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Macroeconomic Prospects in the Digital Economy

# Paper Submission
# (Impact of Digitisation on Manufacturing)

**Title:** Manufacturing in the Digital Economy: The Rise of Regionalisation as an Organisation Strategy

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**Abstract**

Since the 1980s large manufacturing conglomerates have been charactierised by big vertically integrated supply chains. The drive to minimise cost saw multinational enterprises (MNEs) establishment of huge manufacturing facilities in low cost developing countries while managed by headquarters in developed countries. This however is changing in the digital economy. Three categories of digital technology applications in the manufacturing sector is identified: automation; additive manufacturing (AM) and internet of things (IoT). Analysing how these affect a firm's organisation strategy, this paper finds that automation reduces the cost advantage from offshoring to developing countries. Additive manufacturing on the other hand augment a firm's value chain by accentuating the value of R&D and customer services while IoT allow firms to operate closer to their consumers in real-time. These changes in turn places a premium on the value a customer can bring to firms and necessitate MNEs to increasingly optimise revenue considerations on top of the traditional cost factors. The result: MNEs will be managed regionally, with a focus on strategic functional activities and much smaller manufacturing facilities. This paper introduces a new dimension to firm organisation – a regionalisation strategy – to account for the change in manufacturing that is brought upon by the digital economy.

**Keywords**: Digital Economy, Regionalisation, Industry 4.0, Automation, 3D manufacturing, Internet of Things (IoT), Multinational Enterprise, Offshore, Outsource

## Introduction

The manufacturing sector is no stranger to technological innovations. In the 18th century, it was the steam engine. In the 19th century, electricity. In the 20th century, information and communication technology (ICT – think telephone, fax, personal computers and emails). Now in the 21st century, the manufacturing sector is being disrupted by yet another technological innovation; digital technology. Cushioned in the digital economy, the use of digital technologies in manufacturing is revolutionising not just the manufacturing of goods per se, but also the whole value chain of the manufacturing sector. This should come as no surprise. After all, each technological innovation did bring with it an ushering in of a "new era" so to speak – steam engine and electricity ushered in the industrial revolution while ICT ushered in globalisation and the emergence of global value chains (GVCs).

At the core of GVCs is a phenomenon known as fragmentation of production. Put simply, product fragmentation is the breaking down of the production process into more discrete functions and smaller activities (Kimura and Ando, 2005) and occurs along two dimensions: control (outsourcing) and geography (offshoring) (Mudambi, 2008). The literature on product fragmentation has its roots in the seminal contribution of Jones and Kierzkowski (1990) who verified international fragmentation among Multinational Enterprises (MNEs). They highlighted that international fragmentation of various production blocks was necessarily contained within a multinational organisation. This established the common practice back then for MNEs to offshore large manufacturing facilitates in low cost developing countries while still managed and controlled by the organisation which are commonly headquartered in developed countries (Kumpe and Bolwijn, 1988; Baldwin 2016).

This however is changing with the emergence of digital technologies in manufacturing. While the impact of the digital economy on manufacturing is widespread, one thread that has gained popular attention is the observed retreat and downscale of MNEs from and in developing countries (Boston Consulting Group (BCG), 2015; Tett, 2017). This trend is both worrying and unexpected. The operations of MNEs in developing countries have been acknowledged to be a catalyst for economic development by creating employment opportunities, stimulating technology transfer and even to the extent of improving domestic institutions in their host countries. Furthermore, the innovation of ICT made lofty promises. Baldwin (2016) argues for a "second unbundling"; a phenomenon where ICT decreases the cost of moving ideas hence enabling manufacturing stages to be dispersed. This has been the linchpin of globalisation and GVCs. GVCs in turn offers opportunities for small and medium-sized enterprises (SMEs) in developing countries to participate in global trade while MNEs benefit from production flexibility, cost competitiveness and reduced business risk – a win-win for both (Harvie and Charoenrat, 2015). The retreat and downscale of MNEs in the digital economy therefore threatens to disrupt the standard process of economic development among developing countries and alter the dynamics of GVCs.

On the other hand, however, it is commonplace to still hear of MNEs expanding their operations and production abroad. General Electric for example invested $200 million in India for its new locomotive factory (Mann and Spegele, 2017); Unilever's $270 million personal care brands production facility in Dubai is the largest greenfield project by a multinational in the region (Nair, 2015); and IKEA's $210 million regional distribution centre in Malaysia (Zainul, 2017). Quantitative studies on back-shoring activities seem to corroborate this. Kinkel (2014) finds a ratio of one to four for back-shoring to offshoring over the past 15 years among German manufacturing companies. Extending the study to include other European countries, Dachs and Kinkel (2013) find a similar ratio of one re-shoring company to three to four off-shoring companies.

To make sense of this contradiction, this paper reviews the literature on firm organisation to identify the factors that affect a firm's decision and the gap in the literature. Section three then analyses how the applications of digital technologies in the manufacturing sector alter an MNE's strategy considerations. More specifically, this paper identifies three digital technology applications – automation, additive manufacturing, and internet of things – and find that they collectively allow MNEs to move closer to their customers. Section four lays out a discussion on how these changes in turn necessitate MNEs to operate closer to their customers and prioritise customer centricity in order to effectively compete in the digital economy. The author suggests a new dimension to firm organisation – a regionalisation strategy – to account for the fundamental shift from cost to revenue. The paper then concludes by providing an explanation to the aforementioned contradiction.

## 2. Firm Organisation Strategy

### 2.1. Approaches to firm organisation

Early approaches to firm organisation can be traced back to Jones and Kierzkowski (1990) who pioneered the theory of fragmentation and Krugman (1991) who pioneered the study of new economic geography. The theory of fragmentation asserts that under increasing returns to scale, greater levels of outputs encourage firms to further fragment their manufacturing process into separate production blocks. Fragmentation therefore implies a dissaglomeration of manufacturing – a view that has been used to explain the emergence of trade in parts and components over trade in finished goods (Jones et al., 2004). The new economic geography however argues for a case of agglomeration; a phenomenon where economic activity tends to concentrate in a particular geographical space but not in others. Despite being a powerful tool to explain firm organisation, these two schools of thought fail to account for the complexity in firm organisation strategy. Mainly, both schools of thought are ownership-blind; that is, outsourcing and in-house production are not differentiated as two separate strategies.

