Manufacturing: facts, trends and implications

En este trabajo se analiza por qué la fabricación, y especialmente la fabricación avanzada, constituyen la base de la prosperidad nacional. También se discute la evolución de las tecnologías esenciales que afectarán tanto a las actividades de servicios y manufacturas como su impacto en las empresas y en la sociedad en términos de mejoras en la productividad, habilidades y puestos de trabajo, formas de organización y dispersión y concentración global de las actividades de creación de valor. Se concluye que, en los países con una alta complejidad económica, los desarrollos tecnológicos producidos tendrán un efecto positivo en la prosperidad nacional, siempre y cuando se cree y mantenga una política adecuada, especialmente en lo que se refiere al desarrollo de un contingente de mano de obra altamente cualificada y suficientemente grande. Para los países con una baja complejidad económica la perspectiva es más difícil y a menos que se persiga con éxito una política para aumentar rápidamente la complejidad económica, es probable que se reduzca la prosperidad nacional afectando más negativamente con altos niveles de desempleo a las personas con una falta de adecuación de sus habilidades en un contexto de baja y descendente demanda de trabajo restante.

Lan honetan, fabrikazioa –eta bereziki, fabrikazio aurreratua– oparotasun nazionalaren oinarria izatearen arrazoia aztertzen da. Halaber, bai zerbitzu- eta manufaktura-jardueretan bai enpresetan eta gizartean eragina izango duten funtsezko teknologien bilakaera eztabaidatuko da; produktibitatea, gaitasunak, lanpostuak, antolatzeko moduak eta balioa sortzeko jardueren kontzentrazio eta sakabanaketa globala hobetzea eragingo duten teknologiena, hain zuzen. Ondorioztatzen denez, konplexutasun ekonomiko handiko herrialdeetan, garapen teknologikoek oparotasun nazionalean eragin positiboa izango dute, betiere politika egokia ezartzen bada eta horri eusten bazaio; bereziki, goi-mailako kualifikazioa duen behar adinako eskulana garatzeari dagokionez. Konplexutasun ekonomiko txikiko herrialdeen kasuan, ikuspegia zailagoa da, eta, konplexutasun ekonomikoa azkar areagotzeko politika arrakastatsu bat ezarri ezean, baliteke oparotasun nazionala murriztea eta horrek beren gaitasunak egokitu ez dituzten pertsonengan, langabezia-tasa handia dutenengan, eragin negatiboagoa izatea beherantz doan lan-eskaera txikiko testuinguruan.

This paper articulates why manufacturing, and specifically advanced manufacturing, forms the basis for national prosperity. It also discusses the future developments of key technologies that will impact both manufacturing and service activities and their impact on both firms and society in terms of productivity improvements, skills and jobs, organizational forms and global dispersion and concentration of value creating activities. It concludes that in countries with a high economic complexity the technology-enabled developments will have a positive effect on national prosperity as long as a sensible and predictable policy environment is created and maintained, especially in relation to the development of a sufficiently large and relevantly skilled labour pool. For countries with a low economic complexity, it concludes that the outlook is more challenging and unless a policy to rapidly increase the economic complexity is successfully pursued the overarching outcome is likely to be one of reduced national prosperity further negatively impacted by high levels of unemployment of individuals with a skill mismatch as compared to the low and reducing remaining demand for labour.

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1. THE LINK BETWEEN ECONOMIC COMPLEXITY AND NATIONAL PROSPERITY[1]

Future national prosperity is a function of present and future economic complexity: the higher the economic complexity, the higher the potential to create national prosperity. In order for high economic complexity to translate into the creation of high national prosperity, the following conditions should be met (Hausmann *et al.*, 2011; Roos, 2012a; Roos, 2014a):

1. A broad portfolio of products and services with a high level of export.
2. A high level of uniqueness across all these products and services i.e. not many other countries (preferably none) are able to produce and export these products and services.
3. The complexity of these products and services should be high in their own right i.e. they should require many different inputs, and a very high share of these inputs should be provided, in terms of value added, by suppliers located in the same country who, due to their unique offerings or their extremely high value for money offerings, form a better solution than sourcing from outside the country.

