Differentiation of Industry 4.0 Models

The 4th Industrial Revolution from different Regional Perspectives in the Global North and Global South

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Abstract

This paper addresses the regionally different approaches or strategies in selected countries from the Global North as well as the Global South in discussing the *Fourth (4th) Industrial Revolution* (4IR) and its representation in manufacturing, *Industry 4.0* (I4.0). The 4IR marks a digitally-enabled and technologically driven paradigmatic change that will not only disrupt industries and the economic system, but will have its effects on the society and environment as a whole. As technological, economic and societal innovations and transformations are closely linked with one another, the 4IR will bring opportunities and challenges that require country-specific adaptation and mitigation strategies that address both, a country's strengths and weaknesses. The core premise of this comparative analysis is the existence of a basic difference in the motivation between on the one hand the frontrunner countries in the Global North that so far coin the global 4IR/ I4.0 discourse and on the other hand the countries in the Global South that aim to utilize this transformation processes to catch up in the global competition. The selected countries and their strategic approaches towards the 4IR represent fully industrialized (*Germany's Industrie 4.0, Japan's Society 5.0,* and *USA's Industrial Internet of Things*) and emerging industrial economies (*China's Made-in-China 2025, Indonesia's Making Indonesia 4.0,* and *Mexico's Crafting the Future*).

Keywords[1]: B10, B22, H11, H50, I25, J24, O14, O15, R11, R58

[1] **JEL Classification Codes: B10** (General: History of Economic Thought, Methodology, and Heterodox Approaches), **B22** (Macroeconomics), **H11** (Public Economics: Structure, Scope, and Performance of Government), **H50** (General: National Government Expenditures and Related Policies), **I25** (Education and Economic Development), **J24** (Human Capital • Skills • Occupational Choice • Labor Productivity), **O14** (Industrialization • Manufacturing and Service Industries • Choice of Technology), **O15** (Human Resources • Human Development • Income Distribution • Migration), **R11** (Regional Economic Activity: Growth, Development, Environmental Issues, and Changes), **R58** (Regional Development Planning and Policy) (see https://www.aeaweb.org/econlit/jelCodes.php?view=jel#R)

Nomenclature

1IR	First (1^{st}) Industrial Revolution
2IR	Second (2^{nd}) Industrial Revolution
3IR	Third (3^{rd}) Industrial Revolution
4IR	Fourth (4^{th}) Industrial Revolution
AEM	Space Agency, Mexico
AI	Artificial Intelligence
AM	Advanced Manufacturing, USA
AMITI	Association of Information Technologies, Mexico
AMP	Advanced Manufacturing Partnership, USA
AR	Augmented Reality
ASEAN	Association of Southeast Asian Nations
BKPM	Investment Coordination Board, Indonesia
BMBF	Federal Ministry of Education and Research, Germany
BMWi	Federal Ministry for Economic Affairs and Energy, Germany
BPO	Business Process Outsourcing
BUAP	Benemarita University of Puebla, Mexico
CAO	Cabinet Office, Japan
CEO	Chief Executive Officer
CF	Crafting the Future, Mexico
CHN	China
CIMAT	Center for Research in Mathematics, Mexico
CISTP	China Institute for Science and Technology Policy, Tsinghua University
CONACYT	National Council for Science and Technology, Mexico
CPC	Central Committee of the Communist Party of China, China
CPS	Cyber Physical Systems
CRF	Construction of Research Facilities, USA
DEU	Germany
DTTL	Deloitte Touche Tohmatsu Limited
EDB	Economic Development Board
EIE	Emerging Industrial Economies
EU	European Union
FDI	Foreign Direct Investment
FOMEX	Mixed-Hybrid Fund, Mexico
FORDECYT	Institutional Fund for the Regional Promotion of Scientific and Technological Development and Innovation, Mexico
FTA	Free Trade Agreements
G20	Group of Twenty
GDP	Gross Domestic Product
GOB	Government of Mexico, Mexico
GVA	Gross Value Added
HVMC	High-Value Manufacturing Catapult, United Kingdom
I4.0	Industry 4.0
IC	Industrialized Countries
ICT	Information and Communication Technologies
IdF	L'Industrie du Futur, France
IDN	Indonesia
IDR	Indonesian Rupiah
IIC	Industrial Internet Consortium, USA
IIoT	Industrial Internet of Things, USA
IoT	Internet of Things
IoTAC	Internet of Things Acceleration Consortium, Japan
IoTS	Internet of Things Services

IR	Industrial Revolution
ISIC	International Standard Industrial Classification of all economic activities
IT	Information Technology
ITS	Industrial Technology Services, USA
IVI	Industrial Value Chain Initiative, Japan
IVRA	Industrial Value Chain Reference Architecture – Next, Japan
JPN	Japan
KANTEI	The Prime Minister of Japan and His Cabinet, Japan
KINAS	National Industrial Committee, Indonesia
KPMG	Klynveld Peat Marwick Goerdeler
MCE	Manufacturing Centers of Excellence, USA
METI	Ministry of Economy, Trade and Industry, Japan
MEX	Mexico
MEXT	Ministry of Education, Culture, Sports, Science and Technology, Japan
MHLW	Ministry of Health, Labor and Welfare, Japan
MI4.0	Making Indonesia 4.0, Indonesia
MIC2025	Made-in-China 2025, China
MIIT	Ministry of Industry and Information Technology, China
MNCs	Multi-National Corporations
MOD	Ministry of Defense, Indonesia
MOEC	Ministry of Education and Culture, Indonesia
MOF	Ministry of Finance, Indonesia
MOH	Ministry of Health, Indonesia
MOI	Ministry of Industry, Indonesia
MOM	Ministry of Manpower, Indonesia
MORA	Ministry of Religious Affairs, Indonesia
MORTHE	Ministry of Research, Technology and Higher Education, Indonesia
MOSOE	Ministry of State Owned Enterprises, Indonesia
MOST	Ministry of Science and Technology, China
MOST	Ministry of Science and Technology, Thailand
MTT	Manufacturing Technology Testbeds, USA
MVA	Manufacturing Value Added
MYS	Mean Years of Schooling
NAFTA	North American Free Trade Agreement
NDRC	National Development and Reform Commission, China
NDS	National Digital Strategy, Mexico
NIC	Newly Industrializing Countries
NIST	National Institute of Standards and Technology, USA
NMIP	Network for Manufacturing Innovation Program, USA
NNMI	National Network for Manufacturing Innovation, USA
NSTC	National Science and Technology Council, USA
ÖAW	Austrian Academy of Sciences
OECD	Organization for Economic Co-operation and Development
PCAST	President's Council of Advisors on Science and Technology, USA
pp.	Percentage Points
PPP	Purchasing Power Parity
PWC	PricewaterhouseCoopers
RAUN	Regional Academy on the United Nations
R&D	Research and Development
RRI	Robot Revolution Initiative, Japan
RTA	Regional Trade Agreements
S5.0	Society 5.0, Japan
SDG	Sustainable Development Goals
SGI	Services of General Interest

SE	Secretariat of Economy, Mexico
SI	Smart Industry, Netherlands
SME	Small and Medium Enterprises
SMNDP	Ministry of National Development Planning, Indonesia
STEM	Science, technology, engineering, and mathematics
STRS	Scientific and Technical Research Services, USA
TBY	The Business Year
UN	United Nations
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USCC	United States Chamber of Commerce
US$	United States Dollar
VIC	Vienna International Centre
VID	Vienna Institute of Demography
VR	Virtual Reality
WEF	World Economic Forum
WTO	World Trade Organization
WWII	Second (2nd) World War

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> *"You cannot wait until a house burns down to buy fire insurance on it. We cannot wait until there are massive dislocations in our society to prepare for the Fourth Industrial Revolution."*
> — Prof. Robert J. SHILLER (Economist, Yale University and 2013 Nobel laureate in economics)[2]

1 Introduction

The *Fourth (4th) Industrial Revolution* (4IR) and its representation in manufacturing, *Industry 4.0* (I4.0), is not a futuristic concept, but is happening now. The 4IR as paradigmatic change will have far-reaching implications for nations, industries, academia and people all around the world. In this era of transformation, it requires a vision to conceptualize, facilitate and implement comprehensive adaptation and mitigation strategies.

The world is facing major challenges, like eradicating poverty (incl. extreme poverty), hunger, rising inequalities (incl. gender inequality), (youth) unemployment, more frequent and intense natural disasters, spiraling conflict, violent extremism, terrorism and related humanitarian crisis and forced displacement of people, natural resource depletion, environmental degradation (incl. desertification, droughts, loss of biodiversity, etc.), climate change, etc. (UN, 2015). Therefore the United Nations adopted the 2030 Agenda for Sustainable Development by addressing those challenges with outlining 17 majors Sustainable Development Goals (SDGs) with 169 targets to end poverty and hunger, protect the planet, and ensure prosperity for all (UN General Assembly, 2015). The 4IR is expected to positively contribute to accelerate the global progress towards the SDGs (World Bank, 2018a), whereby I4.0 is often envisaged as savior with solely beneficiary aspects, where technology innovation triggers economic growth, the creation of jobs and generates prosperity as well as energy and resource efficiency in mitigating climate change impacts (European Commission, 2017a; Fukuyama, 2018; Heider, 2016; Herold, 2016; Keidanren, 2017; Sorko et al., 2016; The Economist, 2017; United Nations, 2016). Indeed, I4.0 will bring innovative technologies to create broader access to clean energy, including more environmental and sustainable production value chains as well as it might enhance smallholder production or potentially has equalizing effects on wages on a global level (Norton, 2017; Schwab, 2017; UNIDO, 2017a, 2017b).

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[2] At the WEF 2016 Annual Meeting in Davos (Switzerland) nine quotes that sum up the Fourth Industrial Revolution were collected (see https://www.weforum.org/agenda/2016/01/9-quotes-that-sum-up-the-fourth-industrial-revolution/) (Herold, 2016; WEF, 2016)

But on the other hand, this emerging technological progress will create a structural transformation that will affect the future location of global centers of manufacturing and might involve the risk that especially low-income countries fail to succeed in the global competition for attracting industry. One threat might be that wealth inequality will further increase and leave poor countries behind, if they cannot adapt fast enough for creating an I4.0 equipped economy and high-skilled labor force. Additionally, struggles might occur to integrate smallholders and SMEs in rural economies in the new production schemes as well as to stay competitive in a global economy, when the comparative advantage of low labor costs diminishes and production sites might be relocated closer to the consumer. There is a chance that people, especially in low income countries, could be excluded from this transformation, enforcing the global economic inequality (Norton, 2017; Schwab, 2017; Singh, 2016; UNDP, 2018a). To ensure an inclusive and sustainable transformation, Norton (2017) argues to incorporate politics and revise the tax system to the emerging needs of a changing global economic system. Key challenges for a timely and successful achievement of the SDGs worldwide are **(A)** a substantial *lack of global leadership* to inspire policy change, investment, inclusion, awareness, and mobilization towards the SDGs, **(B)** a *knowledge of the SDG facets*, including the implications of I4.0 on how people might work, produce, consume and spend their time after the now emerging transformation, and **(C)** a need to *unify targets* for all countries, e.g. setting universal standards for clean energy production, clean water, etc. (Singh, 2016; Tsvetkova, 2017).

As a step towards understanding the processes and potential global implications of the 4IR and I4.0 further research has to be conducted, taking regional perspectives, strategies and challenges into account. Thereby, a distinction in the analysis between countries/ regions in different development stages is required to sketch different approaches and create a broader understanding for the potential prospective development. This conceptual paper focuses on the reappraisal of the perceptions as well as adaptation and mitigation strategies of case study countries in the Global North and Global South (Grugel and Hout, 1999) to open up the analytical frame not only on Industrialized Countries (IC), but also Emerging Industrial Economies (EIE) in the so called Global South (UNIDO, 2017a). This is especially relevant as most research and political strategies are originating in countries in the Global North, what has notable implications on the global discourse on the 4IR and I4.0 (Buer et al., 2018; Buica, 2016; Liao et al., 2017).

In the context of the *Regional Academy on the United Nations* (RAUN), under the superordinate theme *"Innovations for Development: 'Towards Peaceful, Sustainable and Inclusive Societies'"* this work aims to contribute to this research desideratum by pursuing the question what general concepts of 4IR/ I4.0 can be identified, how they might differ, and how countries in different development contexts approach this topic and from what perspective and thematic foci the topic is tackled.

The paper starts with contextualizing and differentiate the 4IR and I4.0 from a theoretical and historical perspective (see Section 2) before illustrating the research design (see Section 3). This will provide the basis for examining regional public and private approaches to cope with the opportunities and challenges of the 4IR in the Global North (see Section 4.1) and Global South (see Section 4.2) before comparing the regionally different strategies (see Section 4.3) and providing concluding remarks (see Section 5) with a comparison of the different approaches found towards I4.0.

2 Theoretical & Historical Framework

The term "*Industrie 4.0*" (I4.0) was first used by Henning Kagermann, the head of the German National Academy of Science and Engineering (Acatech), in 2011, and has since then become very popular (Kagermann et al., 2018, 2011). I4.0 describes "*[…] the use in industrial production of recent, and often interconnected, digital technologies that enable new and more efficient processes, and which in some cases yield new goods and services*." (OECD, 2017a). The term "*Industry 4.0*" is often used interchangeably for the "*4th Industrial Revolution*" (4IR), and even within the scientific community there are neither clear distinctions nor is there a uniform usage of the two denominations. Therefore the terminology has become very fuzzy. However, both terms describe different phenomena and therefore need to be differentiated from one another. But first, the historical development of the steadily changing and advancing industrial sector has to set a framework for defining as what is nowadays known as I4.0.

2.1 Historical Developments

In general, industrial revolutions mark a "*significant technological development*", (Sung, 2018) that has occurred in the past or is about to occur. Thus far there have been identified four industrial revolutions (see Figure 1). The 1st Industrial Revolution (1IR) began in the late 18th century and was mainly characterized by the invention of mechanical systems, e.g. steam locomotives and weaving looms, which were operated with the biggest technological innovation of this era, namely steam power.

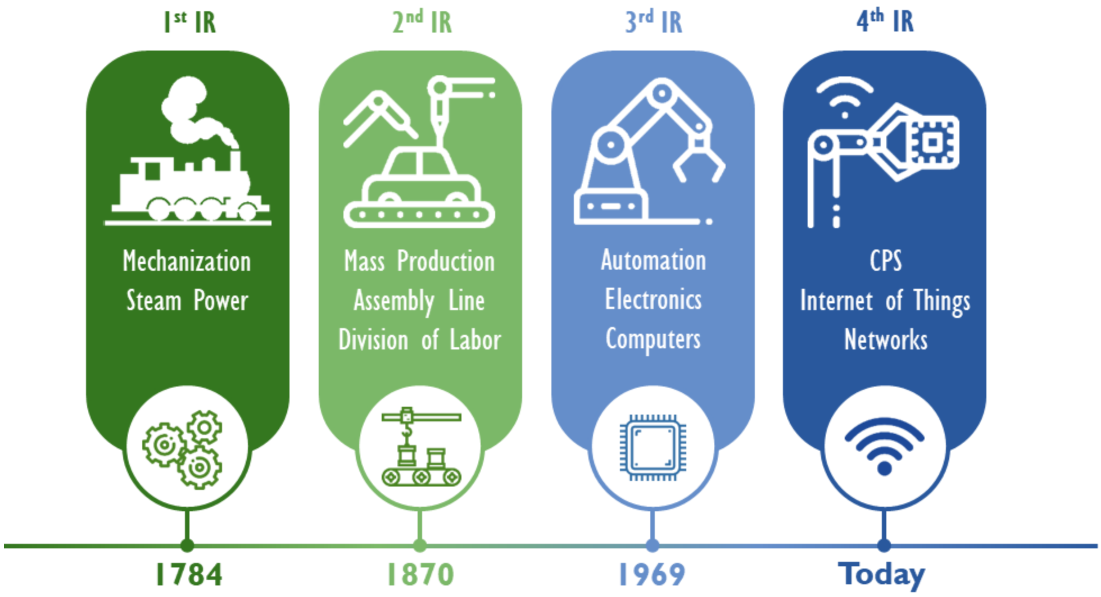

Figure 1: The Four Industrial Revolutions (IR) (authors illustration)[3]

Electrification and the novel installation of assembly lines to implement mass production chains and division of labor are the primal innovations that characterize the 2nd Industrial Revolution (2IR) in the late 19th century. With the introduction of automation, micro-electronics

[3] The vectors files used in this figure are retrieved from the Free Vector Icon Platform Flaticon.com and adapted by the authors (see https://www.flaticon.com/)

and computer technology to the world of manufacturing the 3rd Industrial Revolution (3IR) started in the Mid-late 20th century (Xu et al., 2018). The 4th Industrial Revolution (4IR) (Schwab, 2017) marks a „*[…] systemic transformation that includes an impact on civil society, governance structures, and human identity […]*", (Sung, 2018). This new production paradigm of smart and connected production systems is based on *Information and Communication Technologies* (ICT). Humans, machines and virtual worlds start interacting with each other within the framework of this paradigm (Van der Elst and Williams, 2017).