The literature on firm organisation has since been commonly explored along two dimensions: control and location, and the interaction between them (Mudambi, 2008). This approach is represented in Table 1. The first dimension addresses “what to produce?” where firms have a choice between vertical integration or specialisation. The second dimension on the other hand addresses “where to produce?”; a choice between geographical concentration or dispersion. Their interaction then forms 4 strategies: domestic in-house; domestic outsource; in-house offshore; and offshore outsource. The two dimensional approach to firm organisation allows firms to have a control and location strategy choice which are not mutually exclusive – in that one can happen in the presence of the other. Additionally, while it is analytically convenient to assume exclusivity, manufacturing networks in reality are formed with sophisticated combination of intra-firm and arm’s length transactions alongside geographical decisions to offshore or manufacture domestically (Kimura and Ando, 2005).

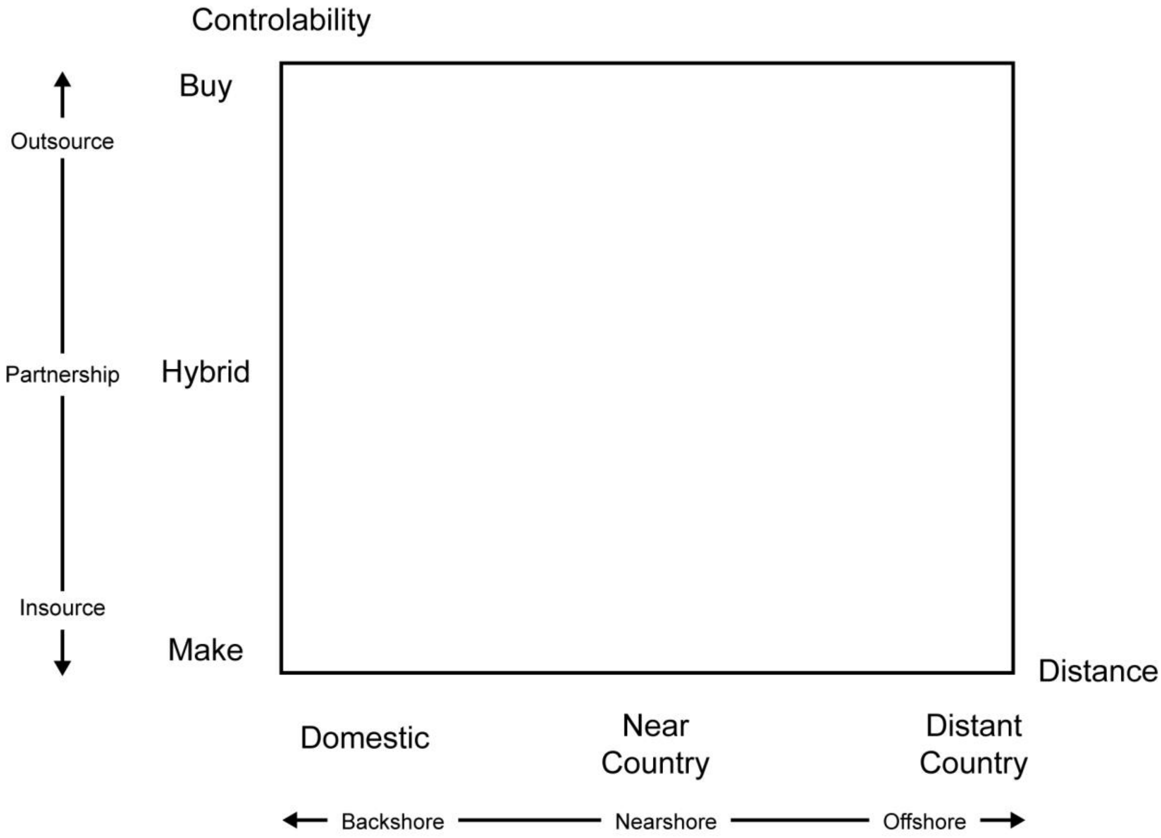
**Table 1: Two Dimension Approach to Firm Organisation**

<table>
<tr><td></td><td colspan="3">Location Strategy</td></tr>
<tr><td rowspan="3">Control Strategy</td><td></td><td>Concentrated</td><td>Dispersed</td></tr>
<tr><td>Vertical Integration</td><td>1. Domestic in-house</td><td>3. In-house offshore</td></tr>
<tr><td>Specialisation</td><td>2. Domestic outsource</td><td>4. Offshore Outsource</td></tr>
</table>

Source: Mudambi (2008)

Another approach to firm organisation that has been explored in the literature is the hybrid approach that takes into account the dynamic nature of firm strategy. That is, rather than perceiving control and location strategy as categorical choices, they should be perceived as a continuum of strategy choices. Control, for example should be interpreted as the degree of controllability. Such an interpretation provides an allowance for firms to outsource, yet retain somewhat of control. Outsourcing through long-term contracting for example allows a firm to retain greater control than competitive spot bidding contracting would (Williamson, 2008). Location, on the other hand should be interpreted as distance. For instance, offshoring of a production block can take place at a bordering country or a distant country (Fratocchi et al., 2014). In addition, the hybrid approach also allows for firms to choose their starting point and move freely along both dimensions. Firms therefore face a dynamic combination of choice between backshore, nearshore and offshore; and insource, partnership, and outsource. Figure 1 illustrates this hybrid approach to firm organisation. Firms can be on any point within the square, representing a combination between some degree of controllability and some degree of distance from their domestic starting point.

**Figure 1: Hybrid Approach to Firm Organisation**




Source: Author

**2.2. Conceptualising Control Strategy**

The decision of control is largely determined by the push and pull factors of firm ownership. On one hand, a firm can opt to fully integrate manufacturing – i.e. retain full ownership and control over every stage of production. This includes the establishing of new departments or manufacturing facilities that performs differentiated functions under existing governance structures and the establishing of subsidiaries in which the firm owns more than 50 per cent of the common shares to retain control. On the other hand, a firm can also opt to outsource manufacturing – i.e. delegate part of activities to an unaffiliated company or outside contractor.

