

Introduction to Industry 4.0- Essay (ACPA7004)

Assignment 2

The impact of adopting Industry 4.0 technologies by SMEs in smaller countries and what this undertaking entails.

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Introduction.

There are many definitions of Industry 4.0 as there are commentators on the subject, but according to Winkelhaus and Grosse 2020, (Ref.1) “Industry 4.0 is a highly integrated smart factory, in which individual goods are produced sustainably in a mass production manner to fulfil customers demands in a global competition”. To what extent smaller countries can hope to be in position to ‘fulfil customer demands in a global competition’ with any goods is dependent upon many factors, only some of which may be helped by the adoption of Industry 4.0 methods and technology. In this essay I will attempt to demonstrate the variety of requirements for these rapidly developing technologies, and the current routes which show the importance within smaller countries of attempting the adoption – or otherwise – of Industry 4.0 technologies.

The term ‘smaller countries’ does not universally refer to ‘developing countries’, many larger countries such as Indonesia, Egypt and much of the central middle east are classed as developing or ‘newly developed’ countries. Similarly, smaller countries include some highly commercialised and industrialised small nations, so the classification and distinction is not clear. For this essay I shall extend the definition of smaller countries to include those less developed countries with smaller economies, not by defining them by their geographical size.

As far back as 2016, some years into the coined ‘4th Industrial Revolution’, Klaus Schwab of the World Economic Forum (Ref. 2) was predicting that “Industry 4.0 is a process of socio-technical change that affects the physical, digital, and biological domains, based on the innovative and effective exploitation of a wide range of new and emerging, prevalently digital, technologies through their fusion and interaction.”. In smaller countries and those outside those classed as ‘developed’, that socio-technical change is, however, more likely to be limited by local expediency rather than a desire for change unsupported by resources and ready markets.

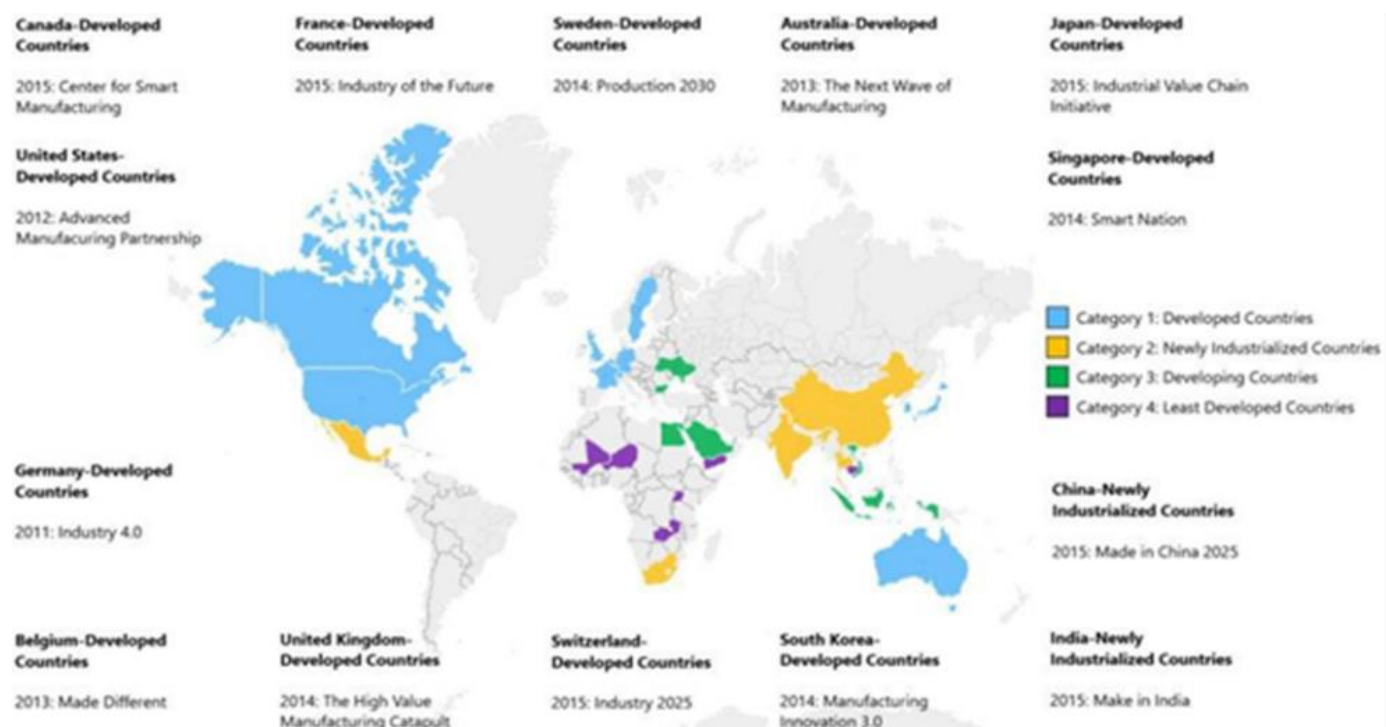
All waves of industrial and technological progress have been accompanied by sharper inequalities between countries. The disparity in income per capita between the ‘developed’ and ‘developing’ countries is currently over \$40,000 – will the adoption of Industry 4.0 methods allow smaller countries to advance their economies, or will the inability to fund, skill and power these new technologies enlarge that gap still further?