2.2 Theoretical Framework - Linking Technological Advances with Economic Performance

In structuralist paradigms technological and/ or basic innovations are interlinked with the economic performance of market economies and therefore with societal transformations, e.g. changing skill requirements of the labor market. From an evolutionary economic point of view these technological innovations are linked with the emergence of successive economic cycles. One basic innovation heralds the start of an economic upswing in the market economy. Hence, many complementary products, services, manufacturing processes or organizational forms derive from this initial major technological innovation. These alter the economy as a whole as well as its economic sectors. As described with the four IR cyclical economic development and growth is induced by those basic innovations. Although Nikolai Kondratieff (1926) empirically observed these waves and is eponymous for them, eventually Joseph Schumpeter (1939) formulated the so called *Theory of Long Waves*, which is still of high relevance in economic research, e.g. in *Neo-Schumpeterian* paradigms.

2.2.1 Theory of Long Waves (Kondratieff Waves)

The *Theory of Long Waves* refers to technological innovations as drivers of economic booms or upswings. These so-called *Kondratieff Waves* describe long-term economic cycles of recurring economic upswings and subsequent recessions as result of successive industrial revolutions. Innovations potentially create macroeconomic profits that last until the market is saturated and the economic performance of formerly (fast) growing economic sectors and industries is slowing down, stagnating and shrinking again, resulting in an economic recession or even depression. As each cycle is highly coined by a dominant "*techno-economic paradigm*" (Freeman, 2008) that creates new dynamic industries and influences all economic sectors to a certain extent. An economic recession and erosion of profits can only be reversed by the induction of new technologies to initiate another economic wave. Each wave not only creates a new techno-economic paradigm, but has also societal and economic implications like the increase of structural unemployment due the mismatch of the new labor market requirements in skills and qualifications from technological innovations. So, each wave creates high social costs due the declining demand for obsolete skills, occupations, industries and services (Kondratieff 1926, Williamson und Lindert 1980, Freeman 2008). Each new wave of technological and economic development is surrounded by different contexts, e.g. economic, societal, political etc., than the previous one (Freeman, 2008). Not every IR has more than one basic innovation to induce a long wave, thus they do not necessarily overlap entirely.

The emergence of every IR can be linked with distinct geographical locations and countries as innovations are not spatially distributed at random. Therefore every long wave has been induced by a few regional centers, where basic innovations have spawn (Schumpeter, 1939). The emerged economic growth in these regions made innovations quantifiable and in further consequence observable. With each new economic wave respectively IR those centers of innovations have changed. Usually the initial innovations are spread from the centers, which are only a few countries, to other nations.

While the first long wave was spatially located in England, the second as well as the third wave had shifted the technological innovation centers to Germany, Japan and the United States (Dosi, 2007; Freeman, 2008). Since the fourth wave many *Newly Industrializing Countries* (NIC) came into focus next to the before mentioned forerunners in technological innovations. The leading countries had comparative advantages in newly emerging manufacturing processes, while others were not able to adapt quickly enough to the new challenges and requirements. The results are spatial processes of differentiation due to the concentration of technological innovations and hence economic growth. In the past increasing industrialization was perceived as guarantee of a country's economic growth and development as described in Rostow's stage model (1960).

2.2.2 Stage Model of Development

Rostow's (1960) linkage of development and economic growth in his stage model provides a quasi-deterministic assumption that all countries follow the same development pathway[4]. According to this model countries are more or less advanced in these stages, opening a gap between countries worldwide. A distinction between countries of the Global North and Global South evolved in order to differentiate between the few fully industrialized or fully developed countries and the rest. In this process of differentiation the importance of nation states increased steadily although in the recent decades the importance of globalization is not to be denied. (ibid.) Freeman (2008) calls the dissimilar national environments, where innovative processes take place, "*national systems of innovation*". Various development paths that lead to uneven development between but also within countries can be identified and remain a feature of the global(ized) economic system.

In this highly competitive system, countries and industries occasionally "*[…] have forged ahead, whilst others have fallen far behind.*", (Freeman, 2008) in the described economic cycles. During the previous IR, countries with the most pro-active policies for innovation and growth were catching-up to the forerunners, which lead to the rearrangement of the global economic power structures. England, for example, initiated the first wave as well as the 1IR but has fallen behind as the top frontrunner since then. Countries like Germany and the US were able to catch up with England and stay upfront also because of policies accelerating long-term economic growth through industrialization.

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[4] Rowstow's (1960) "*Stages of Growth*"-Model is one of the most prominent historical models of economic growth within the modernization theories. It has been widely criticized for its deterministic, Western-centric perspective on development and neglecting power asymmetries that potentially hinder development, especially in the Global South.

2.3 Defining "*Industry 4.0*" in contrast to the "*4th Industrial Revolution*"

With the emergence of the 4IR the question how to position or how to be positioned as a country in the new techno-economic paradigm has arisen. In order to stay ahead, catch up or prevent from falling behind, countries and companies are pushing strategy papers, which take their national environments into account. These policies aim to restructure the industrial production processes by promoting digitalization and automation manufacturing to increase productivity, competitiveness and sustainability, whilst lowering the (labor) costs. Industry 4.0 (I4.0) is considered as "*[…] manufacturing in the current context […] separate from the fourth industrial revolution in term of scope*.", (Sung, 2018). Although I4.0 is not considered as being consistently defined by the scientific community and mainly known as an *"[…] umbrella term used to describe a group of connected technological advances that provide a foundation for increased digitalization of the business environment […]*", (Skobelev and Borovik, 2017).

Industry 4.0 (I4.0) basically represents the economic point of view, which primarily takes manufacturing/ production into consideration. In its core, the I4.0 concept contains the following aspects:

› **Digitalization** of manufacturing (European Commission, 2017a; UNIDO, 2017a, 2017b)
› **Decentralization** of manufacturing (UNDP, 2018a)
› Vertical and horizontal **integration of the value chain** (BMBF, 2017a; European Commission, 2017b; Forschungsunion, 2012; Heilmann et al., 2016; Plattform Industrie 4.0, 2015; Schroeder, 2016)
› Increased **productivity** (BMBF, 2017a; European Commission, 2017b; Heilmann et al., 2016; Plattform Industrie 4.0, 2015; Schroeder, 2016)
› **Flexibility** (real-time production, customization, etc.) (BMBF, 2017a; European Commission, 2017b; Heilmann et al., 2016; Plattform Industrie 4.0, 2015; Schroeder, 2016)

Components: Cyber-Physical-Systems (CPS), Internet of Things (IoT), and **Technological innovations:** Big Data, additive production (e.g. 3D printing), Cloud computing, Artificial Intelligence (AI), collaborative robotics, Virtual Reality (VR), Augmented Reality (AR) (BKPM, 2017; BMBF, 2017a; Business Sweden, 2018; CPC, 2016; European Commission, 2017b; Forschungsunion, 2012; GOB, 2014; Heilmann et al., 2016, 2016; IIC, 2018, 2015; IVI, 2016; KANTEI, 2016a, 2016b, 2016c, 2016d, 2013a; MOI, 2018a; NSTC, 2018a, 2018b; Plattform Industrie 4.0, 2015; RRI, 2018a, 2018b, 2015; Santiago, 2018; Schroeder, 2016; SE, 2016; TBY, 2018; Waldenberger, 2018)

4IR emerging technologies: Advanced materials, Cloud technology (incl. Big Data), Autonomous vehicles (incl. drones), Synthetic biology, Virtual (VR) and Augmented Reality (AR), Artificial Intelligence (AI), Robots, Blockchain, 3D printing, and IoT. (Herweijer et al., 2017; UNDP, 2018a)

Although most of these technological components are existing today (in other applications), I4.0 is still a futuristic concept (Drath and Horch, 2014). However, I4.0 will influence the ways of manufacturing significantly and raise questions on who, how, where and when will (be) produced (Van der Elst and Williams, 2017). It also has emerged as technological framework for integrating and extending manufacturing processes at both intra- and inter-organizational levels (Xu et al., 2018). In contrast, the 4IR refers to a systemic change with a holistic view that also takes effects on society, governance, environment, etc. into consideration.

When considering the potential implications of I4.0 and 4IR on the SDGs, the I4.0 as such is primarily limited to SDG 9 (Industry, Innovation and Infrastructure) (Fujitsu, 2018; UNDP, 2018a; United Nations, 2016). On the other hand, the 4IR might have impact on the majority of all 17 SDGs and many aspects of society because of the broader context, what can create opportunities, but also threats, especially to emerging and developing countries in the Global South (see Table 5 in Annex Section 7.3). To sum up, I4.0 is one small part of the 4IR, which mainly focuses on the production/ manufacturing process (UNDP, 2018a).

3 Research Design

3.1 Hypothesis & Research Questions

The aim of this study is to review and evaluate the *Industry 4.0* (I4.0) concept as such from a theoretical perspective within the *4th Industrial Revolution* (4IR) framework and discuss it from a regional perspective by referencing to country cases from the Global North and Global South. From the theoretical standpoint we argue, that due to different development paths and socio-economic contexts each country is tackling the 4IR in different ways, whereby the core motivations and strategies of the countries within the Global North and Global South are expected to be more closely related than between the North-South divide. Some countries want to stay in the position as a forerunner (especially countries from the Global North) while others want to or try to catch up in this process (especially countries from the Global South). Selecting the countries according to the Global North/ South divide should reflect on the countries' techno-economic position as whether they want to stay upfront (fully developed economies) or need to catch up (emerging industrial economies, developing economies as well as least developed countries). To achieve these various aims countries need to adapt their 4IR policies as well as strategies accordingly, not only to their current position in the technological field but also to many other areas, e.g. labor force, environment, energy efficiency, etc. (Hallward-Driemeier and Nayyar, 2018; Herold, 2016; Schwab, 2017; UNDP, 2018a; UNIDO, 2017b; WEF, 2018a, 2018b).

The basic hypothesis pivots on the following statement: *"There are different interpretations of the 4th Industrial Revolution and the Industry 4.0 concept within the political and scientific discourse depending on regional and also national contexts."*

This premise disembogued to the articulation of the following two research questions that shall be answered in the research process:

- *"Which concepts of the I4.0 can be identified within the 4IR discourse and how do they differ from each other?"*
- *"How do different countries in different contexts approach the 4IR?"*

3.2 Methodological Approach and Measurement

To operationalize these research questions a *systematic literature review* of scientific literature and national policy papers on 4IR and I4.0 has been conducted. Based on the review a *matrix* was created to compare and contrast the different concepts of I4.0 from the regional perspectives, contextualizing the regional socio-economic pathways by using *descriptive quantitative analysis*. (Buer et al., 2018; Heilmann et al., 2016; Liao et al., 2017; Xu et al., 2018)

The systematic literature review refers to the systematic comparison of available literature about the 4IR/ I4.0 by categorizing the paper contents according the discussed topics ("T") as illustrated in Table 1. In a first step, papers and reports on 4IR/ I4.0 were collected, before extending the search parameters to global, regional and country-specific policies and strategies. On this way, we aim to not only cover an academic perspective on 4IR/ I4.0, but also include country perspectives from national governments, industry and academia.

Table 1. Schematic illustration of the systematic literature review matrix (authors illustration)

Author	Year	Title	Geo	Type	Concept	Abstract	Aim	T1	T2	(…)	T+n	Institute	Keywords
A1	●	●	●	●	●	●	●	●	●	(…)	●	●	●
A2	●	●	●	●	●	●	●	●	○	(…)	○	●	●
(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)	(…)
A+n	●	●	●	●	●	●	●	○	●	(…)	●	●	●

Apart of the systematic juxtaposition of the theoretical and regional perspectives on (the) 4IR/ I4.0 within the literature, the country-specific perspectives are contextualized with the national strategic plans aiming at a successful adaptation to (the) 4IR/ I4.0 and the socioeconomic patterns and pathways of the selected countries. The focus is set on indicators that are potentially reflecting SDG related goals, e.g. share of Manufacturing Value Added (MVA), patent applications, trade in goods and services, or high-tech exports. This allows the thematic arrangement of national adaptation approaches in the context of the SDGs by highlighting socioeconomic developments in the present and recent past. The required data is retrieved from multiple data sources such as the UN (2017), World Bank (2018b), Wittgenstein Centre (2018), OECD (2018) and Roser (2018).

4 Case Studies

The geographical scope of this paper focuses on the regional macroeconomic disparities of selected countries in the ***Global North*** (Germany, Japan, and United States) and ***Global South*** (China, Mexico, and Indonesia) to illustrate and contextualize the country-specific (political and strategic) approaches in the 4IR discourse. The differentiation is necessary to capture the regional and country-specific perspectives and approaches to the tackle the potential challenges and opportunities arising from the 4IR. The selection of the six country case studies comprises **three selection criteria**:

- **Geography:** The countries have to represent the Global North-South divide **AND** different geographic regions in the world;

- **Economy:** The countries have to represent, in terms of GDP, economically high performing countries;
- **Policy:** The countries have to have or are going to implement an I4.0 related policy to tackle the challenges and opportunities of the 4IR;

Firstly, the Global North-South divide is primarily a political and socio-economic one (Gallas et al., 2016; Grugel and Hout, 1999; Reuveny and Thompson, 2007; Trefzer et al., 2014) and will determine the future regional policies handling the opportunities and challenges of the 4IR. The Global North comprises the so called advanced *Industrialized Countries* (IND) (see in blue, Figure 2), including the most parts of the European Union and Europe, the United States, Canada, the Four Asian Tiger or Little Dragons (Hong Kong, Singapore, South Korea and Taiwan) as well as Japan, Macau, Brunei, Israel, Australia and New Zealand. The Global South (see in green, Figure 2) basically covers all the other nations that are not yet considered as advanced as the Global North, whereby those countries comprise a mixture of *Emerging Industrial Economies* (EIE), *Other Developing Countries* (ODC) as well as *Least Developed Countries* (LDC) illustrated in Figure 2 (UNIDO, 2017a)[5].

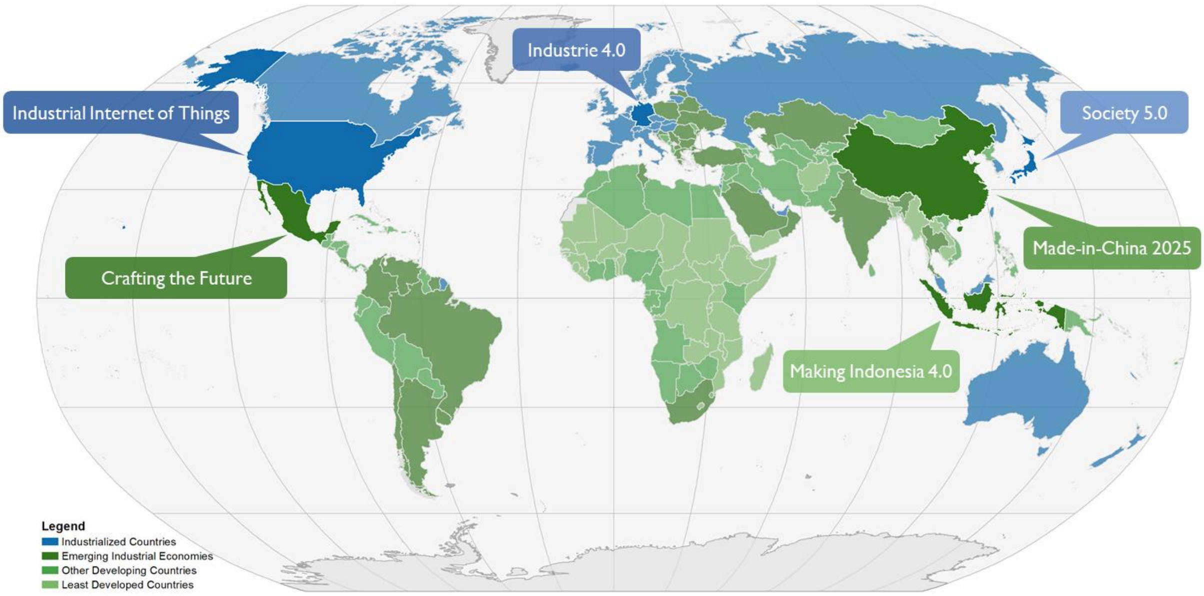

Figure 2. Case Studies by level of industrial development (UNIDO, 2017a) and I4.0 related policies (authors' illustration)

Secondly, the selection of case countries for this study aims to include countries from both, Global North and South, from different geographical regions with a significant economic performance in the global economy. The level of a country's economic performance is predominantly measured by its *Gross Domestic Product* (GDP). When ranking the Top-5 countries of the Global North and South by GDP in US$ (see Table 2) there are 10 members of the G20 or Group

[5] For a detailed list on the UN categorization of countries to "*industrialized nations*", "*emerging industrial economies*", "*other developing countries*" and "*least developed countries*" see (UNIDO, 2017a).

of Twenty[6] displayed, which is a powerful global conglomerate to promote international financial stability.