These two control strategies then exert opposing forces on a firm's control decision. Grossman and Helpman (2002) emphasises a tradeoff between the cost of running larger, less specialised governance structure and the cost from search frictions and imperfect contracting. It is commonly argued that by running a larger integrated organisation, firms lose out on lower production costs that comes with specializing – mainly from reduction in unitary fixed costs but also from lower variable costs (Daraio et al., 2015). By producing everything in-house, large manufacturing organisations would have to invest heavily in plant and equipment (Gilley and Rasheed, 2000), and in some cases may only use certain manufacturing capacity occasionally. This incurs a huge fixed cost that will affect a firm's return on assets (ROA) and net profit (Kumar and Eickhoff, 2005). Belcourt (2006) further proposes that cost savings from outsourcing occurs because specialised firms are able to divide input costs across more users. Additionally, these costs savings are also seen across various activities. For example, Rank Xerox, the manufacturer of document processing products gained cost savings from 5 per cent to 62 per cent depending on activity by outsourcing its facilities management (e.g. cleaning, catering, security and gardening) (Houston and Youngs, 1996).

The cost of running large integrated organisations is not just confined to monetary costs. Lonsdale and Cox (1998) argues that specialised firms are better able to concentrate scare resources on the core of the business. With this, firms should concentrate and specialise on what they do better than anyone else and outsource the rest to specialised suppliers (Belcourt, 2006), who equally, are better than everyone else in what they do. This is particularly so in high technology manufacturing that experience aggressive levels of development in technology. By outsourcing, firms are better able to ensure that every segment of their production activity utilises the latest technology that is available in the market. Mudambi (2008), for example finds that Apple's organisation strategy to outsource all non-R&D activities outperform Nokia's strategy of vertically integrating its entire manufacturing process across a wide range of financial measures.

Firms that choose to specialise however must search for a suitable partner, therefore facing the cost from search frictions and imperfect contracting. The idea here is that finding a suitable partner or changing an outsource partner for that matter, is costly to firms. For one, firms that outsource face an adaptation cost (Ulset, 1996) which are incurred when modifying contracts (e.g. cost to revise agreements and penalty clauses from contract termination). This is more so for manufacturing goods that require inputs to be fixed according to rigid specifications. Outsourcing firms also face a safeguarding cost that represents the cost of third party firms behaving opportunistically once investments in the relationship have been made (Pisano, 1990). For instance, firms that have adopted certain standards (e.g. sustainable sourcing and good working conditions) could be coerced into providing training to their third party partners. This happens because contracting firms have more to lose in terms of brand reputation should their third party partners get accused to falling short of standards (Jason Burke, 2000).

In addition to search frictions, firms that choose to specialise also bear the cost of "losing control". Jones et al., (2004) characterise these as cost of services. According to them, separate production blocks need to be coordinated through service links such as communication, insurance, management, and monitoring; all of which incurs cost to the firm. The case of defective air bags made by Takata Corp that resulted in the largest automotive recall in history for example illustrates the failure of management and monitoring third party contractors (McLain, 2017). As a result, Subaru, a car manufacturer that was affected by this is reported to have set aside Y81 billion for costs tied to the airbag recall and while other victims are experiencing compensation lags. Loss of control also refers to the inability for firms to be flexible and agile in their decisions (Chesbrough and Teece, 1996). With multiple third-party supplies in their network, specialised firms are inhibited from making marginal managerial changes due to the cost of communicating and re-coordinating these changes across their supply network. An outsourcing firm would then be incentivised to delay any managerial change until absolutely necessary; which may by then cause them their competitive advantage.

**2.3. Conceptualising Location Strategy**

In its simplest form, the decision of location involves the choice of manufacturing domestically, or manufacturing in another country – commonly known as offshoring; the relocation of manufacturing processes outside the country of a firm's headquarters (Bals et al., 2013). Firms can choose to offshore by embarking on greenfield investments (building from the ground up) or through partnerships with already established local firms. It is widely acknowledged both in the literature and in business practice that offshoring activities by MNEs are commonly destined to low-cost developing countries to obtain cost advantages (Stentoft et al., 2016; Arlbjon and Luthje, 2012).

Wu and Zhang (2014) however argues that offshoring decisions are made by evaluating the tradeoff between costs and responsiveness; in that firms which offshore may benefit from cost savings but lose out on being able to respond quickly to changes. Of these cost savings, the prevalence of low wages has notably been a significant driver for firms to offshore. With wage differentials hovering between 50 to 70 per cent lower that of the U.S. in the 1900s (Bureau of Labor Statistics; 2013), offshoring firms were able to significantly lower marginal production costs and therefore raised profits (Glass and Saggi, 2001). Corollary to this, firms that benefitted from lower production costs through offshoring also materialised gains in productivity. One channel through which this happens is by offshoring relatively inefficient production processes to overseas location (Choi and Park, 2016). Using a dataset on German manufacturing enterprises, Wagner (2010) finds that firms who engage in offshoring are more productive than their non-offshoring counterparts. Murphy and Siedschlag (2013) also find similar results using a dataset for enterprises in Ireland. What has been less clear, however is the direction of causality (i.e. whether or not there is a self-selection of more productive firms into offshoring). This has led some to argue that offshoring may also be a natural transition for firms that have performed well in their domestic markets in that they have already maximised productivity gains given domestic input factors (Foerstl et al., 2016).

Firms that benefit from cost savings however, lose out on responsiveness. Wu and Zhang (2014) describes this lost in terms of delivery lead time. With production fragmented across different countries, firms may find themselves not able to respond as swiftly as their non-offshoring counterparts. This is especially so when offshore production further relies on inputs that are sourced from another offshored location. With such lags in delivery lead times, firms may lose out significantly in terms of sales revenue. In relation to this, some have argued for the evaluation of “good candidates” for offshoring. The idea behind this is that certain tasks are more suited for offshoring and would therefore minimise the negative effect of offshoring on responsiveness. Autor et al. (2003) distinguishes between “routine” tasks and “non-routine” where the former have deductive rules while the latter require pattern recognition and inductive reasoning. In the case of an unexpected interruption in the supply chain – say, an earthquake (Lohr, 2011) –, a firm that offshores routine tasks are better able to respond than a firm that offshores non-routine ones because relevant information can be exchanged with fewer misunderstandings (Levy and Murnane, 2004). Following the same line of thought, Leamer and Storper (2001) makes a distinction between tasks that require "codifiable" information as better offshore candidates than tasks that require "tacit" information.

