Industry 4.0 and World Economic Divergence

A novel perspective on the impact of fourth industrial revolution on the world economy

by

Ashutosh Rijal

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List of abbreviations

EM	Emerging Markets
R&D	Research and Development
FTE	Full Time Employee
ASEAN	The Association of Southeast Asian Nations
GDP	Gross Domestic Product
FDI	Foreign Direct Investment
IoT	Internet of Things
CM	Contribution Margin

Abstract

Industry 4.0 is a current trend of digital transformation and integration of processes into the digital environment using automation, big data, and Internet of Things (IoT). The divergence of the world economy, contrary to the convergence infers the increasing gap between developing and developed countries. Although it is true that there are significant productivity and efficiency gains with the upcoming fourth industrial revolution, it is also essential to examine the differences in the impact of automation on these two economies. The thesis is an attempt to investigate how unanticipatedly Industry 4.0 and the upcoming era of automation supports the divergence of the world economy, contributing to the gap between the developed (Japan, USA, Germany) and developing countries (India, Nigeria, Mexico).

The higher the population, the higher the number of people contributing to economy, has been the centre argument for convergence. But how different is the economic impact, when it is the industrial robots working for the economy and when the country even with low population can achieve equally high output? The paper dives over these topics with 1) comparative analysis where an outlook of Industry 4.0 is observed by examining previous three industrial revolutions 2) macroeconomic analysis, where population demographics, labour redeployment and marginal cost-benefit of Industry 4.0 are inferred to discuss divergence of economies. The transdisciplinary paper uses concepts from economics and business disciplines and concludes with policies for developed and developing countries to prepare for the upcoming transition.

1 Introduction

1.1 Problem of the thesis

Unlike other industrial revolutions, Industry 4.0, the trend of automation, big data, and IoT, is often versioned as an evolution than a revolution.[1] It is not only about the increasing complexity that concerns Industry 4.0 but also about its increasing level of influence directly on the workers.[2] There are currently many researches going on industry 4.0 and its productivity and efficiency boost to the economy, however, no attempts were made comparing its impact between developed and developing economy.

Drawing on the concept of Solow growth model, many support the convergence of economies on the idea that developing countries are growing and will continue to grow faster than the developed ones. PwC projection that by 2050, India will surpass the US, subsequently Mexico will surpass Japan, while Nigeria emerges as top 15 largest economies in total Gross Domestic Product (GDP), over stresses the role of the population of a nation and undermines the increasing role of machine and automation with Industry 4.0.[3] The centre argument of convergence is that the larger population will contribute more to the GDP. However, the case with the fourth industrial revolution is different since the highly automated industries will not depend on the number of workers they have to produce goods in large quantity.

Realizing such research gap, this thesis is an attempt to investigate the differences of the impact of Industry 4.0 in advanced countries mainly Japan, Germany and the USA and developing countries mainly Nigeria, Mexico, and India. Factors such as population demographics, marginal benefit, technological adaptation lags and reshoring indicate how unanticipatedly Industry 4.0 supports the diverging world economy and provide valid reasons to rethink the current convergence model.

[1] Cf. (Neugebauer *et al.*, 2016), p. 3.

[2] Cf. (UniGlobal Union, 2016)

[3] Cf. (PwC, 2017)

Comprehensive research on this topic provides an outlook of upcoming economic changes due to Industry 4.0 where the changes range from the shift of job paradigm, labour redeployment to alteration in the global trading pattern. Such extensive outlook will primarily help nations align their economic and development strategies to avoid unanticipated crises and also help workers anticipate upcoming labour redeployment due to automation and industrial robots.

1.2 Aims of the thesis

An overarching aim of the thesis is to discuss divergence between developed and developing countries due to Industry 4.0 challenging the notion of the role of population in the convergence model. The paper will subtly try to examine using the marginal cost-benefit curve and the diverging technological adaptation lag, to explain how the benefit of automation differs between developed and developing nations.[4]

A secondary research aim of the thesis is to examine the change in structure and dynamics of economies due to Industry 4.0. The is because the transition to the fourth industrial revolution is a reshuffling of economic, social and industrial model resulting in the shift of job paradigm, labour redeployment, and other radical structural changes.[5]

The paper further extends to propose policies to two different economies (developed and developing) as its conclusive and pragmatic aim. The aim of policies is not only growth but also simultaneous alignment as bottlenecks or crisis could occur in an economy. Therefore, an essential objective of the industrial policy is the alignment of different elements to make the transition coordinated and efficient. [6]

1.3 Course of research

The paper is a transdisciplinary approach as it uses concepts from mainly development economics and business alongwith political economics and industrial management to examine the impact of Industry 4.0. Hence, a multi-method approach was chosen to justify such an

[4] Cf. (Comin and Mestieri, 2016)

[5] Cf. (Alexander Belderok *et al.*, 2016)

[6] Cf. (Bianchi and Labory, 2017)

extensive idea. The thesis comprises of two simultaneous analysis, 1) Comparative Analysis: where previous three industrial revolutions were examined mostly with literature reviews to construct an outlook of the upcoming fourth industrial revolution. 2) Macroeconomic analysis: where a) a simplified economic model of automation is used to explain the shift of job paradigm and labour redeployment b) population demographics is used to observe how automation favours the demographics of advanced economies more than the developing ones. c) the classical marginal cost-benefit graph is extended to analyse the difference in quantities of firms implementing Industry 4.0 in advanced and developing countries.

By advanced or developed countries or economies, the thesis mainly refers to Japan, USA, and Germany, because a) they are currently the most proficient at implementing Industry 4.0, [7] b) they have high wages and aging population. Mexico, India, and Nigeria on the hand will be mainly emphasized as the developing countries or economies as a) they have booming population and b) low wages.

Countries with declining population but average wages like China or countries with increasing population but high wages are excluded from the scope of this paper. It is also important to note that the paper stresses divergence with Industry 4.0 based only on the total GDP of a nation and not GDP per capita. The impact of Industry 4.0 on a per capita level is also excluded from the scope of the thesis.

[7] Cf. (Statista, 2016)

2 Definition and Background

2.1 Industry 4.0 and its framework

Industry 4.0, the fourth industrial revolution is a current trend of digital transformation and integration of processes into the digital environment. It is gradually implemented, often with the interaction between physical objects with cyber objects and services (cyber-physical systems). The framework consists of nine major technology pillars: 1) Automation 2) Simulation 3) System Integration 4) Internet of Things 5) Cyber-physical systems and Cybersecurity 6) Cloud Computing 7) Additive Manufacturing 8) Augmented Reality and 9) Big Data.[8]

These technology drivers will trigger radical changes in manufacturing system regime, business models, system equilibria and the economy. A full-fledged Industry 4.0 system running with all the technology pillars ensures productivity gains with increased in total output, improved safety and errors (due to precision of System Integrity), higher agility and quality (due to better information flows), increase in performance and efficiency, and labour cost savings (due to automation).[9] Increase in technological complexity followed by the increase in steps of implementation, Industry 4.0 is often versioned as an evolution than a revolution as it will have a considerate impact on both businesses and economies.[10]

2.2 Industry 4.0 Business Model Canvas

Industry 4.0 comes with the transformation of simple machines to automated self-learning machines. Following business model canvas will explain the fundaments of Industry 4.0 and help understand the transition to it.