Table 2. GDP in 2016 at constant 2010 prices in US Dollars (World Bank, 2018b)

Global North			Global South		
#	Country	GDP in US$	#	Country	GDP in US$
1	United States	16920.3bn	2	China	9505.3bn
3	Japan	6040.7bn	7	India	2456.0bn
4	Germany	3781.7bn	8	Brazil	2248.1bn
5	France	2810.5bn	15	Mexico	1259.0bn
6	United Kingdom	2753.8bn	17	Indonesia	1037.7bn

Thirdly, to narrow the list of countries down, countries with a national I4.0 strategic plan had to be selected to allow a review and evaluation of the regionally diverging approaches facing the 4IR. The aim was to select countries with initiatives/ strategies in different stages of implementation, from planning via early stage of implementation to advanced stage of implementation. With Germany (*Industrie 4.0*), Japan (*Society 5.0*) and USA (*Industrial Internet of Things*) three countries that can be described as global frontrunners in the promotion of the 4IR were selected, whereby Germany and USA are already in an advanced stage of implementation. The Global South finds itself represented in this study with China (*Made in China 2025*), Indonesia (*Indonesia 4.0*) and Mexico (*Crafting the Future*), which are either in early stages of implementation or still conceptualize their initiatives. (see Figure 3)

Within the EU there are more national policy initiatives, e.g. "*L'Industrie du Futur*" (IdF) (European Commission, 2017c) in France, "*High-Value Manufacturing Catapult*" (HVMC) (European Commission, 2017d) in the UK or "*Smart Industry*" (SI) in the Netherlands (European Commission, 2017a; European Commission, 2017e) (see Figure 3) to name a few. But also countries in the Global South are showing a raised awareness for the challenges and opportunities the 4IR might bring by creating their own strategies, e.g. Singapore's Industry 4.0 (e.g. Smart Industry Readiness Index, see *The Singapore Smart Industry Readiness Index. Catalysing the transformation of manufacturing*, 2017) or Thailand 4.0 (MOI, 2018b; Thailand MOST, 2017), which shall not be further discussed in this paper. (see Figure 3)

The description of the country-specific case studies will start with Germany [DEU] that is considered to be the initiator and instigator of the global 4IR discourse by pushing and coining the terminology *"Industrie 4.0"* that became a synonym for the 4IR all over the world. Germany carried this discourse also into the committees and panels of the European Union that made Industry 4.0 a European policy target (European Commission, 2017a, 2017e, 2017b). Beside the EU, the World Economic Forum (WEF) founded its own *Centre for the Fourth Industrial Revolution* that shall promote this topic globally (WEF, 2018b, 2018a, 2017) beside other institutions like the United Nations (UNDP, 2018a; UNIDO, 2017b, 2017a) or World Bank (Hallward-Driemeier and Nayyar, 2018; World Bank, 2018c, 2017).

[6] The G20 or Group of Twenty comprise a mix of the world's largest advanced and emerging economies, representing about two-thirds of the world's population, 85 percent of the global GDP and over 75 percent of global trade. (see http://g20.org.tr/about-g20/g20-members/)

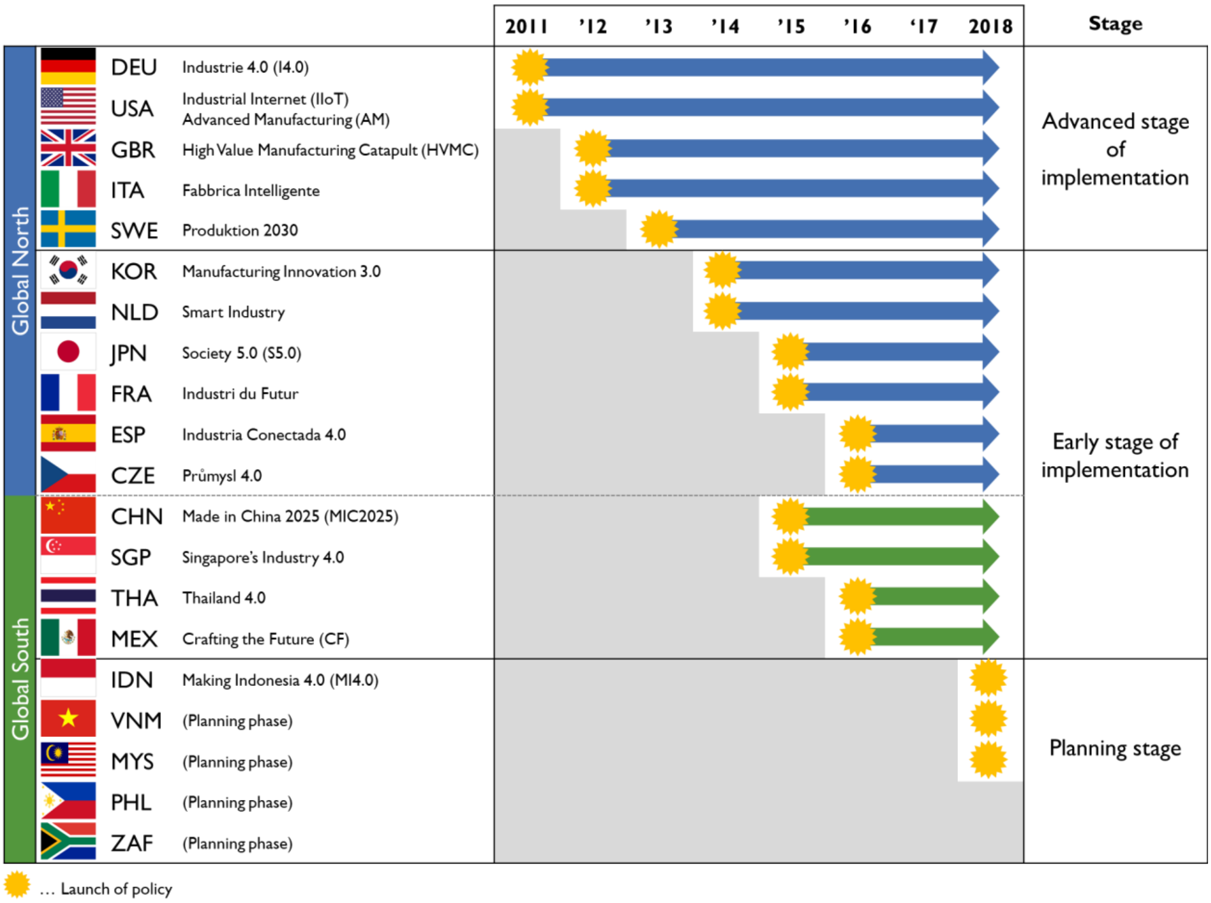

Figure 3. Selected countries in the Global North/ South that have or are going to launch I4.0 related initiatives by year of policy launch and stage of implementation (European Commission, 2017a; MOI, 2018b; PCAST, 2011; SE, 2016) (authors illustration)

Nevertheless, the 4IR is predominantly discussed in the globally leading economies (Buer et al., 2018; Buica, 2016; Liao et al., 2017), the so called Global North like Japan [JPN] and the United States [USA], while within the countries of the Global South the awareness of the importance of this topic as well as creating national policies has only recently started to evolve. This circumstance also hindered the selection of case study countries to the extent, that due the lack of documented policies, no Other (ODC) or Least Developing Countries (LDC) have been selected for this study.

The three case study countries from the Global South solely represent Emerging Industrial Economies (EIE). The leading economic role in the so called Global South has been taken over by China [CHN] that invests huge efforts and money into catching up with the other leading economies. Despite China's global macroeconomic performance, the country is still considered as an emerging industrial economy (UNIDO, 2017a) on the verge to become a fully industrialized country. The other two case studies for the Global South representing Latin America and South East Asia are Mexico [MEX] and Indonesia [IDN].

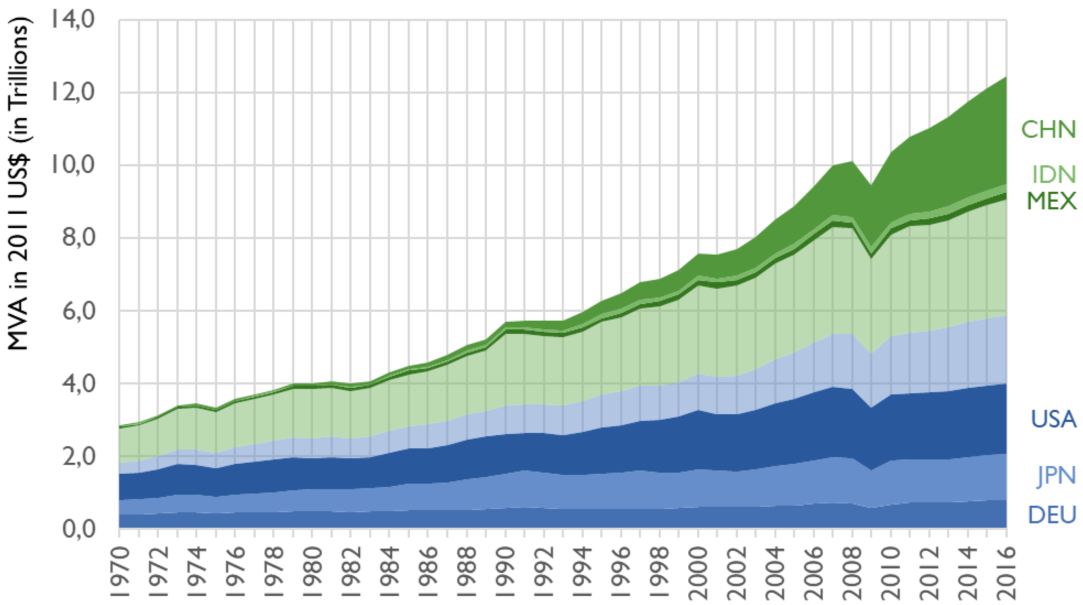

Figure 4. Manufacturing (ISIC D) Value Added in 2011, 1970-2016 (in trillion US$) (World Bank, 2018b) (authors illustration)

The countries reside among the Top-5 nations in the Global South when it comes to GDP and are members of the G20. Additionally both countries have a high share of GVA by industry (IDN: 22.2 percent | MEX: 16.0 percent in 2016) (World Bank, 2018b), which will be affected by the development shaped by the 4IR. In total, the six case countries generated 7.4 trillion US$ MVA, which made up 59 percent of the global MVA in 2016 (see Figure 4). (World Bank, 2018b)

4.1 "Global North"

4.1.1 Germany's "Industrie 4.0" (I4.0) – Strategy

Today, Germany has a leading position in machinery and plant engineering as well as supplier of factory equipment, including the field of digitalization and automation of manufacturing (BMBF, 2013; Forschungsunion, 2012; Heilmann et al., 2016). In a global competitive economy, the *Federal Ministry of Education and Research* (BMBF)[7] sees the German production and innovation location endangered (BMBF, 2013; Forschungsunion, 2012; Plattform Industrie 4.0, 2015). Since the end of WWII the manufacturing and production sector, including mining, construction, manufacturing and utilities, have been the driving forces in the revitalization of the German economy and labor market (Heilmann et al., 2016). The industrial specialization in high-tech manufacturing, e.g. automobile industries, aviation, ICT, automation, etc. (Forschungsunion, 2012), has not only created economic growth, but also generated employment and in 2016 approximately 27.3 percent of the German labor force were working in the manufacturing and production sector contributing 27.9 percent value added (MVA) to the GDP (see Figure 8 in Section 4.2.1). (World Bank, 2018b) The German private and public sector have strong international trade relationships, which make up about 86.9 percent of the GDP in 2017

[7] Federal Ministry of Education and Research (German: Bundesministerium für Bildung und Forschung, BMBF) (see https://www.bmbf.de/en/index.html)

(World Bank, 2018b). Thereof 47.2 pp are contributed by exports (OECD, 2018). In total, 16.9 percent of all manufactured exports are high-technology exports (see Figure 5), totaling in 189.6 billion US$ in 2016 (World Bank, 2018b). The national economy is depending on exporting their manufactured goods, especially in the high-technology segment to create revenue (BMBF, 2017b, 2014; European Commission, 2017b; Heilmann et al., 2016; Plattform Industrie 4.0, 2015).

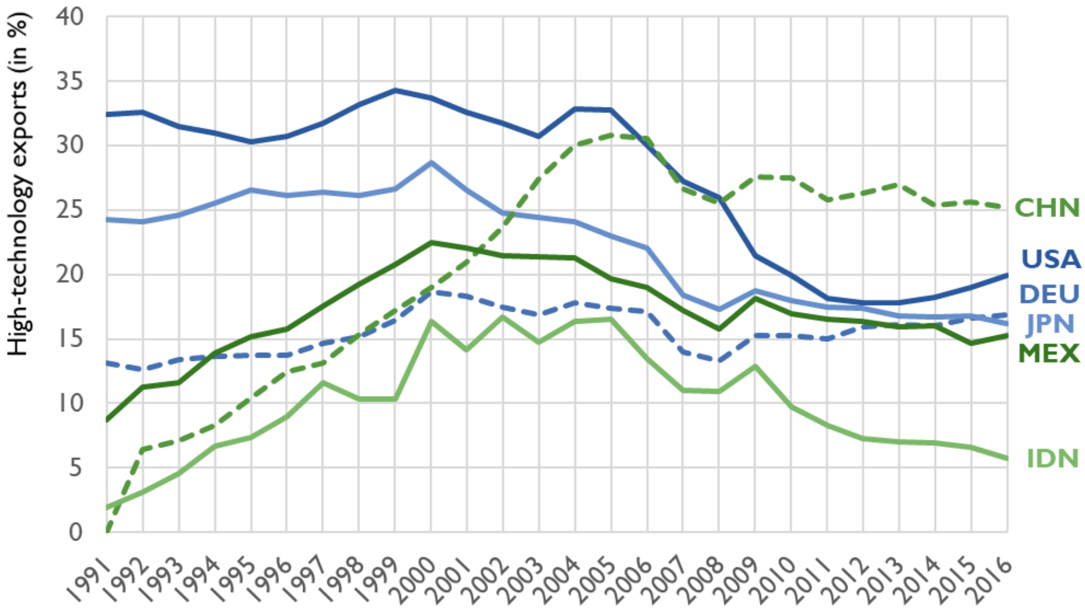

Figure 5. High-technology exports, 1991-2016 (% of manufactured exports) (World Bank, 2018b) (authors illustration)

To maintain its position as a thriving economy in the future, the German government started early on to create strategic initiatives and policies to shape its prospective industrial orientation and capacities (European Commission, 2017b). In the beginnings of the I4.0 discourse in Germany the national strategies and white papers of the government and industry associations were still using the terminology *"embedded systems"* (BMBF, 2007, 2006; Heilmann et al., 2016; ZVEI, 2009). The Ministry of Education and Research (BMBF) and the Ministry for Economic Affairs and Energy (BMWi) are promoting the I4.0 national strategic initiative and led the basis for it with long-term strategies like the High-Tech 2020 Strategy (BMBF, 2017b, 2014, 2006; European Commission, 2017b), the Digital Strategy 2025 (BMWi, 2016; Hohmann, 2018) and ICT 2020 Strategy (BMBF, 2007). In those strategy papers the discourse was not solely concentrated on the manufacturing capacities as it is now, but also included the energy sector, the health system and other economic sectors (BMBF, 2007, 2006). This changed with the introduction of the term *"Industrie 4.0"* at the Hannover Fair (Hannover Messe) in April 2011 (Kagermann et al., 2011) when the thematic focus shifted to the manufacturing industries and branches where Germany was obtaining positions as global market leaders. I4.0 is described as the *"[…] national strategic initiative from the German government […] [which] aims to drive digital manufacturing forward by increasing digitalization and the interconnection of products, value chains and business models. It also aims to support research, the networking of industry partners and standardization."*, (European Commission, 2017b).