Pushing the idea of location further, firms that decide to offshore have to also decide which country to offshore to. Kinkel and Maloca (2009) argues that firms are driven to move manufacturing abroad to exploit proximity to customers/markets. This is especially so for firms that are seeking to gain entry in new markets. Fraja and Norman (2000) represents this by a firm's decision between offshoring or bearing the cost of exporting: the nearer a firm's offshore facility is to their market, the lower the cost of exporting (reaching their customers) given all else the same. Extending this idea further, the cost of exporting is also highly affected by institutional and regulatory changes. Domestic policies like subsidies, tax structures and labour market regulations weigh in heavily on a firm's offshore-location decision (Gray et al., 2013). In addition, firms have to also consider direct exporting cost that could be accrued because of poor transport infrastructure, inefficient ports and under-developed logistics sector in the country of choice. Amiti and Wei (2009) further suggest that learning externalities may affect a firm's decision to offshore to a specific country. Learning externalities may be generated in a country that have a vibrant network of both domestic and international suppliers in order to facilitate learning and innovation. Countries that possess these networks are also predicted to further create demand through a loop of circular causation (Krugman, 1991). Manufacturers will therefore concentrate to where the market is larger, which in turn will attract more manufacturers.

### 2.4. Identifying the Gaps

The depth in literature on firm organisation reflects the inextricability of both location and control decisions to an MNE. Despite being – at its core – two different strategies, a common thread that runs along both axis is the cost of production. In the case of control, cost of production is weighed against the cost of search frictions while in the decision for location, cost of production is weighed against the cost of communication. This current approach to firm organisation is thus heavily anchored in a firm's supply consideration. That is, firms first optimise the cost of production in their decision to organise while other factors fall into the periphery and are only considered subsequently.

In addition, the literature on location decisions have hitherto been built on the assumption that a firm's point of reference is its headquarters. This poses a few analytical drawbacks. Firstly, location decisions are implicitly assumed to be taken in relation to the location of a firm's headquarters and therefore restricts a firm's choice to base their location decisions on other strategic factors (e.g. tasks or consumer market). Secondly, this assumption also reinforces the polarisation bias in the literature where the world is grouped into two clusters: (1) low-cost developing countries and (2) high-wage developed countries. Given that the phenomenon of offshoring is inextricably linked to the notion of low-cost developing countries, the negation of it therefore links high-wage countries with the headquarters of MNEs. Using a firm's headquarters as a point of reference then implicitly appoints developed countries as headquarter locations while developing countries as production locations.

## 3. The Digital Economy and its Effect on Manufacturing MNEs

### 3.1. The Digital Economy and Industry 4.0

The digital economy; defined here as the deliberate use of digital technologies in every economic activity, (BCS, 2013; Reiners, 2016) has disrupted the economy as we know it and is thus getting much attention. Cutting through all the attention, one common thread that has gained traction is the illusiveness of the digital economy in being methodically categorised due to its pervasive nature. For example, the digital economy can be thought of in different ways: in terms of its applications (e.g. customer interface and e-commerce); characteristics (e.g. innovation and infrastructure); or even by economic actors (e.g. public sector, households and businesses). The digital economy is therefore understood to be an overarching description of the economy as a whole with various elements packaged under it. The digital economy, after all is not just part of the economy; it is the economy (Anderson and Wladawsky-Berger, 2016). To date, government strategies have therefore focused on elements of the digital economy that best suit their goals rather than having a single, blanket national digital economy strategy that is transferable across countries.

Following this line of thought, studying the manufacturing sector in the digital economy is best done by studying elements of the digital economy; in this case, the application of the digital economy through Industry 4.0 (the fourth industrial revolution). Industry 4.0 here refers to the "trend of improved automation, machine-to-machine and human-to-machine communication, artificial intelligence, continued technological improvements and digitisation in manufacturing" (Australian Government, n.d.) and is driven by four disruptions: (1) the rise in data volumes, computational power and connectivity; (2) the emergence analytics and business-intelligence capabilities; (3) new forms of human-machine interaction; and (4) improvements in transferring digital instructions to the physical world (Baur and Wee, 2015). While the applications of Industry 4.0 are wide and varies by industry, I take an approach of categorising these applications into three broad categories – automation, additive manufacturing (AM), and internet of things (IoT) – to enable a more systematic study (Frey and Osborne, 2015; IBM, 2015) in analysing how the organisation of manufacturing multinational enterprises are changing in the digital economy.

### 3.2. Automation

While automation itself is not new, recent advances in robotics, artificial intelligence and neural networks are quickly learning to do what used to be exclusively a human privilege. IBM's Watson, for example, correctly diagnosed a 60-year-old woman with a rare form of leukemia that had eluded her doctors for months. Google's DeepMind outperformed a professional human lip-reader despite learning only in a fraction of the time taken by the human. McKinsey Global Institute (MGI, 2017) estimates that on average, 60 per cent of all occupations have at least 30 per cent of activities that are automatable while BCG (2015) predicts that by 2025, around 25 per cent of tasks across all manufacturing industries globally will be performed by robots. The use of robots however does not have a uniform effect across the board. Data from the International Federation of Robotics (IFR, 2017) show that growth of robot sales in 2016 were dominated by the electrical and electronics industry (41 per cent growth) while the automotive industry had the highest capital stock of industrial robots. The dynamics of how automation affects the labour market has therefore garnered much attention.

One influential approach taken in the literature is to study the effects of automation at the skills level. That is, to identify skill requirements for various occupations and ascertain the likelihood of those skills to be replaced by automation. Using this approach, Frey and Osborne (2013) distinguish between high, medium and low risk occupations and find that most workers in transportation and logistics, office and administrative support, and labour in production occupations are at high risk of automation. This result reflects the ability of automation to outperform humans in occupations that mainly consist of tasks that follow a well-defined routine (Jaimovich and Siu, 2012). What is surprising however is that Frey and Osborne (2013) also find that a substantial share of employment in service occupations are at high risk of automation. Using a similar methodology, MGI (2017) corroborates this finding by showing that occupations in the middle of the skill and income distribution are more likely to be automated than others at the top and bottom. Additionally, the manufacturing sector is more greatly affected by automation. Manufacturing sector is found to be the second most susceptible to automation (60 per cent automation potential), after only accommodation and food services while the U.S. Bureau of Labor Statistics (BLS) projects a 550,000 loss of manufacturing jobs in the future; one in only four sectors to show negative numbers out of the 14 sectors studied (BLS, 2013). This bodes well with a dominant body of work in the literature that argues for a polarisation in labour markets where in the presence of automation, employment growth in high income cognitive jobs and low income manual occupations are accompanied by the decline in middle income routine jobs (Goos and Manning, 2007).