The Essay

The requirement for Industry 4.0 Technologies and the approaches to promote adoption.

The requirement for the technologies classified as 'Industry 4.0' – which includes a list of newly-coined technological pillars most of which were unheard of within the last 10 years : artificial intelligence, nanotechnology, biotechnology, blockchain, data science/Big Data, and the Internet of Things (IoT) – will depend greatly on real access and need for those technologies, and the funds and motivation to put them in place, particularly within smaller countries. The inevitable careers pitch of the current western world educators is that “ ..in XX years most jobs will be in roles (..i.e. for technologies...) that are not even invented yet...”. This may be true in the world those educators see daily, but that statement fails to recognise that penetration of these technologies will not be universal across the globe. Indeed, the degree to which job roles, and employment in general, changes in the upcoming years may well be strongly dependent upon the access to and desirability of the Industry 4.0 technologies to the local micro and macro economies across the globe.

It is correct at this stage to see how the need for Industry 4.0 technologies is being recognised across the globe, and what range of motivations and directions exist, and how countries and major manufacturers within them are adopting INDUSTRY 4.0 technologies. This is outlined in the schematic below, from Siau et al (Ref 3):



Clear strategies developed by countries across the world for driving Industry 4.0 development.
(Ref: 3)

Siau et al (Ref 3) go on to examine the range of approaches in seeing the need for Industry 4.0 technologies in their countries, and how they choose to drive the adoption of 4.0. In Germany, the leading global company Siemens has fashioned itself as a 'digital enterprise' which affects every aspect

of the company's operations. This isn't limited to manufacturing but managing, delivering, and purchasing procedures. With three main Industry 4.0 technologies adopted – intelligent data management, and open cloud platform, and AI – which replaces humans for production and the management of production. It aims to improve the quality of decision making at all levels with this move, on top of pure production efficiency improvements. Not surprisingly, as a nation famed for its technological mindset and respect for the trained engineer, Germany is focussing its response to exploit Industry 4.0 with “engineering excellence”.

United States has a different tack, with its lead in IT, the push across the US is into ‘industrial internet’, which is from combining big data, analytical tools, wireless internet, and physical and industrial equipment. Smaller companies are being encouraged by the US to engage in a ‘radical innovation,’ encouraging start-ups to take advantage of the Industry 4.0 technologies.

Switzerland as a smaller country has always recognised its unique position in geography and role. The Swiss are concentrating on developing Industry 4.0 to safeguard and expand the interests of Swiss companies, and further the security of the Swiss workforce. Switzerland ranks high in innovation and human development terms and is accepted as leading the way in Industry 4.0 development.