The German efforts regarding I4.0 have become institutionalized by founding the *"Plattform Industrie 4.0"*, funded with € 200 million by BMBF and BMWi, with the aim to coordinate I4.0 related initiatives and to serve as a central contact point for policy-makers (European Commission, 2017b; Forschungsunion, 2012; Plattform Industrie 4.0, 2015). The I4.0 initiative has the objective to consolidate the German technological leadership in mechanical engineering, machinery and plant engineering as well as supplier of factory equipment (European Commission, 2017b; Heilmann et al., 2016; Plattform Industrie 4.0, 2015; Schroeder, 2016, 2016).

The primarily policy driven efforts in Germany to facilitate a feasible I4.0 strategy is designed to support the specialization in and market demand for high-tech manufacturing, which means it is shaped by the supply side. The target audience is mainly considered to be manufacturers/ producers and SMEs. The aim is to create a more efficient cross-linkage and vertical integration of production chains among enterprises due to CPS to maintain the manufacturing capacities, strengthen the international competitiveness and increase the share of (high-technology) manufactured exports (BMBF, 2017a; Heilmann et al., 2016; Schroeder, 2016).

The German government is advancing digital manufacturing, innovations in R&D, networks and cooperation of industry partners, and standardization with the I4.0 initiative (BMBF, 2017a; European Commission, 2017b; Plattform Industrie 4.0, 2018a). The promotion of the German I4.0 is funded by public-private partnerships. The main technological innovations are horizontal and vertical integration of the value chain within the so-called smart factory enabled by embedded systems, Cyber Security, Big Data, Cloud Computing, IoTS, IoT and CPS (BMBF, 2017a; European Commission, 2017b; Forschungsunion, 2012; Heilmann et al., 2016; Plattform Industrie 4.0, 2015; Schroeder, 2016). Those systems are tested, according to Plattform Industrie 4.0 (2018a), in over 280 R&D centers as well as technological clusters and testbeds (BMBF, 2017a; Plattform Industrie 4.0, 2018b, 2018c, 2018a, 2015) and over 500 locations that conduct I4.0 related funded projects (BMBF, 2018).

The biggest strength of the German I4.0 strategy is the comprehensive strategic framework, which involves policy-makers, industry, science and social partners to push the I4.0 agenda. On the other side, the key challenges or weaknesses are concerning the potential involvement of SME's to adapt their management and shop-floor organization as well as to maneuver along the demarcation lines of different stakeholder goals, e.g. between industry and trade union or among competing German companies to establish a joint approach (European Commission, 2017a, 2017b). Further challenges include the economic capacity to adapt to accelerating product and innovation life cycles, emergence of new business models as well as the need for customization in manufacturing in the global competition. This will increase the pressure on the national manufacturing sector to internationalize value chains, what may weaken the German production and innovation location as well as the labor market. (BMBF, 2017a; European Commission, 2017b; Heilmann et al., 2016; Plattform Industrie 4.0, 2015; Schroeder, 2016)

Technological changes affect not only the economic productivity but also the society and especially the workforce as well as the environment. Therefore it is necessary to rethink the relation of society, education and work. Within the German discourse little consideration has been put on the implications of technological innovations on society as such. Although the strategy papers articulate the framework for succeeding in the 4IR, no profound details on societal coping strategies that should handle I4.0 induced unemployment of unskilled workers or other potentially negative effects. The environmental dimension of the German I4.0 strategy is also underrepresented.

4.1.2 Japan's "Society 5.0" (S5.0) – Approach

After WWII and the necessary reconstruction of the Japanese economy, the manufacturing sector inherited an elevated position to persist in the global economic competition. The industrial sector is held in high esteem as it was decisive in the economic recovery due to its economic value added and the multiplier effects on other sectors. The economic reinvigoration of Japan from 1950 to 1970 was interplayed with large-scale developments like education expansion (Goujon et al., 2016; Speringer et al., 2018), the expansion of Services of General Interest (SGIs), but also infrastructures like roads, railway, bridges, water pipes, sewage system, etc. (Fukuyama, 2018). Today, Japan ranks among the countries with the highest mean-years of schooling in the world (Goujon et al., 2016; KC et al., 2018; Lutz et al., 2018; UNDP, 2018b; Wittgenstein Centre, 2018) and has the third largest economy after USA and China, when it comes to the total GDP volume (World Bank, 2018b). In the last decades Japan has brought forth multiple multinational corporations (MNCs) in manufacturing industries, electronic and mechanical engineering, automation engineering, IT, and automobile production. Japan holds a leading positing in robotics and AI (Fujino and Konno, 2016; KANTEI, 2013a, 2013b). This reflects in the potential innovative capacity of Japan, e.g. when looking at standardized annual patent applications per million inhabitants (see Figure 6), which has stood out compared to other countries over the last decades, but with a notable decline since the early 2000s (World Bank, 2018b).

Despite this socio-economic success story, Japan is facing severe demographic, political and societal challenges, e.g. rapid ageing[8] affecting the productivity and innovative capacities, which they aim to tackle with creating a new human-centered society, namely Society 5.0 (S5.0)[9] (Fukuyama, 2018; Harayama and Fukuyama, 2017; Waldenberger, 2018). This S5.0 initiative has to be evaluated as direct response to Germany's *"Industrie 4.0"* – strategy to ensure the maintenance, revitalization and competitiveness of Japan's economy (KANTEI, 2013b, 2013a). The most prominent public stakeholders are the Cabinet Office (CAO), the Prime Minister of Japan and his Cabinet (KANTEI), the Ministry of Economy, Trade and Industry (METI) and Japan's leading business organization, namely Keidanren (Fukuyama, 2018; Waldenberger, 2018).

[8] From 1950 onwards the share of population aged 65+ years increased from 7.7 percent to 33.1 percent in 2018 and is expected to surpass the 40 percent in 2038 (UN, 2017).

[9] The four previous human society development stages are: hunter and gatherer in harmonious coexistence with nature (Society 1.0), agrarian with increasing organization and nation-building (Society 2.0), industrial with invention of mass production (Society 3.0), and information society that utilizes information networks to connect assets (Society 4.0) (Fukuyama, 2018; Waldenberger, 2018)

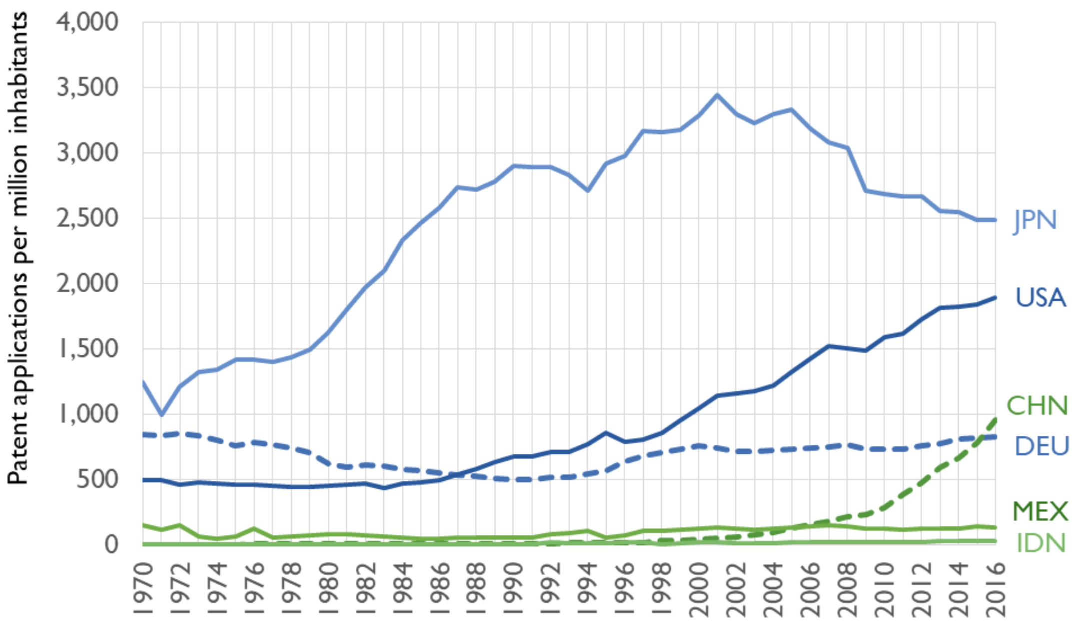

Figure 6. Patent applications, 1970-2016 (per million inhabitants) (World Bank, 2018b) (authors illustration)

In general, automatization respectively digitalization in manufacturing processes is nothing new to the Japanese industry and public discourse. Beside organizing since 1998 the annual Global ICT Summit, Japan has launched several general economic growth policies (KANTEI, 2018, 2017a, 2017b, 2016a, 2016c, 2016d, 2016b, 2016e), industrial policies (METI, 2017, 2016, 2015), science and technology policies (CAO, 2018, 2017, 2016) and an ICT strategy (MIC, 2017, 2016) in line with the S5.0 initiative (Fukuyama, 2018; Keidanren, 2018; Waldenberger, 2018). Apart from the public sector, the industry responded by establishing in 2015 three major industry consortia, namely the *Robot Revolution Initiative* (RRI), the *Industrial Value Chain Initiative* (IVI), and the *Internet of Things Acceleration Consortium* (IoTAC) beside some smaller ones like the Japan Association of New Economy or the Internet Association Japan (IVI, 2016; RRI, 2018a, 2018b, 2015; Waldenberger, 2018).

IVI, for instance, tries to promote a knowledge and technology based society in Japan until 2020. On this pathway, standards and regulations for interconnected production technologies shall be developed and internationally adopted. So far production optimization was only concerned in big enterprises, but with IVI this shall spread over to SMEs by integrating them into the production and value chains (IVI, 2016; IVRA Next, 2018; Nishioka, 2017). Another focus area is human capital, which appears in the reorientation of education policies, where natural sciences and economy shall be promoted (Heilmann et al., 2016; KANTEI, 2016a; METI, 2016).

The public and private sector have shown a very strong response to international initiatives on I4.0, because the economic future competitiveness is relying on it. Globally known enterprises like Toyota, Honda, Fujitsu, Hitachi, Yamaha and many more are highly aware of this topic and the potentials of optimizing production processes to regain innovative capacities and remain competitive (Harayama and Fukuyama, 2017; Heilmann et al., 2016; Waldenberger, 2018). Apart from that, Japanese research institutes are frontrunners in material science, engineering technology and electronic semiconductor research due to high investments in ICT and R&D, what makes the country highly competitive in the international market (Heilmann et al., 2016; Waldenberger, 2018). Most of the initiatives pushing the 4IR forward are originating in the private sector, but the government takes up a vivid role in funding less profitable sectors, like the Smart Japan ICT Strategy (2014) that aims at the development of eGovernment systems, Smart Cities and Smart Agriculture (KANTEI, 2016a; METI, 2016).

While Germany and USA focus on the optimization of production processes, Japan is more specialized on robotics. As described in the *Monodzukiri*[10] *White Paper*, Japan perceives itself as global leader in robotics, which also has a historical dimension (METI, 2016). In comparison to other countries of the Global North, Japan has a competitive advantage as this was the country's strategy to revive its economy in the past and shall lead on to the future. Currently, there are 250.000 operational robots registered and in use in Japan, even before the US (~140.000) (OECD, 2017b). The overarching goal is to become a global center for innovation in robotics and to include robotic technologies, AI and IoT based on Big Data analysis in all parts of everyday life (KANTEI, 2016a, 2016d, 2016c, 2016b). This holistic ambition coins the term *"Super Smart Society"* as well as *"Society 5.0"* (Heilmann et al., 2016; KANTEI, 2016c; Skobelev and Borovik, 2017). Robotic technologies will be included in automobile production, manifold electric branches right up to the health sector and elderly care, which tackle the challenges of the demographic aging in Japan (METI, 2015). The new technologies and business models created within the 4IR shall not only deploy Japans status, but also bring production back to the country (KANTEI, 2016a; METI, 2016).

Major challenges associated with the 4IR are the lack of a vibrant startup eco-system (Joh, 2017; Waldenberger, 2018) and the deprived innovation culture within Japanese enterprises, which is shaped by the approach to find in-house-solutions (*"not-invented-here-syndrome"*) (Heilmann et al., 2016). This often creates problems with data security and leaks. Since 2010 approximately one third of all enterprises and about 55 percent of the enterprises with more than 250 employees indicated digital security incidents, what are the highest shares among OECD countries (OECD, 2017b). The open innovation culture was considered to be a taboo for a long time. In an era of accelerating technological life cycles in the production industries, this kind of open innovation culture is essential. The capacities to adapt their company culture, customization of products and establishing international networks will affect the competitiveness and global market leadership. Other challenges in this process might be the lacking of a start-up culture because young skilled workforce often prefers an employment in big enterprises and job security (KANTEI, 2016a; METI, 2016).

4.1.3 USA's "Industrial Internet of Things" (IIoT) – Initiative

In the 20th century, the United States of America has become the biggest global economy according to the GDP. Holding a share of 11.7 percent of the GVA to the GDP in 2016, totaling in 1.9 trillion US$ (World Bank, 2018b), the industrial sector is an important job creator (see Figure 8 in Section 4.2.1). The overall US GDP has increased since 1970 from 4.8 to 16.9 trillion

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[10] Monodzukiri describes the principle of producing goods. The White Paper was produced in a cooperation of Ministry of Economy, Trade and Industry (METI), Ministry of Health, Labor and Welfare (MHLW) and Ministry of Education, Culture, Sports, Science and Technology (MEXT);

US$ in 2016. Nonetheless, the USA lost many jobs in the manufacturing sector due to offshoring industrial labor to low-wage countries. This affects all manufacturing branches that produce durable goods, for sectors such as construction, infrastructure, mechanical engineering (e.g. automobile, military, etc.), building machineries, appliances, utilities, etc. With offshoring the industrial labor, the share of employment in industry has been declining from 24.7 percent in 1991 to 18.9 percent in 2017 (World Bank, 2018b). This decline also affected the country's global (economic) competitiveness and innovation capacity. Nevertheless, the US ranks among the Top-10 countries in the world when it comes to Mean Years of Schooling (MYS) in 2015 (Goujon et al., 2016; UNDP, 2018b; Wittgenstein Centre, 2018) or GDP per capita PPP in 2017 (World Bank, 2018b). When it comes to access to internet the US hardly makes the Top-40 with 76.2 percent of the population that had access to internet in 2016 (World Bank, 2018b). This is a rather small figure for a highly industrialized country in the Global North (see Figure 7).

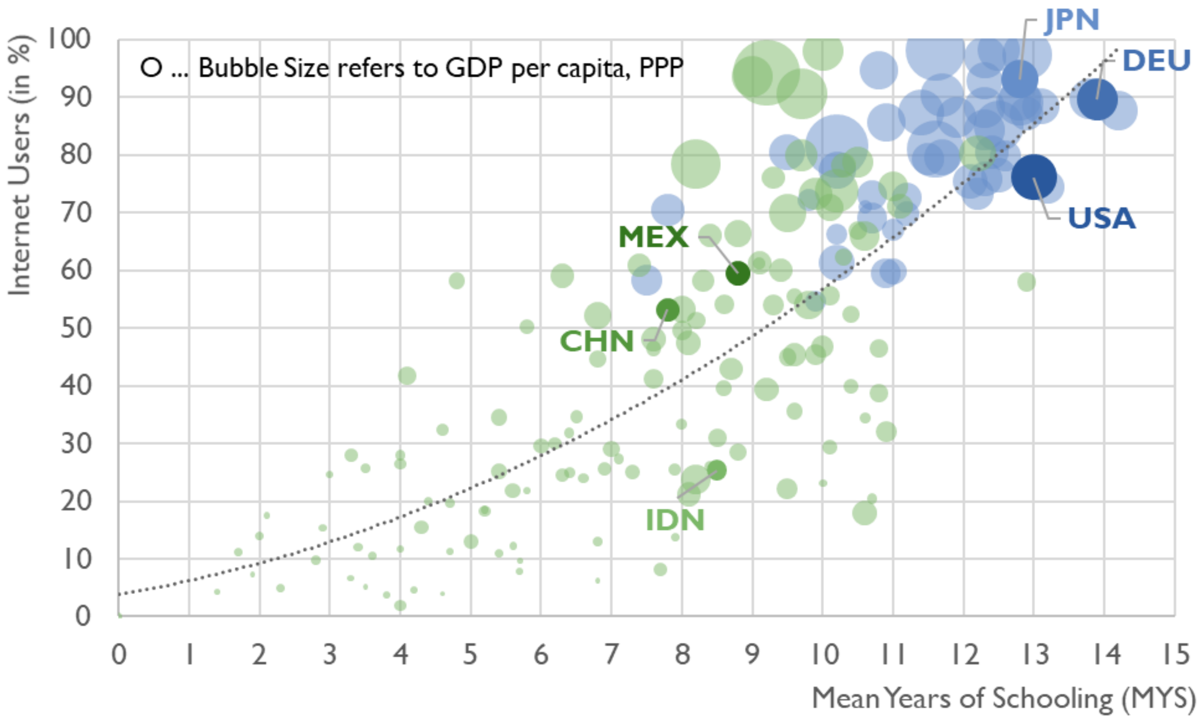

Figure 7. Comparison of Mean Years of Schooling (x-axis) in 2015 (Goujon et al., 2016; UNDP, 2018b; Wittgenstein Centre, 2018), Share of Internet Users (y-axis) in 2016 (World Bank, 2018b), and GDP per capita, PPP (constant 2011 International Dollar) in 2017 (Feenstra et al., 2015; World Bank, 2018b) (authors illustration)

Historically, the industrial sector had been attributed a particular role in the economy because of its multiplier effect for other sectors. The shift from industry to service sector oriented economy is nowadays perceived as problematic, because this has weakened the USA's position in the global manufacturing value chains. Aiming on reindustrializing, the national economy and reshoring skilled industrial jobs, the USA pushes innovations in production and value chains, coordination of information, digitalization, automation, computation, software, sensing and networking (NSTC, 2018a, 2018b). This shall also reinforce the (high-technology) export achievements, increase the share of high-technology exports as part of the overall manufactured exports and to maintain as well as strengthen the international competitiveness (see Figure 5 in Section 4.1.1).

