding to direct research agendas towards ICT, the development of IoT, big data applications, and others. The PEII 2015-2025 determines the government entities, programmes and initiatives that have the potential and interest to build synergies (Box 6). Other countries aim at collaboration and strategic exchange with foreign organizations with a recognized leadership in I4.0.

In South Africa, the IPAP 2017/18-2019/20 explicitly and determinedly focuses on supporting domestic firms to benefit from technology transfer, diffusion and acquisition, including investment from global Original Equipment Manufacturers (OEMs) in key strategic value chains. This will accompany a strategy for the adoption of locally developed technologies, jointly led by DTI and DST, with contributions from the Economic Development Department (EDD), the Department of Defence (DoD) and the Department of Health (DoH). IPAP 2017/18-2019/20 also proposes establishing a Sovereign Innovation Fund (SIF) to serve as a national financing instrument which, among other mandates, will aim to provide funding for high-technology developments, particularly in areas linked to I4.0 (Department of Trade and Industry, 2016b). The government has pledged seed investment of ZAR 1-1.5 billion (~USD 111 million) for 2019/2020.

Box 6 Chile is seeking a synergetic approach to I4.0

The PEII 2015-2025 assumes close collaboration between public, private and academic sectors. The opportunities and priorities identified by CORFO guide PEII implementation and focus on three areas, namely mining (particularly copper), agriculture and food and Smart Cities. Programme implementation will generate synergies and complementarities with other ongoing initiatives at national and sectoral level:

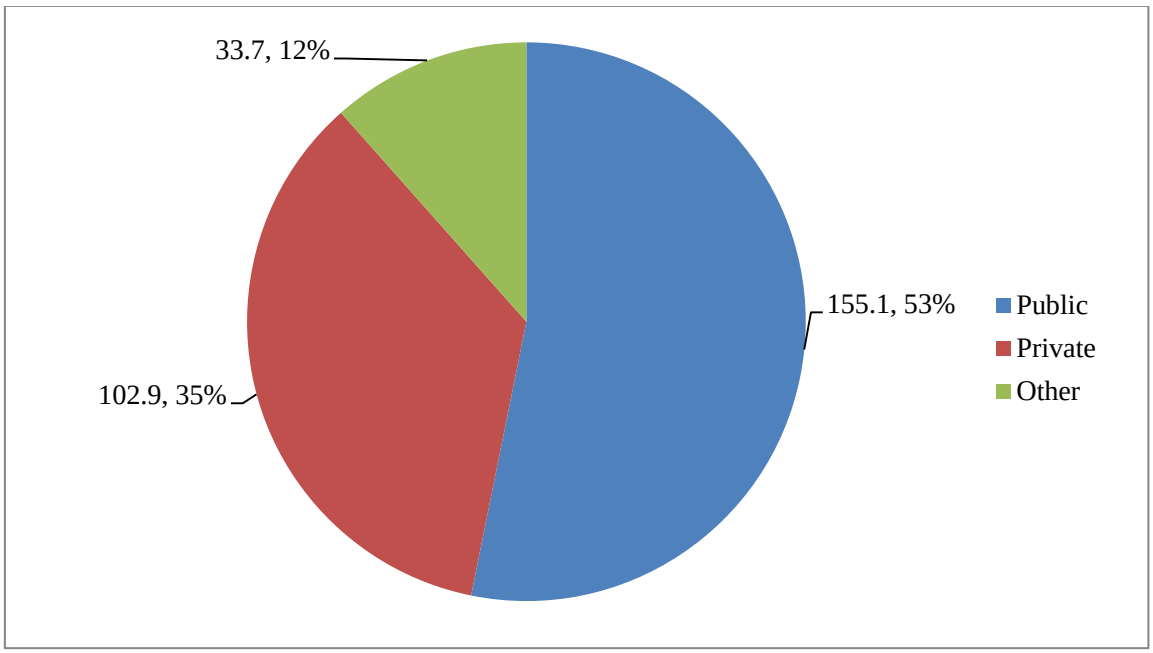
- Strategic Mining Programme (Programa Estratégico de Minería) on interoperability initiatives in mining (project SOMIN); development of smart mining initiatives, among others;
- Strategic programme health + development (Programa Estratégico Salud + Desarrollo) in telemedicine and interoperability of technological solutions in health;
- Strategic regional programme Santiago Smart City (Programa Estratégico Regional Santiago Ciudad Inteligente) through investments in smart city-enabling infrastructure;
- Programa Estratégico de Construcción Sustentable (PECS) by applying the Building Information Modelling initiative in construction;
- Strategic Programme Healthy Food (Programa Estratégico Alimentos Saludables) entails initiatives supporting smart production and traceability, including the development of specialized labs;
- Strategic Programme Solar Industry (Programa Estratégico Industria Solar) involving smart grid projects and other projects aiming to optimize the use of solar energy;
- Facilitating the implementation of Agenda Digital 2020 and support in areas related to astro-engineering in collaboration with the Ministry of Economy;
- Coordination with and technical support for the Ministry of Energy and other entities responsible for public lighting, including standards, tele-management; transport solutions and infrastructure.

Source: CORFO (2016)

4.1.5 Timelines to implement I4.0 development strategies vary across countries

The expected implementation of I4.0 strategies or roadmaps generally combines short- and long-term perspectives; they usually, but not always, include well-defined milestones to evaluate progress. Countries such as Kazakhstan, Viet Nam and Mexico have set time horizons from between 2020 and 2030 to carry out initial strategic interventions, but the intended milestones remain broadly defined. South Africa and Malaysia are sticking to the predetermined timeframe for the implementation of already existing industrial development strategies, particularly since I4.0 interventions have yet to be refined. Chile is ahead of the pack, not only because implementation of the PEII includes intermediate targets for 2015-2017 (short term), 2018-2020 (medium term) and 2020-2025 (long term), but because unlike other countries, each period includes estimates of required investments and their possible sources (Figure 3). Of the total requirement of USD 291.7 million, some USD 72.3 million (~24.8 per cent) will target high priority projects over the coming decade.

Figure 3 **PEII 2015-2025 implementation roadmap, estimated investment by source of funding**



Source: CORFO (2016)

4.1.6 The development of I4.0 strategies lends itself to experimentation and learning from past policy experiences, or to acquire knowledge from multiple actors

Building on different pieces of evidence, governments foster shared visions around I4.0 among domestic agents; they seek tested policy tools that can be scaled up, that can inform the design of policy incentives or uncover gaps between large companies and SMEs. In Chile, PEII 2015-2025 taps into accumulated learning from the digitalization in the construction industry through the Building Information Modelling initiative, which is part of the Strategic Programme for Sustainable Construction (Programa Estratégico de Construcción Sustentable - PECS) and included a task force to identify challenges and opportunities associated with the industry's digital modernization.

Various I4.0 roadmaps include proposals for additional diagnostic studies on strategic industries, individual I4.0 technologies and design or urban ecosystems (smart cities), while governments expect to have leverage on ongoing initiatives and pilot projects. The expected outputs from these exercises include sectoral "white papers", proposals for the creation of clusters of firms specialized in a particular technology or a set of technologies in the I4.0 suite (Argentina, Chile, Mexico, Malaysia), or the provision of guidelines and mechanisms to institutionalize efforts, for example, the proposal for a National Institute of Industry 4.0 as a

public-private entity responsible for elaborating and coordinating the implementation of Mexico's I4.0 strategy.

In other cases, the goal is to develop independent evaluations carried out or sponsored by the private sector. This is the case of Turkey where in-depth studies on industries such as automotive, white goods, textiles, chemicals, food and beverages and machinery have been conducted (Tansan et al., 2016). As noted earlier, a private entity has carried out specialized studies on the readiness of India's automotive industry for I.4.0 (Grant Thornton, 2017).