Intuitively, this finding can be extrapolated to include country comparisons. Building on the work of Frey and Osborne, the World Bank found that developing countries are more susceptible to automation compared to the OECD while the U.S. is the least susceptible. (World Bank, 2016; Frey and Osborne, 2013). This is not surprising, given that mid-skilled jobs represent a larger share of the labour market in developing countries. Additionally, the phenomena of job polarisation also verify the prediction that demand for high-skilled labour will grow in the event of automation. That is, automation requires the support of new high skilled jobs like data analytics, information mining and network managers in place of substituted mid-skilled jobs. As West (2015) argues, “work will be transformed but humans still will be needed to manage the digital world”. Studying employment opportunities created by new technologies, Berger and Frey (2014) find that workers in these positions are better educated, earn much higher wages, and are more likely to have a STEM degree.

The likelihood of automation however does not necessarily translate to realised automation. Many firms will be reluctant to invest in automation if the cost of employing human labour is still significantly cheaper than the cost of owning and operating a robotics system. This economic barrier however is beginning to fall. For example, BCG (2015) estimates that the cost of a robotics system that has a high degree of flexibility is around $28 per hour today. By 2020, this cost is projected to fall to less than $20 per hour; below that of an average human worker’s wage. Estimating specifically for a robotics system for spot welding, they find that developments in automation have translated into an annual 8 per cent improvement in the cost of robotics and is expected to be sustained for the foreseeable future. This rapid decline in automation costs in turn reduces manufacturing cost and at the same time, increases their cost competitiveness (Frey and Osborne, 2015). BCG (2015) further estimates that manufacturing labour costs from automation in China, Germany and U.S. will be 18 to 25 per cent lower while 33 per cent lower in South Korea. With lower labour costs, developed countries that pursue automation will further increase their relative competitiveness in that their manufacturing cost will be lower than high cost nations that lag in automation and lower than what it used to be compared to low cost manufacturing nations. It is therefore explainable why 74 per cent of total robot sales in 2016 were in China, Korea, Japan, U.S., and Germany.

Manufacturing firms that once fragmented production to take advantage of low skilled and low wage labour in developing countries have to reconsider their sourcing strategy. Firstly, advances in automation has enabled most jobs in the manufacturing sector to be automated, more so those that have been offshored to developing countries. Secondly, the declining cost of automation is closing the cost differential between manufacturing in a developed and developing country while decreasing the relative cost of manufacturing in a developed country. In addition, the process of automation will require a supply of high skilled labour which are more easily found in developed countries. Given these considerations, relocating production facilities to developed countries may be more cost effective for manufacturing firms in the digital economy.