[1] To contextualise the issues raised in this paper, examples are used. As far as data availability allows it, these examples refer to Spain.

A country's economic complexity is a function of its nationally distributed diversity of useful technical expertise and specialized capital equipment, the value of which cannot fully be realized without the other necessary factors of co-specialized relationships, processes, systems, information and knowledge (of which a large amount is tacit and therefore difficult to acquire).

This diversity contributes to higher efficiency, effectiveness and increased productivity of both labour and capital, and is reflected in the economic structure that emerges for holding and combining all these resources (Roos, 2014a). It is the continuous development of this structure that allows for increased absorption, diffusion and utilization of all these resources. In turn, this leads to increased specialization and increased ability to absorb, distribute and deploy the result of this increased specialization in a virtuous circle (Roos, 2014a). This continuous and positive process is necessary and must be guided forward in order for the nation to maintain and increase its absolute and relative economic complexity and hence its ability to generate national prosperity (Roos, 2014a). This is clearly seen in the competitive advantages countries with an effective and continuous process of this type enjoy, with the subsequent prosperity generated from competitive advantages that differ from normal price-based competition. Examples of such countries are Germany, Japan, Switzerland and Sweden.

The potential for high economic complexity is grounded in a society's ability to accumulate and effectively exploit the wealth of productive knowledge that is widely distributed in small units among its individuals and organizations. [2] This reasoning is an extension of Adam Smith's idea that economic progress is the result of an increasingly specialized division of labour (Smith, 1776; Young, 1928; Pisano & Shih, 2009) grounded in a cumulative body of knowledge which we, as individuals, would not have the capacity or ability to hold or master. If necessary expertise is lacking it is not possible to develop and produce more advanced offerings, which provides the argument for ensuring both a deep and broad level of expertise within a country. Development and production of advanced offerings takes place in an environment of mutual dependence that requires cooperation between different actors. This is why there is a strong correlation between the level of cooperation in a national innovation system and the level of growth in economic complexity and hence, prosperity. The more these interdependencies involve actors who are, or may be, localized within a country or region, the greater the potential for that country or region to absorb the benefits generated from a locally or nationally-anchored complex value chain (Roos, 2014a).

[2] From this it can be seen that anything that reduces the transaction cost of reaching out and connecting to agents in the system would drive an increase in both productivity and economic complexity. This is why the initial benefits of ICT originated in the "C" (not the "I"), and why the next level of benefits sits in the additional reduction in coordination costs for managing complex networks. This will add the "I" to the "C", and as a side effect, is likely to reduce the total transaction and coordination costs of external structures to below the cost of organizational internal structures and hence generate completely new organizational forms.