Singapore stands as the leader of Industry 4.0 amongst Asian countries and has registered the need to link Industry 4.0 into both government and private sectors and are planning to develop the country into a Smart Nation. Their government unit A*STAR (‘Agency for Science, Technology and Research’) has launched two model factories to draw in smaller enterprises to learn and adopt Industry 4.0 technologies.

In the developed but smaller countries of South Korea and Japan, the stress has been placed on the scaling the countries industrial operations as Industry 4.0 emerges. They are constructing smart factories across their economies to address this with a focus on enhancing technology and quality of the industrial output to grow both domestic and export potential.

Newly industrialised countries such as Thailand, Mexico, The Philippines, and South Africa, may well have a good current base of production, but the future development of Industry 4.0 may well be a challenge form education, skills, and governmental support.

The most interesting cases noted by Siau et al which are most pertinent to our brief, are those countries such as Bulgaria, Saudi Arabia, Egypt, and Vietnam where possibly the information areas of Industry 4.0 are being implemented – AI, cloud computing and data - but where there is little base of current production to foster an Industry 4.0 manufacturing initiative. These countries demonstrate a most important blocker to the development, the lack of a coherent industrial base.

As a final group, the least developed countries such as Yemen, Zambia, Cambodia, and Mali have little in terms of meaningful industrial base, and the educational base and potential development is far from being able to support the INDUSTRY 4.0 core technologies IoT and cloud computing.

As noted by Utikal (Ref 4), he suggests “Data is the new oil” - with current uptake of technology towards 4.0 being akin to the drive to adopt oil as the universal demonstrator of industrialisation in the previous, mechanisation revolution. With the press for Industry 4.0 technology to supplement and even replace manufacturing, we can only hope that the opportunities are realised to educate and improve the well-being and life-chances of a high proportion of workers where a drive to Industry 4.0 adoption is gaining ground – and make Industry 4.0 the socially sustainable Industrial Revolution.

Societal factors arising from the impact of Industry 4.0 adoption.

There may well be societal issues we would be unfamiliar in the westernised world. The day-to-day security of staff and technology in the local environment may well be subject to volatile political and social unrest, including lawlessness and corruption. Amaro (Ref 5) notes that there is no security of work and learning in regions of Northern Mexico, with consequently little opportunity for investment into stable advances in technology and training of the workforce.

We know that the advance of technological change will affect inequality through the number of available employment positions, the salaries that can be applied, and the willingness of businesses to invest as the profits are there to be made from doing so. As the Industry 4.0 increases productivity there will be a need, and the ability, to add more and higher skilled workers, possibly adding to the cycle of increases in productivity and more advance into Industry 4.0 technologies and methods.

Amaro continues by suggesting that currently available skills levels drive – or restrict - the likely benefits of Industry 4.0 technologies. Relatively easy access to cheap labour for assembly and tasks not complex enough for mechanisation, are unlikely to benefit from adoption of higher levels of technology approaching into Industry 4.0 complexity. The same point, however, arises with smaller countries as with the more developed high activity countries, that the most important skills assets are still the professionally qualified worker, not the automation.

Most firms in developing countries are a long way from using, or even having access to, the degree of education that will be necessary in their workforce to implement 4.0 Technologies, as illustrated on the graph below showing Degree of education, by Country Development level:



Mean years of schooling for different groups of countries – after Siau, Xi and Zou, Cutter 2019.

(Ref: 4)

The graph of mean educational attendance above illustrates the education of labour into Industry 4.0 readiness will suffer the same blockers, barriers and resource limits as more traditional education does

in large or small countries. It is likely to be more acute in those least developed and smaller countries. Resources for teaching will always be limited and the proximity of available low skilled work as a necessary for life and well-being will always be difficult to overcome in retaining workers in training and education beyond the mean years shown as typical above.

