Chapter 2

Universal Indicators and Tools for Measuring the Economy-wide Impacts of I4R

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November 2020

This chapter should be cited as

Wyes, H. (2020), 'Universal Indicators and Tools for Measuring the Economy-wide Impacts of I4R', in Anbumozhi, V., K. Ramanathan and H. Wyes (eds.), *Assessing the Readiness for Industry 4.0 and the Circular Economy*, Jakarta: ERIA, pp.31-55.

CHAPTER 2

Universal Indicators and Tools for Measuring the Economy-wide Impacts of Industry 4.0 Readiness

Heinrich Wyes

1. How is Industry 4.0 Related to the Overall Industry Climate in the World and ASEAN?

Globalisation, digitalisation, process technologies diffusion, network complexity, energy-saving, waste and inefficiencies reductions, the requests of customised products and the variability in customer demand have determined the need for a change in the manufacturing industry.

Since 2011, several initiatives addressing the theme of digitally connected industrial production have sprung up around the world, for example the Industrial Internet Consortium in the United States (US) and the Industrial Value Chain Initiative in Japan. The German government has promoted the Industry 4.0 initiative in cooperation with industrial and scientific organisations. The promotion of industrial change, the acquisition of a leadership position in the manufacturing sector in the world, increased productivity, and a lower resource footprint have been the main objectives for Germany (Bartodziej, 2017) as manufacturing companies are faced with increasingly competitive markets.

In 2012, the term 'Industry 4.0' was further refined. The following year, the understanding emerged that the entire value-added process – from product development and purchasing through to production, sales, and customer use – would be accompanied by a 'digital twin'. In this context, a digital twin refers to a digital replica of potential and actual physical production devices and industrial processes.

Soon realism set in in 2015, when it became clear that the Fourth Industrial Revolution would start incrementally by digitally capturing every facility and every process. Thus, 2016 became the year of the sensors that made an existing factory digital and Internet-enabled. The relevant data would be processed by industrial Internet platforms that would make the many data-based services possible. In 2018, the manufacturing industry moved away from physical production to software development for services. Artificial intelligence (AI) machines and systems became able to be combined in different ways and on demand. The factory become a stage where people, machines, and products are redone as required to be configured

Nowadays, the value creation process is based on the management of a large amount of data, known as 'big data', which can connect businesses and customers from all over the world (Xie et al., 2016). The chief economic potential of Industry 4.0 lies in its ability to accelerate both corporate decision-making and adaptation processes. This applies to processes for driving efficiency in engineering, manufacturing, services, and sales and marketing, as well as to changes to the business model. Industry 4.0 has become the new economic model for the industrial world (Peressotti, 2016).

A first global asset efficiency study to better understand the maturity of cyber-physical system deployments was prepared under the name of Industry 4.0: The State of the Nations (Infosys, 2015). This report allows comparisons amongst different types of industries and nations by looking at the leading organisations in five advanced manufacturing countries. It provides insights that decision makers in the Association of Southeast Asian Nations (ASEAN) region can use to help develop a roadmap for improving asset efficiency, amongst others that:

- Eighty-five percent of responding businesses saw the potential of Industry 4.0.
- Only 15% have dedicated strategies for Industry 4.0 in place.
- Eighty-nine percent of respondents are aware of the potential of information efficiency through the implementation of data standards.
- Only 11% have systematically implemented data security and standards.
- Eighty-one percent of respondents are aware of monitoring machine status for maintenance goals, but just 17% have put the principles into practice.
- Eighty-eight percent consider energy management to be important. Yet, only a small percentage implement practices into their processes.

Across the five countries surveyed in the report – China, France, Germany, the United Kingdom (UK), and the US – the level of maturity of Industry 4.0 varied significantly. While no country can claim to be the global early adopter in implementing Industry 4.0 in the context of asset efficiency, the percentage of companies in China that claim to be early adopters is significantly higher than anywhere else. It is expected that a number of factors are driving this; notably, the focused initiatives and investment from the Chinese government to develop more sustainable industry growth. Also, manufacturing is core for China, and the market is accustomed to rapidly implementing new technology, especially in green-field sites free of legacy infrastructures.

Germany (21%), the UK (26%), and the US (32%) have similar maturity footprints, both in terms of 2015 status and 2020 ambition. This could be because of their historical leadership in manufacturing. In France (14%), the Industry 4.0 implementation is comparatively less mature. The economic downturn and recent unsuccessful digitisation programs could be contributing factors.

A comparison of the average maturity rate in 2015 and the expected rate in 2020 reflects this progress of Industry 4.0 adoption. The study also revealed that the rate of progress expected in each country over the next five years is expected to be broadly the same. However, in France, average maturity rates are expected to be lower in 2020 than Chinese companies are, on average, claiming in 2015.

Further to the Industry 4.0: The State of the Nations report, the Global Manufacturing Competitiveness Index (Deloitte, 2017) outlines the competitiveness and attractiveness of a country and provides an overview about how the manufacturing sector contributes to the growth process in each country. For the manufacturing sector the competitiveness drivers are identified in three elements:

- Training activities, to have a high-qualified resource for realising high productivity levels;
- Digital innovation, to ensure high levels of competitiveness; and
- The definition of rules and regulations, to protect the technology transfer and intellectual property, as well as to establish incentives and subsidies in support of high-tech investments.

From the rankings in Table 2.1, it is possible to see how Germany and the United States achieved a score improvement through the implementation of Industry 4.0 policies.