4.1.7 Strategic partnerships with foreign agents intends to speed up the learning curve

Collaboration and strategic partnerships with foreign agents is expected to help countries leapfrog by benefiting from know-how and experiences to pilot I4.0 initiatives at home. This approach is evident in India where Bosch is expected to begin implementation of smart manufacturing at its 15 centres in India by 2018; similarly, General Electric has invested USD 200 million in its only multi-modal factory in India where digitally interlinked supply chains, distribution networks and servicing units form part of this intelligent ecosystem (Make In India, 2017).

Several countries, including Brazil, Egypt, India, Kazakhstan, Mexico, Malaysia, Thailand and Viet Nam, have entered into strategic partnerships with German organizations to jointly implement I4.0 enabling strategies (Portal Brasil, n.d.; Ministry of Economy, 2016; MITI, 2017; Thailand 4.0, 2017; Grant Thornton, 2017). The German Chamber of Commerce in the host country, specialized institutes or large multinational firms with recognized leadership in I4.0 technologies and services are often selected as partners. Proposed or ongoing activities include:

- Broad collaboration on STI issues (Brazil)
- Facilitation of industrial promotion initiatives (India)
- Setting up technology transfer offices to help the host country become a major regional provider of I4.0 technologies and services (Mexico, Malaysia)
- Signing memorandum of understanding on I4.0 (Egypt)[14]
- Jointly organizing workshops, conferences and other awareness raising activities targeting domestic agents, mainly firms.

[14] Ministry of Industry (2017).

Thailand 4.0 has embedded collaboration with German organizations as part of the national I4.0 strategy (Box 7). Siemens, the Fraunhofer Institute and other German entities have become strategic technology partners in areas related to technology transfer, human resources development and joint implementation of pilot projects, targeted SME support for automation and data management tools, but also business models involving I4.0.

Box 7 Thai-German collaboration to underpin the development of I4.0

The Ministry of Industry (MOI) and the Ministry of Science and Technology (MOST) are collaborating with a number of German organizations to facilitate knowledge transfer as part of the development of Thailand I4.0. The strategy is sector-specific and needs- and solutions-oriented. The process is participatory as it includes the Federation of Thai Industries (FTI) and the German-Thai Chamber of Commerce (GTCC). Initiatives linked to this collaboration include:

- An "Industrie 4.0 Plattform" built on the German model to facilitate regular meetings of key stakeholders supporting the implementation of Thailand I4.0;
- A I4.0 Learning Centre (Industry Transformation Centre) modelled after the Competence Centre in Darmstadt, Germany. Related to this is the intention to explore linkages with the German Innovation Fund Schemes ("Zentrales Innovationsprogramm Mittelstand" – ZIM Fund).

Source: Author, based on Thailand 4.0 (2017) and GTCC (2017)

Another set of partnerships include large multinational ICT firms or large international consulting firms to carry out studies on the state of specific I4.0 technologies or to pilot models and initiatives around I4.0. One example of the first type of partnership involved Microsoft and Fundación Chile, which jointly conducted a study on the state of adoption of cloud computing in the country (Fundación Chile and Microsoft, 2016). The findings indicate that the penetration of these technologies among Chilean firms remains low. Barriers to adoption include high upfront investment or rigidities in tariff costs while there are gaps in the understanding of senior private sector executives about the security risks associated with the novel technologies. Moreover, there is a need to improve awareness about the potential applications of cloud computing in business, government and to support entrepreneurship (Fundación Chile and Microsoft, 2016).

An example of the second type of partnership, a pioneering initiative related to the concept of the learning factory[15], is the Brazil Model Factory (Fábrica Modelo Brasil) jointly launched by SENAI (Serviço Nacional de Aprendizagem Industrial) and McKinsey & Company (Box 8).

[15] Baena et al. (2017) assert that the learning factory is a relatively novel activity, which is insufficiently diffused across Latin America.

Box 8 Fábrica Modelo Brasil – the first model factory in Latin America

Fábrica Modelo Brasil (FMB) is the first model factory in Latin America, established in 2012 as a joint project between McKinsey & Company and SENAI-CIMATEC. The investment amounts to BRL 4 million (~USD 1.2 million). Located at the SENAI campus in the Salvador province, FMB has a mandate to provide training and assist in the diffusion of lean manufacturing. The factory is fully functional "with real products, operators, machines and a realistic performance management system" (Baena et al., 2017, p. 74), and a focus on training programmes for microenterprise and SMEs. McKinsey & Co. supported factory design, the development of the lean curriculum and staff training.

The FMB offers customized training in areas related to performance improvement in supplier networks, streamlining core processes or enhancing the skills of frontline employees, among others. McKinsey & Co. offers coaching, role modelling, and performance metrics to reinforce learning. Initial pilot experiences have delivered promising results in the form of productivity gains through relatively simple reorganization procedures within participating firms.

FMB is linked to McKinsey's global network of digital capability centres, with locations in Europe, Asia and North America.

Source: Author based on Sistema FIEB (2017) and McKinsey & Company (2015)

Partnering with foreign entities can help define national investment strategies around I4.0. This is exemplified by Kazakhstan, which with support from the World Bank is developing a draft government programme expected to set "clear coordination mechanisms for all state and local executive bodies" (Strategy 2050, 2017), including the intended contribution of "Kazakh Invest" in the implementation of investments. Efforts include the identification of investment sources—domestic and foreign, public and private—and initiatives to improve the investment climate according to OECD recommendations (Strategy 2050, 2017).

4.1.8 I4.0 strategies pursue heterogeneous objectives – some common issues can be identified

The stated objectives largely reflect the extent of development of framework conditions required for I4.0, notably the degree of digitalization and automation of productive processes throughout the economy. Countries in which the national strategies are still being developed have identified broad but generally similar objectives; these can be clustered and are presented in Table 5.

Table 5 Strategic approaches to I4.0 pursue different objectives

Objectives	Examples
Creating framework conditions	• Fostering the domestic digital industry by considering opportunities across economic sectors and their potential for internationalization; • Developing enabling digital ecosystems to underpin industrial transformation; • Enhancing the extent of the domestic economy's digitalization in general and of the manufacturing sector in particular through investments in digital infrastructure; • Promoting systemic capabilities and identifying education, training and skill requirements for employment in I4.0 industries; • Supporting innovation-driven economies; • Facilitating the coordination of supply and demand for technological solutions through public-private collaboration.
Promoting specific behaviours	• Enhancing interactions between industry and S&T organizations; • Supporting strategic sectors and their linkages with other economic activities.
Enhancing performance	• Escaping the middle-income trap, balancing opportunities for growth and development; • Promoting technological upgrading, innovation and diffusion and the adoption of novel technologies; • Contributing to productivity and value addition in the domestic industry; • Strengthening domestic participation in (global) value chains; • Increasing the domestic value addition of manufactured exports; • Reducing dependence on commodities towards more value-added products; • Decreasing the manufacturing sector's dependency on low-skilled/foreign labour.
Developing policy tools	• Developing mechanisms to identify and select priority sectors and to link them with the rest of the economy; • Adopting mechanisms, notably funding, to support the development of I4.0.
Offsetting negative effects	• Offsetting negative impacts on employment and fostering development of labour-intensive activities in other parts of the economy.

Source: Author based on Portal Brasil (2017d), CORFO (2016), Department of Trade and Industry (2017, 1:3), Ministry of Economy (2016), Infosepp (2015), MITI (2017), Nguyễn Xuân Phúc (2017) and Thailand 4.0 (2017).