Table 1. **SPAIN'S RELATIVE POSITION IN TERMS OF ECONOMIC COMPLEXITY COMPARED TO OTHER COUNTRIES OVER TIME**

Ranking	1964	1968	1978	1988	1998	2008	2012
No. 1	Switzerland	Japan	Japan	Japan	Japan	Japan	Japan
No. 2	Sweden	Switzerland	Sweden	Sweden	Switzerland	Switzerland	Switzerland
No. 3	Austria	Sweden	Switzerland	Switzerland	Sweden	Sweden	Sweden
No. 4	United Kingdom	Austria	Austria	United Kingdom	United Kingdom	Austria	Korea, Rep.
No. 5	Japan	United Kingdom	United Kingdom	Austria	Finland	Finland	Finland
No. 6	France	United States	United States	France	United States	Singapore	United Kingdom
No. 7	United States	Italy	France	Finland	Austria	United Kingdom	Austria
No. 8	Italy	France	Italy	Italy	France	France	Singapore
No. 9	Belgium	Finland	Belgium	Denmark	Belgium	Korea, Rep.	United States
No. 10	Norway	Norway	Finland	United States	Ireland	United States	France
No. 11	Denmark	Belgium	Denmark	Belgium	Italy	Hungary	Hungary
No. 12	Finland	Denmark	Norway	Ireland	Denmark	Italy	Israel
No. 13	The Netherlands	The Netherlands	Ireland	The Netherlands	The Netherlands	Denmark	Ireland
No. 14	Hong Kong SAR China	Hong Kong SAR China	The Netherlands	Norway	Israel	Ireland	Denmark
No. 15	Poland	Hungary	Canada	**Spain**	Singapore	Israel	Italy
No. 16	Ireland	Panama	**Spain**		**Spain**	Mexico	The Netherlands
No. 17	Hungary	Ireland				Belgium	Poland
No. 18	Portugal	Poland				The Netherlands	Belgium
No. 19	Korea, Rep.	Portugal				Poland	China
No. 20	Israel	Canada				Hong Kong SAR China	Malaysia
No. 21	Panama	Korea, Rep.				Romania	Mexico
No. 22	Canada	**Spain**				**Spain**	Hong Kong SAR China
No. 23	Bulgaria						**Spain**
No. 24	**Spain**						

Source: (http://atlas.media.mit.edu/rankings/country/).

Table 1 illustrates Spain's relative position in terms of economic complexity compared to other countries over time. As can be seen, Spain's relative position has had a ∩-shaped development. A peak around 1988 was preceded by a 24-year long 10-position rise and followed by a 24-year long 9-position decline. Take note that the real situation in terms of ranking is in fact worse than the table indicates, since countries that have emerged over time [like the Baltic countries] or changed [like Germany] are excluded from the comparison. Given this trend it will be difficult for Spain to maintain or increase its absolute or relative prosperity.

When analyzing more in detail what drives the economic complexity of a country, it turns out that services generally have a lower economic complexity than the products they are related to. It also shows that the production of the equipment used to manufacture goods generally has higher economic complexity than the production of the goods themselves. Furthermore, the production of multifarious systems generally leads to a higher economic complexity than the production of the components or subsystems that make up the overarching system. As an example, the production of a submarine leads to a +/- 2.5-3 times higher economic complexity than the production of a frigate or main battle tank and to an approximate 3-4 times higher complexity than the production of an armoured modular vehicle. This difference in complexity is not linearly proportional to the number of components used as there are approximately 350,000 components in a submarine compared to around 23,000 in an armoured modular vehicle. From this it is clear that the integration of complex systems inside a country using the highest possible domestic share of the supply chain (given that each supplier offers the globally best trade-off between performance and price) leads to an increasing national economic complexity, resulting in substantially higher economic benefits. This has been illustrated by Eliasson (2010) in a study where he concluded that if the spill-over value is divided by the development investment, a multiplier of at least 2.6 could be applied to the highly complex Swedish Griffin Fighter project. These identified spill-over effects that stem from the core technologies applied, related technologies, general engineering technologies and general industrial technologies, all contribute to the industrial commons, i.e. the economic complexity and development of localized industrial competence provoking further agglomeration benefits (Roos, 2014b).

These spill-over effects vary from very low to very high as a consequence of the economic complexity of the region in which the system integration and production takes place, as can be deduced from the review by Birkler *et al.* (2015).

As further examples, the production of equipment for food e.g. separators, control systems, etc. has approximately twice the economic complexity of the food produced using this equipment. Similarly, production of machinery for paper and pulp production has a 50% higher complexity than the production of paper or pulp. Finally, services in the form of financial services have a 30% higher economic complexity than the production of transport services (Hausmann & Hidalgo, 2013).