Table 2.1: Global Manufacturing Competitiveness Index for the First 10 Countries

2011		
Rank	Country	Index Score
1	China	100.00%
2	India	81.50%
3	Republic of Korea	67.90%
4	United States	58.40%
5	Brazil	54.10%
6	Japan	51.10%
7	Mexico	48.40%
8	Germany	48.00%
9	Singapore	46.90%
10	Poland	44.90%

2013		
Rank	Country	Index Score
1	China	100.00%
2	Germany	79.80%
3	United States	78.40%
4	India	76.50%
5	Republic of Korea	75.90%
6	Taiwan	75.70%
7	Canada	72.40%
8	Brazil	71.30%
9	Singapore	66.40%
10	Japan	66.00%

2016		
Rank	Country	Index Score
1	China	100.00%
2	United States	99.50%
3	Germany	93.90%
4	Japan	80.40%
5	Republic of Korea	76.70%
6	United Kingdom	75.80%
7	Taiwan	72.90%
8	Mexico	69.50%
9	Canada	68.70%
10	Singapore	68.40%

Source: Deloitte (2017), with author's modification.

Leading enterprises in the development and application of Industry 4.0 created a consortium in 2016 in order to come up with a Global Industry 4.0 Maturity Index. The evolving global Industry 4.0 Maturity Index (Acatech, 2017) provides a tool to establish companies' current Industry 4.0 maturity stage and to identify measures to achieve a higher maturity stage in order to maximise the economic benefits of Industry 4.0 and digitalisation and prepare them for the step-by-step transformation.

2. What Indicators and Tools of Industry 4.0 for the Circular Economy Are Related to Societal and Sustainability Objectives?

Beyond addressing the developments associated with the Fourth Industrial Revolution from just a technological perspective, companies and societies also need to transform their organisation and culture. The key question is whether intelligent machines are replacing people and what societal changes are to be expected?

An ageing population, a gigantic modernisation and rationalisation wave, and a sharp increase in inequality in income and wealth are expected in Europe in the next 10–15 years. The distortions in the labour market erode the middle class and generate social and economic instability. Against this backdrop, companies need to streamline technology and at the same time target the top people. In addition, it is necessary to adapt to the changing patterns of consumption of large sections of the population. The digitisation wave over-compensates for shortages of skilled workers. For decades, companies have been able to access an almost inexhaustible potential workforce. First, the baby boomers flooded the labour market, then more and more working women and well-educated migrants joined. But the era of abundance is ending. Over the next 10–15 years, ageing populations throughout the developed world will trigger an unprecedented shortage of workers. In Europe, the total number of people employed will be shrinking. China is even under more pressure as a result of the one-child policy.

To compensate for the labour shortage, companies will increasingly invest in digital technologies that are now available across all industries. The suppliers of digital technologies can look forward to a huge boom. Rationalisation using AI, networking, and robots will increase labour productivity in the 2020s compared to 2015 on average by 30%. Productivity improvements of 50% are possible in the production, energy, and logistics sectors, as well as in the transport, trade, and hospitality sectors, and up to 20% in education and health care (Sinn, 2018). Autonomous cars, speech recognition software, and self-learning machines will also perform various service tasks in simple administrative jobs as well as in highly qualified professions, such as legal or financial advice.

As the demand for goods and services grows significantly slower than production potential, more and more jobs are lost over time. In Europe during the next 10 years, up to a quarter of the currently existing jobs will disappear. Despite declining populations, unemployment will therefore increase again.

Job losses or declining salaries in extinct occupations are no longer a prospect for only low-qualified, low-income earners in the decade of digitisation. Even educated populations with medium-to-good incomes will suffer from rapid structural change. Only the approximately 20% qualified specialists, who are excellently prepared for the digitised world, will have a bright future. All companies are vying for highly coveted digital experts.

Demography and technology in the 2020s will disturb the fragile balance between rich and poor in Europe. More and more people are being decoupled from economic dynamism. The already strong disparity in income, and thus also regarding pensions and assets, continues to increase. The prosperous middle class, the foundation of democratic societies, is shrinking. There is a threat of division into a few profiteers of the technology boom and a growing group of those suspended who no longer participate in economic and social progress.

Governments in many countries will react to these societal upheavals with countermeasures. Domestic interventions, such as stricter regulations on markets, increased cartel laws, and tax increases, as well as increased transfer services, are important. Moreover, as the number of pensioners and the unemployed increases, serious financing problems can arise in social systems.

The coming decade will be characterised by paradoxes. Shortages of skilled workers exist alongside mass unemployment; digital companies are achieving unprecedented stock market values while established firms are disappearing from the market; and some areas are booming due to new technologies while other sectors are becoming obsolete. Politics is becoming increasingly unpredictable in the face of growing inequality and social tensions for businesses. Social change is causing massive changes in consumer behaviour.

Over the years, the erosion of the middle class has also become more and more a brake on growth. If investment is reduced because most businesses are digitised and modernised, stagnation or even recession looms worldwide.

The European economic drivers should focus on a prolonged period of high economic and political risks and prepare their companies for this extreme volatility with greater flexibility and resilience. Whoever decides quickly is closely connected with their customers and can rely on a dedicated workforce, and not only recovers from external shocks faster but also gains momentum back.