4.1.9 The choice of strategic sectors is heterogeneous

The Digital Transformation Monitor (2017b) asserts that national strategies around I4.0 in developed countries usually have no clear technology or sectoral focus; rather, national initiatives "tend to be relatively open with regard to the application of specific technology or sectoral areas" (p. 4). Moreover, existing initiatives usually centre around technology and infrastructure, while skills development is often a secondary goal (Digital Transformation Monitor, 2017b).[16]

This seemingly heterogeneous approach is also visible in middle-income countries. Several countries, including Argentina, Indonesia, Kazakhstan, Malaysia and Mexico, have identified industries perceived as role models because I4.0 has already permeated their operations or industries that have potential for I4.0 to fully thrive once concrete barriers are removed. These industries would be used as examples that can be emulated or scaled up. Alternatively, the definition of strategic industries coincides with those already identified in the national industrialization plans of countries such as Malaysia, Morocco, South Africa, Thailand and Viet Nam, or those subject to specific industry development strategies (for example, the 2007 White Paper for ICTs in Argentina; mining, particularly copper, in Chile). The development of digital industries is particularly important as they significantly contribute to the building of framework conditions for I4.0 (Chile, Ethiopia and Kenya). Concerns about the implications on training and skill requirements as well as the proper allocation of roles and responsibilities among different agents with a stake in I4.0 have been raised. While concerns about employment are pervasive, South Africa appears to be the only country to explicitly consider those industries that can help offset any pernicious impacts on manufacturing employment as priority industries (DTI, 2016).

A distinction is often made between sunset and sunrise industries, albeit with different designations. For instance, Malaysia distinguishes between catalytic industries (energy and electricity, machinery and equipment and chemical) and new growth industries (aerospace and medical devices) "as game changers for the manufacturing sector" (MITI, 2017)[17]. Similarly,

[16] According to the document, Sweden and the Netherlands are two interesting exceptions. In the former case, industry, academia and research groups share responsibility for the design and implementation of the Produktion 2030 initiative, with significant industrial co-financing. Smart Industry builds bottom-up based on a triple-helix type of approach (Digital Transformation Monitor, 2017b).

[17] The government acknowledges that energy and electricity, aerospace and the automotive industry are more advanced industries in terms of readiness for and actual adoption of I4.0 (MITI, 2017).

Thailand has identified ten strategic industries based on two development strategies[18] (Board of Investment, 2017; Thailand's Government Public Relations Department, 2016b):

- Reforming existing industrial sectors ("First S-Curve"): (i) Automotive; (ii) Electronics; (iii) Affluent tourism and medical tourism; (iv) Agriculture and biotechnology; and (v) Food; and,
- Scaling up the development of future growth engines ("New S-Curve"): (i) Automation and robotics; (ii) Aviation and logistics; (iii) Biofuels and biochemicals; (iv) Digital industry; and (v) Medical hub.

A summary of strategic industries mentioned in I4.0 strategies or policy planning processes is presented in Figure 4. Aerospace is the leading industry, followed by agriculture, suggesting a dual economic structure of several middle-income countries. The presence of digital technologies and automation and robotics suggests that the country's focus is on new industries, while the presence of mining, electronics, automotive or chemicals suggests that the country is undertaking efforts to build I4.0 on existing comparative advantages. In other countries, cross-cutting or generic technologies such as biotechnology or digital technologies are being prioritized, while knowledge-intensive services such as design or health services are also considered.

The importance of supporting the development of technologies in the I4.0 suite (3-D printing, IoT, robotics) through individual technology roadmaps (Box 9) is also recognized.

Box 9 Thailand's approach to the development of robotics

In August 2017, Thailand approved a "roadmap" and "measurements" for robotics and automation industry development as proposed by the Ministry of Industry; the initiative aims to bring together the private, public, and education sectors around three elements (Thailand's Government Public Relations Department, 2017), namely:

- Stimulating demand for robots in production and service industries, with expected investments totalling THB 12 billion in the first year, expanding to THB 200 billion within five years;
- Enhancing the supply and capability of robots and automation, "especially the System Integrator (SI), which will become a creator of robots and automation in the future". The government aims to increase the number of SI's in the country from currently 200 to 1,400 within five years;
- Establishing a Centre of Robotic Excellence with the mandate to provide staff development and upgrade robotics and automation technologies to accomplish complex robot production. It will consist of a pilot public-private cooperation network involving domestic and leading private agencies from abroad. The goal is to develop at least 150 prototype robots within five years, to share knowledge of high-tech robotics with 200 entrepreneurs and to train at least 25,000 people.

Source: Author compilation

[18] Until August 2016, the Thai Board of Investment[18] (BOI) reported around THB 144 billion (USD 4.05 billion) in new investments targeting these 10 targeted industries; such investment amounted to 48% of total inward FDI (Board of Investment, 2017).

Figure 4 Strategic industries included in strategic approaches to I4.0

Source: Author based on policy documents included in this study

4.1.10 Is it possible to capture value from I4.0?

López-Gómez et al. (2017) suggest that a country's ability to capture value from I4.0 depends on its capacity to address one or all of four challenges:

- Adopting I4.0 systems to capitalize on the gains in efficiency, flexibility, speed/responsiveness, precision and customization they offer;
- Becoming a manufacturer/supplier of key I4.0 technologies;
- Providing knowledge management and analysis tools or services via IoT and other I4.0 technologies;
- Building key I4.0 enabling infrastructures to underpin the expansion if I4.0.

A study by Hallward-Driemeier and Nayyar (2017) on the technological and organizational trends affecting the future of manufacturing as a driver of development calls for a shift in development strategies along two dimensions. First, setting framework conditions as needed to help domestic agents, notably workers and firms, prepare for I4.0. The strategy should aim to offset any potential disruptions and to capture any opportunities associated with I4.0 by creating space for new businesses, jobs and markets. Second, the authors advocate a shift "from "production" to the broader "manufacturing process," which expands the sources of productivity and job opportunities" (p. 167).

4.1.11 What middle-income countries can do to foster readiness for I4.0

Policy interventions to enhance readiness for I4.0 can be clustered in three main types of framework conditions (López-Gómez et al., 2017):

- Developing infrastructure to support industrial transformation and transform the economic environment (smart cities, cyber security, environment, health, energy, among others). The range of intervention is broad, from studies on specific ICT activities or individual technologies in the I4.0 suite, to the creation of digital parks, often linked to FDI promotion or facilitating connections with international initiatives around digitalization and I4.0.
- Introducing dedicated programmes, facilities and incentive mechanisms. We have repeatedly emphasized the significance of efforts to build awareness and rally the interest of domestic agents. Several initiatives with different degrees of maturity are ongoing and involve distinct partnerships with academic organizations, domestic and foreign firms and others. Proposals for novel schemes to support R&D on I4.0 are multiplying at research granting organizations.
- Enhancing vocational training and higher education programmes around I4.0-related competencies in ways that anticipate the implications of I4.0 on skills, employability and the functioning of education systems. Responses are diverse, from strengthening STEM education at various levels to the development of specialized programmes in collaboration with the private sector.

Examples of specific interventions targeting the framework conditions for I4.0 are presented in Annex 1.

4.1.12 There is no single way to monitor and evaluate progress

Heterogeneous indicators are used to measure progress made towards I4.0. Countries such as India have defined broad macro-level indicators linked to overall industrialization strategies. More precisely, the new National Policy for Advanced Manufacturing seeks to increase the share of manufacturing relative to GDP, from 16 per cent in 2016 to 25 per cent in 2025 (Grant Thornton, 2017). The main challenge is to draw precise links from the promotion of I4.0 and performance at such aggregate level.