On the societal facet, let us briefly consider Wales as a separate economy, in the same way it proudly considers itself a separate, smaller country within the United Kingdom. Within Welsh Government's report 'Wales 4.0' of 2019 (Ref 6) the authors laid out the challenges and opportunities for Wales from Industry 4.0. The introduction included a question – what would a national conversation conclude on what digital innovation would mean for the people and working communities across Wales? In doing that they should of course consider the high-tech innovative businesses of the future who will use, benefit, and develop Industry 4.0. But it should also encompass the complete Welsh society, working or not, it's opportunity to work and leisure, its well-being, and its ambition to progress into the future. They go on to state that although the Welsh Government can positively affect the direction and adoption of Industry 4.0 technology, as they say, it's "...not simply up to them to decide what to do.". The conversation and the ongoing action should be informed by the whole workforce and society. This question should be the same question asked for all smaller countries – the question is too important for only short-term politicians and self-interested business to consider.

Defining parameters of readiness for Industry 4.0.

Studies of the penetration of Industry 4.0 technologies are still scarce, and many focus on advanced economies strongly and smaller countries very lightly. But in Derela 2022 (Ref 6) they point out that Industry 4.0 diffusion remains low in the countries they studied – namely Ghana, Viet Nam, and Thailand, with less than 5 percent of those companies surveyed currently adopting the most advanced levels of digital technologies. Their paper does point out however, that the adoption of Industry 4.0 technologies aligns strongly with companies' involvement in Global value chains (GVC). This is tempered by the admission that uneven commercial relationships in a value chain may limit participating companies in smaller economies from upgrading their technology levels, as they may perceive it would lose them the GVC involvement. We will go on to illustrate later that losing the GVC connection has been a positive development tool for some smaller country manufacturing economies progressing into Industry 4.0.

Derela does suggest that firms' international linkages play a role in explaining technology adoption patterns in those countries. There are positive effects of policy efforts which aim to support the internationalization of domestic firms' capabilities, but with transfer of technologies staying limited to relatively mature technologies somewhat behind the frontier-level of Industry 4.0.

They also found that the availability of investments is vital in upgrading the internal resources of small countries and the skill levels of local businesses, and generally show benefits where the education policies are aimed at raising the skill level of workers and managers in developing economies.

Egypt	Selected Key Facts	Key Opportunities and Challenge	Implication for I4.0/Sustainability
Technology & Innovation Ranks 53/100	Technology platform (42/100) with FDI and technology transfer (61/100); weak technology absorption on company level (84/100) Ability to innovate (72/100): venture capital deal flow (46/100); R&D expenditure (ranks 49/100); Companies embrace disruptive ideas (95/100); scientific and technical publication (57/100)	Building of manufacturing processes as a challenge; weak position in FDI and technology transfer and weak technology absorption capacity Weak ability to innovate Companies not embracing disruptive ideas	Potential for leapfrogging given – special attention has to be given to the question how the basic capabilities for generating and disseminating innovation can be fostered
Human Capital Ranks 85/100	Current labor force with weak profile (78/100): still very high number of unskilled workers: mean years of schooling (82/100), limited digital skills (64/100) Future labor force in a weak position (95/100): Quality of universities (45/100); Vocational training (100/100); On the job training (100/100); School life expectancy (71/100)	Upgrading of skillset as major challenge Low level out of school plus severe challenges in the fields of vocational and on the job training	Upskilling of workforce needed in order to have high tech manufacturing processes in Egypt Developing a vocational training and on the job training culture as major challenge Integrate Industry 4.0 and sustainability topics into curriculum for academic and non-academic trainings Making sustainability issues meaningful for unskilled workers
Global Trade & Investment Ranks 75/100	Trade (96/100): High trade barriers Investment (30/100): High greenfield investments (9/100); investment inflow (37/100) Infrastructure (54/100): electricity infrastructure (56/100); transport infrastructure (53/100)	Global trade is not systematically used as a mean for enhancing learning on Industry 4.0 high greenfield investments can be a mean for knowledge transfer Infrastructure as a challenge for Industry 4.0	Global trade and investment as a relevant field for improving sustainable economic development – but trade barriers as a major barrier Infrastructure as a field for further improvement
Institutional framework (78/100)	Future orientation of government (56/100) Regulatory efficiency (74/100) Rule of law (79/100) Incidence of corruption (75/100)	Uncertainties with regard to the institutional framework prevent deployment of Industry 4.0 technologies and limit willingness to experiment with new technologies	Factor has to be taken into account as a limiting factor for future development

Some defining parameters for study on how prepared countries are to adopt Industry 4.0 is suggested by Utikal et al (Ref 4), Egypt as an illustration.