This means that to create the basis for sustainable prosperity, a country must have industrial activities involving systems, products and services with high economic complexity. From the above it also follows that manufacturing, and especially system suppliers and system integrators, is the foundation for achieving high economic complexity and high prosperity. This can be illustrated by means of the Spanish case if one looks at the ranking of Gross Regional Product (GRP) per Capita for the Spanish Autonomous Communities (Table 2), which is topped by communities with a sophisticated industrial base. In the case of Madrid, which is a headquarters and public sector-based economy, the GRP per capita would not be sustainable without the industrial base located elsewhere that procures, exports, or imports the inputs required by the products and services provided on behalf of the firms that locate their headquarters in Madrid and the tax revenue generated from this industrial base located elsewhere.

Table 2. **GROSS REGIONAL PRODUCT PER CAPITA - SELECTED SPANISH AUTONOMOUS COMMUNITIES**

Autonomous community	Euro (2012)	Exceeding the Spanish national average by
Basque Country	30,829	+35,4%
Community of Madrid	29,385	+29,0%
Navarre	29,071	+27,7%
Catalonia	27,248	+19,7%
Aragon	25,540	+12,2%

Source: INE, 2013.

2. THE ARGUMENT FOR MANUFACTURING

Given that the physical production of multifarious systems has the highest complexity of all types of production, it is clear that maintaining a sophisticated manufacturing industry is critical for national prosperity. Approaching the issue of national prosperity from another angle, the arguments for such a sophisticated (frequently labelled: advanced) manufacturing base can be broken down into five key arguments that both underpin and complement the argument for economic complexity.

2.1. Manufacturing is the biggest spender of applied research and innovation with spill-over effects into the rest of the economy

The absolute majority of R&D spending in the world is geared towards manufacturing. This manufacturing R&D is not evenly spread and it is clear that countries with a high level of R&D have an advantage over those with lower R&D.

According to the National Science Foundation's 2008 Business R&D and Innovation Survey of US businesses, 22% of manufacturing companies (against only 8% of non-manufacturing companies) introduced a new or significantly improved good or service between 2006 and 2008. The same percentages apply to manufacturing and non-manufacturing companies' use of new production, distribution, and support activity processes during that time. All manufacturing industries, including such reputedly "low technology" ones as wood products, furniture, and textiles, exceeded the non-manufacturing averages for both product and process introductions. By comparison, only a few science and information technology-intensive non-manufacturing industries (software, telecommunications / Internet service / Web search / data processing, computer systems design & related services, and scientific R&D services) equalled or exceeded the manufacturing averages (Boroush, 2010). And there are no indications that this pattern is fundamentally different in any other developed nation.

In the UK, manufacturing businesses are more likely to engage in R&D with 41% of manufacturing firms with ten or more employees allocating resources to R&D in 2010 compared with an average of 23% of businesses in other sectors (Foresight, 2013).

In the US, manufacturing firms spend close to 70% of all business R&D (National Science Foundation, 2011) and they employ almost 60% of all domestic scientists and engineers (Wolfe, 2009).

Between 2000 and 2011, 72%-79% of total UK business R&D expenditure was associated with manufacturing (Office for National Statistics, 2010). In 2010, 26% of UK manufacturing businesses with ten or more employees carried out process innovation, whereas this was only the case for less than 14% for non-manufacturers. Meanwhile, 44% of UK manufacturing businesses with ten or more employees undertook product innovation versus less than 26% of the non-manufacturers (Department for Business, Innovation and Skills, 2012).

One of the key areas of research and innovation for securing tomorrow's successful manufacturing industries are the so-called "Key Enabling Technologies"[3] (KET). Mastering of KETs needs to be a strategic priority to ensure the competitiveness of domestic industry and thereby its ability to produce future innovative offerings that can successfully compete on the global market. KETs have specific charac-

[3] In this paper key enabling technologies include information and communication technologies including big data, big data analytics, artificial intelligence and internet-of-things; advanced production technologies including additive manufacturing and robotics; industrial biotechnology including microbial consortia engineering and synthetic biology; photonics; advanced materials including lightweight and ultra-strong materials, materials that can withstand aggressive environments, surface coatings, electronic and photonic materials, smart multifunctional materials and structures, biomaterial; nanotechnology; micro and nano-electronics. It is important to note that this list will change as science and technology continues to advance, in other words KET is a dynamic concept.

teristics that separate them from other "enabling technologies": they are embedded in innovative products across many sectors, they underpin strategic value chains, and they form industry sectors in their own right.