To revitalize the American manufacturing sector, the US President's Council of Advisors on Science and Technology (PCAST) recommended in 2011 the implementation of the *"Advanced Manufacturing"* (AM) – Initiative to facilitate public-private partnerships between government, academia and industry to expedite research on new technologies in manufacturing processes (PCAST, 2011). In 2012, the National Network for Manufacturing Innovation (NNMI), today also known as Manufacturing USA, was founded to establish a network of research institutes to promote manufacturing technologies (NNMI, 2018).

In 2014, US Congressional Senate passed the Revitalize American Manufacturing and Innovation Act of 2014 (United States. Cong. House, 2014) to establish and convene a nationwide network to coordinate the efforts of the individual manufacturing innovation institutes (United States. Cong. House, 2014; United States. Senate, 2014). This led to the establishment of the *Network for Manufacturing Innovation Program* (NMIP) within the *National Institute of Standards and Technology* (NIST), which is a subdivision of the US Department of Commerce, that has a budget of 1.2 billion US$ (2018) to support Scientific and Technical Research Services (STRS), Industrial Technology Services (ITS), and Construction of Research Facilities (CRF). (NIST, 2018; United States. Cong. House, 2018; United States. Senate, 2017) Initially the funding was recommended to be 500 million US$ per year appropriated to the Departments of Defense, Commerce and Energy to promote AM principles (PCAST, 2011), just to be increased in the following years to almost 1 billion US$ per year (McCormack, 2012; PCAST, 2012).

In the US context, the term I4.0 is not used, but instead *Industrial Internet of Things* (IIoT)[11] and *Advanced Manufacturing* (AM) are the key terms (NSTC, 2018a, 2016a, 2012). The AM - initiative not only covers elements of I4.0, but is used in a broader context. This includes the innovative usage of cutting-edge materials and capabilities, such as nano- and biotechnology, physics or chemistry. Explicitly, knowledge from natural and life sciences are included in the implementation of the US strategies. The aims of this initiative are to develop new manufacturing technologies, educate and train the manufacturing workforce as well as expanding the capabilities of the domestic manufacturing supply chain (NSTC, 2018a, 2018b, 2012).

Apart from the public AM – initiatives, the private sector has a very strong interest in the promotion of I4.0 technologies in the digitalization of manufacturing. Especially, General Electric was essential in framing the term *Industrial Internet of Things* (IIoT) and co-founding the *Industrial Internet Consortium* (IIC) in 2014 together with AT&T, Cisco, IBM and Intel (Diab, 2018; Diab et al., 2017; Evans and Annunziata, 2012; Heilmann et al., 2016; IIC, 2015). The aim of the IIC is the coordination and widespread enablement of the IIoT among their 258 members, including MNCs, SMEs, nonprofit, academic, and government organizations (e.g. NIST), to increase their innovative and adaptive capacities to the 4IR (Diab, 2018; Diab et al., 2017; IIC, 2015). The IIC and IIoT are conceptually not confined to the industrial or manufacturing

[11] The term IIoT is a combination of the Internet and Industrial Revolution. From the US perspective the current IR is just the third (Rifkin, 2011). The first revolution is characterized by mechanical- and mass-production. The second revolution is marked by the invention and global diffusion of the internet. The third revolution combines the achievements of the first both in the so-called Industrial Internet of Things (Evans and Annunziata, 2012).

sector, but include major parts of the service sector, e.g. energy, healthcare, agriculture, aviation and shipping, but also mining, transportation, retail and smart cities, including the creation of testbeds for IIoT applications (Heilmann et al., 2016; IIC, 2018, 2015).

Similar to Germany, the overall strategy in the US is to support the industrial specialization and create a market demand for high-technology manufacturing. This supply side perspective is supported by manufacturers, producers, agriculture and to a minor extend by the government and research (NSTC, 2018a, 2018b). Funding is mainly provided via public-private-partnerships to support technological development, the establishment of R&D centers and technological testbeds (McCormack, 2012; NSTC, 2018b, 2016a; PCAST, 2011).

In the US, the technological focus differs from Germany and Japan as all technologies that can be more efficient by connecting them to the internet are considered. This includes, beside embedded systems, integration of production and value chains, smart and digital manufacturing (e.g. 3D printing), ICT, automation, AI, advanced industrial robotics also data generation and predictive analysis based on Big Data. In this context, Cyber Security is probably the most important focal point in the general discourse (NSTC, 2018b, 2016a, 2012).

Under the umbrella of the *Advanced Manufacturing Partnership* (AMP), research initiatives are funded via public-private partnerships, e.g. *Manufacturing Centers of Excellence* (MCE), *National Network for Manufacturing Innovation* (NNMI) and *Manufacturing Technology Testbeds* (MTT). The main purpose of these centers is to do research on new technologies, production processes, products and requirements of reeducation of the workforce (NSTC, 2016b; PCAST, 2012).

4.2 "Global South"

4.2.1 China's "Made-in-China 2025" (MIC2025) – Strategy

China is considered to be the most thriving economy and potential sales market in the world with one of the highest average annual GDP per capita growth rates (2016: +6.1 percent). China's economic reform began in 1978 with the aim to lift people out of poverty (Li, 2017). Since the opening up of the country for foreign investments and the economic reform to allow privatization in the early 1980s, an unprecedented economic growth took off and is still continuing today (Brandt and Rawski, 2008; Butollo and Lüthje, 2017; Rawski, 2008). Before these reforms the Chinese industry was largely stagnant with limited policies to improve the quality and productivity of the manufacturing sector. In the 1980s, foreign enterprises and foreign capital had started to gain influence in the Chinese industry accompanied with large-scale privatizations. There are three critical indicators, namely manufacturing capability, human capital, and R&D, that have been the major source of China's socio-economic change in the last decades and in the years to come (Li, 2017). In this context, China established itself as the world`s extended manufacturing workshop, which generated low-wage jobs for unskilled workers. As a result, the economy started to thrive and absolute poverty, especially in urban areas, declined, while the quality of living standards increased (Benjamin et al., 2008; Brandt and Rawski, 2008; Wübbeke et al., 2016).

In 2016, China's Manufacturing Value Added (MVA) is roughly accounting for 31.4 percent of the total GDP, totaling in about 2.98 trillion US$ (World Bank, 2018b). The MVA has increased since 1970 (12.1 percent) peaking in 2012 (32.0 percent) (see Figure 8). With the strengthening of the manufacturing sector, China has blossomed out of being solely a source of natural resources and durable goods for export, e.g. coal, concrete, steel, textiles, etc., and a mere extension of the world's manufacturing base to an increasingly attractive sales market as well as trading partner. The thriving economy is driven by foreign investments and massive public spending's to develop the national economy. (Butollo and Lüthje, 2017; Heilmann et al., 2016; Rawski, 2008; Wübbeke et al., 2016)

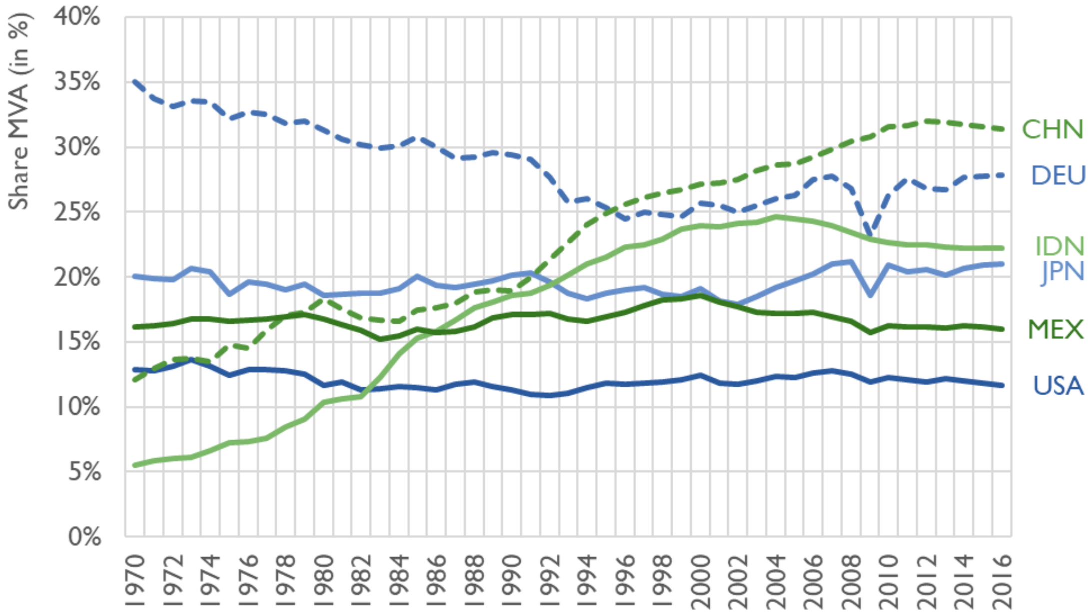

Figure 8. Manufacturing Value Added (MVA) to GDP, 1970-2016 (in %) (World Bank, 2018b) (authors illustration)

The major challenge is the controlled downsizing of labor-intensive economic sectors with low-skilled workers and the simultaneous creation and expansion of a high-skilled labor market segment (Butollo and Lüthje, 2017; Wübbeke et al., 2016). By deliberately losing the comparative advantage in the low-skilled and low-wage economic branches compared to other high-wage economies, the economic competitiveness might suffer (Brandt and Rawski, 2008; Heilmann et al., 2016; Rawski, 2008).

In 2016, the *13th Five-Year Plan for Economic and Social Development of the People's Republic of China* promoted China's economy and society to become innovation-based and high-technology related (CPC, 2016; KPMG, 2016; Wübbeke et al., 2016; Zenglein, 2018). The industrial sector shall incorporate more own, innovative and sustainable ideas to further develop the Chinese economy. Hence, the Chinese government adopted two central political strategies, namely the *Made-in-China 2025* (MIC2025) and *Internet Plus Strategy* brought forth in 2015 (Li, 2017). The MIC2025 is a strategic plan to move China up the value chain by emancipating itself from a global manufacturing production workshop into a globally competing industrialized power (Butollo and Lüthje, 2017; Malkin, 2018; State Council, 2018a, 2018b, 2017; Wübbeke et al., 2016). The MIC2025 was developed by China's *National Development and Reform Commission*

(NDRC) and by the *Ministry of Science & Technology* (MOST), with contributions from the *Ministry of Industry and Information Technology* (MIIT) (Butollo and Lüthje, 2017; State Council, 2017). China thereby orientates alongside the German I4.0 concept, which also aims to increase their collaboration in the future. (CPC, 2016; Li, 2017) Generally speaking, the MIC2025 strategy is interpreted as an attempt to foster progress within the diversified China. (CPC, 2016; Li, 2017)

The plan is to launch an industrial transformation from labor intense production to knowledge intensive manufacturing, whereby MIC2025 demarks the first stage of a three phase masterplan (Liu, 2016; State Council, 2015). In the first phase (until 2025), namely the MIC2025, China thrives to get on the list of the top global manufacturing powers in the world and gain influence in the global economy (Baker-McKenzie, 2017; Wübbeke et al., 2016; Yuan, 2018; Zenglein, 2018). In the second phase (2026 to 2035), China aims to become a medium-level world's manufacturing power camp. In the third phase (2036 to 2049), China envisions to be one of the leading global manufacturing powers (Li, 2017; State Council, 2015; Wübbeke et al., 2016; Zenglein, 2018). In this process, China wants to move from "*Made-in-China*" to "*Designed-in-China*" in order to push innovative industries and achieving more control over the entire value chain of the product life cycles (Li, 2017; Liu, 2016; State Council, 2017).

The MIC2025 strategy largely focusses on the electronic and mechanical engineering, construction, and automobile utilities sectors (State Council, 2017; Yuan, 2018), with implementing manufacturing innovation centers for technology and R&D (MIIT, 2016, 2015; State Council, 2018a, 2015). Ten technologies are being prioritized: information technology, high-end numerical control machinery and automation, aerospace and aviation equipment, maritime engineering equipment and high-tech vessel manufacturing, rail equipment, energy-saving vehicles, electrical equipment, new materials, biomedicine and high performance medical apparatus and agricultural equipment (State Council, 2018a, 2017, 2015; Wübbeke et al., 2016; Zenglein, 2018).

In addition, automation is to be spilled over to other sectors, e.g. agriculture, energy, financial services, logistics or transportation. Technologies to be used are anchored in the so called Internet Plus strategy. Especially mobile internet, cloud computing, Big Data, IoT are promoted there. Other technologies promoted within the MIC2025 are AI and robotics as *"[…] initiatives to secure China a favorable position in the new round of technological revolution […]"*, (CISTP, 2018), with a focus on the challenges and possibilities these technologies might bring for the Chinese economy (Barton et al., 2017; CISTP, 2018). The driving force behind these aspirations is the government, more precisely the Central Committee of the Communist Party of China. The government provides the framework and the funding for MIC2025 related purposes (CPC, 2016; Li, 2017), where the total amount remains unclear, but is expected to be in the three-digit billion US$ range (Malkin, 2018; USCC, 2017; Wübbeke et al., 2016)[12].

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[12] (Malkin, 2018) lists, referring to Wübbeke et al. (2016) and other sources, a number of public funding sources for MIC2025, including MIIT and China Development Bank (45 billion US$), Special Constructive Fund (270 billion US$), Shaanxi MIC2025 fund (117 billion US$), Gansu MIC 2025 fund (37 billion US$), etc. in the coming years, where the total amount and specifically for MIC2025 initiatives reserved funds remain unclear.

In China, the 4IR is conceptualized as digitalization in the sense of virtualization, cloud computing, IoT and customization. The Chinese population is very affine to the internet itself, what makes the shift to internet based consumption easy. A demand side approach to the 4IR is pursued as can be seen with e.g. Alibaba. This is also an example for the promotion of Chinese brands. As a consequence, a new innovation driven economy model shall develop from ecommerce retail, which also is expected to secure economic growth, jobs and quality of life. (Butollo and Lüthje, 2017; CPC, 2016; Li, 2017)

In order to implement all the objectives mentioned in the strategy papers, China has to overcome major challenges. First, the uneven development within the country respectively between urban and rural areas needs to be overcome and standardized. As a consequence of the countries' inner-regional disparities, unskilled workers from the countryside are flocking to the cities for jobs. As digitalization increases a lot of unskilled labor will be set free, therefore (re-)education measures have to be implemented (State Council, 2015). Another major issue is that most of the factories in China are rather poorly equipped and relate heavily on manpower and manual labor. It often lacks capital to bring these onto another level of industrialization (CPC, 2016; Li, 2017; State Council, 2017, 2015), but China established - as mentioned earlier – diverse multi-billion public funding schemes to support the national MIC2025 strategy (Malkin, 2018; USCC, 2017; Wübbeke et al., 2016). The plans for enhancing automation are primarily driven by the political system and reads like a wish list (CPC, 2016; State Council, 2017, 2015). However, the MIC2025 roadmap is in place and the first concrete landmark projects have been initiated (State Council, 2018a, 2018b).