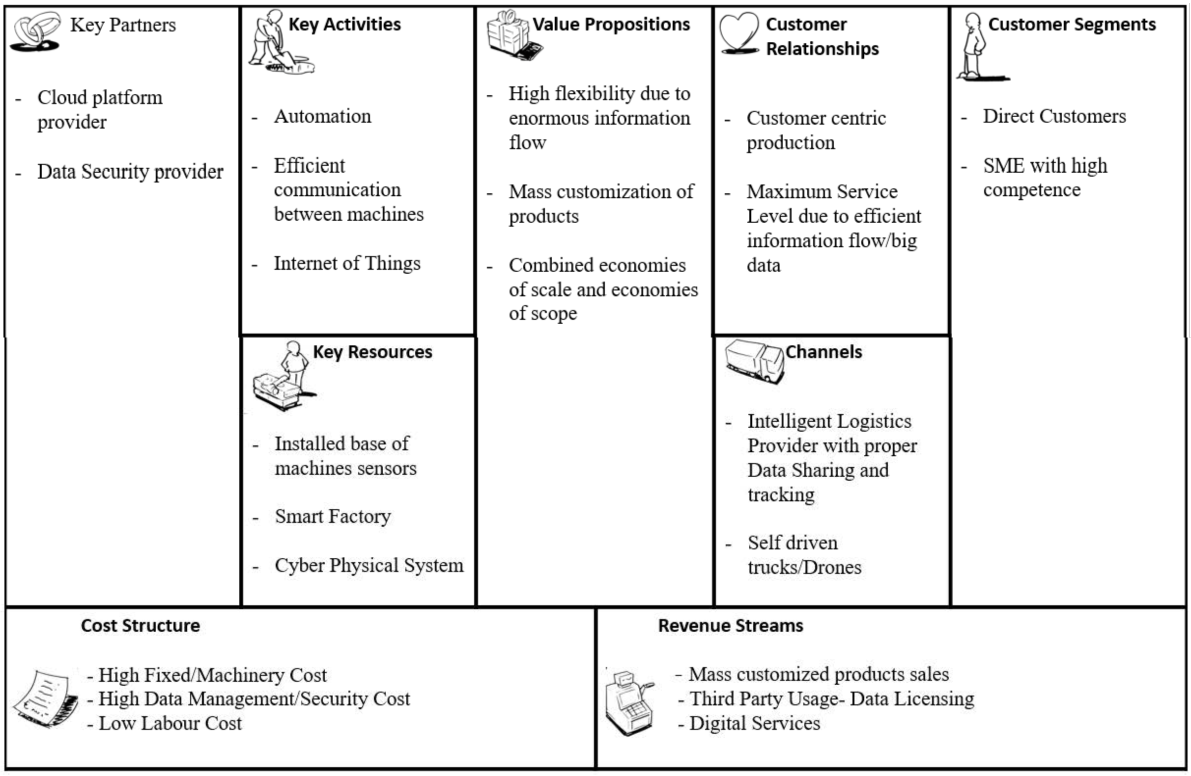
Figure 1 is an example of how a business model canvas of a manufacturing firm would look like with Industry 4.0. This manufacturing firm will have cloud platform and data security provider as its key partners.

[8] Cf (Vaidya, Ambad and Bhosle, 2018)

[9] Cf (Manyika *et al.*, 2017), p.42

[10] Cf (Neugebauer *et al.*, 2016), p.3.

Figure 1: Industry 4.0 Business Model Canvas (a manufacturing firm)



Source: own creation

Tremendous use of data in manufacturing processes will increase the need for external data security management and cloud storage provider. Information flow will be an important part of the value-adding process.[11] The firm will have automation and IoT as its key activities and smart factory and cyber-physical systems as its key resources. With the help of these technologies, this firm will produce mass customized products combining economies of scale and economies of scope.

The high flexibility provided by big data and information flows will ensure customer eccentric production and increase in service level to the customers. Moreover, the product innovation becomes a vital source of competitive advantage.[12] Cost Structure, on the other hand, includes high machinery cost (fixed cost) due to expensive high-tech production lines; however, it will also help the firm to reduce the low skilled labour cost (variable cost). From a business

[11] Cf. (Cotteleer and Sniderman, 2017), pp.2-3

[12] Cf (Bianchi and Labory, 2017), p.

perspective, this will have an impact on the Contribution Margin ratio (CM ratio), the break-even point and the degree of operating leverage.[13] The impacts can be summarized as follows.

Table 1: Impacts of Industry 4.0

S.N.	Firms with Industry 4.0	Reasons
1	Higher CM ratio	- higher fixed costs than variable cost increases CM ratio
2	Higher Operating leverage	- larger CM ratio allows more operating leverage
3	Higher Profit volatility	- As operating leverage is higher and variable cost is lower, profits are sensitive. In increasing sales, there are rapid profit gains, but in decreasing sales, there is a rapid profit loss.
4	Higher Break-even point	- Higher machinery cost requires more time to breakeven
5	Small margin of safety	- Automated production lines allow less latitude of flexibility and more market sensitivity than labour intensive production lines

Albeit the manufacturing firm with Industry 4.0 will likely have low latitude of flexibility and sensitive profitability, the total output growth and productivity increase can be expected through a) mass customized production lines with robotics, and 3-D printing, b) deploying augmented reality and simulations to understand the ventured market better c) labour cost savings with automation. [14] It is the latter that concerns economist and policy makers as it infers possible labour redeployment and creates differences between advanced and developing countries. Further discussion on the differences between economies will be discussed in detail further in the thesis.

[13] Cf (Seal, Garrison and Noreen, 2012), p. 247 - 249

[14] Cf (Lorenz *et al.*, 2015)

3 Comparative Analysis: previous industrial revolutions

3.1 Introduction

It is necessary to realize that industrial revolution is not an entirely new concept. There were previous industrial revolutions and manufacturing structural changes in the past, and it is essential to understand and analyse previous industrial revolutions and shift in manufacturing regime to interpret the dynamics and possible economic impact of upcoming fourth industrial revolution. This section is a comparative analysis as it broods over previous three industrial revolutions and examines their effects on economy creating an economic outlook of Industry 4.0.

First industrial revolution triggered by steam and water power occurred from the 18th to early 19th century. Second industrial revolution building upon electric power peaked during 1870–1914.[15] Use of electronics and computer technology for mass production triggered third industrial revolution around 1970. Finally, ongoing fourth industrial revolution is a current trend of automation, machine learning, and big data. The upcoming sections will examine the fundaments of industrial revolutions to discuss anticipated structural changes for policy-making which will be further discussed towards the end of this thesis.

3.2 Radical Structural Change

Incremental change is considered as a slight upgrade or enhancement of existing processes while radical change is considered as a significant upgrade or disruptive innovation and it is the latter that corresponds to industrial revolutions. Radical technological innovation leading to radical structural changes is one way to look at industrial revolutions.

Structural change in the other hand is a multi-dimensional process, involving the introduction of new 1) technology 2) manufacturing system, and 3) job skill.[16] Let's consider the first industrial revolution, invention of steam engine the new radical technology leads to the new production system of mechanization and massive coal consumption, which leads to new job

[15] Cf (Mokyr and Strotz, 1999), p. 1.

[16] Cf (Bianchi and Labory, 2017), p. 2.

skill as the workers are replaced from agriculture and craft production to industries and prompted to migrate from rural to cities.

If we look at the trend, this radical structural change did not occur in the most populated country, nor the country with cheap labour cost but instead in Britain where the wages were higher than in other countries. The size of the population has little or anything to do with technological progress.[17] Allen argues that the Jenny mechanized weaving tool was profitable and was worth going through the cost of implementation not in India but only in Britain, due to Britain's higher wages.[18] It is the cost saving driving factor that incentivizes human for such structural change. Having Jenny in India for weaving purposes would mean comparatively less benefit as the cost of labour in India was lower. Despite low wages in developing countries, a similar pattern of adaption could be expected in the upcoming fourth industrial revolution. This point will be further discussed in Marginal Cost Benefit section in details.

Albeit the industrial revolutions were peculiar in various ways, they had quite a few things in common. Every time change in technology and change in competition/demand pattern triggered structural changes which on the other hand triggered institutional changes.[19] If we consider the third industrial revolution, computer and the internet created the need for social networking and information sharing on the internet, implying institutional change with laws for cybercrime and copyrights. The fourth industrial revolution could bring similar if not the same change in competition and institutional structure.