Several countries propose evaluating performance based on the expected value of the domestic market for specific I4.0 technologies or applications. Connected to this, more specific performance indicators are derived, often but not necessarily always consistent with specific programmes or interventions. For instance, the Malaysian market for IoT is expected to reach MYR 9.8 billion by 2020. Entrepreneurship oriented towards IoT applications and services will

be enhanced through various SME development and incubation programmes. Target areas for the development of the IoT industry include “healthcare, logistics, agriculture, smart cities, halal industry and advanced manufacturing” (Economic Planning Unit, 2016, pp. 15–16). Similarly, the value of Mexico’s market for IoT services is expected to amount to around USD 8 billion (Ministry of Economy, 2016). This milestone should underpin the creation of a unified database of organizations according to their I4.0 readiness. Progress in research and innovation strategies to create regionally productive jobs, such as smart specializations, including ICT clusters and other strategic industries, is also anticipated.

It is also common to use international indexes on competitiveness and related performance indicators as benchmarks. For instance, Mexico aspires to join the top 10 countries in the Ranking on Economic Complexity Index published by Harvard University and the Massachusetts Institute of Technology (MIT) by 2030.

Additional indicators reflect the type of actors involved in I4.0 initiatives. Mexico has set the establishment of two regional clusters as a target with a mandate to develop I4.0 hyper-flexible manufacturing operating systems by 2019 and 2021, which will provide a platform for systems integration and applications development. The clusters should reflect regional productive specializations, using current infrastructure and capabilities, and collaboration mechanisms that include price clubs, supply information systems, shared infrastructure and technology packages, among others.

Among the countries reviewed in this study, Chile provides an example of a country with more advanced planning around I4.0; it has specified precise mid- to long-term targets for the implementation of PEII 2015-2025. These targets are aligned with the programme objectives described in Table 6.

Table 7 provides a summary on the aspects discussed above.

Table 6 Targets and milestones for the implementation of PEII 2015-2025 in Chile

Objective	Indicators	Baseline 2015	Mid-term 2018-2020	Long-term 2025
Develop an enabling digital ecosystem to underpin industrial transformation	• Average speed available in national broadband (Mbps) • Penetration of high-speed internet ➢ % households ➢ % businesses • Deficit human resources in ICTs	4 2% 8% 14,500	10 10% 25% 5 industries with specialization	100 50% 50% Reduce deficit by 50%
Facilitate coordination between industrial supply and demand	• Private sector participation in PEII implementation	<25%	>50%	>75%
Develop a mechanism to identify and select priority industries	• Number of industries involved in the programme	4 (cities, mining, health and agriculture)	All industries in baseline consolidated	10 industries
Contribute to productivity and value addition in domestic industry	• Interoperability in mining • Interoperability and introduction of sensor technologies in agriculture • Urban areas with smart city-enabling infrastructure	Non-existent Non-existent 0	Define minimum standards Define standards for inclusion of sensors in selected produce 2 metropolitan areas benefit from smart city infrastructure	Interoperability as common practice in 5 of the leading firms in metal mining at global level 15% of cultivated areas (fruits) with precision agriculture Metropolitan areas with smart city-enabling infrastructure and applications

Source: CORFO (2016)

Table 7 Summary of case studies

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators	Policy synergies
Argentina	Working group/ mechanism set up to develop a strategy	TBD	MSTPI and INTI	TBD	Diagnostic studies underway or to be carried out in: biotechnology, franchising, software, electric vehicles, textiles, health technologies, computers, aeronautics and aero spatial, shoes, robotics and 3-D printing	TBD	TBD	Yes
Brazil	Working group/ mechanism set up to develop a strategy	TBD	MDIC	TBD	TBD	TBD	TBD	Yes
Chile	PEII 2015-2025	2015-2017 (short-term), 2018-2020 (medium-term) and 2020-2025 (long-term)	CORFO	Develop an enabling digital ecosystem to underpin industrial transformation Facilitate coordination between industrial supply and demand Develop a mechanism to identify and select priority industries Contribute to productivity and value addition in the domestic industry	Mining (particularly cupper), agriculture and food and smart cities. Other industries to be identified in the future	Public-private partnerships	Increase available speed in national broadband Penetration of high-speed internet Reduce deficit of human resources in ICTs Private sector participation in PEII implementation Number of industries involved in the programme Interoperability in mining Interoperability and introduction of sensor technologies in agriculture Urban areas with smart city-enabling infrastructure	Yes

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators	Policy synergies
Mexico	Roadmap	2030	Ministry of Economy	Increase the value content of Mexican manufactured exports; Enhance industry-academia collaboration as the basis for innovation; Become a dynamic market for IoT within a decade from the adoption of the roadmap	Automotive, aerospace and chemicals as case studies of the country's manufacturing paradigms. Other industries will be designed based on findings from other thematic roadmaps	Pilot programmes Structural reforms Boost digitization and access to internet services in the country	In 2019 and 2021, two regional clusters should be in place with a mandate to develop I4.0 hyper-flexible manufacturing operating systems, which will represent the platform for systems integration and applications development. By 2022, the value of the domestic market for IoTs should amount to ~USD8 billion	Yes
India	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Malaysia	Working group/ mechanism set up to develop a strategy	TBD	MITI	TBD	TBD	TBD	TBD	Yes
Thailand	20-YNS and 12-NESDP	2017-2036	Ministry of Industry	Help Thailand overcome middle-income trap Reduce disparities, and imbalanced development Promote a science, technology and innovation-driven economy	Identification of 10 existing (5) and emerging (5) strategic industries	Digital parks, development zones Learning centres International collaboration mechanisms Investment in high-speed internet infrastructure Institutional reforms to create framework conditions for the development of key industries, including	TBD	Yes

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators	Policy synergies
						specific incentives (corporate tax reductions, R&D subsidies)		
Viet Nam	In progress under Directive (16/CT-TTg)	2025 with milestones for 2020	MOST is the leading agency but responsibilities were distributed across different agencies at different government levels	Strengthening the country's capacity to address I4.0	Broadly defined as ICTs, education, science and technology, but also in fiscal and foreign trade	TBD	TBD	Yes
Ethiopia	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Kenya	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
South Africa	IPAP 2017/18-2019/20	Variable depending on initiatives	DTI and DST	Enhanced policy coordination Reform of institutional environment to boost R&D, innovation and commercialization of domestic technologies Enhance digitalization of the economy	Broadly defined	Inter-agency collaborative initiatives Development of scenarios for the development of I4.0 and required policy responses Specific funding for I4.0-related activities Initiatives to promote uptake and diffusion of domestic-generated technologies	Targets for government seed investment Number of initiatives to protect employment by supporting non-I4.0 industries	Yes

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators	Policy synergies
Egypt	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Morocco	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Kazakhstan	Government decree expected end of 2017	2025	TBD	TBD	Mining and others TBD	Foster modernization of key, strategic large firms	TBD	TBD
Turkey	Working group/ mechanism set up to develop a strategy	TBD		TBD	Industries such as automotive, white goods, textiles, chemicals, food and beverages, and machinery will be used as models to inform the domestic strategy	TBD	TBD	TBD

Notes: IPAP: Industrial Policy Action Plan; PEII, Programa Estratégico Industrias Inteligentes; 20-YNS: 20-Year National Strategy (2017-2036); 12-NESDP: 12th National Economic and Social Development Plan (2017-2021); MOST: Ministry of Science and Technology; MITI: Ministry of International Trade and Industry; TBD: To be defined.