A study by Oxford University researchers came to the alarming conclusion that almost every second job was easily replaced by learning machines (Walsh, 2017). This fear is not new, as US economist Jeremy Rifkin wrote in his 1995 book, The End of Work: 'Intelligent machines replace human beings in countless tasks, they drive millions of workers and employees into the queues of the unemployed, or – worse still – under the poverty line' (Rifkin, 1995). It is expected that Industry 4.0 favours the further division of labour into comparatively few high-paying, high-skilled jobs and a variety of lower-paid jobs.

Researchers at the ZEW–Leibniz Centre for European Economic Research (ZEW) in Mannheim have explored the question of why the 'end of work' persists despite the triumph of computers and industrial robots. On behalf of the German Federal Ministry of Research, they examined where German companies have been using networked production technologies since 2011, and how this has had an impact on the overall number of jobs. According to their study, the ZEW team 'wants to contribute significantly to the understanding of the actual change in the division of labour between man and machine' (ZEW, 2018).

The authors rely on data collected where this change takes place: in the factories. The results of the study are remarkable. Between 2011 and 2016, many companies increased the use of technologies that fall into the areas of Industry 3.0 and Industry 4.0. Industry 3.0 is understood to mean robots and computers, while Industry 4.0 largely comprises self-controlling machines, so-called 'smart factories'. The net employment effects of technology investment were as follows: the modernisation of production replaced within five years replaced 5% of employees.

While machines have displaced many people in the past because they can perform certain activities better and cheaper, the job balance of digitisation is positive. At the same time, the investments set in motion further processes, which in turn had a positive effect on the number of employees:

- The use of high technology has made many companies more competitive. They therefore produce larger quantities at cheaper prices, and for this reason have sometimes hired more people in other positions.
- Due to a 'multiplier effect'; the more productive companies generate new income in the form of wages, profits, and capital income. The higher incomes of the employees and shareholders of the companies created jobs in other parts of the economy.

These positive effects of technological change have even overcompensated for the 5% loss of employment due to the increased use of machinery, according to the ZEW (2018), which highlighted that digitisation from 2011 to 2016 led to job creation by 1%.

This development is likely to continue in the future. Based on the information provided by the companies surveyed, the ZEW estimates that the further spread of Industry 3.0 and Industry 4.0 technologies in companies will lead to an increase in employment by 1.5%–1.8% in 2021.

A similar effect had previously been associated with the use of information technology (IT) in businesses, which has cost many clerks and secretaries their jobs. Overall, however, while computerisation has increased according to calculations by the ZEW for the period from 1995 to 2011, employment increased by almost 0.2% per year.

Depending on the industry, however, the effects differ significantly. Particularly strong employment growth is evident in the electronics industry, vehicle construction, and other manufacturing industries. These sectors benefit from the fact that they themselves produce computer-aided technologies, which are becoming increasingly widespread. In particular, many jobs were lost in the construction and the health sectors. In the construction industry more and more building modules are prefabricated industrially. In turn, changes in medicine rarely lead to cost reductions, and the use of modern technology usually does not increase demand either.

The study also shows that technological change is nevertheless causing changes in the labour market. The jobs that are newly created usually place much higher demands on the workforce. From 2011 to 2016, the increased use of Industry 3.0 and Industry 4.0 systems has led, above all, to the loss of jobs that are heavily influenced by recurring routine activities. An example of this is the replacement of human labour in the assembly of heavy machinery by industrial robots. The newly created jobs, however, show a more complex requirement profile. The robots replace skilled workers but must be programmed and monitored by engineers. Digitisation will therefore change the structure of employment. Highly rewarded analytical and interactive professions are gaining importance. The downside of development is that investments in new technology have already promoted inequality in the past five years. Salaries in high-wage occupations have grown much stronger than in medium- and low-paid areas.

3. How Did European Countries Score?

3.1. The World's Two Industrial Fractures

The global industrial footprint has changed dramatically over the past 20 years. In 1991, the world's manufacturing value added stood at €3,451 billion. Over 60% of that could be attributed to six major industrial nations: the US, Japan, Germany, Italy, the UK, and France. At that time, emerging countries only produced 21% of the manufacturing value added. This gap is even more striking when looking at the evolution of industrial jobs in different countries. The number of manufacturing jobs in China and Brazil increased by 39% and 23%, respectively, whereas in Germany this figure decreased by 8%, in France by 20%, and in the UK by 29% (Roland Berger, 2014). This can be contributed to three main factors:

- The major productivity gains achieved in mature economies over the last few decades.
- The loss of market share to newly emerging competitors.
- Outsourcing of activities, such as logistics, facility management, maintenance, and different types of professional services to the service industry. This outsourcing often resulted in the relocation of the activity.

With this outsourcing trend now ending, increased productivity and international competition are the main drivers of the decrease in industrial employment. But while some traditional industrialised countries have adapted to this new situation, others have not.

The first fracture appeared with the rise of emerging countries. This incursion was led by Brazil, Russia, India, and China (the BRIC countries), but European countries, such as Poland, Romania, and the Czech Republic, soon followed. During the last three decades, the traditional industrialised countries saw their average manufacturing value added increase by 17%, while in the emerging industrial countries it increased by 179%. The emerging countries now represent 40% of the total manufacturing value added worldwide.

A second fracture appeared amongst the traditional industrialised countries. A few have retained high industrial value added despite the significant decline in jobs; Germany, Italy, and Switzerland have kept their industrialisation rate (manufacturing value added as a percentage of total value added) around 20% over the past 10 years. Others, however, saw both industrial employment and value added fall. This is the case for France, whose rate of industrialisation decreased from 15% in 2001 to 11% in 2011. Spain and the UK followed the same trend.