Utikal (Ref 4) undertook a review a range of countries and illustrated their preparedness for adoption on Industry 4.0 (Ref 4). He proposed some using some key indicators to measure preparedness, breaking them down into 'Technology and Innovation', 'Human Capital', 'Global trade and Investment', and an 'Institutional Framework'. This is done for a variety of countries, but notably for smaller countries, such as the example of Egypt shown above. His study identifies the current state of INDUSTRY 4.0 development, training, investment links, and the desire and capability of the country's institutions to drive Industry 4.0 effectively.

Utikal also notes the potential for countries to "leapfrog" – advancing technology by leaving aside the normal staging of technology development and moving straight to Industry 4.0 linked technology. This shortcut the investment in time and money by implementing the interim advanced analogue technologies and straight into digitally enabled manufacturing. This carries with it the danger of isolating those corners of Industry where the normal early stages of digital development have not reached, and investment may well be less likely to reach with focus on the Industry 4.0 advancements.

Lee (Ref 7). Where there are late adopters of the Industry 4.0 environment, there may well be pathways for countries to implement Industry 4.0 technologies that would place them at a stage of accelerated development over their peers. We can view the well-known example of mobile phones gaining very quick traction in countries where no countrywide landline network existed. The committed uptake of Industry 4.0 is still concentrated firmly in a small group of leading countries, but with the 'leapfrogging'

principle, there may well be chances for smaller countries to align themselves towards, if not on a par with, some of these. This 'leapfrogging' can allow smaller countries to escape the extensive re-tooling of existing facilities the Industry 4.0 smart factories can be invested in directly, from the ground up.

Although skills is an accepted issue in this case, very often a small percentage of high level skills are attained by some specialists, who are then able to promote an alternative pathway that is capable of achievement locally. This isn't constrained by existing manufacturing infrastructure and can bypass patents by initiating a step forward ahead of them, possibly from early exposure to that technology. The Chinese example of Huawei learning from early progressions by Ericsson to go on to develop their own technology on a rapidly divergent path to leap ahead of their earlier collaborators.

Several encouragements to diverge from established brands can be identified and allow the leapfrogging to thrive. One is loosening Intellectual Property Rights (IPR) allows those lagging as they cannot pursue the prohibitive levels of R&D, the latecomer can make small but significant advances which allows them to trade these advances and promote their own imminent innovation as they assimilate the technologies. A second is by pursuing short life-cycle advances where less expensive and shorter bouts of funded R&D produce results, allowing income profits and growth, but these are quickly surpassed and learned from, again with other advances with palatable levels of R&D spend. China and South Korea are examples of this, concentrating on short-cycle innovation, working their ways into longer cycle product development as investment, skilled training and technology uptake allows.

Finally, as noted earlier, the reliance on a global value chain (GVC) may well be counter productive to long term development of advanced and smart, Industry 4.0 technology industries. If smaller countries can disengage from the GVC's and develop domestic value chain they may well be able to advance significantly, re-entering the GVC with high-end segments of markets at a much higher price point. China and South Korea demonstrate this excellently.

In the readiness for adoption of Industry 4.0 in smaller countries, changing from traditional analogue to Industry 4.0 pre-supposes that there is existing IT infrastructure to build digital platforms on, and that an unrestricted and reliable internet is available where and when needed. It is common in some countries to have government-led policies to restrict both internet access and content, indeed this is the case in many countries across the globe. This does not bode well for open access to Industry 4.0 education and training, open source or otherwise. This will need to be widespread and open access, to teach and promote Industry 4.0 technology to those in vocational or home-led learning. There's also a need for the capacity in industrial and service sectors to supply with the information to produce and sell. In smaller countries this may well be in existence but a poor degree of operability and readiness for adjusting for differing input and production is unlikely to be helpful. Both the high technology skillsets and the investment into manufacturing upgrades would be needed to produce and environment for growth of manufacturing and associated services (Ref 8).