Source: Author

5. Concluding remarks

That economists are not fortune-tellers who can, to any degree of certainty, predict the future is well known; their tools, however, can "help people avoid jumping to fallacious conclusions" (Hausman and Gutting, 2015). This vantage point seems appropriate to assess the profound social, economic, political and organizational transformations expected from I4.0. Despite the frequently uncritical reading of the technological trends underpinning the Fourth Industrial Revolution, particularly among large international consulting firms, it remains problematic to determine their impacts on industrial activity and society at large. Even in pioneering countries such as Germany or the U.S., concrete policy initiatives around I4.0 remain, at best, at initial stages of implementation. Despite the emerging calls to direct I4.0 towards achieving development goals such as energy efficiency and environmental sustainability, it is evident that we are still struggling to answer "more immediate" questions on the potential implications of I4.0 on economic performance (UNIDO, 2017). Objective, evidence-based debates in academic, political and economic circles should continue to inform the decision-making of those responsible to ensure that national economies are able to adjust and endorse I4.0.

The stakes are high. According to Lee and Malerba (2017), this new wave of technological change has the potential to alter industrial leadership, while affecting the prospects and conditions by a whole host of middle-income economies to catch up. Industrial policy debates are pertinent within an evolving institutional framework around the development of global manufacturing, including a possible revival of protectionist inclinations even in former free market champions (Buttonwood, 2017; The Economist, 2017a). From the Obama administration's decision to bail out the U.S. car manufacturing industry to the more radical "blame it on your neighbour" stance of the current U.S. administration, the intent is to help manufacturing firms deal with recent economic crises or to allow them to undertake the transformations required to ensure long-term sustainability and their continued capacity to provide sustainable growth and domestic employment (Buttonwood, 2017; The Economist, 2017b; Kiley, 2016; European Commission, 2017; UNIDO, 2017). The growth of robotics in the U.S. can be explained by efforts to enhance competitiveness and the back shoring of operations previously sent abroad (IFR, 2017).

As the drive for competitiveness and leadership continues to fuel innovation and the development of I4.0, further research is needed to document the extent to which we are indeed entering a new cycle of forging ahead, catching up or falling behind in global manufacturing. Are developing countries

facing additional risks of falling behind? Where is the new leadership emerging? How can industrialized economies continue to prevail, affording their populations the level of well-being enjoyed thus far?

In response to the opportunities and challenges imposed by I4.0, those expecting real solutions yearn to see policymakers come up with well-designed national strategic plans. As noted in Section 3, however, regardless of the interpretation and labels used by different countries to characterize the transition towards advanced manufacturing practices, it is still too early to draw conclusions from ongoing efforts around I4.0. Policymakers should be wary of one-size-fits all solutions. The ability to endorse I4.0 is highly contextual; it requires a profound understanding of current productive and technological structures of domestic manufacturing firms and careful consideration of any gaps in the framework conditions surrounding the manufacturing sector. Enhancing digitalization and the development of a digital culture among different social and economic agents are obvious priorities.

This paper demonstrates that while middle-income countries generally acknowledge the significance of I4.0, in practice, the rhetoric is yet to translate into practical, consistent and well-thought out action. Policymakers are slowly getting ready for I4.0; they are in the learning mode, looking for exemplary experiences domestically and abroad to inform policymaking. This lack of structured strategy contrasts with the top-down approach observed in highly industrialized countries; for instance, the Digital Transformation Monitor (2017b) finds that while diverse stakeholders are participating in the design and development of national I4.0 strategies, national governments remain in the driver's seat. What may perhaps be more troublesome is the fact that the approach to I4.0 in several middle-income countries requires stronger links to broader national development strategies. We concur with the Digital Transformation Monitor (2017b) that it is crucial for national strategies on I4.0 to include clearly specified objectives with measurable milestones and consistent indicators associated with rigorous monitoring and evaluation mechanisms. This is also relevant in the case of developed countries, where clearly specified annual or multiannual targets remain absent (Digital Transformation Monitor, 2017b).[19]

The absence of carefully planned investment requirements to underpin I4.0 strategies or roadmaps is conspicuously absent in middle-income countries. This is in stark contrast with more industrialized countries, in which public funding plays a major role. And yet clear efforts are being

[19] Digital Transformation Monitor (2017b) identifies the United Kingdom's High-Value Manufacturing Catapult as a notable exception, as it has introduced clear targets and monitoring and evaluation cycles.

made to attract private investment with an emphasis on the leveraging power associated with public funding (Digital Transformation Monitor, 2017b). The United Kingdom is an interesting case in point, having achieved a private-public funding leverage ratio of about 17:1, exceeding that observed in any other European initiative by more than threefold. This success can to a large extent be explained by the ability to secure significant private funds through competitive R&D contracts and strategic and dedicated support schemes for SME engagement with key industrial partners (Digital Transformation Monitor, 2017b). The provision of tax incentives for private R&D is considered an interesting feature of France's L'Industrie du Future.

On the positive side—and consistent with developed country approaches to I4.0—developing country responses also recognize that a diversity of actors needs to participate in designing and implementing advanced manufacturing strategies. Multi-stakeholder participatory processes constitute a basic tenet of strategic policy responses to I4.0. However, while collaborative approaches to I4.0 may facilitate the convergence of industrial and other types of policies, successful collaboration is not always warranted. The organizations involved differ in terms of their institutional structure and practices according to historical circumstances, innovation priorities, etc. (López-Gómez et al., 2017). This diversity of actors invites reflection on the co-evolutionary processes that need to emerge to facilitate smooth adoption of I4.0. Enhanced policy coordination at different levels is expected to influence future policymaking (OECD, 2017). The Digital Transformation Monitor (2017b) cautions, however, that while the trend is to create large multi-stakeholder platforms, the bulk of existing initiatives, particularly in developed countries, mostly respond to the needs of individual firms or organizations.

Technologies that are part of the I4.0 suite are transversal, suitable for applications tailored to the needs of specific industries. This flexibility contributes to explaining the heterogeneity of industries middle-income countries are placing their bids on. As discussed in this paper, the most obvious starting point is to focus on industries that already possess some comparative advantage. While many such industries are high-tech driven, interest in agriculture and the service sector should not be negligible. Malaysia, Thailand and South Africa have undertaken efforts to distinguish sunset from sunrise industries, while they are open to consider new industries that have yet to emerge, as I4.0-related technologies and associated markets gain momentum. Those industries are expected to provide new opportunities for employment and income.

Limited progress towards developing national I.4.0 strategies in middle-income countries makes it difficult to identify policy instruments that may enable the domestic economy's transition towards I4.0. This underscores the importance of the already mentioned attitude towards learning from ongoing pilot projects carried out by diverse organizations domestically and abroad. While this multiplicity of actions necessarily implies a heterogeneous set of indicators to assess progress, Section 4.1.8 decries the fact that performance indicators remain loosely defined; assessing progress in the implementation of national I4.0 strategies remains problematic. Committing to improvements in monitoring and evaluation would help policymakers make sense of the emerging evidence and to validate what works and what does not, and in which contexts.

International policy coordination and collaboration should continue to buttress efforts to leap forward, enabling organizations and countries to share knowledge and experiences. Policymakers should keep an eye on emerging questions around intellectual property rights, standard compliance and other issues involving consumers and reproductions of protected products that are expected to emerge as advanced manufacturing gains momentum (Hall, 2013).

Just like the technological trends underpinning I4.0 are expected to deepen in coming years, countries included in our review should continue to make progress in their efforts around I4.0, while other countries are expected to follow suit, launching their own roadmaps or full-fledged development strategies. Given this state of flux, any conclusion or recommendations stemming from a paper like this can be expected to be relatively short-lived. The discussion should inform the trails being followed and the decisions being made by early adopters, while providing some useful leads to those policymakers still grappling with questions on how to initiate their march towards I4.0.

References

Baena, Felipe, Alvaro Guarin, Julian Mora, Joel Sauza, and Sebastian Retat. 2017. "Learning Factory: The Path to Industry 4.0." *Procedia Manufacturing*, 7th Conference on Learning Factories, CLF 2017, 9 (January):73–80. https://doi.org/10.1016/j.promfg.2017.04.022.