3.3 Transition between System Equilibria

Another way to understand industrial revolutions is the system equilibria transition. Solow inferred in his growth model, the economy always tries to remain in a steady state of capital equilibrium, but it is through different saving curve that the steady state of capital equilibrium changes.[20] Technology plays a similar role as it changes the system equilibria of an economy.

[17] Cf. (Voth, 2003), p.1.

[18] Cf. (Allen, 2007)

[19] Cf. (Smith, 1985)

[20] Cf. (Todaro and Smith, 2015), p. 155-158

It can be understood that economy remains in a system equilibrium before an industrial revolution but during the revolution, it transits and achieves a higher system equilibrium.

There are however problems with the transition, and these include "system and network failures, strategic failures, coordination problems, and structural dynamic issues."[21] These issues are mainly because of different timing of adaptation of equipment, workers, and capital. For instance, during the transition, equipment changes quickly as technology progresses, but the workers take more time to adapt to new skills for new production processes.

It is because of the difference in adaptation, the system equilibria transitions usually incorporate unemployment. The transition due to the third industrial revolution led to elimination of 1.4 million typists and secretaries as digital editing was easier with computers.[22] Not to mention, there were simultaneously million other jobs created by computers. The arrival of new technology to the market has always sparkled anxiety and fear in people, sometimes even leading to mass protests. This anxiety dates back to the first industrial revolution when Queen Elizabeth I denies permission to operate knitting machine discovered by William Lee in 1589, as she was sceptical about its effect on hand knitters.[23] However, the difference is the monarchical government-imposed intervention back then whilst the democratic government of today impose conditions and provide assistance. Regardless of the type of government system, fear of change with the introduction of new technology and system equilibria transition is prevalent.

The fourth industrial revolution drives similar anxiety in people as the fear of "robots replacing humans" is quite ubiquitous and it is partly true. To understand this, it is important to realize how an economy has always created winners and losers, and how an economic decision is made based on a cost-benefit evaluation. Between 1993 and 2014, the American automobile industry laid off 28% of its employees but more than doubled its productivity, meanwhile, the health sector had 28% new jobs opening and improved productivity by 16% over the same period.[24] Similarly, since 19000, employment in the agriculture industry in the US is rapidly shrinking

[21] Cf (Bianchi and Labory, 2017), p. 1.

[22] Cf (Manyika *et al.*, 2017), p. 40.

[23] Cf (Hills, 1989), pp. 171

[24] Cf (The Economist, 2018)

from around 50 to 3 percent due to increasing employment in manufacturing and service industry.[25] As Joseph Schumpeter infers "creative destruction" to explain the phenomenon, introduction of new technology has created jobs to balance those which got disappeared.[26] There have always been positive links between jobs creation, increase in output and introduction of technology.[27] And the pattern is similar with other industrial revolution transitions.

An industrial revolution, therefore, is economy thriving to achieve higher system equilibrium, but as there are many issues that come along with transitions, there is unemployment. Winners and losers are prevalent in every economic policy, but the former has always outnumbered latter during industrial revolutions. Also, the important thing to note is that none of the industrial transitions resulted in long-term mass unemployment but rather increase in jobs and productivity.

3.4 Manufacturing Regime Shift

The dynamic shifts in manufacturing regimes can also explain industrial revolutions. Manufacturing regimes are basically production systems that exist during certain period. These shifts are usually due to changes in technology coupled with changes in customer demand (in terms of volume and variety).

It started on an individual level with craft production; there was higher flexibility but low volume of production. As Marx infers, bourgeoisie started realizing the power of collective people, and economics of scale which led to mass production.[28] Hence, the first industrial revolution was a shift from craft production to machinery production.[29] Any workers previously able to carry out all the means of production are alienated and specialized in small repetitive tasks, this led to the third manufacturing regime of mass production. The third shift as the figure above shows is the regime of flexible manufacturing. Toyota first introduced it as lean

[25] Cf (United States Department of Labor, 2018)

[26] Cf (Caballero, 2008)

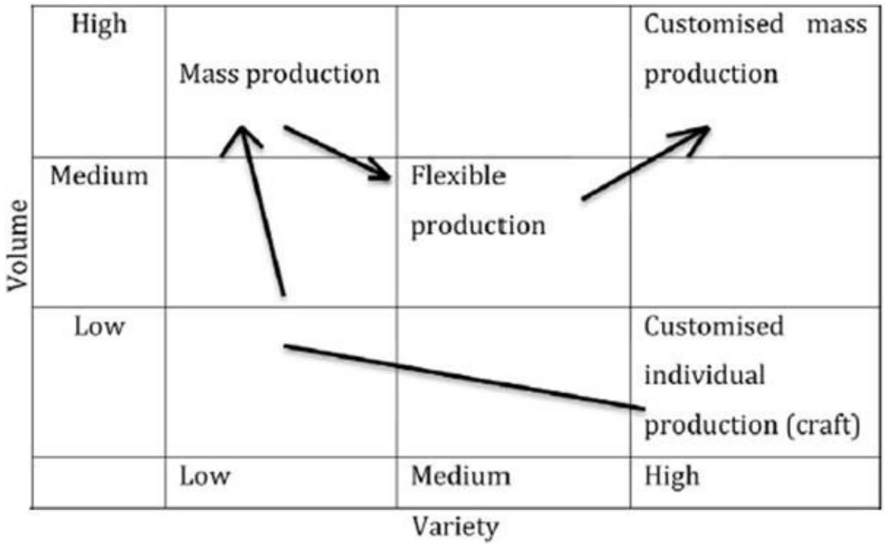
[27] Cf (McKinsey&Company, 2017), p. 31.

[28] Cf (Marx, 1859)

[29] Cf (Hoppit, 1990), pp. 175

production where products are manufactured in mass with some degree of product differentiation.

Figure 2: Manufacturing Regime Shift



Source: (Bianchi and Labory, 2017), p.5.

The combination of Just-In-Time delivery with the standardized platform but differentiated modules was the fundamental idea behind flexible manufacturing.[30] Interestingly, this new manufacturing system reduced the number of rivals and competition as firms could achieve the first-mover advantage by producing a range of products in volume. The number of car manufacturers reduced from 100 to 35 as firms started producing flexible.[31] This was due to the acquisition of niche firms by big giants due to the advantage of corporate power entailing a shift from competitive market to oligopolistic competition. The macroeconomic analysis will further continue the discussion on the first mover and competitive advantage of corporates.

The fourth and the ongoing shift points towards mass customization where firms benefit from the combination of economies of scale and scope. This means firms will be producing a range of products in low cost and high volume with the help of automated production lines, 3D printing and enormous amount of information interaction with big data. As machines communicate with each other through sensors, information exchange will be an essential value

[30] Cf (Toyota Motor, 2018)

[31] Cf (Bianchi and Labory, 2006), p. 31.

adding tool. Increase in customer’s demand for product variety and volume due to increasing world population are the key drivers of this shift.

4 Macroeconomic Analysis: Industry 4.0

4.1 Shift in Job Paradigm and Labour Redeployment

This section will mainly discuss the shift in job paradigm and possible structural changes in employment due to industrial revolutions on a macroeconomic level.