From the above it is clear that economies with a low share of manufacturing in the economy will have a relatively poor R&D performance (no matter how large and successful their university and service sectors may be) and will hence suffer from the lack of associated spill-over effects. If the economy also has a low relative volume and performance of research in KETs, the future performance and size of any existing manufacturing sector is likely to decline with the associated negative effects on economic complexity and national prosperity as a consequence.

In addition to the above, manufacturing needs be innovative to respond to the emerging issues and global trends that matter to customers and consumers in order to stay relevant (i.e. be able to create value), and to lay the foundations for appropriating the value created.[4]

Harvard professors Pisano and Shih (2009) have summed up the connection between a nation's loss of manufacturing and its loss of innovative capabilities: "*In reality, there are relatively few high-tech industries where the manufacturing process is not a factor in developing new —especially radically new— products. That's because in most of these industries, product and process innovation are intertwined. So the decline of manufacturing in a region sets off a chain reaction. Once manufacturing is outsourced, process-engineering expertise can't be maintained, since it depends on daily interactions with manufacturing. Without process-engineering capabilities, companies find it increasingly difficult to conduct advanced research on next-generation process technologies. Without the ability to develop such new processes, they find they can no longer develop new products. In the long term, then, an economy that lacks an infrastructure for advanced process engineering and manufacturing will lose its ability to innovate.*"

2.2. **Manufacturing is the key driver of productivity improvement with spill-over effects for the rest of the economy**

In addition to, and closely linked with, economic complexity it is ultimately productivity improvements that matter for any country since these improvements can be converted into social good, e.g. higher living standards. Only a country with consistently higher productivity improvements than its competitors will be able to generate and maintain the high living standards expected and required by its population. Higher productivity improvements follow from higher economic complexity since the requirements to produce something that nobody else can produce will require solving problems that are not previously solved and many of these solutions will have productivity-enhancing effects. The creation and deployment of producti-

[4] For more on this see e.g. Roos, 2011a; 2011b, 2012c; 2014c.

vity-enhancing innovations follow from the generation of new knowledge, enabling both the creation and deployment of these innovations.

This creation and deployment process is impacted by the cost and availability of both internal and external knowledge (Antonelli, 2013). This means that the lower the cost of accessing new knowledge, the higher the connectivity of the firm as relates to potential contributors of knowledge. In turn, the higher the frequency of unexpected events the firm is exposed to, the more likely it is that the firm will be able to create and implement an innovation that results in improved total factor productivity. Firms at the global productivity frontier are on average 4-5 times more productive than non-frontier firms in terms of multi-factor productivity, while this difference is more than 10 times with respect to labour productivity which includes capital intensity (McGowan *et al.*, 2015). Hence, the higher the economic complexity of the region, domain and economy in which the firm operates and is located, the higher its productivity improvement.

Enhancing manufacturing growth requires increasing productivity and inventing better manufacturing technologies that become embodied in capital equipment innovations and production system innovations. Today, these innovation activities are increasingly complemented with investing in understanding what general purpose technologies (including KETs) can be used for (whether or not the prospective applications are profitable) and how they can be pursued most effectively (Dosi *et al.*, 2009; Gambardella & McGahan, 2010; Koren, 2010; Regalado, 2012; Conti *et al.*, 2013).