Baxter, Will. 2017. "Thailand 4.0 and the Future of Work in the Kingdom." Background article. International Labour Office. http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/documents/meetingdocument/wcms_549062.pdf.

Berger, Roland. 2016. "The Industrie 4.0 Transition Quantified. How the Fourth Industrial Revolution Is Reshuffling the Economic, Social and Industrial Model." Think, Act beyond Mainstream.

Board of Investment. 2017. "Thailand 4.0 Means Opportunity Thailand." *Thailand Investment Review*, 2017.

Buttonwood. 2017. "The Manufacturing Jobs Delusion." *The Economist*, 2017. http://www.economist.com/blogs/buttonwood/2017/01/economics-and-finance.

Cassidy, John. 2002. *Dot.Con: The Greatest Story Ever Sold*. 1st edition. New York: Harper.

CESSI Argentina. n.d. "Cámara de La Industria Argentina Del Software | CESSI Argentina." CESSI Realizó El Evento Panorama de La Transformación Digital de La Producción. Accessed September 20, 2017a. http://www.cessi.org.ar/index.php?lang=ingles.

———. n.d. "Mapa de La Transformación Digital: News | CESSI Argentina." CESSI. Accessed September 20, 2017b. http://www.cessi.org.ar/view-news-mapa-de-la-transformacion-digital-2023.

CORFO. 2016. "Programa Estratégico Industrias Inteligentes. Resumen Ejecutivo." Chilean Economic Development Agency. http://www.agendaproductividad.cl/wp-content/uploads/sites/22/2014/10/Programa-Estrat%C3%A9gico-Industrias-Inteligentes.pdf.

Daudt, Gabriel, and Luiz Daniel Willcox. 2016. "Reflexões Críticas a Partir Das Experiências Dos Estados Unidos E Da Alemanha Em Manufatura Avançada." *BNDES Setorial* 44:5–45.

Deloitte. 2016. "Industry 4.0 Is Africa Ready for Digital Transformation?" Deloitte.

Department of Trade and Industry. 2016a. *Industrial Policy Action Plan 2017/18 - 2019/20. Economic Sectors, Employment and Infrastructure Development Cluster*. Vol. 1. 2 vols. Department of Trade and Industry Republic of South Africa.

———. 2016b. *Industrial Policy Action Plan 2017/18 - 2019/20. Economic Sectors, Employment and Infrastructure Development Cluster*. Vol. 2. 2 vols. Department of Trade and Industry Republic of South Africa.

Digital Transformation Monitor. 2017a. "Germany: Industrie 4.0." European Commission. https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Industrie%204.0.pdf.

———. 2017b. “Key Lessons from National Industry 4.0 Policy Initiatives in Europe.” European Commission. https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Policy%20initiative%20comparison%20v1.pdf.

DTI. 2016. “Industrial Policy Action Plan IPAP 2016/17-2018/19.” Department of Trade and Industry Republic of South Africa. http://www.thedti.gov.za/DownloadFileAction?id=1082.

Economic Planning Unit. 2016. “Strategy Paper 15: Driving ICT in the Knowledge Economy.” 15. Strategy Paper. Economic Planning Unit. http://www.epu.gov.my/sites/default/files/Strategy%20Paper%2015.pdf.

European Commission. 2017. “New Industrial Policy Strategy.” Text. European Commission. 2017. https://ec.europa.eu/commission/news/new-industrial-policy-strategy-2017-sep-18_en.

Federal Ministry for Economic Affairs and Energy. 2017. “Plattform Industrie 4.0.” 2017. http://www.plattform-i40.de/I40/Navigation/EN/Home/home.html.

Fundación Chile, and Microsoft. 2016. “Chile 4.0. Cloud Computing Y El Futuro de La Productividad.” Fundacion Chile. https://fch.cl/recurso/corporativo/chile-4-0-cloud-computing-futuro-la-productividad/.

Gates, Doug, and Michael Bremicker. 2017. “Beyond the Hype. Separating Ambition from Reality in i4.0.” KPMG International. https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2017/05/beyond-the-hype-separating-ambition-from-reality-in-i4.0.pdf.

GMIS. 2017. “Global Manufacturing and Industrialisation Summit.” The Summit. 2017. https://gmisummit.com/thesummit/.

Gobierno Nuevo León. 2017. “Inicia Revolución Tecnológica ‘Nuevo León 4.0.’” http://www.nl.gob.mx/noticias/inicia-revolucion-tecnologica-nuevo-leon-40.

Government of the Republic of Kazakhstan. 2017. “Analysis of Kazakh Industry’s Preparedness for Industry 4.0 to Be Completed next Month.” News. 2017. http://www.government.kz/en/novosti/1011306-analysis-of-kazakh-industry-s-preparedness-for-industry-4-0-to-be-completed-next-month.html.

Grant Thornton. 2017. “India’s Readiness for Industry 4.0. A Focus on Automotive Sector.” http://www.grantthornton.in/globalassets/1.-member-firms/india/assets/pdfs/indias_readiness_for_industry_4_a_focus_on_automotive_sector.pdf.

GTCC. 2017. “Corporates and SMEs Focus of Industry 4.0.” Deutsch-Thailändische Industrie- Und Handelskammer. 2017. http://thailand.ahk.de/en/business-info/news/single-view/artikel/corporates-and-smes-focus-of-industry-40/?cHash=0d308a0232a7d845f191c631b7e79fdf.

Hall, Brownyn. 2013. “Is Intellectual Property Important for Future Manufacturing Activities?” Future of Manufacturing Project Evidence Paper 12. Foresight, Government Office for Science, UK. https://moodle.adaptland.it/pluginfile.php/27504/mod_resource/content/3/ep12-intellectual-property-importance-uk-manufacturing.pdf.

Hallward-Driemeier, Mary, and Gaurav Nayyar. 2017. *Trouble in the Making? The Future of Manufacturing-Led Development*. Conference edition. World Bank.

Harnhirun, Somchai. n.d. "Ministry of Industry's Role in Thailand 4.0." http://www.jtecs.or.jp/wp-content/uploads/hpb-media/PPTTNI.pdf.

Hausman, Daniel, and Gary Gutting. 2015. "What Economics Can (and Can't) Do." Opinionator. 2015. //opinionator.blogs.nytimes.com/2015/07/14/what-economics-can-and-cant-do/.

IFR. 2017. "Executive Summary World Robotics 2017 Industrial Robots." International Federation of Robotics. https://ifr.org/downloads/press/Executive_Summary_WR_2017_Industrial_Robots.pdf.

Indonesia Economic Forum. 2016. "Industry Minister Says Indonesia Is Preparing for Industry 4.0." Indonesia Economic Forum 2016. 2016. http://www.indonesiaeconomicforum.com/article/read/industry-minister-says-indonesia-is-preparing-for-industry-40.

Infosepp. 2015. "Industria 4.0: Escenarios E Impactos Para La Formulacion de Poiticas Tecnologicas En Los Umbrales de La Cuarta Revoulcion Industrial." *Infosepp* 5 (21):1–4.

Kiley, David. 2016. "As Obama Takes Victory Lap over Auto Industry Rescue, Here Are the Lessons of the Bailout." *Forbes*, 2016. https://www.forbes.com/sites/davidkiley5/2016/01/20/obamas-takes-victory-lap-over-auto-industry-rescue/#2edbb1f23e83.

Lee, Keun, and Franco Malerba. 2017. "Theory and Empirical Evidence of Catch-up Cycles and Changes in Industrial Leadership." *Research Policy* 46 (2):337. https://doi.org/10.1016/j.respol.2016.09.008.