Figure 3: Decreasing Average Annual Hours Worked

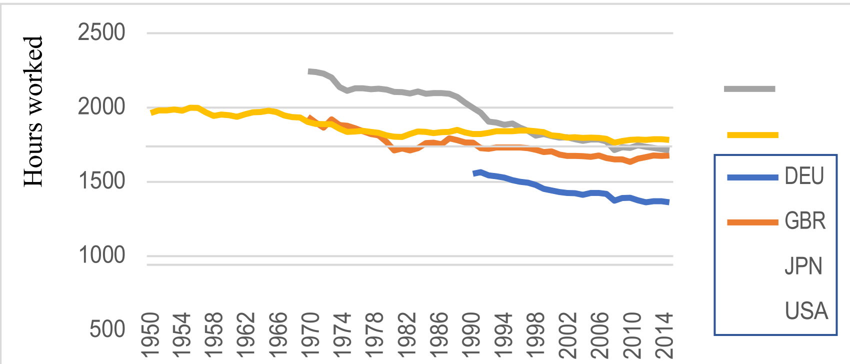


Image: own creation Data: (OCED, 2018)

Figure 3 shows how the annual hours worked has been decreasing over time allowing more leisure time to people in advanced countries. During the Industrial Revolution, these industrializing western countries worked longer than the developing countries. Developed countries worked for 66 hrs/week whilst the developing countries worked only for 45 hrs/ week.[32] However, after the industrial revolution, the working hours has substantially decreased because the introduction of new technologies has increased efficiency and productivity at work. The average annual working hours for example in France decreased by 35% from 1950-2014.[33] The trend is expected to be similar with Industry 4.0; Scandinavian countries like Sweden are

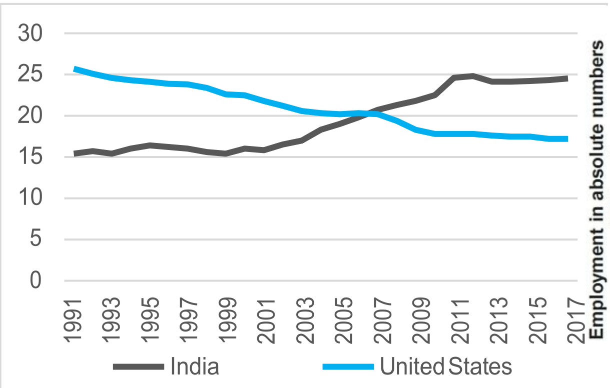
[32] Cf (Voth, 2003), pp. 223.

[33] Cf ((CityGroup, 2016), p. 10.

already moving toward six hours a day working model.[34] Hence, Industry 4.0 is likely to push the working hours further below in developed countries, as industrial robots will be responsible for most of the labour-intensive tasks.

Figure 4 shows another significant paradigm shift where the number of people employed in industries in developed countries like the US is decreasing while in developing countries like India is increasing. The booming population in labour intensive countries increases employment in industries allowing less room for automation in the developing countries. On the contrary, aging population and decreasing involvement of workers in industries in advanced countries like Germany increase the need for industrial robots and automation. Only in western Europe- Germany, Italy, France, the UK and Spain, it is anticipated that $1.7 trillion in wages are potential automatable activities. [35] This means the workers will need to work along with machines meticulously and acquire skills needed for Industry 4.0.

Figure 5: Employment in industries (% of total employment) **Figure 4: Employment in the EU by Qualification**



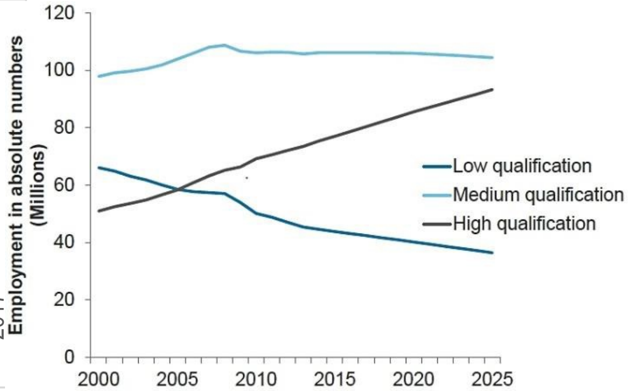


Image: own creation Data: (The World Bank, 2018) Source: (Cedefop, 2008) & (CityGroup, 2016), p.48

An outlook on employment qualification in the EU conducted by Cedefop and CityGroup (Figure 5) shows how the demand of low skilled has been decreasing over time in the EU and will likely further decrease in the fourth industrial revolution. To compensate the decrease in demand, the need for higher-skilled workers is forecasted to increase substantially. This means

[34] Cf (Bernmar, 2017)

[35] Cf (McKinsey&Company, 2017), pp. 8.

the need for human cognitive skills like problem-solving, logical thinking, creativity, social and emotional capabilities that have low automation potential will increase.[36]

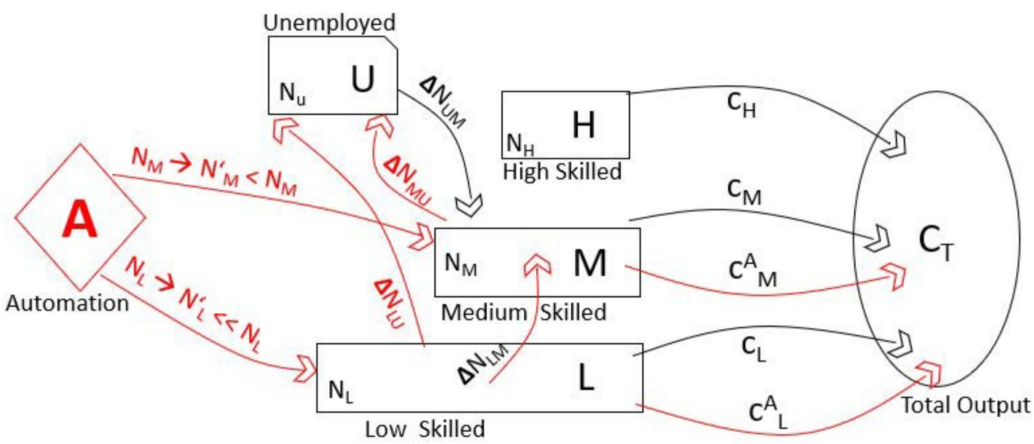
Learning was minimum in mass production as an individual was responsible only for specialized and repetitive tasks. Workers were required to be more skilled and aware of the process in flexible production as they were simultaneously responsible for different processes. While, in customized mass production in Industry 4.0, learning is maximum as the creative and innovative decisions are made by humans, and the machines do the redundant ones.

In developed countries, as automation does the repetitive tasks, works done by humans will be at a premium. Currently, only 10% of the average human work is done with innate human skills involving logical thinking and emotional capabilities.[37] It is expected that automation and artificial intelligence will create more human jobs as workers are freed up to perform tasks with higher capabilities.

Meanwhile, in the developing countries, the migration of low skilled is likely to decrease significantly as the low skilled tasks are expected to be carried out by industrial robots in the advanced economies. As a result, this will further increase the abundance of workers in developing countries which will again push down wages and the automation potential.

Further effects of automation on employment and labour redeployment will be explained using a simple economic model.

Figure 6: Simplified Economic Model for Automation



Source: own creation

[36] Cf (Manyika *et al.*, 2017), pp.126.

[37] Cf. (McKinsey&Company, 2017), p. 37.

In an economy, N_H, N_M N_L, and N_U represent the number of high skilled, medium skilled, low skilled and unemployed workers respectively. As listed by Peter Scott, low skilled jobs are highly likely to be automatized and are characterized as librarians, data entry keyers, and factory labourers. Medium-skilled jobs are likely to be partially automatized and are characterized as operators, managers, and psychiatrist while high skilled jobs are the least susceptible to automation and are categorized as top-level managers, the board of directors, and CEOs.[38] There is a positive correlation between the wage and susceptibility of automation at least for the upcoming decades because it is usually higher and medium skilled that involves decision making, planning, and managing. Therefore, the model leaves the number of high skilled (N_H) undisturbed.