These two fractures cut right across Europe, making the continent's industry extremely diverse. And regarding the future strategy for industrial value creation, Europe seems to be drifting apart as opposed to moving in one direction.

Traditional industrialised countries, such as Germany, Sweden, and Austria, capture important value in key sectors. However, Europe also has several industrialised countries on its eastern side, such as Poland, Romania, and the Czech Republic, where industry's role in the economy has always been strong (over 20% of the national value added). Their main advantage used to lie in low-cost manufacturing, and the value added per job is still lower than in traditional industrialised countries. But recently established plants in these territories are brand new, highly automated, and will enable the rapid development of high-value-added activities. Meanwhile, France, the UK, Spain, and Belgium are facing considerable declines in industrial employment and value added.

In summary, Europe is now at a crossroads. Countries clearly need some industry. But Europe has to determine what the new pattern of industrialisation amongst its member states should be.

Industry is a core element of the European value chain. An industrial imbalance creates a rift in trade policies. Ultimately the growing gap between European countries in terms of industrial performance has an impact on European international trade relationships. On one side of the gap are countries with a strong industrial sector, which are dependent on exports and keen on open borders, and on the other side are countries with a weak industrial sector that are more inclined to put up barriers to protect themselves.

Innovation, automation, and sophisticated processes are at the root of industrial success strategies and have proven to be critical in maintaining a leading position. A successful approach to reindustrialisation should consider the changing environment and align processes, production, and products to the new situation. Europe's industrial future has to be envisioned and designed to cross borders.

The Fourth Industrial Revolution is already on its way. This trend is also affecting the way goods are manufactured and services are offered, and Industry 4.0 will be an answer to the challenges lying ahead of Europe. If the European economy can achieve a strong position within Industry 4.0, divestment will no longer be a threat. Industry 4.0 requires investments. But Industry 4.0 also substantially increases capital productivity through potential benefits such as mass customisation, networks, and the means to meet them with new production technologies, new materials, and new ways of storing, processing, and sharing data.

Digitised products and services generate approximately €110 billion of additional revenue per year for European industry. Companies that have already digitised their product portfolio have grown above average in the past three years. Companies even expect sales to rise by more than 20%. In total, this amounts to an average incremental sales increase of 2.5% per annum. Compared to all industrial companies in the five core industry sectors, this is equivalent to an annual sales potential of more than €30 billion for Germany and reaches up to €110 billion of additional revenue for European industry in total.

Germany's economy is one of the most competitive in the world. Its gross domestic product (GDP) grew by 1.9% in 2016, faster than any other G7 economy, and its employment rate has risen by 10 percentage points over about a decade. This puts Germany in a strong position to face potentially disruptive trends, including an ageing population, rising global competition, and especially digitisation and automation through Industry 4.0. In order to preserve Germany's strong competitive position, business leaders and policymakers will need to do more to harness the potential of new technologies and make the most of Germany's competitive advantages. Quick adoption of automation technology could add up to 2.4 extra percentage points to Germany's annual per capita GDP growth to 2030.

German industry is generally in a good position to capture these opportunities as it has already taken many of the steps needed for digitisation and has the resources to move further quickly. Individual companies are becoming industry leaders in the Internet of Things (IoT). To reap these benefits, however, Germany will need to accelerate its embrace of emerging digital technologies, and policymakers also need to take steps to prepare the workforce for the upcoming transition. Though many of these trends and changes are still evolving, German business and policy leaders can begin with a programme of action items each to ensure competitiveness for a digital future:

- Digitise the public sector: Set a clear and ambitious digitisation target for all levels of government and work aggressively towards it.
- Catch up in lagging sectors: Help the less-digitised German sectors – like construction, real estate, and the fragmented tail in banking – to catch up with the most digitised firms.
- Attract foreign talent, and nurture and retain talent in Germany: Further encourage and facilitate the migration of highly skilled tech leaders to Germany, and work with businesses to motivate more of the best workers to stay.
- Strengthen training and education programmes to help young people – including women and the children of asylum seekers – prepare for the future of work.
- Provide digital infrastructure and ecosystems: Build high-performance broadband networks, drive the European Union (EU) digital single market, and otherwise create an environment where digitised businesses can thrive.

- Plan for future labour markets: Modify labour institutions to better support independent workers and others already navigating the future of work, including those who may be left behind in the transition.
- Set a clear and bold digital agenda from the top: Make digital transformation a priority to improve its chances of success.
- Digitise across value chains: Ensure marketing and distribution, supply chains, and products themselves – amongst other elements – take advantage of digitisation and AI.
- Seek and scale opportunities outside traditional boundaries: Identify new and adjacent markets opened up by the digital age and test them for growth.
- Reinvest savings from digital into new opportunities: New tech tools will change businesses' cost structures, which can create the headroom for additional investments in the tools of the future.
- Embrace flat and agile working structures: The stereotypical 'German engineering' culture will need to adapt to the more flexible working models favoured in the digital age.