All studies show that the productivity improvements of manufacturing outperform those of other sectors in the economy by a wide margin over time.[5] Examples of such productivity-improving activities are, for instance, those taking place in Germany under the umbrella of Industry 4.0, a component of the German industry policy focussing on the cyber-physical interface. Through the deployment and development of technologies like Simulation, Additive Manufacturing, Autonomous Robotics, Augmented Reality, Internet of Things, Vertical and Horizontal System Integration, Big Data Analytics, Cloud-Based Solutions and Cyber Security, manufacturing can be transformed into an integrated system of production cells embodying new man-machine interactions resulting in optimized production flow, a minimized resource footprint, higher levels of efficiencies and a changed relationship between customers, producers and suppliers. The potential productivity gains over the coming 10 years are identified as being in the range of 5-8% or €90-150bn (Rüßmann *et al.*, 2015). As a consequence of both the development of new technology, the products and services that embody these technologies, and the increased demand that will follow for both the technologies, machines and the products produced on the basis of the former, it is forecast that over the next 10 years there will be an increased revenue stream equal to around 1% of Germany's GDP annually. In

[5] See e.g. the data at http://www.euklems.net/

addition, since the demand growth will outstrip the associated productivity growth for the German industry, it is expected that there will be an associated employment growth of around 6% in total for the coming 10 years (Rüßmann *et al.*, 2015). Achieving these benefits will require German manufacturing firms to annually invest between 1% and 1.5% of their turnover in Industry 4.0 associated technologies, tools and services (Rüßmann *et al.*, 2015).

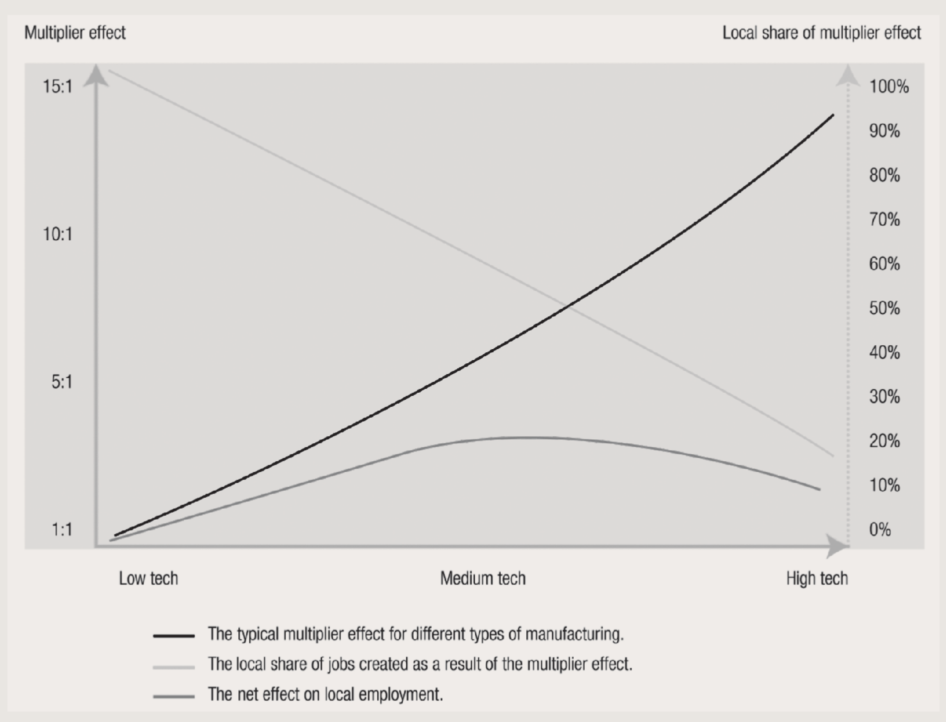
The employment multiplier perspective varies across industry sectors and whilst nations must pursue advanced manufacturing from a strategic prosperity point of view, they may –from a regional employment point of view– be better served tactically by pursuing medium-tech manufacturing that creates geographically concentrated clusters of similar companies and suppliers. This may explain the conflict between the objectives of regional and national governments on the speed of structural change and industry upgrading. The reason for not wanting to pursue low-tech manufacturing is that it is easily superseded by medium and high-tech manufacturing in terms of direct economic contribution to a given region. This is due to the higher skills (and associated higher wages paid by higher technology manufacturing) and the increasingly long supply chains that follow from increasingly high-tech manufacturing, which generates a higher multiplier effect for the host region. This development is increasingly positive for a region as it migrates away from low-tech manufacturing towards medium-tech manufacturing. The pattern changes, however, if a region should continue to evolve from medium-tech manufacturing to high-tech manufacturing. As products become more sophisticated, requiring complex subsystems and unique component inputs that can only be provided by highly specialized suppliers, there will be a need to access advanced global supply networks. As a consequence, the close proximity between the supplier's production activities and manufacturing or final assembly facility location often becomes less important. Although this is a positive development from a national perspective (as it increases the economic complexity and the potential for future national prosperity), it may have a negative employment impact on the region where this development takes place (an impact that can reduce over time as the industry matures and as suppliers emerge locally and are able to substitute global suppliers). Figure 1 shows the resulting relationship between the level of complexity in manufacturing and the potential local economic benefits. As can be seen, the figure suggests there is an optimum level of advanced manufacturing for a region, after which the benefit diminishes. This point could vary considerably and depends on a number of factors, including (Roos, 2014b):