C_H, C_M, and C_L represent the percentage of capital contributed by high skilled, medium skilled and low skilled respectively and C_T represent the total output of a nation. Once the firms start automating, it will directly affect the economy. N_L changes to N'_L and N_M changes to N'_M where $N'_M < N_M$ and $N'_L << N_L$. ΔN_{LM} is the number of low skilled upskilled to medium skilled and ΔN_{LU} is the number of low skilled workers that get unemployed due to automation. ΔN_{MU} is the number of medium skilled that gets unemployed, and ΔN_{UM} is the number of unemployed workers that adjust/upskill their skills and come to medium skilled pool. c^A_M and c^A_L represent the percentage of capital contributed with the help of automation by medium and low skilled workers respectively. With this, it can be assumed that:

$$N_L - N'_L = \Delta N_{LU} + \Delta N_{LM} \qquad \text{--- (i)}$$

$$N_M - N'_M = \Delta N_{MU} - \Delta N_{UM} - \Delta N_{LM} \qquad \text{--- (ii)}$$

$$N'_U = N_U + \Delta N_{MU} + \Delta N_{LU} - \Delta N_{UM} \qquad \text{--- (iii)}$$

And, $c^A_M > c_M$, $c^A_L > c_L$, $N'_M < N_M$ and $N'_L << N_L$

Hence, automation will interact and affect the labour market supply and workforce skills. Higher ΔN_{MU} and ΔN_{LU} would mean an increase in N_U which in return increases the supply of workers and puts downward stress on wages. Simultaneously, the upskilling N_U might take some time to jump into other skill sets; hence the delay in upskilling can also temporarily reduce

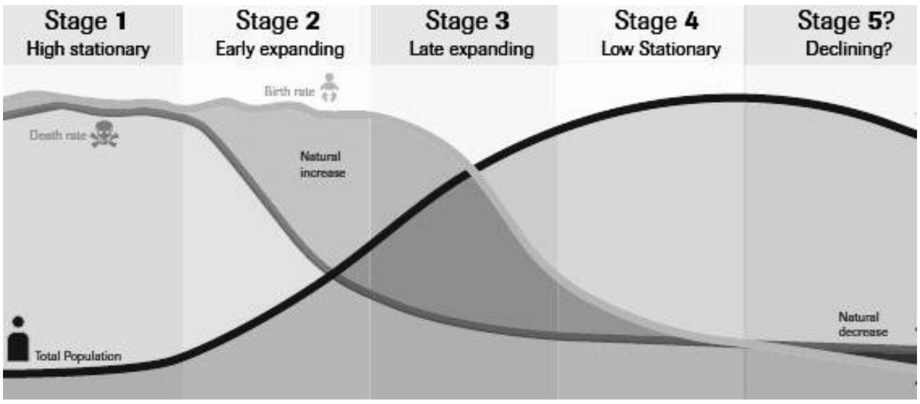
[38] Cf (Scott, 2017)

the total labour supply, T_N.[39] Thus, the labour market dynamics is affected as processes are automated.

4.2 Population demographics

This section will explain how the compatibility of Industry 4.0 and automation differs with different population demographics. The industrial revolution and the period of development of a nation comprises of five major stages. Warren Thompson was the first demographer to observe such distinct development pattern and population change over time in his Demographic Transition Model, 1929.[40]

Figure 7: Warren Thompson Demographic Transition Model



Source: (Grover, 2014)

Stage 1 applies to nations before Industrial Revolution, high birth rate but also high death rate which result in relatively low total population. Stage 2 represents the decrease in death rate as a result of improvement in the health sector. Birth rate, on the other hand, remains constant and the total population booms. Stage 3 indicates amelioration in economic condition and education resulting decrease in birth rate and population growth rate. Stage 4 post economic revolution indicates low birth rate, low death rate, and constant total population. Stage 5 represents negative population growth rate.

Developing countries such as India, Mexico, and Nigeria have higher birth rates of 19, 18 and 39 respectively (crude per 1000 people).[41] This means they are on expanding stage somewhere

39 Cf. (McKinsey&Company, 2017), pp. 10

40 Cf. (Keith Montgometry, 2014)

41 Cf. (Data WorldBank BirthRate, 2018)

in between Stage 2 and Stage 3. The total population in these countries will be increasing over time until Stage 4.

On the other hand, advanced countries such as USA, Germany, and Japan have declining population growth rate of 0.7 %, 1 % and -0.1% respectively.[42] This indicates that they are shifting from low stationery to declining phase somewhere in between Stage 4 and Stage 5. Now let's investigate the population pyramid as it illustrates the population distribution of different age groups.

Figure 8: Population Pyramid (Japan & Germany)

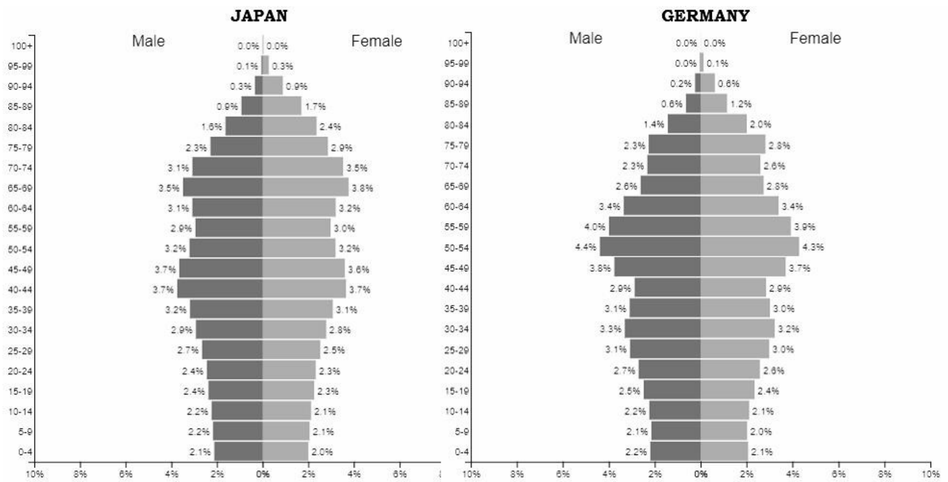


Image: own creation Data: (PopulationPyramid, 2017)

As of 2017, it can be observed from the pyramids that Japan and Germany have 59.9% and 65.6% of economically active adults respectively. In the upcoming decades, this working age group will retire, and these nations need to support a vast number of old population. This shows old dependency burden in advanced economies. It can also be observed that children under age of 15 account for only 12.7% of the total population due to low birth rates in both countries above. This indicates that these countries will face the shortage of labour supply in the future.

Now as Industry 4.0 kicks in, it will be a perfect substitute to automate the production lines to offset the shortage of labour supply in developed countries. With the help of automation, these countries with declining or constant population growth will be able to sustain their living standards even as their labour force shrink.[43] It provides considerable incentive for developed

[42] Cf (Data WorldBank PopulationGrowth, 2018)

[43] Cf (McKinsey&Company, 2017), p.17.

countries like Japan or USA to accelerate the pace of automation by investing in R&D to increase their output despite declining population. The economic growth due to automation can assure continued prosperity in nations with old dependency burden. [44]

On the other hand, population pyramid of developing nations like India and Nigeria shows something contrary.