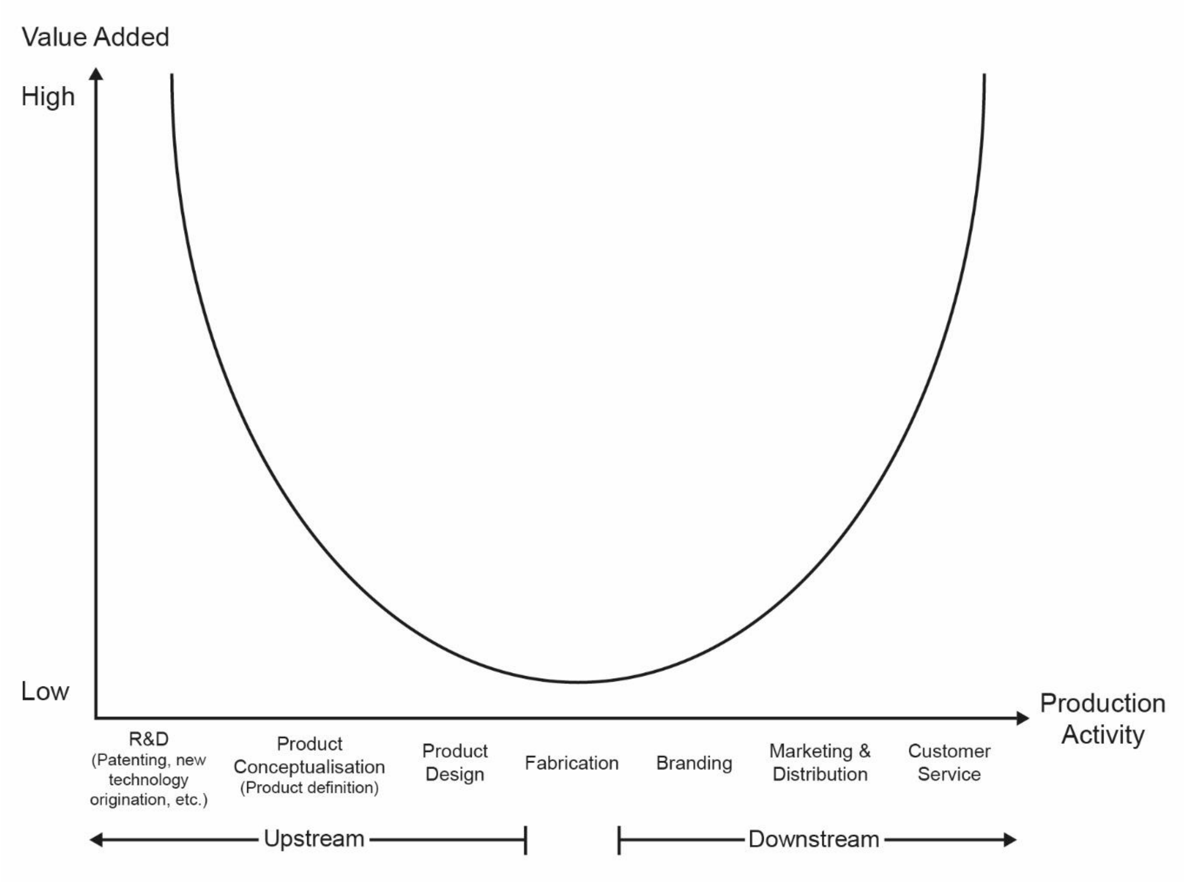
### 3.3. Additive Manufacturing

Additive Manufacturing (AM), or more commonly known as 3D printing is a manufacturing process that allows three-dimensional objects to be printed from digital data in sequential layers using different materials. Although already being around for some time, 3D printing has garnered attention in the manufacturing sector as being a technology application with the potential for disruption under the Industry 4.0 umbrella. This has been attributed to advancement in its capabilities and applications that MGI (2012) describes as "nearing an inflection point"; the point where AM can be commercially viable to be widely used in the industry, and its ability to substitute conventional manufacturing that "subtracts" excess material to make a finished product (Ferdows et al., 2015). Its ability to "add" instead of "subtract" materials forms the linchpin that differentiates AM because it allows products to be manufactured using a mixture of materials and with complex geometries. Where complex geometries are concern, General Electric for example uses AM to print components for its next generation LEAP engine; and 3D Robotics (a U.S.-based startup), for the production of its unmanned aerial vehicles (UAVs) which would otherwise have required the separate use of multiple high-tech equipment. On the other hand, the capability of AM to print a mixture of materials has seen the printing of human organs using "bioprinted tissue" (The Economist, 2017), buildings out of "foam-like" cement (Apis Cor., n.d.), and even the combination of two different alloys to make an engine part for space travel (NASA, 2017).

One of the biggest force of disruption that AM brings to the manufacturing sector perhaps is its ability to manufacture goods that are highly personalised and customisable (Frey and Osborne, 2015). Its ability to print goods right off digital platforms have allowed firms to differentiate their products in sectors that have traditionally been characterised by goods that are commonly homogenous. In healthcare manufacturing for example, Phona, a manufacturer of hearing aids, and Align, a manufacturer of dental braces, have embraced AM as the core of their manufacturing process. In the textile industry on the other hand, Continuum Fashion offers 3D printed bikinis that is customised to individual body shape and measurements (Ibid). One result of this is the shifting of value away from fabrication. Consider the 3D printing of a customised jewelry. Using traditional methods of manufacturing, fabricating a customised jewelry would require skilled craftsmen who are able to materialise a design in the form of a sketch into a mould. With 3D printing however, there is no longer a need for skilled craftsmen because a mould can easily be printed. Instead of a skilled craftsmen then, a digital media designer is now more integral in the manufacture of customised jewelry (i.materialise, 2016)**.** With the use of AM, value added is therefore more realised in the information needed for customisation and in the innovation of new products. Using the "smile curve" to illustrate this (Figure 2), value added will shift away from fabrication activities towards both downstream (marketing, distribution and customer service) and upstream (R&D, product conceptualisation and product design) activities; the right and left of the curve. A premium is therefore placed on R&D and customer service in light of the innovations in AM. This shift in value is more commonly known as servitisation; the phenomenon where manufacturing firms create value by shifting from selling products to selling of services instead (Ren and Gregory, 2007).

Baines et al. (2009) argues that a prominent feature of servitisation is its strong customer centricity, in that goods sold are no longer just on a transactional basis but also on a relational basis. Customers are therefore provided not just with products but with broader more tailored "solutions" to fit the customer's use of the product instead. Rolls Royce for example has substituted the sale of aerospace engines for sale of hours of flight while GE has moved from selling medical diagnostic equipment to providing diagnostics services themselves. The role of customer service here is accentuated for its value in obtaining information and ensuring brand loyalty (Howells, 2000). Particularly, this has been more commonly found in manufacturing sectors with high-installed product bases and long life-cycle like aerospace, locomotive and automotive where the ratios of installed-base-to-new units for automobiles are 13 to 1, 15 to 1 for civil aircraft, and 22 to 1 for locomotives (Wise and Baumgartner, 1999).

**Figure 2: Smile Curve***




Source: Author

* First proposed by Stan Shih, the founder of Acer Inc, the smile curve is a graphical representation of value added for each stage of production. It shows that for every type of production activity, the fabrication stage is the one that adds the least value, thus forming a "smile" (Shin et al., 2012).

This view is shared by Ferdows et al. (2015) who argues that AM will be more likely used for products that are complex in design, advanced in technology and produced in low volumes. In addition, Gebauer et al. (2006) proposes that customer service and marketing begets more sales of products. Through customer service and marketing, manufacturing firms are better able to collect personalised information of their clients and further customise their products to suit their needs, resulting in more sales. An example of this is Coca Cola's "Share a Coke" campaign in Australia that saw the swapping out of Coke branding on bottles and cans with most popular monikers. That summer, Coca Cola sold more than 250 million customised bottles and cans in a nation of just under 23 million people (Coca Cola, 2014).

Moving left of the smile curve towards upstream activities, AM has increased the value of R&D by enabling design and manufacturing to co-locate (Ferdows et al., 2015). Not only does this increase the speed to which firms can develop prototypes, it also more importantly reduces the cost of prototyping (Deloitte, n.d.). This is because AM is an iterative process, since items of different specification and build can be produced without incurring the mould and tooling cost that would otherwise have to be borne in traditional manufacturing. In a way that is reinforcing, the increased value add of customer service and marketing is only to the extent that firms are able to innovate and develop new products that fit their client's needs. GE Healthcare for example, introduced the V-Scan - a handheld ultrasound device - that was specifically produced to address the challenges of meeting healthcare needs in rural China. Equally then, the shift in value away from fabrication activities have also accentuated the value placed on R&D. This has seen the emergence of "factoryless goods producers" (FGP) - firms that perform all the functions typically associated with manufacturing except for the fabrication stage as in the smile curve (Doherty, 2013). The best known FGP is technology manufacturer Apple Inc (Bernard and Fort, 2015). Despite being known for its manufactured products (iPhones, Macbooks and iPads), Apple does none of the production and fabrication but outsources them to a network of first tier suppliers like Foxconn. Apple instead fully specialises in R&D and other upstream activities (design and product development).