For the smaller country, the necessity is for a national digital industrial strategy to be well under way, focussing especially on getting digital technologies used across the country. This will help the local businesses to address and use the technologies and promote re-thinking the markets available. If necessary, even dispensing with legacy production of traditional goods in favour of what the international markets now want and, with work, investment and training, the smaller country can be capable of producing.

The obvious digital and technical skills that will be needed cannot on their own promote the increased use of Industry 4.0. A much broader range of capabilities must be initiated and nurtured to allow a commercial framework of management, enterprise skills and assessment of business risks to operate

in combination. As noted above, the availability of locally relevant open data for local firms to learn and communicate with, must form part of the strategy to boost innovation and take-up. If policymakers can be persuaded to focus on new knowledge capabilities to open the opportunity space for those willing and able to access it, then the knowledge base will be moving wider and faster with the technologies as they develop going forward, not mired in old technologies that have been long surpassed by digital and Industry 4.0. Governments at the smaller country level need to promote the successes of forays into these new digital technologies, but also provide a roadmap and assistance for local businesses to get there. There is a space for legacy industries and production, but as a niche exportable not as the main commercial trade and gross domestic product earner of a smaller, and developing, country.

What is needed to realise Industry 4.0 in smaller and less well-developed countries.

(Ref 4) A prerequisite is that a functioning and accessible and reliable internet connection is available, that all parties to the industry can access and use to communicate with others drive their tech developments... to connect and inform all parties in the production of the goods on demand, timescales, and changes to production.

The ability to bring in the appropriate level of cyber-physical systems into the factories, connecting the machinery to the internet. Where possible goods can be modular and linked by data models, helping to produce not only large production runs but individualised items depending on the market levels and volume addressed.

A level of data analysis capability with linkage to the cloud for big data. To analyse huge amounts of data in real time and look clearly at the value chain as it develops, predict future development, resources, or demand changes, and alter direction of product, or production type, in good time.

With these in place to the investment level that's corrected to initiate the appropriate level of development for the economic levels of the smaller country, the stage is set for the country to capitalise on the introduction of Industry 4.0 techniques.

The investments made so far in Industry 4.0 will be successful only if adequately supported by political backing of an overall modernization, with decision makers needing to be orientated towards innovation to recognize the right path to development. Where companies and staff aren't proactive in absorbing the process of modernization, the Industry 4.0 is unlikely to make the traction it requires and uptake will stall, and therefore competitiveness advantage – or even parity with better adopters- that could be built will fall away.

In human capital terms, even countries like China do not have skillset to address full Industry 4.0. (Ref 4) Even with the leading part that Universities, local and world-wide, plays in educating the China-based technologists needed for Industry 4.0, but matching any vocational and further educational training is proving a barrier, with sections of industry sticking to the traditional (and currently profitable.) analogue production methods. However, China has huge investment in both modernization and new developments will go a long way to gather momentum for those educational so essential across the future workforce.

Institutionally, China has a good framework towards Industry 4.0 investment (Ref 4), however, deployment can only be supported by efficient regulation and adherence to the legal frameworks, and here China falls down, proving a major potential barrier to extensive and free access to learning on Industry 4.0 developments and possibilities across this huge country.

Seja (Ref 9) raises the point that whilst many companies are re-shoring to home countries to capture local consumers' confidence and promote national jobs, what might be seen as a threat to smaller countries may well prove to be a potential blessing for INDUSTRY 4.0 progression. Any progression smaller countries can make into smart techniques manufacturing they can increase their productivities and increase income and prospects to those labour and skilled workers groups that are upskilling to work with the manufacturing change.