This European example indicates that because of Europe's primary resource dependency, Europe increasingly faces the limitations of a linear economy, which is the lost value of materials and products, scarcity of resources, volatile prices, waste generation, environmental degradation, and climate change (Tukker, 2015). It comes as no surprise that the European Commission and Parliament developed a policy package to create a 'resource efficient Europe' (European Commission, 2011). The European Environmental Research and Innovation Policy aims to support the transition to a circular economy in Europe, define and drive the implementation of a transformative agenda to green the economy, and achieve sustainable development. The policy debate so far has focused on waste management, which is the second half of the cycle, and only limited efforts have been done to address the first half, which is eco-design (Bagheri and Kao, 2015).

Employment in the eco-innovation sector continued to increase during the recession, from 3.0–4.2 million jobs (2002–2011), with 20% growth in the recession years (2007–2011). The EU holds a third of the global market, which is worth a €1 trillion. In Europe, it is estimated that resource productivity could grow by up to 3% annually.

This would generate a primary-resource benefit of as much as €0.6 trillion per year by 2030 to Europe's economies. In addition, it would generate €1.2 trillion in non-resource and externality benefits, bringing the total annual benefits to around €1.8 trillion compared with today. This would translate into a GDP increase of as much as 7 percentage points relative to the current development scenario, with an additional positive impact on employment.

Europe's economy remains very resource-dependent. Views differ on how to address this against an economic backdrop of low and jobless growth as well as the struggle to reinvigorate competitiveness and absorb massive technological change. Proponents of the circular economy argue that it offers Europe a major opportunity to increase resource productivity, decrease resource dependence and waste, and increase employment and growth. They maintain that a circular system would improve competitiveness and unleash innovation, and they see abundant circular opportunities that are inherently profitable but remain uncaptured. Others argue that European companies are already capturing most of the economically attractive opportunities to recycle, remanufacture, and reuse. They maintain that reaching higher levels of circularity would involve an economic cost that Europe cannot afford when companies are already struggling with high resource prices. They further point out the high economic and political costs of the transition.

The EU created the so-called Industry 4.0 Readiness Index for the EU's key industrial countries. to analyse EU member states' readiness for the Fourth Industrial Revolution. In creating the new index, the EU followed the methodology the World Economic Forum uses to generate new indices based on the calculation of secondary indices, choosing indicators that are closely related to the innovative performance and development of the countries. The results divide the European economies into four major groups.

The frontrunners are characterised by a large industrial base and very modern, forward-looking business conditions and technologies (Sweden, Austria, and Germany). The traditionalists are found mainly in Eastern Europe. They still thrive on their sound industrial base, but few of them have thus far launched initiatives to take industry into the next era. The third group, the hesitators – a mixture of southern and eastern European countries – lack a reliable industrial base. Many of them suffer from

severe fiscal problems and are therefore not able to make their economies future-proof. The industrial base of the potentialists has been weakening over the past few years. Here we find countries such as France and the UK – in the corporate sector, we find indications of a modern and innovative mindset.

Europe's industry has lost ground in the past two decades. Industry 4.0 provides an opportunity for Europe to reindustrialise and increase its industry share from 15% to 20% of the region's value added. Industry has always played a major central role in the economy of the EU, accounting for 15% of value added (compared to 12% in the US). It serves as a key driver of research, innovation, productivity, job creation and exports. Industry generates 80% of the EU's innovations and 75% of its exports. Including its effect on services, industry could be considered the social and economic engine of Europe. Yet European industry has lost many manufacturing jobs over the last decade and is facing tougher competition from emerging markets.

European industry is fundamentally diverse. While the German industrial sector is gaining market share and seeing productivity grow rapidly, other EU states are on the road to deindustrialisation. French and British industry in particular have seen their market share shrink drastically. Industry 4.0 provides a compelling case for strengthening and developing industry in Europe.

How much will Europe need to invest? Industry 4.0 is an opportunity to change the economic rules of the industry, especially to overcome the deindustrialisation trends faced by some European countries. In the current industry setup, there are ways to maintain Europe's competitive edge compared to low labour-cost countries: selecting high-added-value products or activities, having modern and automated production units with critical size, and implementing manufacturing excellence practices.

From an economic point of view, if industry wants to offer incentives to investors it has to go about it in a different way due to its risk profile. Investors expect a return on capital employed (ROCE) of 15% as an average for European industry. There are countries achieving this with activities that require low capital intensity and low-value-added products. The countries with low labour costs are leveraging a labour-intensive workforce and more manual processes. Those are rare in Europe.

Nevertheless, this box contains France, Spain, and the UK. Due to underinvestment over the years, their industrial assets have progressively lost their value. At the same time, labour costs are high. Therefore, profitability is declining, and competitiveness is decreasing.

Europe has countries with state-of-the-art production processes. They are more competitive due to automation and scale effects and can afford higher margins to pay off their capital needs. Germany has a high ROCE of even greater than 15%, which allows the country's industries to invest its employed capital in future industry technologies. In contrast, France currently earns much lower margins from its industry, preventing it from investing and thus eroding the capital employed.

Industry 4.0 requires investments. But Industry 4.0 also substantially increases capital productivity, as mentioned above, with the potential benefits of mass customisation and networked manufacturing, etc. which optimise the way capital is leveraged.

If the European economy can achieve a strong position within Industry 4.0, divestment will no longer be a threat, and Europe's economy will become more competitive,.