López-Gómez, Carlos, David Leal-Ayala, Michele Palladino, and Eoin O'Sullivan. 2017. "Emerging Trends in Global Advanced Manufacturing: Challenges, Opportunities and Policy Responses." United Nations Industrial Development Organization and University of Cambridge's Institute for Manufacturing.

Mackay, Charles. 1995. *Extraordinary Popular Delusions and the Madness of Crowds*. New edition, Edition. Ware: Wordsworth.

Make In India. 2017. "Towards Smart Manufacturing: Industry 4.O and India." Make In India. 2017. http://www.makeinindia.com/article/-/v/towards-smart-manufacturing-industry-4-0-and-india.

Manyika, James, Jeff Sinclair, Richard Dobbs, Gernot Strube, Louis Rassey, Jan Mischke, Jaana Remes, et al. 2012. "Manufacturing the Future: The next Era of Global Growth and Innovation." McKinsey & Company. http://www.mckinsey.com/business-functions/operations/our-insights/the-future-of-manufacturing.

McKinsey & Company. 2015. "Made in Brazil: Smarter, Leaner Businesses." McKinsey Blog. 2015. http://www.mckinsey.com/about-us/new-at-mckinsey-blog/made-in-brazil-smarter-leaner-businesses.

Ministry of Economy. 2016. “Crafting the Future a Roadmap for Industry 4.0 in Mexico.” Mexico City: Ministry of Economy, Mexico. https://clusterinstitute.com/Documentos/MRT_Industry_I40.pdf.

Ministry of Industry. 2017. “Ministry of Industry and Siemens to Collaborate on Digitalizing Egypt’s Industrial Sector.” Press release 17 September. http://www.middleeast.siemens.com/pool/news_press/170917-egypt-digi-roadshow-en-final.pdf.

MITI. 2017. “Industry 4.0. FAQs on Industry 4.0.” Ministry of International Trade and Industry. 2017. http://www.miti.gov.my/index.php/pages/view/4305.

MOST. 2017. “Industry 4.0 a Test for Large Workforce Sectors.” Ministry of Science and Technology. https://www.most.gov.tw/vietnam/en/detail?article_uid=4c6d7084-6695-448f-a4ff-d4580d254995&menu_id=bf3f7895-149d-4de4-8a72-23105aae7dfd&content_type=P&view_mode=gridView.

Nguyễn Xuân Phúc. 2017. “Directive 16/CT-TTg Strengthening of the Ability to Access the Fourth Industrial Revolution.” THƯ VIỆN PHÁP LUẬT. 2017. https://thuvienphapluat.vn/van-ban/Dau-tu/Directive-16-CT-TTg-strengthening-of-the-ability-to-access-the-Fourth-Industrial-Revolution-361701.aspx.

OECD. 2017. “The next Production Revoution. Implications for Governments and Business.” Organisation for Economic Co-operation and Development. http://www.oecd.org/sti/ind/next-production-revolution.htm.

Perez, Carlota, and Luc Soete. 1988. “Catching up in Technology: Entry Barriers and Windows of Opportunity.” In *Technical Change and Economic Theory*, edited by Giovanni Dosi, Chris Freeman, Richard R. Nelson, Gerard Silverberg, and Luc Soete, 458–79. London: Francis Pinter.

Portal Brasil. n.d. “Brasil quer fortalecer parceria com a Alemanha na indústria 4.0.” Notícia. Portal Brasil. Accessed September 4, 2017a. http://www.brasil.gov.br/economia-e-emprego/2016/10/brasil-quer-fortalecer-parceria-com-a-alemanha-na-industria-4-0.

———. n.d. “Governo lança diretrizes para plano nacional de manufatura.” Notícia. Portal Brasil. Accessed September 4, 2017b. http://www.brasil.gov.br/economia-e-emprego/2016/11/governo-lanca-diretrizes-para-plano-nacional-de-manufatura.

———. n.d. “Grupo de Trabalho Coordenado Pelo MDIC Debate Estratégia Para a Indústria 4.0.” Accessed September 4, 2017c. http://www.mdic.gov.br/index.php/noticias/2713-grupo-de-trabalho-coordenado-pelo-mdic-debate-estrategia-nacional-para-a-industria-4-0.

———. n.d. “MDIC Instala Grupo de Trabalho Que Definirá Estratégia Nacional Para a Indústria 4.0 No Brasil.” Accessed September 4, 2017d. http://www.mdic.gov.br/index.php/noticias/2640-mdic-instala-grupo-de-trabalho-que-definira-estrategia-nacional-para-a-industria-4-0-no-brasil.

Presidencia de la República. 2017. “Estrategia Digital Nacional.” Gob.mx. 2017. http://www.gob.mx/presidencia/acciones-y-programas/estrategia-digital-nacional-15899.

PwC. 2016a. “2016 Global Industry 4.0 Survey. Industry 4.0: Building the Digital Enterprise.” www.pwc.com/industry40.

———. 2016b. “Industry 4.0: Building the Digital Enterprise. South Africa Highlights.” www.pwc.com/industry40.

Roland Berger GMBH. 2016. “Skill Development for Industry 4.0.” Whitepaper. BRICS Business Council. India Section. http://www.globalskillsummit.com/Whitepaper-Summary.pdf.

Schwab, Klaus. 2016. *The Fourth Industrial Revolution*. New York: Crown Business.

Sistema FIEB. n.d. “Inauguração Da Fábrica Modelo Brasil.” O Portal Da Indústria Baiana. Accessed September 11, 2017. http://fieb.org.br/Evento/1373/Inauguracao-da-Fabrica-Modelo-Brasil.aspx.

Strategy 2050. 2017. “Industry 4.0: How the Fourth Industrial Revolution Works.” strategy2050.kz. 2017. http://strategy2050.kz/en/news/48918/.

Tansan, Burak, Aykan Gökbulut, Çağlar Targotay, and Eern Tevfik. 2016. “Industry 4.0 in Turkey as an Imperative for Global Competitiveness. An Emerging Market Perspective. Executive Summary.” Istanbul: Turkish Industry and Business Association.

Thailand 4.0. 2017. “Industrie 4.0 in Thailand 4.0.” 2017. http://www.industrie4thailand.com/#.

Thailand’s Government Public Relations Department. 2016a. “Developing the Country toward Thailand 4.0.” กรมประชาสัมพันธ์. 2016. http://thailand.prd.go.th/ewt_news.php?nid=4498&filename=index.

———. 2016b. “Thailand’s 20-Year National Strategy and Thailand 4.0 Policy.” กรมประชาสัมพันธ์. 2016. http://thailand.prd.go.th/ewt_news.php?nid=3578&filename=index.

———. 2017. “Government to Drive Robot Industry in Thailand.” กรมประชาสัมพันธ์. 2017. http://thailand.prd.go.th/ewt_news.php?nid=5762&filename=index.

ThailandToday. 2017. “Thailand-20-Year-National-Strategy.pdf.” Thailand-20-Year-National-Strategy (2017-2036). 2017. http://www.thailandtoday.in.th/sites/default/files/Thailand-20-year-national-strategy.pdf.

The Economist. 2017a. “Sew What Now? Worries about Premature Industrialisation.” Special Report. The Economist. https://www.economist.com/news/special-report/21729864-automation-less-threat-workers-emerging-world-it-made-out.

———. 2017b. “Why Old-Fashioned Manufacturing Jobs Won’t Return to the West.” *The Economist*, 2017. http://www.economist.com/blogs/economist-explains/2017/01/economist-explains-8.

The Nation. 2017. “New Law to Make Thailand More Competitive in Targeted Industries.” *The Nation*, 2017, February 15 edition, sec. Economy. http://www.nationmultimedia.com/news/business/EconomyAndTourism/30306346.