4.2.2 Indonesia's "Making Indonesia 4.0" (MI4.0) – Initiative

Indonesia has - in absolute numbers - with 125.4 million people (2016) the fourth largest labor force[13] in the world after China, India and the United States. Approximately 21.7 percent of the working labor force (about 26 million people) are employed in the manufacturing/ industry sector (see Figure 9). Manufacturing accounts for about 22.2 percent of Indonesia's value added to GDP (MVA) in 2016. This share has slowly, but steadily, increased since 1970 (5.5 percent) peaking in 2004 (24.6 percent) (World Bank, 2018b) (see Figure 8 in Section 4.2.1). The contribution of manufacturing to the GDP is totaling roughly in 212.8 billion US$ (Business Sweden, 2018; Jacob, 2005; World Bank, 2018b).

The importance of the manufacturing sector for the Indonesian economy and labor market in the present as well as in the years to come is evident. But, in the future this share of MVA is expected to drop to 16.3 percent with significant damages for the national economy (MOI, 2018a). Therefore, it is not surprising that Indonesia's *Ministry of Industry* (MOI) is articulating for years its strategic orientation to modernize and standardize the manufacturing processes to increase the productivity and competitiveness (MOI, 2015, 2010a, 2010b), especially in the

[13] *"Labor force comprises people ages 15 and older who supply labor for the production of goods and services during a specified period. It includes people who are currently employed and people who are unemployed but seeking work as well as first-time job-seekers. Not everyone who works is included, however. Unpaid workers, family workers, and students are often omitted, and some countries do not count members of the armed forces. Labor force size tends to vary during the year as seasonal workers enter and leave."*, (World Bank, 2018b).

ASEAN regional context (Arbulu et al., 2018; Santiago, 2018; WEF, 2017). Those ambitions, when facing the challenges and opportunities of the 4IR for Indonesia, have led to the conceptualization and implementation of the "*Making Indonesia 4.0*" (MI4.0)-Initiative to enter the era of the 4IR (BKPM, 2017; MOI, 2018c, 2018a, 2018b) by thinking outside the box and evaluating the key lessons learnt from other countries' 4IR policies[14] (MOI, 2018b). This initiative shall help to stay competitive in the 4IR era and keep/ lift the MVA by at least 21.4 (accelerated scenario) up to 26.1 percent (aspiration scenario) (MOI, 2018a).

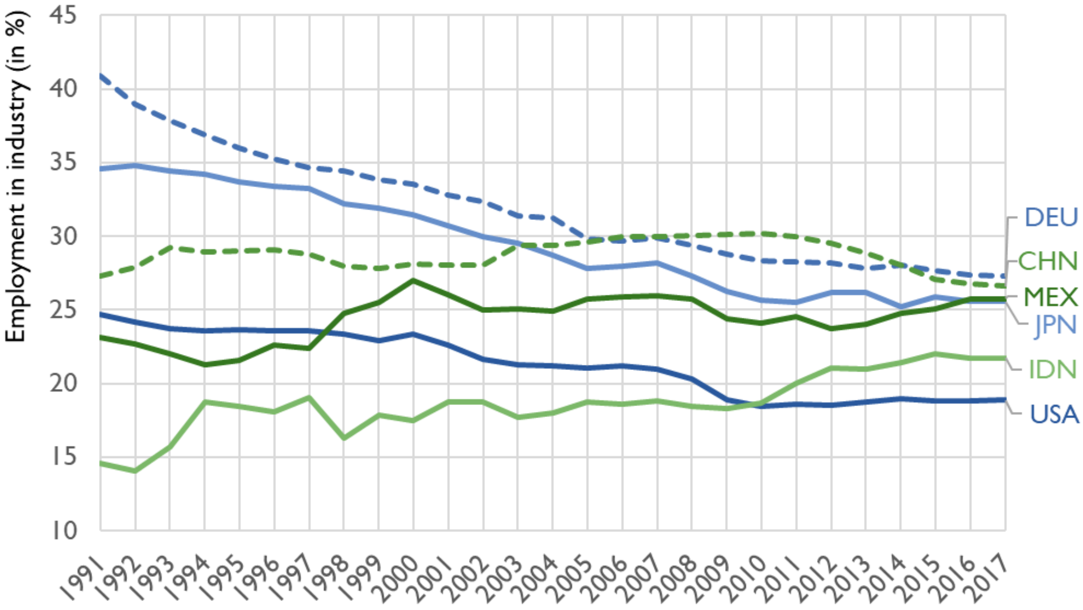

Figure 9. Employment in Industry, 1991-2017 (in % of total employment) (World Bank, 2018b) (authors illustration)

The greater aspiration of the MI4.0 initiative is to lift Indonesia in the ranks of the 10 biggest economies by the end of the 2018-2030 programming period. The MI4.0 initiative shall directly influence the economy by reviving the production sector and regaining a net exporter position, while the indirect effects are expected to be the improvement of Indonesia's financial strength, enhanced government spending and investment to create a robust economy and better labor market. The quantifiable aims are the increase of the net export contribution to the GDP up to 10 percent, doubling the labor productivity rate over the labor costs, allocating 2 percent of GDP to R&D and technology innovation fields (BKPM, 2017; MOI, 2018b).

In the process of adapting to the technological requirements of the MI4.0, the Ministry of Industry identified its MI4.0 roadmap five main technologies to subsidize to prompt the Indonesian capacities in the 4IR, namely IoT, AI and Big Data (Cloud Computing), Human-Machine Interface, robotics and sensor technology, as well as advanced production methods (e.g. 3D printing) (BKPM, 2017; Business Sweden, 2018; MOI, 2018c). The MI4.0 Initiative consists of 10 national priorities: (1) improve flow of goods/ materials, (2) develop/ redesign industrial

[14] The (MOI 2018c) made a cross-country comparison of 4IR initiatives in different stages of implementation from (A) advanced stage with visible benefits (Germany, United Kingdom, USA), (B) early stage of implementation (China, Japan, South Korea), and (C) planning phase (Malaysia, Philippines , Singapore, Thailand, Vietnam), to derive the key lessons to be learnt.

zones, (3) embrace sustainability standards, (4) empowerment of SME's, (5) build a nationwide digital infrastructure, (6) attract FDI's, (7) improve Human Capital quality, (8) develop innovative ecosystems, (9) design incentives for technology investments, and (10) harmonize regulations and policies (BKPM, 2017; MOI, 2018c, 2018a; Saputra, 2018).

To implement the MI4.0 strategy the government focuses on five core economic sectors to strengthen the fundamental structure of the Indonesian economy, namely the food and beverage industry, automotive industry, electronic industry, chemical industry, and textile industry (BKPM, 2017; MOI, 2018c, 2018a). The implementation of the MI4.0 roadmap requires collaborative approaches among multiple ministries[15], associations, the industry (e.g. Indofood, United Tractors, Astra Int., Chandra Asri Petrochemical, or SriTex) and academia (e.g. University of Indonesia, Institute of Technology Bandung, or Universidas Gadjah Mada) to create synergies (MOI, 2018a). Therefore, the MOI recommended to establish a *National Industrial Committee* (KINAS) to facilitate nation-wide, interagency, cross stakeholders alignment to push the national 4IR implementation (MOI, 2018a). Another already existing service is for instance the *Indonesian Investment Coordinating Board* (BKPM)[16], which is an investment service agency of the Indonesian government to promote and coordinate investments in the Indonesian economy (BKPM, 2017).

The Ministry of Industry, which primarily pushes conceptually and financially the MI4.0 agenda, had with a planned budget of 2.8 trillion Indonesian Rupiah (IDR) [~189 million US$] one of the lowest ministerial budgets[17] and only makes up roughly 1.2 per mill[18] of the overall Indonesian budget expenditures in 2018 (MOF, 2018a, 2018b). But this budget got slightly increased by 53.9 billion IDR [~361.6 thousand US$] in July 2018 to finance measures in line with the MI4.0 initiative (MOI, 2018d). In the fiscal year 2019 the overall MOI budget will be increased by 2.73 trillion IDR to overall 5.3 trillion IDR [~355 million US$] to promote actions within the MI4.0 initiative (MOI, 2018e)[19].

The increasing budgetary investments in the MI4.0 adaptation strategies in Indonesia are founded on the expectation that those policies will increase the economic performance, productivity and exports. Additionally, it is perceived that the 4IR will create new types of works, job requirements and opportunities that will demand a high skilled labor force (BKPM, 2017; Lindsay et al., 2016; MORTHE, 2015; Nasir, 2018) that yet has to be created (di Gropello et al., 2011). At the moment, the workforce's skill sets, e.g. from ICT graduates, often fall short of what the industrial sector requires (Mourshed et al., 2013; Nasir, 2018; World Bank, 2018c).

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[15] The involved ministries are Ministry of Industry (MOI), Ministry of National Development Planning (SMNDP), Ministry of State Owned Enterprises (MOSOE), Ministry of Manpower (MOM), Ministry of Education and Culture (MOEC), and Ministry of Research, Technology and Higher Education (MORTHE) (BKPM, 2017);

[16] (see https://www3.bkpm.go.id/)

[17] The highest budget among ministries had the Ministry of Defense (MOD) with 105.7 trillion IDR before the Ministry of Religious Affairs (MORA) [62.2 trillion IDR] and the Ministry of Health (MOH) [59.1 trillion IDR] (MOF, 2018a);

[18] In 2018, the Indonesian State Revenue was 1,894.7 trillion Indonesian Rupiah (IDR) [~127 billion US$] while at the same time spending 2,200.7 trillion IDR [~148 billion US$] (MOF, 2018b).

[19] Here has to be mentioned that related investments like increase in expenditures in education/ academia or R&D, are not explicitly imputed to the MI4.0 initiative.

This fact contributes to high youth unemployment rates between 14 to 20 percent over the last decade (Tobias et al., 2014; World Bank, 2018b). The Ministry of Research, Technology and Higher Education (MORTHE) pushes the agenda to improve the access, relevance and quality of higher education to increase the innovation, science and technology capability to support the country's economic competitiveness in the 4IR era (MORTHE, 2018, 2015; Nasir, 2018). Therefore, Indonesia has to overcome not only the still persistent lack in the quality of education, skills and talent development, but also tackle other challenges, e.g. the underdeveloped (digital) infrastructure, inefficient productivity and supply/ production chains, lacks in R&D capabilities, highly fragmented industry and left-behind SME's, overcomplicated regulations/ policies, and limited domestic funding and technologies (MOI, 2018a; Supriyadi and Tania, 2018).

4.2.3 Mexico's "Crafting the Future" (CF) – Approach

According to the World Trade Organization (WTO), Mexico was in 2016 and 2017 the 13th largest exporter in world merchandise trade by exporting manufactured goods as cars, vehicle parts, trucks and vans, television and radio equipment, computers, telephones, etc. (Hausmann et al., 2014; WTO, 2018, 2017). Mexico maintains 12 multi- and bilateral Free Trade Agreements (FTA) with altogether 46 countries (ProMéxico, 2017a) to facilitate and promote the country's export-based-economy.[20] (Kuwayama, 2009; ProMéxico, 2017b). About 77.6 percent of Mexico's GDP (World Bank, 2018b) was from international trade in 2017, whereby 37.9 percent are contributed by exports and 39.7 percent by imports (OECD, 2018). Since 1970, the contribution of trade to the GDP has steadily increased from 17.4 percent with a recognizable drop in 1993-1994, when Mexico slithered into an economic recession and hyperinflation. With the implementation of the North American Free Trade Agreement (NAFTA) in 1994, the international trade and the national economy started to recover (Kuwayama, 2009; World Bank, 2018b) (see Figure 10). In 2016, Mexico produced more than 80 percent of all high-tech exports in Latin America (SE 2016).

As an export-oriented economy, Mexico has a vital interest in the developments, opportunities and challenges connoted with 4IR in order to support its position in the global competition in trading manufactured goods (ProMéxico, 2014a, 2011). Mexico's 4IR aspirations focus on implementing digital manufacturing via IoT (ProMéxico, 2014b) to ensure its competitiveness in exporting manufactured goods and services. Furthermore the country is trying to build a sustainable economy capable of persisting in the global competition (ProMéxico, 2014a) by establishing R&D clusters and invest in the human capital for long-term, sustainable economic growth (GOB, 2014; Santiago, 2018; SE, 2016).

[20] Apart of the 12 FTAs, Mexico had in 2017 33 Reciprocal Investment Promotion and Protection Agreements and nine Economic Complementation and Partial Scope Agreements with 46 countries across the Americas, the Asia-Pacific region, and the European Union in force (ProMéxico, 2017a). According to the WTO, Mexico participates in 18 of worldwide 311 Regional Trade Agreements (RTA) in 2019 (WTO, 2019).

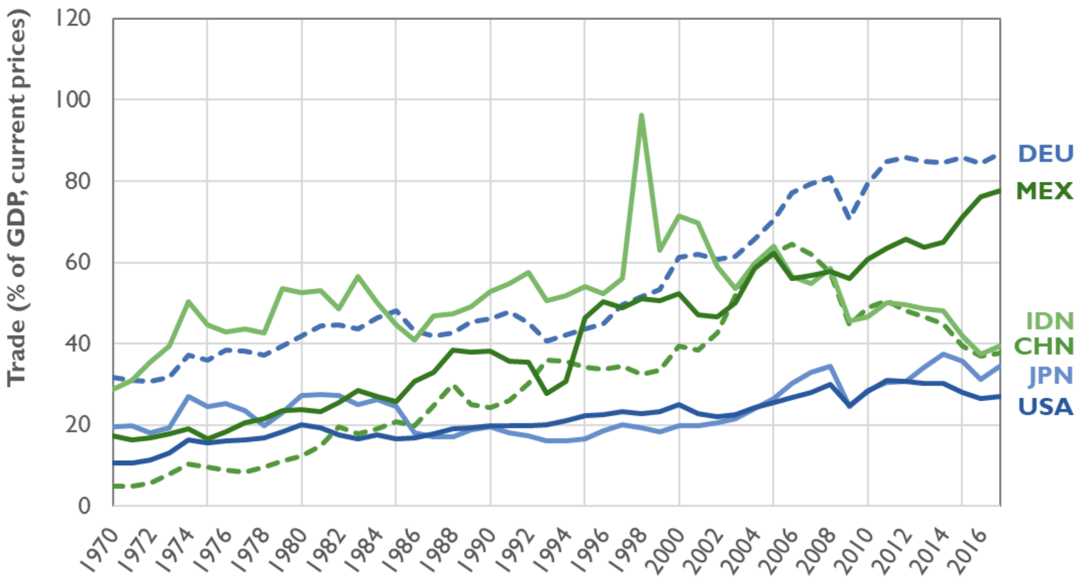

Figure 10. Trade in Goods and Services, 1970-2017 (Imports/ Exports, % of GDP) (OECD, 2018; World Bank, 2018b) (authors illustration)

Following the example of Germany, the Mexican government enacted in 2016 its first national I4.0 strategy "*Crafting the Future: A Roadmap for Industry 4.0 in Mexico*" (Santiago, 2018; SE, 2016), further abbreviated as CF, it consists of multiple sector specific strategies. The CF - strategy is an extension of the *National Digital Strategy* (GOB, 2013a), which is in-line with the *National Development Plan 2013-2018* (GOB, 2013b), and the *Program for Science, Technology, and Innovation* (GOB, 2014; OECD, 2016; Rullán-Rosanis and Casanova, 2015). These national strategy papers towards the 4IR have been designed in cooperation with government entities (CONACYT[21], AEM[22], ProSoft 3.0[23], ProMéxico[24]), science and academia (e.g. specialized education programs in Mexican states, for example in Guadalajara, Monterrey, Querétaro, Mexico City and Puebla), international ICT companies as well as MNCs (e.g. Intel, Continental Automotive, Honeywell, the Volkswagen Group) and trade associations (AMITI[25]) (KPMG, 2017; Santiago, 2018; SE, 2016).

The CF strategy highlights three strategic manufacturing sectors with high rates of MVA that would benefit from the adoption of new technologies to create a higher level of automation and digital production, namely chemical industry (ProMéxico, 2018a), aerospace economy (ProMéxico, 2015), and automotive (ProMéxico, 2018b) industry (SE, 2016; Santiago 2018). Beside these focus sectors, the Mexico's digitalization strategy also proposes roadmaps for other national industries like space industry (ProMéxico, 2017c, 2012), energy sector (ProMéxico, 2017d), logistics (ProMéxico, 2018c), etc. Mexico pushed these roadmaps *"[…] to present a first*

[21] Mexican National Council for Science and Technology (Spanish: Consejo Nacional de Ciencia y Tecnología, CONACYT) (see http://www.conacyt.gob.mx/)
[22] Mexican Space Agency (Spanish: Agencia Espacial Mexicana, AEM) (see https://www.gob.mx/aem)
[23] Prosoft 3.0 is the Mexican government's program to develop industrial software and innovation. (see https://prosoft.economia.gob.mx/Prosoft3.0/)
[24] ProMéxico (Spanish: ProMéxico) (see http://www.promexico.gob.mx/en/mx/home)
[25] AMITI (Spanish: Asociación Mexicana de la Industria de Tecnologías de Información) (see https://amiti.org.mx)

approach towards national value added strategy for the manufacturing industry through the implementation of Industry 4.0 strategies and technologies.", (SE, 2016). The strategies focus on establishing smart factories in the production process via technological advancements (e.g. 3D printing, robotics, cloud computing, Big Data analysis). A reinvigorated R&D network shall strengthen the Mexican economy and companies, where research centers[26]and universities provide technologies and services regionally (GOB, 2014; Santiago, 2018; SE, 2016). As of 2018, Mexico has over 98 research and development centers in 26 states related to advanced manufacturing and innovation plus 34 industrial clusters focused on I4.0 technologies and IoT solutions (ProMéxico, 2017e, 2018d; TBY, 2018)was[27].