The EU Commission set the goal of boosting manufacturing's share of GDP in Europe from 15% to 20% by 2020. This objective is challenging because advanced manufacturing economies, such as Germany, Poland, and Austria, will not be able to boost their shares much more. Even in China, manufacturing only accounts for 30% of the economy – and this figure is declining. Against this backdrop, reaching the 20% goal in Europe would mean that countries such as the UK and France, which for decades have been shutting down their industries and are now at around the 10% mark, would have to re-establish manufacturing on a huge scale in less than a few years. This target is certainly not achievable considering today's situation (Industry 3.0). Instead, it can only be achieved by taking part in the Fourth Industrial Revolution. Reaching 20% means that Europe must create €500 billion in value added and 6 million jobs (provided current GDP growth and inflation remain the same). This would not mean that a product currently manufactured in China will be manufactured by a European worker: it will be manufactured by a European robot or machine, which is programmed by a European engineer.

Currently, the industrial investment level in Europe is €30 billion lower than the level of depreciation, meaning that assets are slowly losing value. Therefore, to achieve the goal by 2030, European firms must keep investing about €90 billion per year to generate the necessary additional value added. This would add up to €1,350 billion over the next 15 years. This amount is not so large at the European level and is far below numerous investment activities of European politics, such as the bailout programmes for indebted member states or subsidies for the agricultural sector.

Europe's ability to switch over to Industry 4.0 will be a major competitive advantage for an economy over its global competitors. Europe as a whole is in better shape to embrace the new industrial world than many people think. Besides having a solid industrial base, many countries are in a good position (equipment, knowledge, expertise, networks) for converting to Industry 4.0. European companies have a chance to develop a competitive edge here.

4. What Are the European Lessons from the Industry 4.0 Readiness Rollout for ASEAN and East Asia?

The ASEAN region has a unique opportunity to leapfrog to the forefront of the fast-moving global digital economy. Many of the fundamentals are already in place in the region. It has:

- A robust economy, generating US$2.5 trillion GDP and growing at 6% per year;
- a literate population of more than 600 million people, with 40% under 30 years of age;
- smartphone penetration of around 35% that is growing rapidly;
- a well-developed ICT cluster with a track record of innovation and investment in new technology; and
- a renewed sense of optimism and urgency for economic integration with the implementation of the ASEAN Economic Community, which pledges to promote the free movement of goods, services, investment, skilled labour, and the free flow of capital.

The ASEAN digital economy currently generates approximately US$150 billion in revenue per year (Kearney, 2016). Connectivity and online services are the biggest components, each accounting for 35%–40% of overall revenues. The user interface (including devices, systems, and software) constitutes the third-largest segment, accounting for close to 20% of revenues. However, these elements are growing at very different speeds. For example, connectivity revenues are expected to grow just 3%–5% per year, whereas online services are likely to grow at more than a 15% compound annual growth rate over the next five years.

The industrial Internet is already a key subject in the industry, and this trend will become increasingly more important in the future (Wan et al., 2016). However, companies in the ASEAN region should take on numerous challenges for the successful and timely implementation of digital concepts. In this respect, the expected high investment levels and the often-unclear cost benefits for new Industry 4.0 applications remain limiting factors. Many companies have not yet developed specific plans for the implementation of Industry 4.0 solutions and have also not made any larger investments. This is because the solutions are new for many companies and require significant internal adjustments. The quantification of potential is also complex and diverse. There is an urgent need for more transparency and the exchange of experiences across industry sectors (Buhr, 2017).

Added value proposition: As organisations shift in Europe towards Industry 4.0-driven products and services, it is increasingly important to develop a sales strategy that can deliver state-of-the-art solutions that utilise some of the aforementioned considerations: know the client, start the sales process earlier, expand the scope of relationships both within and outside of the customers' organisations, explore new service offerings, develop a strong understanding of the data and the possibilities, and start with smaller pilot programmes to demonstrate value. Doing so requires a shift in thinking and a willingness also to change the sales mindset. Manufacturers in the ASEAN region may not get this relationship just right in the early days, but they can use the experience to invest and learn, incorporating new types of skills for the staff, new ways of selling for the teams, and potentially new business partnerships with the clients. The results, when successful, can mean new business opportunities and revenue streams as well as a longer-term focus on shifting customer concerns, collaboration, and creating value.

Employee qualification is an important topic across all industry sectors. The digital change will alter the requirements for employees across all steps of the value chain – from development on through to production and sales. Processes and business models will become more agile and data-based and require completely new employee skills and qualifications. The need for software developers and data analysts in industry will once again significantly increase, which requires appropriate training and education programmes.

So far, ASEAN (as a single community) lags its global peers in the digital economy, yet it has the potential to enter the top-five digital economies in the world by 2025. Moreover, the implementation of a radical digital agenda could add US$1 trillion to the region's GDP over the next 10 years. A decade from now, ASEAN's manufacturing sector is likely to have embraced Industry 4.0 technologies.

5. What Are the Perceived Key Barriers to the Implementation of Integrated Industry 4.0 and Circular Economy Concept in ASEAN Countires and Companies?

Key lessons from national Industry 4.0 policy initiatives in Europe are a result of framing the respective policies. The first policy dimension is financing, as the majority of the national Industry 4.0 initiatives are primarily financed through public means. However, private sector co-financing has played a part. Secondly, national Industry 4.0 initiatives tend to focus on technology and infrastructure, with skills development as a secondary goal. In terms of governance and implementation, most of the national Industry 4.0 policies examined essentially adopted a top-down approach to designing, initiating, and implementing the initiatives. What this means is that while other stakeholders have been consulted and played a part in relevant national initiatives to follow Industry 4.0 policies, governments are in the driver seat. In general, the participation of diverse actors is a defining strength of the national Industry 4.0 policies.