Figure 9: Population Pyramid (India & Nigeria)

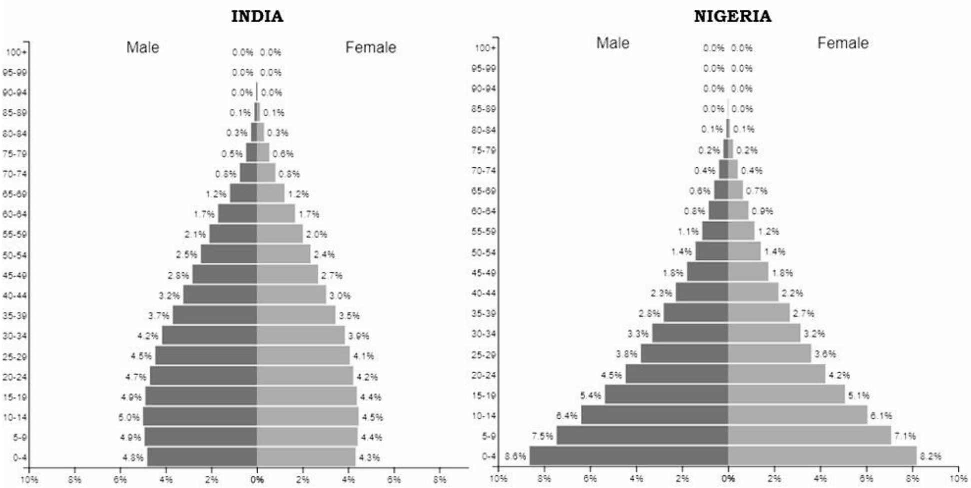


Image: own creation Data: (PopulationPyramid, 2017)

As of 2017, children under the age of 15 comprise 27.9 % and 43.9% of total population in India and Nigeria respectively. Such pyramid indicates youth dependency and reflects increase in the work force and population boom in the upcoming decades. A hidden momentum of population growth can be observed implying that even after a decrease in birth rate, the population in developing countries will continue to increase. [45] This is because the vast pool of existing young population increases the base of potential future parents.

In this case, Industry 4.0 will be counter-intuitive as the population is booming in these countries. The abundant supply of labour reduces the labour cost substantially and automating production lines will not be as beneficial as in advanced economies. Although there might be some productivity incentive for developing nations to implement Industry 4.0, the cost incentive will be negligible.

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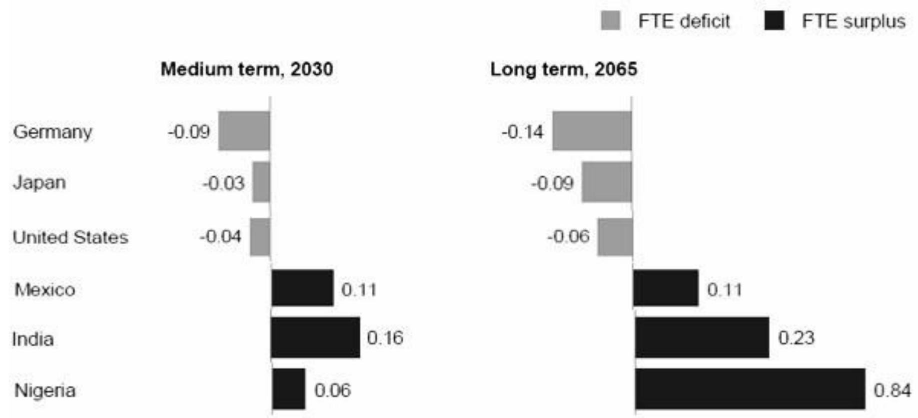
[44] Cf (Manyika *et al.*, 2017)

[45] Cf (Espenshade and Tannen, 2015), pp. 572-573

McKinsey Global Institute analysis shows how the population demographics influence the adaptation of Industry 4.0.

Figure 10: Full Time Employee Projection



Source: (McKinsey&Company, 2017), pp. 91.

It is estimated that the developing countries like Mexico, India, and Nigeria will have Full-Time Employees (FTE) surplus of 0.11%, 0.16% and 0.006% of the number of FTE by 2030. Industry 4.0 and its automation hence is not the best solution for these countries with the booming population. It is the developing countries that need to worry about creating jobs for the surplus population in the upcoming industrial revolution.[46] Even after succeeding to collect the investment cost for implementation, automating the production lines and cutting down existing labour cost when there is an enormous pool of unemployed cheap labour waiting to get the job, do not make economic sense.

Meanwhile, aging countries like Japan and Germany can significantly benefit from Industry 4.0 as they are likely to face FTE deficits and automation would help offset the need for working population in these countries. With this, it can be realized that the benefit of Industry 4.0 to different demographics is biased; in one economy, the ample and cheap labour supply makes it impotent whilst in the other it properly blends with the demographic changes and compensates the slow economic growth.

[46] Cf (McKinsey&Company, 2017), pp. 105.

4.3 Reshoring, the reverse offshoring

Offshoring is an outsourcing process where firms in a country reallocate their business process to another country to benefit from a) raw materials, b) customers/markets and/or c) cheap labour. It is the latter that concerns Industry 4.0. Offshoring manufacturing processes to benefit from cheap labour will not be viable when automation kicks in. Firms with the help of automation could manufacture even in countries with higher wages as automation decreases the need for low skilled workers in factories.

The trend shows that offshoring is not only diminishing but going reverse. The velocity of production fragmentation is decreasing across countries as the firms in the US and EU are slowly bringing their business processes back to their own country from low wage countries.[47] As firms become more capital intensive due to Industry 4.0, the low wage advantage of labour intensive countries will diminish, making it lucrative for investors to re-shore manufacturing processes back home.[48] Hence, it is likely that industrial robotics will substantially change manufacturing competitiveness of countries and alter the supply chain networks.

A survey conducted by Citigroup with a sample size of 236 manufacturing Western companies, 70% believed that automation and 3D printing would encourage firms to bring manufacturing process back to their home country. Also, 22% stated that North America has the most to gain from automation, followed by Europe (17%) and Japan (16%). On the other hand, 24 % stated China, followed by ASEAN (18%), and Latin America (15%) have the most to lose from automation. [49] This is due to the loss of cost competitiveness of labour-intensive countries like India or Mexico, because of Industry 4.0.[50]

Reshoring and slowing foreign direct investment will significantly affect labour-intensive countries like Nigeria and India because FDI is a crucial source of employment, technology spill overs and economic development in these countries. Only during the first quarter of the

[47] Cf (Worstall, 2011)

[48] Cf (Lorenz *et al.*, 2015), p. 3.

[49] Cf (CityGroup, 2016), pp. 27.

[50] Cf (Sirkin, Zinser and Rose, 2014)

financial year 2017 (April to June 2017), the total FDI investments stood in India at US$ 14,550 million.[51]

To sum up, reshoring for western countries would mean the creation of new jobs, less complexity in supply chain and reduction of market risk associated with offshoring. On the other hand, reshoring of western firms for labour-intensive developing countries would mean loss of cost advantage, reduction in jobs, increase in technology adaption lag, and loss of potential rapid economic growth. Hence, the divergence of these two economies due to reshoring can be anticipated.

4.4 Marginal Cost-Benefit Analysis

The following section will further explain the divergence of advanced and developing economies with the help of classical marginal cost-benefit curve.

Marginal Benefit of Industry 4.0 can be understood as the incremental change in the total benefit of implementing one additional unit of Industry 4.0 in their workspaces. Although firms' total benefit could increase as they increase their automation level, the marginal benefit (i.e., the additional utility for additional automation) decreases. It is for that reason the marginal benefit of Industry 4.0 has diminishing marginal utility and is downward sloping.

On the other hand, the marginal cost of Industry 4.0 can be understood as the incremental change in the total cost of implementing one additional unit of Industry 4.0 in their workspaces. As the additional cost of an additional automation increases when firms increase their automation level, the marginal cost of Industry 4.0 is upward sloping.

We also know that one of the major incentives for companies to implement automated production lines is to reduce their labour cost. However, if labourers are in ample supply and significantly cheaper than automation, this could be counterintuitive for automation. Only when the cost of initiative for any problem is equal or below the wage of workers in a specific country, adaptation begins.[52] Hence, it will not make economic sense to implement Industry 4.0 in countries like India, or Nigeria that already have plenty of unemployed cheap labour force.