Similar to Germany and Japan, Mexico's CF strategy has been initiated and funded in partnership with the government and MNCs. The Mexican *Secretaría de Economía* (SE) implements and governs the CF development. In 2018, Mexico established and funded its first state testbed initiative, Nuevo Léon 4.0, within the CONCACYT framework and the state government of Nuevo León. This initiative aims to promote this region as an innovation, business, education, and research development hub to support the CF initiative in Mexico (Nuevo León 4.0, 2018; Santiago, 2018; Waterfield, 2018). State funding for the CF initiatives under CONCACYT also includes regional research development[28] with the *Institutional Fund for the Regional Promotion of Scientific and Technological Development and Innovation* (FORDECYT[29]) and a Mixed/ Hybrid Fund (FOMEX[30]). FOMEX is funded from city, state, and federal government entities to support scientific and technological development (Gobierno Nuevo León, 2018a, 2018b, 2018c; ProMéxico, 2017a).

While the total amount of public and private investments for CF initiatives is unknown, it is expected that MNCs will be major financial contributors and the driving forces in the implementation of strategic CF projects (GOB, 2014; Rullán-Rosanis and Casanova, 2015; Santiago, 2018; SE, 2016). For instance, AMITI is one of Mexico's national sponsors for advancing the 4IR, along with corporations such as Intel, Continental, Volkswagen, Honeywell, and General Electric (Santiago, 2018; SE, 2016).

[26] As of 2018, Mexican educational and research institutions have formed state-initiated and public-private partnerships connected to Mexico's key strategy markets, e.g. CIMAT for robotic manufacturing and research, Infotec/ Fiware: National Laboratory of the Internet of the Future, and Inter-Institutional Complex of Education under the partnership of the Volkswagen Group and Benemarita University of Puebla (BUAP). (Santiago, 2018; SE, 2016)
[27] This includes an Industrial Design and Big Data Cluster in Jalisco, Intelligent Factories in Chihuahua, or Automation Technologies in Nueva Leon (TBY, 2018; Waterfield, 2018).
[28] FORDECYT has dedicated 130 million pesos (~ 6.5 million US$) for a new 1,000-square-meter research facility for the Molds, Dies, and Tools Consortium of three government research centres to support training Mexican research, developing new technologies, and implementing new business models in the domestic market (ProMéxico, 2017a).
[29] Institutional Fund for the Regional Promotion of Scientific and Technological Development and Innovation (Spanish: Fondo Institucional de Fomento Regional para el Desarrollo Científico, Tecnológico, FORDECYT) (see https://www.conacyt.gob.mx/index.php/fondo-institucional-de-fomento-regional-para-el-desarrollo-cientifico-tecnologico-y-de-innovacion-fordecyt)
[30] (see https://www.conacyt.gob.mx/index.php/fondos-y-apoyos/fondos-mixtos)

Contrary to other case country initiatives, the CF initiative reveals a gap between MNCs and Mexican SMEs moving towards the 4IR (GOB, 2014; Santiago, 2018; SE, 2016). Other challenges that might hinder Mexican companies to implement 4IR systems are weak (digital and technological) infrastructure, inefficient regulatory frameworks, deficiencies in the innovative environment, misalignments between academia and industry, undeveloped domestic market, etc. (Dutz et al., 2018; GOB, 2014; SE, 2016). Threats for Mexico to develop its CF strategy is the lack of access to financial resources for SMEs, low diffusion of I4.0 best practices in clusters and technological parks as well as the prioritization of technological acquisition over development of own technology (SE, 2016). A key element for the digital transformation will be the functional intertwine of Mexican human talent and technological transfers derived from investments (ProMéxico, 2018e) to create new employability and labor opportunities (ProMéxico, 2018f, 2018g). Without a feasible strategy to tackle the potential weaknesses and threats of the 4IR, Mexico will not be able to develop an economy for a sustainable and inclusive future for everyone[31] (GOB, 2014, 2013a; Kaplinsky, 2000; SE, 2016).

4.3 Comparison

When comparing the different country-specific approaches outlined in this section, a quite heterogeneous picture of regional adaptation and mitigation strategies as well as efforts were unveiled that range from monothematic orientations on innovation capacities in the digitalization processes of manufacturing (e.g. Germany's smart factory within I4.0, see BMBF, 2017b, 2014; European Commission, 2017a; Forschungsunion, 2012; Plattform Industrie 4.0, 2018a, 2015) to a very holistic approach that literally covers the majority of the UNs SDG targets (e.g. Japan's Smart City and Super Smart Society within Society 5.0, see Fukuyama, 2018; Harayama and Fukuyama, 2017; Heider, 2016; Keidanren, 2017). Although none of the presented national strategies toward 4IR are explicitly addressing the SDGs as such, some are implicitly targeting a broader spectrum of topics covered in the SDGs than others.

Beside the contextual scope of the different countries, the initiators and driving stakeholders as well as their thematic leadership and sphere of influence in coining the I4.0 related initiatives and strategies are quite variably interpreted. While the adaptation and mitigation strategies related to the 4IR/ I4.0 are predominantly government and policy driven, the influence of the different industry or private sectors varies among the selected case studies. For example, the governments of China, Germany and Indonesia are pro-actively working on related strategies, e.g. High-Tech Strategy (Germany) or the Internet-Plus-Actionplan (China). On the other hand, in Japan, USA and Mexico different industries and MNCs have been leveraging the national governments to implement strategies and coordination networks in order to enable a faster industrial adaptation to the 4IR/ I4.0 transformation. In the case of the USA and Japan, the national industrial sector has been having a stagnating and declining economic per-

[31] Long-term social and economic development is one of the core aims of Mexico's 2013 National Digital Strategy (NDS) for ICT development in the country: NDS' mission is to *"[…] facilitate access to and promote the use of ICTs in everyday life of society and government so that they contribute to economic and social development, and improve people's quality of life."* (GOB, 2013a).

formance and productivity to the national GDP, where the opportunities of the 4IR shall reposition and revitalize the national economies. In Mexico, MNCs try to push their agenda to open a new market and utilize the favorable geographical and economic position of the country as production location in the Americas at the interface between the export markets in North America, Latin America and the Caribbean[32].

This supply side driven approach is based on the production of a wider variety of goods and services for the domestic and international market to create revenue via exports. On the other hand, the demand side aims to increase consumer demand for goods and services. While the Global North countries can be considered as a mix of supply and demand side because of their unique selling points, e.g. Germany's knowledge in smart factories and Japan's expertise in robotics and AI. Both examples created an international sales market for their own knowledge, services and high-tech products. The case countries from the Global South are currently covering only the supply-side by producing mainly resources, materials, and (manufactured) goods for export. So far, the innovative capacities to create a demand side for the national products and services are limited for the countries in the Global South. Only China decidedly aims to create a demand side for Chinese brands. An innovation driven economy shall be developed to ensure economic growth, jobs and quality of life in China.

The strategic foci of the countries in the Global North and Global South are denoted by a dichotomy between countries that aim to deploy (stay in front) or to advance (catching-up) their position in the global economic competition. For the case countries in the Global North, strategies to deploy and maintain their leading positions within the global economy can be found. China, for instance, aims to move up the value chain by emancipating itself from a global manufacturing production workshop into a globally competing industrialized power, while Mexico and Indonesia aim to increase their economic ties in their geographical region by fostering their domestic market and by enlarging their export capacities to lift themselves in the ranks of the 10 biggest global economies. Preconditions on many levels, e.g. skill-level, workforce composition, etc. play an important part in achieving the goals, especially in the countries of the Global South. All selected case studies have in common that the export capacities occupy a central strategic importance in the political perception of each country that shall ensure economic prosperity in the future.

Core technologies and innovations (Table 3) associated and explicitly mentioned within all strategies addressing the 4IR in the case studies are CPS/ embedded systems, IoT, and Big Data. Other innovations are more dependent on the context of the countries, e.g. mainly countries from the Global North are concerned with cyber security as potential copyright infringements due to their leading position in these fields are likely to occur. Japan has a strong focus on AI, robotics as well as trying to implement the 4IR as a holistic concept with the smart city and super-smart society.

[32] Most prominently in the media was the announcement of General Motors to idle five factories in the USA, while in parallel announcing the opening of a new production site in Mexico. (see https://www.nytimes.com/2018/11/26/business/general-motors-cutbacks.html)

The effects of the 4IR on society and environment are reflected in each country's strategy, but weighted differently. While some countries simply mention potential implications on the society or labor market, without going into detail (e.g. Germany), especially the countries in the Global South are discussing this subjects broader. The major concerns are negative implications of the 4IR on labor market and social equality due to potentially increasing unemployment rates for low-skilled workers. Therefore, the redefinition of required skillsets and the re-education of the workforce are central elements in the country-specific strategies from the Global South. In the Global North this is less of a concern and often discussed in combination with universal income schemes (Norton, 2017) to mitigate the potential negative effects on the society. However, the focus in the Global North is predominantly on the industrial productivity, in contrast to the case countries of the Global South, where competitiveness and economic advancement are mainly considered with its socioeconomic consequences for the population, especially vulnerable groups like low-skilled workers (in the informal sector), women, rural population, etc.

Table 3. Technologies highlighted in the countries strategies (authors illustration)

Technologies / Innovations		I4.0 (DEU)	S5.0 (JPN)	IIoT (USA)	MIC2025 (CHN)	CF (MEX)	MI4.0 (IDN)
CPS / embedded systems		●	●	●	●	●	●
IoT		●	●	●	●	●	●
Cyber Security		●	●	●			
Data Analytics	Cloud Services	●			●	●	●
	Big Data	●	●	●	●	●	●
AI / Human-Machine Interaction			●	●	●		●
Smart Services / Smart City / Super Smart Society			●				
Advanced Production	Smart factory	●				●	
	Robotics		●	●	●	●	●
	3D printing	●		●			●
	sensor tech.						●

A detailed overview of the country-specific policies, stakeholders, aims, challenges, etc. can be found in Annex Table 5 in Section 7.3.

5 Conclusion

The 4IR is inevitable. It will sooner or later initiate a global transformation of economic, societal and political systems with implications on the environment and the way of living of soon to be 8 billion inhabitants worldwide. The SDGs are a noble attempt to mitigate the adaptation stress to this upcoming future by defining goals and targets to create a sustainable future to promote prosperity and end poverty while saving the planet (United Nations, 2016). The preparedness to cope with the challenges is essential to succeed and to leverage from the opportunities the 4IR will bring (Heider, 2016; Melamed, 2015; The Economist, 2017). The question if and how the 4IR might benefit or cripple the efforts to mitigate and adapt to climate change, social and spatial inequality, poverty, malnutrition, etc. cannot be comprehensively answered now, but only in the years to come.

The SDGs aim to ensure a globally sustainable future for environment and society by ultimately aspiring a socioeconomic convergence of all countries to end poverty and hunger. However, it is not been said if such a socioeconomic convergence is a realistic outcome of the 4IR or if the development gap between the so-called frontrunners and latecomers might open even more and solidifies the apparent global economic hierarchy, which often manifests in the formation of international economic forums, networks and summits like the G20 or the WEF.

An indication of the disruption potential for the global economic hierarchy within the 4IR can be drawn from history with the relay of the United Kingdom as globally leading economy after the 1IR, among others due to the stagnation of innovation capacities, promoting its replacement with Germany, and later Japan and USA. Today, China is challenging the old global power structures by claiming its economic supremacy from the USA. China arose from a struggling, less developed country to an Emerging Industrial Economy (EIE) in the near future becoming an Industrialized Country (IC) that might supersede the USA as largest global economy. The potential country-specific future pathways cannot be deduced solely from strategic policy papers, but those make it possible to evaluate the country-specific readiness and willingness to face the challenges and opportunities that supposedly are ahead of us with the 4IR. Who knows what country might jiggle this hierarchy in the future, when a however shaped 5IR might re-transform yet another time the human life as we know it.

As we have shown, every case country has different perspectives and aims toward the 4IR, which are influenced by a unique historical, political, societal, economic, environmental, etc. framework. Due to this circumstance, there might not be one singular solution or approach to face the 4IR, as there are evolving distinct "*national systems of innovation*" (Freeman, 2008). Therefore, each country has to be analyzed individually in order to give country-specific recommendations how challenges and threats can be embraced or withstood. From the research done in this paper, a variety of different strategies facing the 4IR in a different way can be presented and shall be used as a basis for further research.

The keys for success in this global competition might be socioeconomic versatility and adaptation capacities to prepare the national production and manufacturing sector, workforce, social system etc. for a potential paradigmatic shifts as the 4IR. The earlier strategies, policies and mechanisms are in place to prepare for this foreseeable transformation of the global economy and way of living, the easier it will be to discard potential weaknesses and threats. Those measures will require the recognition that I4.0 and 4IR are not interchangeable terms for the same process, but have quite different scopes to distinguish. To misinterpret the 4IR as I4.0 in coping with an all spheres of life pervading transformation might short-changes the importance of a holistic strategic approach to reduce the societal vulnerability and tackle challenges and threats the 4IR might causes.

A uniform usage and distinct definitions of the terms 4IR and I4.0 is important in the context of tackling the SDGs to be able to talk about the same phenomena. The 4IR is to be understood as a process of transformation on many levels, e.g. economy, society, environment, etc. It is an umbrella term of the emergence of new technologies and also innovations derived from these new technologies. Everyone's life will – sooner or later – be affected by the 4IR. In contrast to the broader notion of the 4IR, the term "*Industrie 4.0*" is mainly referring to the technological advances made/ used in the manufacturing sector. Although the term is used widely and interchangeably all over the world with the 4IR, I4.0 summarizes only a few of these new technologies that are used especially in the (German) manufacturing sector, e.g. in the smart factory.

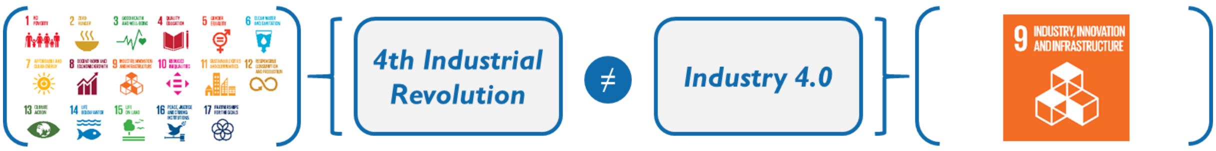

Figure 11. 4th Industrial Revolution vs. Industry 4.0

The 4IR can mean a threat, if not addressed in time with mid- and long-term adaptation and mitigation strategies, e.g. to cope with 4IR induced increasing unemployment, endangerment of social and gender equality between high and low-skilled population, reduction of the tax base, obsoleting of education curricula, resurgence of the informal sector, loss of export-led manufacturing, regionalization of supply chains, etc. (UNDP, 2018a). By only addressing I4.0 in the SDGs (SDG 9: Industry, Innovation and Infrastructure) and not the 4IR as a whole, it might hinder efforts to provide sustainable development. The potential consequences of the newly emerging digitalization in manufacturing processes are only implicitly conquered in the SDGs. To ensure an inclusive socioeconomic transformation of the society in the 4IR it is advisable to evaluate the consequences, challenges and opportunities of this process in the context of the SDG targets.

When talking about the 4IR, it is required not only to rethink production and manufacturing (e.g. decentralization of production, mass-customization, etc.) but because of this disruption it will become necessary to also discuss work and labor (e.g. unemployment, working time, etc.), skillsets and quality of education (e.g. adaptation of education system, low to high skilled labor force, etc.) etc. On a meta level, questions about the purpose of work and life (e.g. basic income, creative industries, etc.) have to be raised and will sooner or later become inescapable. Also Drath and Horch (2014) argue, that an IR is merely motivated by *"[…] the new way[s] of working rather than the technical novelty […]"* on its own. As the discourse around 4IR/ I4.0 seems to be rather narrow, we argue for a broadening of the perspective as the issues intertwined are far-reaching as well.