There is a significant development in training in manufacturing development where public and private funded 'Industry 4.0 competence centres' provide technological consulting, technology transfer and research to SMEs - Germany has 25 such centres, France has the CLARTE initiative, and the US has 'Automation Alley'. For smaller countries, Singapore has a publicly run 'competence centre' – NAMIC - to increase the local competitiveness and to drive innovation through technology driven manufacturing. The hope is to initiate a local innovation network and to facilitate access to certified manufacturing training and improve the human capital of its workforce. Local Publicly funded support is of growing importance, for smaller and less developed countries – India has 'Technology Centre Systems Project', and Bangladesh has the 'Export Competitiveness for Jobs', as well as those sponsored by other countries, such as German government funded GIZ in Tunisia (Ref 9).

Seja (Ref 9) outlines the model steps that shape any support package for developing 4.0, with particular reference to SME's, who are world-wide by far the biggest drivers of manufacturing, growth, and employment:

- Are there sectors with global supply chain links that Industry 4.0 can help
- What skills levels are there, or can be developed readily, to support Industry 4.0
- Does local Industry demand those new production methods?
- Can sustainable finance be found to support these production methods?
- How does the regulatory environment support Industry 4.0, and can it be readily revised to help Industry 4.0?
- Plan a government support model to reach as wide a net of SME's as possible
- Gauge success and failures and revise or replace support as needed.
- Ensure the successes, and lessons learned, are heavily promoted, in and out of country, regardless of the sector – the resolution of issues are invaluable to all.

However well these steps are brought to the fore, in a smaller country context the decision making and abilities to progress change are more focused on short- and medium-term expediency than long term foresight and planning.

Conclusions:

The human capital element of any country is critical if any nation seeks a competitive edge to lead and benefit from adopting Industry 4.0 Technologies. Developing and lesser developed countries face greater challenges in education than those with a larger and more stable manufacturing bases and need to make strong and deliberate commitments to education.

Where existing non-digital manufacturing exists, the re-skilling and upskilling their most at-risk workforce is vital to avoid leaving large elements of the workforce disenfranchised and bitter, and without employment. The example of the UK coalmines is a shameful demonstration of this outcome in one of the strongest economies of the western world, and indeed, the globe.

Clearly, Industry 4.0 is here, and it will advance in importance and accelerate in its development and its effects on manufacturing. Smaller countries need to bring together a coherent roadmap to assess the need, and the potential areas they will need to potential adapt, to capitalize on Industry 4.0. Avoiding or ignoring Industry 4.0 is unthinkable for long term local and global competitiveness, and for the long-term well-being of the country's population.

In smaller and less developed countries, the current limits of education will only be highlighted more starkly with the need to adapt for Industry 4.0. Proposals such as MOOCs (massive open online courses) might be possible to supplement traditional education, but as there are over 4 billion people globally who cannot access the Internet, this type of initiative isn't going to reach those who need it most. Without sufficient traditional or digital education, people in the smaller and less advantaged countries have little chance to grow their skills in preparation for Industry 4.0. The conclusion must be that **the inability to fund, skill and power these new technologies will enlarge the income gap still further.**

Perhaps the adage of manufacturing relying on the economies of scale will be changed by the implementation of Industry 4.0 technology. The onset of smart manufacturing will increasingly enable businesses to produce modular and individualised products that can be possible without the high costs of prototyping, physical modelling and that previously would have ruled out a bespoke approach to production.

The volume production industries may well persist using old non-digital methods, but with the flexibility of Industry 4.0 the approach to manufacturing can be businesses offering one or more elements of production, linked to produce a viable value-chain of services, to replace and update old style services and activities, and reconfigure production that had proved uneconomic in the past. As we have identified, if its investment confidence that fails to drive penetration of Industry 4.0 into the smaller countries, then the potential for smaller specifically targeted investment into linked enterprises of this type driven by Industry 4.0 might prove more attractive, and the seed corn for wider adoption.

My conclusion is that I can see no evidence from the collected readiness measures and commentaries viewed as part of this study, that the adoption of Industry 4.0 methods will allow smaller countries to advance their economies sufficiently to provide the socially responsible and sustainable Industrial Revolution that could be a reality under Industry 4.0.

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