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[51] Cf (Industry Ministry India, 2017)

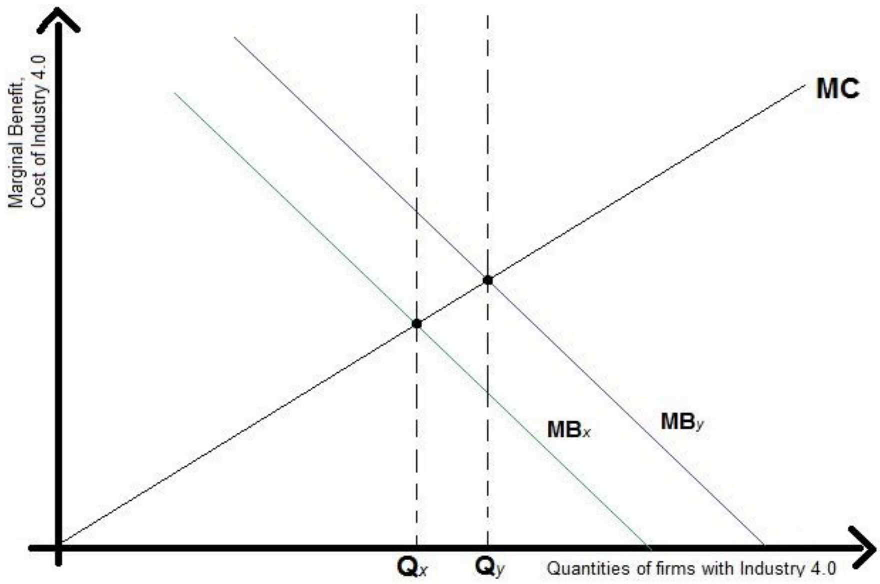
[52] Cf (McKinsey&Company, 2017)

Geography affects labour market dynamics, not only in terms of demographics but also in terms of different wages of workers.[53] This means the marginal benefit of industry 4.0 in developed countries with expensive labour force is higher than the marginal benefit of industry 4.0 in developing countries with the cheap labour force.

This brings us to following two cases. MB_x represents the marginal benefit of Industry 4.0 and Q_x represents the quantity of firms with Industry 4.0 in a developing economy with low labour cost. Similarly, MB_y represents the marginal benefit of Industry 4.0 and Q_y represents the quantity of firms with Industry 4.0 in an advanced economy with high labour cost. As discussed above, the difference of labour cost between two economies places MB_y higher than MB_x.

CASE A:

Figure 11: Industry 4.0 Marginal Cost Benefit, Case A



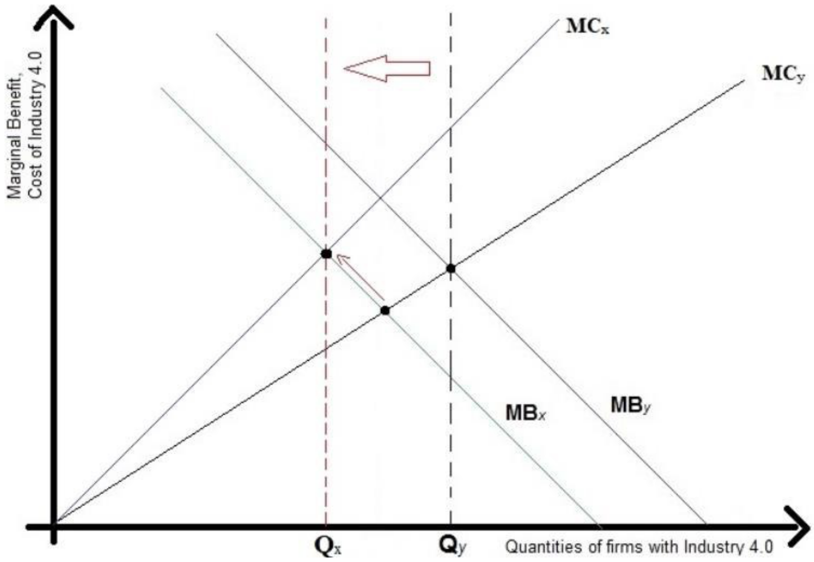
Source: own creation

This case assumes that the Marginal Cost of implementing Industry 4.0 in the advanced and developing economy is the same. It is clear from the figure above that the quantity of firms with Industry 4.0 in a developed country (Q_y) is higher than the quantity of firms with Industry 4.0 in a developing country (Q_x), if the marginal cost remains the same.

[53] Cf (Manyika *et al.*, 2017)

CASE B:

Figure 12: Industry 4.0 Marginal Cost Benefit, Case B



Source: own creation

This case assumes that the marginal cost of Industry 4.0 in developing country is higher than the marginal cost of the developed country. This could be mainly because 1) the cost of automating the production lines could be higher in developing countries (infrastructure availability), 2) the cost of upskilling labour force is higher in developing economy as there are more unskilled workers present. Factors such as government efficiency and infrastructure availability also come into play, things like corruption will negatively affect the ease of introducing new business and technology adaption.

It can be observed from Figure Y that the quantity of firms with Industry 4.0 in a developing country (Q_x) is again lower than the quantity of firms with Industry 4.0 in a developed country (Q_y) if the marginal cost increases. However, interestingly, the gap between Q_x and Q_y widens with increasing marginal cost. In both cases, compared to developing countries, not only the marginal benefit of Industry 4.0 in developed countries will be higher, but also the quantity of firms implementing Industry 4.0. The economic cost of investment is a critical barrier to Industry 4.0 implementation and adoption in emerging markets would mean investment despite the lower marginal benefit. This clearly indicates divergence of these two economies.

Technology Adaption Lag

As the quantity of firms investing or implementing Industry 4.0 will be more in the developed country, this gives a competitive and first mover advantage to firms in advance economies. It is more likely that the firms in developed countries will be Industry 4.0 innovators and first movers, and firms in developing countries will be technology followers due to marginal benefit difference.

It can be assumed that developing countries could also benefit being better technology followers. However, since the first industrial revolution, the pattern shows that the technological gap between these two economies has been ever increasing. With regression analysis, (If Technology Has Arrived Everywhere, Why Has Income Diverged?) Comin & Mestieri 2016 infers that the intensity of use of technologies has been decreasing with the emergence of new technologies, and so does the gap between these two economies.[54] This is because it takes time for technology followers to adopt new technology in such a way that it contributes to the nation's output. Developing countries are getting worse at the widespread use of adopted technologies and even when technologies are adopted; there has certainly not been convergence in a long-term penetration rate.[55]

On the other hand, first movers to invest in Industry 4.0 will be highly profitable since they will benefit the most from combining volume with variety with mass customization. According to the survey conducted by PwC on over 2000 companies from 26 countries, "first movers are almost three times more successful in combining high revenues increases with significant gains in cost reduction".[56] The survey identified 71 companies setting Industry 4.0 at the fastest pace, and they are already profiting a substantial advantage over their competitors.

Such discrepancy was identified even between companies in the same economy; a possible disparity can already be imagined, when two firms in two different economies compete, but one has reasonably higher marginal benefit compared to the other. It is important to consider that the small disparity now could snowball over time to more substantial cost competitiveness shifts

[54] Cf (Comin and Mestieri, 2016), p. 24.

[55] Cf (CityGroup, 2016), p.16.

[56] Cf (PwC, 2016), p.12.

which could detriment the growth of developing countries.[57] Hence, upcoming technological lag and first mover advantage of Industry 4.0 will further stretch the divergence of the world economy as the firms in advanced economies will have a significant benefit over developing economies.

5 Final Consideration

5.1 Result and critical reflection

The comparative analysis of the thesis reflected how the industrial revolution is not an entirely new concept. There were previous industrial revolutions in the past, and it is important to realize that the pattern of these revolutions is similar. Industrial revolutions can be characterized in three ways: 1) Radical Structural change, triggered by the introduction of new technology, manufacturing processes, and new job skills. The cost-saving driving factor incentivizes human for structural changes as the first industrial revolution did not occur in a country with low wages or high population but instead in Britain where the cost-saving incentive was to reduce existing high wages. Another way to look at industrial revolution is 2) System Equilibria Transition where an economy remains in a system equilibrium before an industrial revolution, but during the revolution, it transits and achieves a higher system equilibrium. However, there are several problems associated with the transition: labour redeployment due to strategic failures, temporary unemployment due to coordination problems and structural dynamics issues. 3) The dynamic shifts in manufacturing regimes can also explain industrial revolution where an economy shifts its production processes (for example: from mass production to flexible production) due to changes in technology coupled with changes in customer demand in terms of volume and variety.