When it comes to the perception of preparedness for the global manufacturing competition that inevitably will kindle in the competition for production locations, investments, etc. The conception of a 4IR strategy shows to be favorable for the evaluation of a production location by global CEO's (see Figure 12) as all of the case studies, Germany, Japan, Mexico, Indonesia and USA, got ranked higher in the Global CEO Survey after having announced their 4IR strategies.

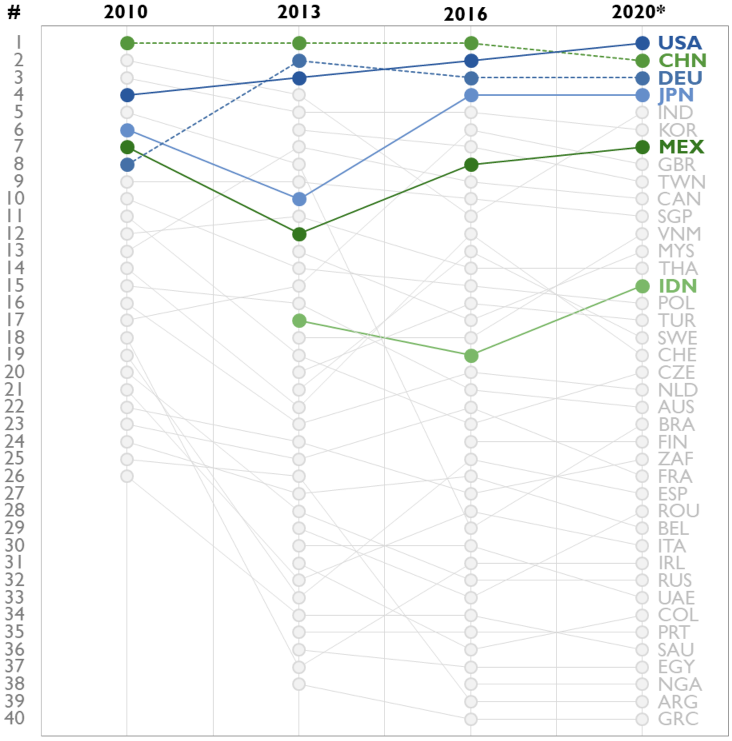

Figure 12. Global CEO Survey - Global Manufacturing Competitiveness Index: Country Rankings, 2010-2020[33] (DTTL, 2016, 2013, 2010) (authors illustration)

Which countries will utilize the 4IR best in the years to come is not reasonably to argue, but it can be said that those will have a head start who foster initiatives, approaches, strategies and policies early on to tackle the 4IR. So far predominantly countries in the GN, but also multiple countries in Asia assigned to the GS, are in a planning, early or advanced implementation phase of their 4IR policies (Figure 3). Especially, ODC and LCD countries lack of sufficient efforts to develop such strategies so far, which reflect the case study selection of this paper. We recommend to analyze and monitor existing country-specific adaptation and mitigation policies tackling the 4IR/ I4.0. Some kind of monitoring system would allow to generate longitudinal data on policies and the transformation process itself. This would provide lessons learned for other countries (especially ODC and LCD) that might have no related policies in place yet. Indonesia, for example, has analysed multiple other approaches before conceptualizing their own MI4.0 policy paper.

[33] The ranks for 2020 are projected values based on the Global CEO Survey 2016 (DTTL, 2016, 2013, 2010).

The 4IR is still at its beginning, hence opportunities as well as challenges that this process will bring can only be estimated. Not only the questions addressed in this paper will need more (comparative) research, but a variety of research desiderata will emerge.

To conclude, we want to refer once again to a statement made by Prof. Schwab (2017) in his book "*The Fourth Industrial Revolution*" to highlight the momentum of this transformation:

"Shaping the fourth industrial revolution to ensure that it is empowering and human-centered, rather than divisive and dehumanizing, is not a task for any single stakeholder or sector or for any one region, industry or culture. The fundamental and global nature of this revolution means it will affect and be influenced by all countries, economies, sectors and people. It is, therefore, critical that we invest attention and energy in multistakeholder cooperation across academic, social, political, national and industry boundaries. These interactions and collaborations are needed to create positive, common and hope-filled narratives, enabling individuals and groups from all parts of the world to participate in, and benefit from, the ongoing transformations."

— Prof. Klaus M. **SCHWAB** (Engineer and Economist, Founder and Executive Chairman of the World Economic Forum)[34]

[34] (see Schwab, 2017)

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6.2 Internet Resources

AEA - American Economic Association - https://www.aeaweb.org/econlit/jelCodes.php?view=jel#R

AEM - Mexican Space Agency – https://www.gob.mx/aem/

AMITI - Mexican Association of Information Technologies, Mexico - https://www.amiti.org.mx

BKPM - Indonesian Investment Coordination Board, Indonesia - https://www3.bkpm.go.id/

BMBF - Federal Ministry of Education and Research, Germany - https://www.bmbf.de/en/index.html

CONACYT - National Council for Science and Technology, Mexico - http://www.conacyt.gob.mx/

CONACYT - National Council for Science and Technology, Mexico - https://www.conacyt.gob.mx/index.php/fondo-institucional-de-fomento-regional-para-el-desarrollo-cientifico-tecnologico-y-de-innovacion-fordecyt

CONACYT - National Council for Science and Technology, Mexico - https://www.conacyt.gob.mx/index.php/fondos-y-apoyos/fondos-mixtos

FLATICON – Free Vector Icon Platform - https://www.flaticon.com/

FORDECYT - Institutional Fund for the Regional Promotion of Scientific and Technological Development and Innovation - https://www.conacyt.gob.mx/index.php/fondo-institucional-de-fomento-regional-para-el-desarrollo-cientifico-tecnologico-y-de-innovacion-fordecyt

G20 - Group of Twenty - http://g20.org.tr/about-g20/g20-members/

GOB - Government of Mexico, Mexico - https://www.gob.mx/aem

New York Times - https://www.nytimes.com/2018/11/26/business/general-motors-cut-backs.html

ProMéxico - http://www.promexico.gob.mx/en/mx/home

Prosoft 3.0 - https://prosoft.economia.gob.mx/Prosoft3.0/

RAUN – Regional Academy on the United Nations - http://www.ra-un.org/

WEF - World Economic Forum - https://www.weforum.org/agenda/2016/01/9-quotes-that-sum-up-the-fourth-industrial-revolution/

7 Annex

7.1 Authors and Contributors

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Judith Schnelzer is co-author of this paper. She conceptualized and refined a research idea, conducted literature research, created a research design, selected a method/ statistical tests, performed (statistical) analysis / computations, interpreted the (statistical) analysis, wrote chapters of the paper (Introduction, Methods, Results incl. General, Germany, Japan, Discussion, Conclusion, Limitations of the study, Future Directions), reviewed the paper critically.

All authors contributed by reading and approving the final version of this manuscript.

Contributor: Heather Saenz is a contributor to this paper by helping with the literature research for Mexico and writing a draft of the Mexico section.

7.2 List of Tables and Figures

7.2.1 List of Tables

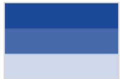
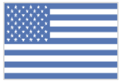
7.2.2 List of Figures

7.3 Additional Tables & Figures

Table 4. 4IR related threats and opportunities to selected SDGs (UNDP, 2018a) (authors illustration)

SDGs	Threats	Opportunities
1 NO POVERTY	- Increased unemployment - End of export-led manufacturing - Reduced tax base	+ More efficient welfare + AI and Big Data-enabled fin-tech + New livelihoods in gig economy
2 ZERO HUNGER	- Lower disposable income for food - Reverse migration to food-insecure rural areas - Micronutrient-deficient diets	+ Food supply chain optimization + Improved manufactured food quality + Yield improvement
3 GOOD HEALTH AND WELL-BEING	- Health spending constraints - Lack of safeguards in gig economy - Job insecurity	+ Advanced health diagnostics + Telemedicine + Blockchain and AI-optimized Patient data
4 QUALITY EDUCATION	- Obsolete education curricula - Reduced public spending - Widening gap between high and low-skilled	+ Low cost e-learning tools + Speech recognition for learning + AI-based marking optimizes teacher time allocation
5 GENDER EQUALITY	- Gender pay imbalance in STEM - Reduced women employment in BPO and retail - Algorithm-driven decision bias	+ Women opportunity in automation-proof sectors (e.g. care) + Reduced decision maker bias
8 DECENT WORK AND ECONOMIC GROWTH	- Resurgence of informal sector - Loss of export-led manufacturing model - Regionalization of supply chains	+ New, improved livelihoods + Reinvigoration of rural areas through internet-enabled entrepreneurship
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	- Decline of BPO sector - Decline of developing economy technological innovation - Polarized industrialization	+ ICT infrastructure investments (e.g. 4G/5G) + Emergence of new innovation champions
10 REDUCED INEQUALITIES	- Racial / ethnic bias - Wealth polarization - Higher wages of STEM-trained middle classes	+ ♀ excel in creative industries / e-commerce + Internet inclusion give more independent means of income
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	- Social media bots generate misinformation - Cyberterrorism vulnerability - AI-based surveillance	+ Blockchain-powered citizen data management + Human rights enforcement through social media listening

Table 5. 4IR related initiatives, approaches, strategies and policies for selected countries in the Global North and Global South (authors illustration)

Concept	**Industrie 4.0 (I4.0)**	**Society 5.0 (S5.0)**	**Industrial Internet of Things (IIoT)**	**Made in China 2025 (MIC2025)**	**Crafting the Future (CF)**	**Making Indonesia 4.0 (MI4.0)**
Countries	*Germany* 	*Japan* 	*USA* 	*China* 	*Mexico* 	*Indonesia* 
Launch Year	2011	2015	2011	2015	2016	2018
Initiators	government, policy driven	industry driven, politically coordinated	government, policy and industry driven	government, policy driven	government, policy and industry driven	government, policy driven
Target Group	manufacturers/producers, SMEs and policy makers	manufacturers/producers and society	manufacturers/producers, agriculture, policy makers and research	manufacturers/producers, agriculture and policy makers	manufacturers/producers, SMEs and research	manufacturers/producers, SMEs, policy makers and research
Implementation Strategies & Networks	•Hightech-Strategy •Digital Strategie 2025/ Plattform Industrie 4.0 •ICT 2020 Strategy	•Super Smart Society (Society 5.0) Service Platform •5th S&T Basic Plan, Industrial Value Chain Initiative (IVI)	•Advanced Manufacturing (Partnership) (AMP) •Industrial Internet Consortium (IIC) •Manufacturing Centers of Excellence (MCE) •National Network for Manufacturing Innovation (NNMI) •Manufacturing Technology Testbeds (MTT)	•MIC2025 •Internet-Plus-Action-plan •AI Development Report	•Roadmap for Crafting the Future •National Digital Strategy •25-year "Program for Science, Technology, and Innovation" •ProMéxico	•Making Indonesia 4.0 Initiative •National Industrial Committee (KINAS) [concept] •Indonesian Investment Coordinating Board (BKPM)
Stage of Implementation	Advanced	Early	Advanced	Early	Early	Planning
Supply / Demand Side	supply & demand side	supply & demand side	supply side (and demand)	supply side (and demand)	supply side	supply side
Funding Model	mixed (public & private)	mixed (public & private)	mainly private	public	mixed (public & private)	public
Status Quo	leading position in plant construction and engineering	leading position in robotics and AI, lack in cybersecurity	offshoring of industrial labor, increased international competition	investment driven global production workshop, internet affine population	export driven economy, with high MVA	export driven economy, with high MVA

Concept	**Industrie 4.0 (I4.0)**	**Society 5.0 (S5.0)**	**Industrial Internet of Things (IIoT)**	**Made in China 2025 (MIC2025)**	**Crafting the Future (CF)**	**Making Indonesia 4.0 (MI4.0)**
					and share of employment in manufacturing	and share of employment in manufacturing
Aims	digital manufacturing, research & innovation, cooperation of different stakeholders, and standardization	Super Smart Society (people and robots/AI), made-to-order services, internationalization of industry, competitiveness, resettle outsourced industry, vertical integration of industrial value chains	Reindustrialization, funding of innovative production, use and coordination of information, automation, computation, software, sensing and networking, innovation capacities, ensuring skilled labor market	From global workbench to innovation-driven economic growth via increase innovation capacity, integration of IT and production, strengthen industrial basis (I30), promoting Chinese brands, eco-friendly green and sustainable development, service oriented and internationalized production, vertical integration of production and value chains	Implementing digital manufacturing to maintain Mexico's competitive advantage and export capacities, with focus on developing R&D sector, strengthen Mexican firms (SME), and establish Mexico as a regional center for Industry 4.0 production/supplier	Enter the list of 10 biggest economies by 2030, increase of the net export contribution to GDP to 10 percent, doubling labor productivity rate over the labor costs, allocating 2 percent of GDP to R&D and technology innovation fields
Strategic Focus	deployment, competitiveness, export	deployment, competitiveness, S&T, innovation	deployment, competitiveness, export	advancement, competitiveness, export	advancement, competitiveness, developing domestic market and regional center	advancement, competitiveness, export, R&D
Approach	industrial manufacturing, mechanical engineering	holistic (healthcare, mobility, infrastructure, finance), industrial manufacturing, mechanical engineering, production innovation centres	production innovation centres and manufacturing testbeds, aviation, shipping, energy and agricultural industries, health services	production innovation centres, funding IT, CNC, robotic, aeronautic gear and avionic, naval gears, low-energy and emission free vehicles, energy technologies, advanced materials, biomedicine, agricultural machines	production innovation centres and manufacturing testbeds in key production sectors like chemical economy, aerospace economy, and automotive industry	industry and labor force: industrial zones and set of measures in 5 focus areas in foods and beverage industry, automotive industry, electronic industry, chemical industry, and textile indus-

Concept	**Industrie 4.0 (I4.0)**	**Society 5.0 (S5.0)**	**Industrial Internet of Things (IIoT)**	**Made in China 2025 (MIC2025)**	**Crafting the Future (CF)**	**Making Indonesia 4.0 (MI4.0)**
						try plus change of education/academic system
Challenges/barriers	internationalization of value chains, accelerating product life cycles, competition, customization of production	stimulus under-funded sectors (i.e. smart agriculture), shift from mass production to mass-customization, in-house research vs. open innovation culture, integration of SMEs	decreasing industry creates lack in innovation capacities	governmental coordination, rural-urban-migration/disparities, urbanization, restructuring of labor market	government coordination, gap between MNCs and SMEs due to lack of access to financial resources for SMEs, low diffusion of I4.0 best practices in clusters and technological parks as well as the prioritization of technological acquisition over development of own technology , weak (digital and technological) infrastructure, inefficient regulatory frameworks, deficiencies in the innovative environment, misalignments between academia and industry, undeveloped domestic market, etc.	limited investment, low productivity, limited FDIs/net exports, weak currency ratio, and high capital costs (debt and equities costs), undeveloped digital platforms, 62 percent of IDN's labor force are in SMEs, raw materials & critical parts are import dependent, no strong government or PPP R&D centers
Technology	CPS, IoT, Big Data, tech. Innovation based on horizontal and vertical integration, cyber security,	CPS, IoT, Big Data, AI, robotics, Big Data, smart city, smart services, cyber security	CPS, IoT, Big Data, AI, robotics, cutting edge materials, nano- and biotechnology, physics, chemistry, cyber secu-	CPS, IoT, Big Data, AI, robotics digitalization (mobile internet, cloud computing, IoT in production, eCommerce)	CPS, IoT, Big Data, robotics, smart factories, data analytics	CPS, IoT, Big Data (Cloud Computing), AI, Human-Machine Interface, robotics, sensor technology, advanced production

Concept	**Industrie 4.0 (I4.0)**	**Society 5.0 (S5.0)**	**Industrial Internet of Things (IIoT)**	**Made in China 2025 (MIC2025)**	**Crafting the Future (CF)**	**Making Indonesia 4.0 (MI4.0)**
	smart factory, embedded systems, Cloud Computing, advanced production methods (e.g. 3D printing)		rity, ICT, advanced production methods (e.g. 3D printing)			methods (e.g. 3D printing)
Potential action fields	rethinking work and education	rethinking education with focus on economic and natural sciences	strengthen skilled industrial labor market	rethinking production, labor and skills	rethinking work and education	rethinking work and education
Discourse	technological change on society and economy, increasing international competition with accelerating innovation cycles and new business models, potential chances of I40	societal and technological integration	business perspective on potentials, policy perspective on international competitiveness	sustainable and innovative economic growth	sustainable and innovative economic growth, strengthen domestic companies and market, maintain net exports	revitalization of industry, increase of productivity, to strengthen net exports, competitiveness, human capital & skills for future labor market