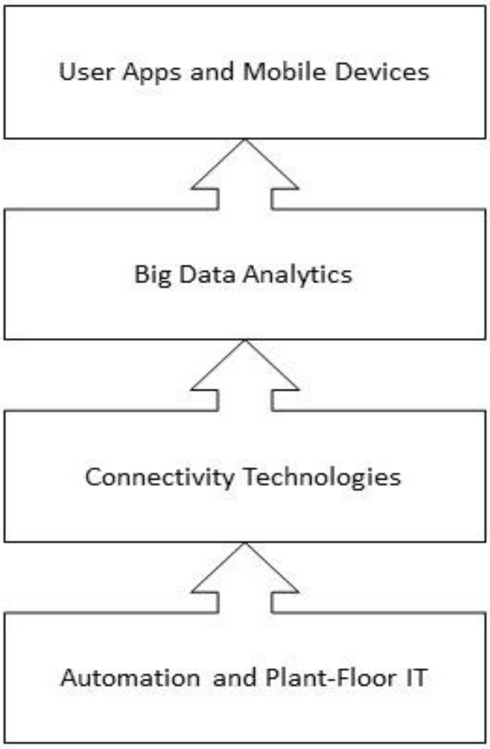
The growth in both its development and user base of AM has slowly and steadily carve value away from the fabrication stage of manufacturing activity and indirectly accentuate the value placed on customisation. With the advent of customisation, both information and innovation have therefore become commoditised in the digital economy, causing MNEs to shift towards servitisation. More specifically, the commoditisation of information is linked to the shift towards downstream activities – with the highest value being attributed to customer service activities – while the commoditisation of innovation is linked to the shift towards upstream activities – with the highest value being attributed to R&D activitites.

### 3.4. Internet of things (IoT)

The Internet of Things (IoT) is defined as "a suite of technologies and applications that equip devices and locations to generate all kinds of information" (Kejriwal and

Mahajan, n.d.). In other words, one could think about it as devices and locations being able to communicate. While the applications of IoT varies according to industry, the manufacturing sector has contributed the most towards global IoT spending – forecasted at 24 per cent or $102.5 billion in 2016 - (International Data Corporation (IDC), 2017) by way of a phenomenon called smart manufacturing. Closely related to the concept of Industry 4.0, smart manufacturing is the deployment of “cyber-physical” systems throughout the production process that allows a digital mapping of possibly the entire supply chain. O’Marah (2015) explains that this in part enabled by four essential stages, or what he calls “the essential IoT technology stack” (Figure 3). Automation and plant-floor IT relates to the use of sensors onto devices to generate information; connectivity technologies relate to the transfer and aggregation of those information; big data analytics relates to the extraction of insights from that information; while user apps relate to the application of those solutions by end-users. To use an analogy from the human body; if various digital technology applications in manufacturing are like the organs, IoT is akin to blood vessels that allow these organs to be connected.

**Figure 3: Essential IoT Technology Stack**




Source: O’Marah (2015)

One core element of IoT is its ability to create cyberphysical systems. That is, IoT allows the combination of both the physical and cyber sphere to the extent where the flow of products is inextricably linked to their flow of information. Cisco's virtual manufacturing execution systems platform (VMES) for example boasts the ability to provide real-time visibility of production operations remotely (Manenti, 2015). This element of IoT is transformative for two reasons: (1) it allows the continuous flow of real time information of the whole supply chain, and (2) it allows this information to be accessed remotely. In its application of real time information, IoT has revolutionised manufacturing operations management (MOM) by accruing considerable gains in process and resource optimisation (Chui et al., 2010). Indeed, manufacturing operations represent over 57 per cent of all IoT manufacturing investment (IDC, 2017). In the event of a disruption to the production process, manufacturers can immediately draw up new optimisation schedules for all the various factors that are involved, taking into account not only processes on the factory floor but also processes along the supply chain - supplier inputs, procurement, warehousing, logistics, and client demand. In essence, manufacturers are able to make real-time adjustments to bottlenecks as they happen, or even before they happen on the production floor. Harley-Davidson paint shop, for example, has the ability to automatically adjust ventilation fan speeds for varying conditions in order to give an exact and consistent coat.

On the other hand, the ability to access all this information remotely ultimately reduces the cost of control. With remote access to continuous real time information of the production process at their fingertips through a tablet, manufacturers can monitor their processes as if they were at multiple places instantaneously. In addition, developments in open source platforms like GE's Predix allows this same level of control over multiple organisations that are able to synchronise their applications using the same platform (General Electric, n.d.). If understood in terms of firm organisation then, IoT reduces the cost of control by both lowering the cost of control over distance and cost of control over outsourced partners or in vertically integrated fragmented production blocks.

What is also evident about IoT, is that manufacturing processes are becoming increasingly quantifiable and accessible. On the factory floor, each unit of production can be identified at every stage of the production process at any time. Instead of the traditional batch-level visibility, IoT enables real time, unit-level visibility (O'Marah, 2015). Fujitsu's digital factory for example is equipped with a "logistics train" – a self-driving electric vehicle – that ensures production units get the components they need only when they need it. Their factory floor is also equipped with displays that show workers which components belong to each other. Similarly, on the downstream end, firms are able to collect highly personalised data on their customers (Chui et al., 2010) and thus gain a deeper understanding of customer needs and contexts in which their products will be used. These developments have seen the emergence of the outcome economy; the advent where manufacturers shift from competing through selling products to competing on delivering measurable results according to customer's requirements (World Economic Forum, 2015). Instead of just providing high-quality products at competitive prices, firms are increasingly focused on solving the "why behind the buy". Rolls-Royce for example sells product reliability - the why behind the buy of a jet engine. Their TotalCare offering thus provides predictive maintenance and repair services for its jet engines, inadvertently assuming the entire risk of time-on-wing and shop visit cost. At the center of the outcome economy; the customer. Firms are therefore beginning to shift their strategic decision to account for demand factors like customer service and experience on top of more traditional supply factors like cost and scalability (Schatsky and Mahidhar, 2013). Customers have therefore command a premium with the use of IoT. Combining this customer centricity and the lowering of control cost, the application of IoT would move firms to locate and operate closer to their customer.