Macroeconomic Analysis on the other hand aimed at four major topics: 1) shift in job paradigm and labour redeployment due to Industry 4.0 reflecting on how the demand of low skilled has been decreasing and the demand for medium and high skilled has been increasing over time. The argument of robots replacing humans is negated while proposing machines working

[57] Cf (CityGroup, 2016), p.28.

alongside humans where robots perform the repetitive tasks and humans perform tasks with higher capabilities involving logical thinking, emotions, and creativity.

2) The population demographics of advanced countries with high wages and aging population favours automation more than the developing countries with the booming population and low wages. Youth dependency and hidden momentum of population in developing countries provide counter-intuitive for these countries to automate their processes when there is a pool of cheap, unemployed surplus employees waiting for jobs. 3) Reshoring, reverse offshoring due to Industry 4.0 also indicates divergence of economies because firms with the help of automation could manufacture even in countries with higher wages as automation decreases the need of low skilled workers in factories. Reshoring and slowing foreign direct investment will significantly affect labour-intensive countries like Nigeria and India because FDI is a crucial source of employment, technology spill overs and economic development in these countries

4) The section Marginal Cost Benefit using classical marginal cost benefit diagram showed how even with different marginal cost, the quantities of firms implementing industry 4.0 in advanced countries would be higher than in developing countries. This difference will contribute to the technology gap, leading to technology adaption lag and ultimately stretching the world economic divergence.

5.2 Institutional Strategy and Policies

It is clear that the effect of the fourth industrial revolution in advanced and developing economies will be different in many ways and so will the policies in these two economies. The productivity of Industry 4.0 is clear for private sectors, but for policymakers the issues are sophisticated. Apart from growth, the aim of the industrial policy is adaptation. Equipment, workforce, and the market have different timings of adaptation, and an industrial policy facilitating alignment should take 'time' into consideration, by being inclusive in distinguishing the transition favouring simultaneous adjustment and adaptation.

Failure in simultaneous alignment during industrial revolution will result in persistence of certain elements or could even cause bottlenecks in the system. For instance, usually, workforce adjustment requires longer time than equipment adjustment. Hence, an industrial policy favouring alignment needs to focus on bottlenecks (here human capital) by adjusting them earlier. Therefore, a key objective of industrial policy during a transition is the alignment of adjustment timings to make the shift coordinated and efficient.[58]

A) Advanced Economies Policy:

Countries like Germany need to prepare for the introduction of new elements such as new skill requirement of human capital and innovation. As industrial robots venture into the market, it is likely that the creative aspect of the labour force is required and hence the focus must be given to the training and upskilling of the workforce. The transition would mean temporary unemployment, and so the nation needs to prepare for labour redeployment maybe with unemployment benefits, for the time being, to encourage the upskilling process since the comprehensive economic benefits of Industry 4.0 can be fully realized only when labours continue to work.

Policies in developed countries should favour increasing returns such as labour specialisation and should avert constraints in the transition.[59] Innovation is an essential competitive advantage; advanced economies should, therefore, embrace the changes and should encourage rapid investment of time and capital into research and development and innovation.

Considering the higher ratio of low skilled people, one of the significant issues of developed countries is rising income inequality with Industry 4.0.[60] Taxing the winners, in this case, the top managers who benefit from productivity gains with Industry 4.0 could be an option to alleviate the gap. However, there are various problems with taxation- a) in a digital economy, the top wealthiest population is adept at avoiding taxation b) identifying taxable activity in a digital economy is complicated (for instance: increasing use of capital in digital platforms such as YouTube and blockchains). Hence, an efficient taxation system is required, and this could be

[58] Cf (Bianchi and Labory, 2017), p.7.

[59] Cf (Scazzieri, 2014)

[60] Cf (Jabbar, 2017)

with the increase in - a) top marginal income tax, b) progressive income tax, c) corporate income tax, and/or d) taxation of goods/service for wealthy.[61]

B) Developing Countries Policy:

Developing countries policy for the upcoming industrial revolution is more alarming and sophisticated than the developed ones. The lower marginal benefit of automation, reshoring of firms from western countries, lower skill and lower wage of human capital provide a counter-intuition for Industry 4.0 in these countries.

At the same time, abstaining from the complexity of Industry 4.0 and continuing the labour-intensive production is also not the right solution. A country progresses by making the processes more complicated and not by complexity reduction as it cripples coordination of structural dynamics leading unsteady development.[62] Interventionist policy for pricing and taxing to avoid automation to save current jobs will hinder system equilibria transition and hence the economic development.

A suitable industrial policy would increase the wages of workers by decreasing the supply to increase the marginal benefit of Industry 4.0. There is no better way to decrease the supply other than population control. A good example is how minimum wages in China increased from 840 CNY/month in 2008 to 2420 CNY/month in 2018, clearly indicating that the country is moving to skilled labour force from a mass of unskilled labour.[63]

Similar, Active Labour market policies (ALMPs) can be adapted to focus on upskilling of human capital with education or skill raising workshops. As high skilled are less susceptible to be replaced, the best hope for developing countries to benefit from Industry 4.0 is the low-skilled reduction with education.[64] An incentive for companies and corporations can be created to organise skill raising programmes to their current low skilled workers to adjust their skills according to Industry 4.0. As the ratio of skilled to unskilled workers increases in developing countries, the room for artificial intelligence and industrial robots increases.

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[61] Cf (CityGroup, 2016), p. 109-114.

[62] Cf (Hirschman, 1958)

[63] Cf (Trading Economics, 2018)

[64] Cf (CityGroup, 2016), p. 20.

5.3 Further Implication and Limitation

The thesis accomplishes to fulfil the research gap as it compares and examines the impact of Industry 4.0 between advanced and developing economies. Although factors like marginal benefit differences, population demographics, technological adaptation lags, and reshoring strongly indicate divergence with Industry 4.0, there could be a room for convergence with drastic institution policy measures. For instance: young dependency will not just reduce the wages of a country but also could bring innovative ideas as it is the young population that quickly adapts to acquire new skill sets. Similarly, technology adaptation lag could be shorter as developing countries can adapt to technologies faster with the help of Industry 4.0's virtual and augmented reality. Hence, some room for convergence can be anticipated albeit most of the factors clearly point towards divergence.

To the understand the dynamics of individual factors, the thesis is open to further extension. An empirical analysis of each element or simulation over time will give even broader and profound insight on Industry 4.0 impact on these two economies. Also, as the thesis mainly refers to six countries, Nigeria, India, Mexico, Germany, Japan and the USA, the inclusion of other countries with increasing population and high wages or decreasing population and low wages will provide even more comprehensive perspective on the world economy.

All things considered, the thesis is a comprehensive research providing an outlook of upcoming economic changes due to Industry 4.0 where the changes range from the shift of job paradigm, labour redeployment to alteration in the global trading pattern. The outlook aims to primarily help countries to align their development policies to avoid bottlenecks during the transition, and also help workers anticipate upcoming labour redeployment due to automation and industrial robots.

For further reading of the LET group please refer to Güller et al., 2017; Reynolds, & Uygun, 2017; Karakaya et al., 2016; Uygun & Reynolds, 2016; Güller et al., 2013; Uygun & Straub, 2013; Uygun & Straub, 2012; Uygun & Wagner, 2011; Uygun, 2012; Uygun & Schmidt, 2011; Uygun & Kuhn, 2011; Uygun et al., 2012; Besenfelder et al, 2013a; and Besenfelder et al. 2013b.

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