Collaboration with industry actors/stakeholders is most frequently cited as a driving force by the implementing authorities. In some cases, industry proactively encouraged the creation of the initiatives, giving the initiatives additional impetus.

The involvement of regional authorities which are engaged in adopting Industry 4.0 strategies at the regional level – often in the framework of smart specialisation strategies – have regularly allowed for greater policy alignment between the national and regional levels. Last but not least, the initiative of public authorities in pushing forward the Industry 4.0 policies is also amongst the key drivers. The public impetus can be particularly useful when industries are too segregated or fragmented to reach consensus amongst industry actors. The example of Industrie 4.0 in Germany shows how a large Industry 4.0 platform can reduce industry segregation and improve networking.

Yet, there are several major roadblocks standing between ASEAN and an advanced digital economy and society. To bring about a full digital revolution, the following barriers will need to be addressed:

- Weak business case for building broadband
- Regulations inhibiting innovation in mobile financial services and e-commerce
- Low consumer awareness and trust, which hinder the uptake of digital services
- No single digital market
- Limited supply of local content, primarily due to a weak local digital ecosystem

Gaps in the policy enablers required to support devices, networks, and applications mean that many ASEAN Member States are lagging the potential of innovative sectors associated with the digital economy, such as mobile financial services, e-commerce, and cloud services.

Still, the ASEAN region has the potential to leapfrog other countries and rank as an elite global digital economy. A true digital revolution will transform ASEAN by 2025. Singapore, Malaysia, and Thailand would be in the top 20 of the global digital rankings, while all other ASEAN countries would be ranked in the top 40 worldwide. Achieving this ambition would go hand in hand with delivering a substantial increase in GDP across the 10-nation bloc. Transforming ASEAN into a global digital economy powerhouse could potentially generate an additional US$1 trillion in GDP over the next 10 years. Realising this goal will require a joint effort and a shared vision across ASEAN.

The uplift to GDP will be driven by three major factors: an increase in broadband penetration; higher worker productivity; and new digital industries, such as e-commerce and mobile financial services.

Digitisation is not limited to ICT industries. It is also disrupting traditional industries. It involves three key elements: (1) digitising product and service offerings (for example, remote health monitoring), (2) digitising customer engagement (for example, digital channels for sales and digital self-serve channels), and (3) digitising internal operations to increase productivity (for example, digitising the sales force). As labour costs rise in the manufacturing and engineering sectors, digitisation will help ASEAN move up the economic value chain. Technology sensors and devices are being integrated into equipment and machinery through the IoT, while advances in computational ability are enabling the analysis of huge information (big data) related to production, logistics, and sales. In the future, factories will be far more flexible than today in terms of producing individual products and achieving higher efficiency. Manufacturing will be faster, lower-cost, and higher-quality.

Over the next decade, Industry 4.0 will emerge in Southeast Asia, aided by support from far-sighted business and political leaders. Industry 4.0 consists of the intelligent networking of product development and production, logistics, customers, and beyond. We will begin to see intelligent machines and smart factories that will bring about the Fourth Industrial Revolution. The resulting revolution in ASEAN's manufacturing sector will increase the region's productivity and competitiveness, while lowering unemployment rates and creating higher-wage jobs.

Discrete manufacturing industries, from the automotive to the electrical and electronics sectors, will all benefit from the operational efficiencies reaped from new technologies. In Singapore and Malaysia, high-value product manufacturing, such as printed electronics and miniaturisation, could undergo a high degree of automation and optimisation. These sectors will be amongst the first to integrate Industry 4.0 into their production platforms.

A true single digital market requires member states to align their digital visions and strategies to create a single, borderless digital market and harmonised digital regulations. ASEAN is quite far from realising this ideal.

Only three countries – Singapore, Malaysia, and the Philippines – have a mature and comprehensive digital strategy. Indonesia has an ICT master plan focused primarily on connectivity until 2016, with a subsequent focus on creating a digital Indonesia. Thailand and Viet Nam's digital strategies were works in progress as of September 2015, with only high-level information available at the time of writing. Cambodia and Brunei Darussalam's digital strategies are quite nascent, with Brunei focusing mostly on digital government.

The harmonisation of regulations needs to begin from the top down. This does not mean creating the same laws in different countries. But there is a need for a common standard that applies to digital services in ASEAN, like the EU's privacy directive or the streamlined sales tax system in the US for cross-state e-commerce transactions. Today, different ASEAN countries are taking very different approaches to infrastructure, spectrum sharing, and spectrum trading, while the maturity of cybersecurity and data protection policies varies significantly from country to country.

There are five steps policymakers can take to eliminate the roadblocks described in the previous section. These are the following:

- Pursue universal mobile broadband access
- Accelerate innovation in mobile financial services, e-commerce, and connected cities
- Enhance trust and security in ASEAN's digital economy
- Strengthen the local digital economy
- Foster digital innovation within ASEAN

Agility is a strategic characteristic that is becoming increasingly important for successful companies. In this context, agility denotes the ability to implement changes in the company in real time, including fundamental systemic changes to the company's business model, for example.

Consequently, the significance of Industry 4.0 lies in the key role of information processing in enabling rapid organisational adaptation processes. The faster an organisation can adapt to an event that causes a change in its circumstances, the greater the benefits of the adaptation. In this context, the umbrella term 'event' may

relate to a range of different business decisions. Events may be short-term in nature, for instance a production line breakdown, or medium- to long-term, for example a change in product requirements and the associated modifications to the product design itself, to the manufacturing process and to related processes in purchasing, quality, and service.