The Prime Minister of Kazakhstan. 2017. “System-Forming Enterprises of Kazakhstan Are Ready for Changes within the Framework of Industry 4.0.” The Prime Minister of Kazakhstan. Official Website. 2017. https://primeminister.kz/en/news/all/15171.

Tourk, Khairy, and Peter Marsh. 2016. “The New Industrial Revolution and Industrial Upgrading in China: Achievements and Challenges.” *Economic and Political Studies* 4 (2):187–209. https://doi.org/10.1080/20954816.2016.1180769.

UNIDO. 2017. “Accelerating Clean Energy through Industry 4.0: Manufacturing the next Revolution.” United Nations Industrial Development Organization.

World Economic Forum. 2017. “Readiness for the Future of Production: Country Profiles.” White paper. World Economic Forum. https://www.weforum.org/whitepapers/readiness-for-the-future-of-production-country-profiles.

Annex 1 Examples of policy interventions related to I4.0 in middle-income countries

Interventions targeting investments in infrastructure for I4.0

Country	Leading entity	Intervention
Argentina	Ministry of Science, Technology and Productive Innovation (MSTPI)	Prospective studies on software and informatics services and on the future of ICTs and their application in industry in general, and auto parts in particular (Infosepp, 2015)
Malaysia	Economic Planning Unit	In the context of the 11th Malaysia Plan, Strategy Paper 15 provides an overview of issues related to ICTs and the knowledge economy. It recommends building "capabilities and niches in selected technology focus areas [including] digital content, software development and testing, IoT, data centres and cloud services, cyber security and big data analytics" (Economic Planning Unit 2016, pp. 15–13)
Mexico	Various government entities	Adoption of the National Digital Strategy "Estrategia Digital Nacional" for the deployment and expansion of ICT infrastructure and diffusion of ICT services in the country. The Strategy seeks to improve connectivity, inclusion and digital skills, interoperability, establish an adequate legal framework and open data (Presidencia de la República, 2017)
		Telecommunications reform (2013) to ensure universal coverage of television, radio, telephone and data services throughout the country
		Investment Programme in Transport and Communications Infrastructure 2013-2018 intended to close the digital gap (Presidencia de la República, 2017)
Thailand	Government	In 2017, a reform was passed on the institutional framework of the 10 strategic industries. The National Competitive Enhancement Act for Targeted Industries waives corporate income taxes for up to 15 years, and offers a subsidy of THB 10 billion for R&D investments (The Nation, 2017)
		The strategy to attract investment from leading digital firms relies heavily on the development of the Digital Park Thailand, which will offer tech firms tax breaks, unlimited bandwidth, and direct links to Europe and China's "One Belt, One Road" project (Baxter, 2017)
		The Eastern Economic Corridor (EEC) has been identified as the first area-based development for I4.0 and specific industrial policies and investments targeting strategic industries. The EEC builds on the Eastern Seaboard Development Project, which has been in place for more than 30 years, and which has been at the base of Thailand's export- and FDI-driven industrialization strategy

Viet Nam	Ministry of Information and Communications	Prioritize the development or improvement of 4G mobile communication networks, ensuring stable service delivery throughout the country by 2018. Support should be provided for R&D relating to 5G technologies and IoT
	Ministry of Finance	Design tax and financial mechanisms aimed at encouraging private investment in technology modernization, R&D and ICT infrastructures. Emphasis is placed on speeding up the implementation of Resolution No. 41 / NQ-CP of 2016, on tax preferences for the development and application of ICTs
		Launch of an ambitious Silicon Valley Project, which has attracted significant attention from tech multinationals and international investors

Source: Author compilation

Examples of dedicated programmes to support I.4.0 development

Country	Leading entity	Intervention
Chile	CORFO	PEII implementation: Development of transversal synergies and capabilities (development of human resources, interoperability, management, monitoring and evaluation)
		Establishment of self-sustainable, self-governed entities responsible for arranging for technological learning and dissemination labs that function as pilot initiatives to address specific problems, help identify the required stakeholders, and the technological, administrative and other operational processes involved. These entities will be responsible for further digitalization of individual industries, coordinating key sectoral actors, supporting the development of suppliers, human capital and mechanisms to facilitate interoperability, project execution and other activities aligned with specific needs of the respective industry
Mexico	Ministry of Economy	The Programme for the Development of the Software Industry (PROSOFT) promotes projects for the adoption of ICTs, facilitating convergence between advanced manufacturing and digital technologies
Malaysia*	Technical Working Group for Incentives and Funding	Expected to deliver targeted incentives and funding mechanisms to promote the adoption of I4.0
	MITI	Efforts to raise awareness about I4.0, reaching out to different stakeholders including at the state and regional levels. Two major outreach activities took place in 2017 with the participation of national and international stakeholders. Engagement also takes place through one-to-one interactions between the government and individual stakeholders, including online feedback through MITI's website

	Penang Skills Development Centre (PSDC) and German Malaysia Institute	Various platforms are expected to showcase I4.0 applications and attract attention of private firms
	Economic Planning Unit	Plans to reform regulatory frameworks around IoT, strengthening R&D and standards and upgrading infrastructure
		Intention to attract foreign data centres while expanding the growth of local ones through improved guidelines and competitive electricity tariffs and telecommunication costs. Cloud services will follow a similar strategy, attracting leading global cloud service providers and building clusters of domestic firms around them
		Cloud services will follow a similar strategy attracting leading global cloud service providers and building clusters of domestic firms around them
		Adoption of certification programmes linked to different segments of the domestic cybersecurity industry. The priority will be domestically-generated cybersecurity products and services to enable self-reliance
		Regarding big data analytics, concrete initiatives will include collaboration between national and foreign universities around data science programmes, while certification programmes should favour upskilling of the work force
	Multimedia Development Corporation (MDeC), the Malaysian Administrative Modernization and Management Planning Unit (MAMPU) and the National R&D Centre in ICT (MIMOS)	Support the adoption of a National Big Data Analytics framework to push demand for BDA by public and private organizations
	MDeC	Promote partnerships between domestic SMEs and global technology firms, including spin-off centres of excellence across different industries
Thailand		Initiative to support the automotive industry, including an excise tax reduction to 2% for battery electric vehicles (BEVs), hybrid electric vehicles (HEVs) and plug-in electric vehicles (PHEVs), import tax exceptions on electric vehicles (EV) for the first two years and financial support for fuel station investments (Harnhirun, n.d.)
		Establishment of a USD 570 million venture fund targeting start-up development, with emphasis on IoT research, aviation collaboration, e-commerce, e-payments, development of encryption technologies and hardware and software solutions (Baxter, 2017)

Viet Nam	Vietnam Academy of Science and Technology and the Vietnam Academy of Social Sciences	To conduct research and evaluate the trends linked to I4.0, while the work and strategies around I4.0 of other ministries and entities should incorporate regional and local perspectives
		Concrete initiatives in the automotive industry include excise tax reduction to 2% for battery electric vehicles (BEVs), hybrid electric vehicles (HEVs) and plug-in electric vehicles (PHEVs), import tax exceptions on electric vehicles (EV) for the first two years and financial support for fuel station investments (Harnhirun, n.d.)

Notes: *Unless otherwise stated, information extracted from Economic Planning Unit (2016).

Source: Author compilation

Examples of vocational training and higher education programmes around I4.0-related competencies

Country	Leading entity	Intervention
India	Indian Institute of Science (IISc)	IISc is building the country's first smart factory in Bengaluru with seed funding from Boeing Co. (Make In India, 2017)
Viet Nam		Plan to reform education policies, contents and methods, with an emphasis on science, technology, engineering and mathematics (STEM), foreign languages, informatics in general education, etc.

Source: Author compilation

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