## 4. Discussion

### 4.1. Manufacturing in the Digital Economy

The one recurring theme in the analysis so far is the paradigm shift towards customers; that is, manufacturing in the digital economy is at its core, customer centric. While customers did play a role in influencing MNEs organisation strategy, it was only considered at the periphery after cost of production factors were taken into account. This has been the case because MNEs face three considerable barriers in order to unlock customer value in their revenue considerations: (1) Information, (2) Innovation, and (3) Duration. The first involves obtaining sufficient information on what customers want; the second involves the possession of technology in order to manufacture what is wanted; while the third involves the ability to deliver products and attend to customers in time. In the absence of current digital technologies, information on customers are sparse and costly, while available technology does not allow for both mass customisation of manufactured products and rapid innovation of new products. Likewise, a disjointed supply chain preserves the third barrier. This however is no longer the case. Information in the digital economy is now gathered at the individual level, and most times, at hardly any cost. Developments in technology has also enabled MNEs to design manufacturing processes that prioritises innovation and are capable to handle mass customisation accurately. On the other hand, the ability of MNEs to track production in real-time across the supply chain allows them to significantly reduce the duration from fabrication to product delivery.

Of the three barriers, however, Duration is perhaps the only barrier that is not sufficiently addressed by digital technologies and therefore remain as a significant barrier that MNEs have to address. Notwithstanding the shortening of product cycle time, effects of digital technologies on the actual physical journey needed to be made are still limited. For manufactured goods, average travel time for a container vessel from China to the U.S. for example is two weeks to the West Coast and a month to the East Coast, and another six days once goods reach the U.S. – this is excluding the time needed for documentation, customs clearance, handling and inland shipping (Department of Commerce, n.d.). Similarly, flight time from London to Singapore average between 13 to 20 hours – excluding time needed for security clearance and idle waiting. This will drive MNEs to operate closer to their customers – in some cases even if it means taking on higher cost (Neely, 2008). To operate in close proximity to their customers, MNEs will have to strategically consider shifting relevant stages of production or even duplicating some functions across their growth markets (MGI, 2012).

The advent of digital technologies has also allowed firms to relax their cost considerations. With automation closing the gap of manufacturing cost between developing and developed countries, MNEs are granted the option of spreading their manufacturing footprint more evenly across their major markets. That is, it is no longer always necessary for MNEs to offshore their production activities to developing countries in order to minimise cost. This allows considerable room for MNEs to strategically duplicate their operations without being as constrained by cost considerations. Moreover, digital technologies also reduce the cost of both control and distance. What this means is that MNEs can more easily move between outsource and insource; offshore and backshore. Manufacturing in the digital economy therefore both allow and nudges MNEs to not just optimise on cost (supply factors) but increasingly also optimise on revenue (demand factors).

### 4.2. A Third Dimension: Regionalisation

The traditional framework of firm organisation that has its point of reference in a home-based headquarter (firm's country of origin) is ill equipped to account for this shift towards customers. In the traditional framework, MNEs can rely on a strong home-based headquarters to make offshoring and outsourcing decisions because demand is more or less centralised to a few areas. The idea is to begin from a position of full integration of the company in their domestic market and only offshore/outsource selected functions if there are cost savings to be made or as need arises. MNEs however are finding that global growth in demand is being more and more realised in developing countries that are scattered across the globe. Moreover, growth in their domestic markets (especially those in developed economies) are reaching a saturation point. In an analysis of U.S. multinationals, MGI (2012) finds that sales in their home market grew at 6 per cent annually in the past decade while those in emerging markets grew at twice that rate. With key growth markets spreading across the globe, MNEs likewise find themselves having to significantly expand their footprint to capture new growth markets.

Being spread out across the globe in turn poses fundamental challenges to MNEs that want to shift their focus towards customers in the digital economy. For one, significant variation in customer preferences across a wide range of developing markets dictate that MNEs customise their products accordingly. Frito-Lay for example, created Kurkure, a cross between traditional Indian-style street food and Western-style potato chips that is specially catered for the Indian market. Customising products according to market preferences in turn require production processes to be agile because the manufacturing process and requirements may be different from one product to another. Toyota for example, manufacture engines in Asia for most major markets

(Latin America, Africa and Asia) except for the U.S. where preference favour larger vehicles. Likewise, in the downstream, MNEs have to tailor their strategies according to local nuances. Consumers in China, for example, has been acknowledged to respond better to marketing through digital media compared to other markets globally.

With this, I propose that MNEs have to develop regional strategies in order to compete in the digital economy. That is, MNEs should be able to segment their major markets and respond accordingly to each one with minimal reorganisation or interruption to other markets. This is in contrast to traditional global strategies where MNEs are heavily anchored in their country of origin and have one common organisation strategy across their markets and functions. The choice of regional strategy however is best thought of as a degree of regionalising instead of a binary choice of either regional or global. The simplest regional strategy for example is to set up a regional office or hub in selected target markets. These hubs then provide a variety of shared resources and services and act as a channel of communication to a centralised headquarter. A greater degree of regionalisation on the other hand could see an MNE extend managerial decision making and even operating activities to these regional hubs. A full on regional strategy then would see a close duplicate of a headquarter office where certain regions are mandated to supply their own products perform particular roles for the whole organisation.

While the third dimension of regionalisation allow MNEs to account for the shift towards customer centricity, the two dimensions of control and location still holds significant value. MNEs will continue to make complex cost optimising decisions that involves a dynamic mix of location and control strategies. What has changed however is that MNEs can no longer, by default operate from a centralised home-based headquarter. Even if they do, it has to be a deliberate choice of strategy that best optimises both cost and customer centricity. Lastly, as MNEs shift towards regional strategies, they will increasingly need to duplicate strategic functional activities and necessarily scale down wholesale operations as they spread out investments more widely across their consumer markets.

## Conclusion

This paper started off by identifying a phenomenon that is seemingly contradicting. While there seem to be a general traction towards backshoring, MNEs are also reportedly ramping up offshore activity through investments and localisation. I find, however, that rather than being a phenomenon of contrariety, it is instead an organic development of firm organisation strategies as they compete in the digital economy. The application of digital technologies in manufacturing under the Industry 4.0 umbrella unlocks the value that a customer can bring to firms. Now, MNEs not only optimise operations on cost considerations, but also on customer centricity. This has led to a necessity for MNEs to operate close to their consumers and therefore adopt a more regional approach to firm organisation. As a result of this transition, MNEs are strategically re-organising their operations by a mix of selective consolidation (the backshoring bit) and calculated expansion (the offshoring bit).

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