Leaders of high-tech industrial enterprises understand that their most important assets are the machinery and assembly tools on their factory floors. These companies have often spent decades developing their manufacturing plants to produce an ever-increasing array of goods and products that they sell around the world. They have also spent decades improving their industrial processes – including just-in-time inventory – to be as efficient as possible. But given the technology developments that have taken place over the past five years, even the industrial enterprises that are the leaders in lean processes are in danger of being left behind in the 21st century. This is because the mere deep knowledge of industrial practices is not enough to succeed in today's ultra-competitive and technology-enabled marketplace.

By tapping into the principles of Industry 4.0 and adopting emerging technologies, today's set-intensive organisations can hone their ability to stay ahead in a new world where machinery and tools are being amplified by digitisation. This cyber-physical world offers the bold riches of enhanced global competitiveness and entry into radically new marketplaces.

The next 5 years will be vital for ASEAN countries for the adoption of Industry 4.0. The largest improvements that an ASEAN roadmap should focus on are in the following areas:

- Data standards and interoperability between modern and legacy shop floor systems in a multi-vendor environment as a precursor for seamless interaction, which enables multiple aspects of efficiency up the value chain.

- Effective root-cause analysis and corrective actions that build a logical approach in solving problems at their source, rather than just fixing the apparent. This is therefore considered as key for any continuous improvement programme.

- Dynamic asset classification based on asset type, relation to other equipment, hierarchy, complexity, and criticality is an important aspect to build the right model that enhances operational and maintenance efficiencies.
- Real-time production planning and scheduling can optimise all aspects of operations accurately by minimising resources consumed and maximising efficiency.
- Knowledge capture and management enable improved operations and the maintenance of complex machines, as people and their knowledge are intangible assets in industrial manufacturing.
- Manufacturing companies of today will need to adopt advanced technologies to improve in these areas if they plan to achieve higher maturity levels in their journey of Industry 4.0.

Experience with the implementation of lean management principles since the 1990s has taught that it is not enough simply to ring the changes – successful implementation also requires an in-depth understanding of the organisation and a widespread willingness to change amongst its members. Just as lean production is about far more than simply preventing waste, Industry 4.0 is not merely a matter of connecting machines and products via the Internet, the use of new technologies, or the acquisition of knowledge.

References

Acatech (2017), Industry 4.0 Maturity Index. Acatech. https://www.acatech.de/publikation/industrie-4-0-maturity-index-die-digitale-transformation-von-unternehmen-gestalten/

Bagheri, J.L.B. and H.-A. Kao (2015), 'A Cyber-Physical Systems Architecture for Industry 4.0-based Manufacturing Systems', *Manufacturing Letters*, 3, pp.18–23

Bartodziej, C.J. (2018), *The Concept Industry 4.0: An Empirical Analysis of Technologies and Applications in Production Logistics*. Springer.

Buhr, D. (2017), *Social Innovation Policy for Industry 4.0.* Friedrich-Ebert-Stiftung.

European Commission (2011), Resource Efficient Europe. European Commission. https://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

Deloitte (2016), Global Manufacturing Competitiveness Index. Deloitte. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Manufacturing/gx-global-mfg-competitiveness-index-2016.pdf

Infosys (2015), *Industry 4.0: The State of the Nations*. Infosys.

Kearney (2016), *The ASEAN Digital Revolution*. Kearney.

Peressotti, V. (2016), 'Il vero significato di Industry 4.0 Quali impatti avrà sulle aziende', Sistemi & Impresa, 5, *giu.-lug.*, pp.44–46.

Rifkin, J. (1995), *The End of Work: The Decline of The Global Labor Force and the Dawn of the Post-Market Era*. Putnam Publishing Group.

Roland Berger (2014), *Industry 4.0: The New Industrial Revolution How Europe Will Succeed*. Roland Berger.

Tukker A. (2015), 'Product Services for a Resource-efficient and Circular Economy: A Review', *Journal of Cleaner Production*, 97, pp.76–91.

Sinn, W. (2018), Warum es ab 2020 für die Mittelschicht brutal wird. http://www.manager-magazin.de/unternehmen/industrie/die-bedrohung-der-mittelschicht-in-den-2020er-jahren-a-1216677-2.html

Walsh, T. (2017), *Android Dreams: The Past, Present and Future of Artificial Intelligence*. London: Hurst Publishers.

Wan, J., S. Tang, Z. Shu, D. Li, M. Imran, and A.V. Vasilakos (2016), 'Software-Defined Industrial Internet of Things in the Context of Industry 4.0', *IEEE Sensors Journal*, 16(20), pp.7373–80.

Xie, K., Y. Wu, J. Xiao, and Q. Hu. (2016), Value Co-creation between Firms and Customers: The Role of Big Data-based Cooperative Assets, *Information & Management*, 53(8), pp.1034–48.

ZEW–Leibniz Centre for European Economic Research (ZEW) (2018), Digitalisierung und die Zukunft der Arbeit: Makroökonomische Auswirkungen auf Beschäftigung, Arbeitslosigkeit und Löhne von morgen. http://ftp.zew.de/pub/zew-docs/gutachten/DigitalisierungundZukunftderArbeit2018.pdf