- The present economic complexity of the region;
- The maturity, vitality and competitiveness of the manufacturing supply network;
- The presence of similar manufacturing organizations and public infrastructure, such as research universities and technology centres;
- How quickly certain industries migrate towards more or less mature states, and more or less fragmented or consolidated value chains;

- The entrepreneurial activity level in the region; and
- Regional and local investment activities of economic agents.

The optimum level is directly related to economic complexity: in a region with high economic complexity the optimum would be very close to the right-hand side, whereas in a region with a medium level of economic complexity the optimum would be to the right of, but very close to, the medium-tech results shown in Figure 1 (Roos, 2014b). This tension between the short-term employment outcomes and the long-term prosperity outcomes is one reason why there has to be a sophisticated portfolio approach to industry policy.

Figure 1. **THE EFFECT OF ADVANCED MANUFACTURING ON LOCAL EMPLOYMENT**



Source: Roos, 2014b, Figure 3, p. 39.

2.3. Manufacturing makes up the biggest share of world trade and hence is critical for export earnings that pays for the cost of importing goods

The largest share of exports stems from the trade in Manufactured Goods. Manufacturing businesses are also more likely to engage in export activities. UK exports of goods produced by the manufacturing sector totalled £256 billion in

2012, accounting for around 53% of all UK exports (Office for National Statistics, 2012a). In 2010, 60% of manufacturing businesses with ten or more employees exported products and services compared to 26% of non-manufacturers (Harris & Moffat, 2013).

Consequently, any country that aspires to achieve a foreign trade-borne budget surplus will have to be successful in the export of manufacturing industry goods. Hockfield (2011) expressed it in the following way: "*(to) make our economy grow, sell more goods to the world and replenish the work force, we need to restore manufacturing, not the assembly-line jobs of the past, but the high-tech advanced manufacturing of the future.*"

Although ever higher performing ICT technology with its associated infrastructure allows increasing volumes of cross-border trade in services to occur, the share of services in global trade has been surprisingly constant since the 1980s, varying between 20% and 25% (Hoekman & Shepherd, 2015). This is due to the rapid increase in both service trade and intermediary physical inputs following on from disintermediating value and supply chains (Baldwin & Lopez-Gonzalez, 2014).

The ability of firms to compete and grow depends on their access to telecommunications, transportation, financial services and other business services such as accounting and legal services. Global value chains cannot function without services, and they are a vital input into manufactured goods trade. However, high-cost or low-quality services act as a tax on exporters, so services productivity is vital to manufacturing productivity and exports and they are a key determinant of competitiveness. (Debaere *et al.*, 2013; Kelle, 2013; Hoekman, 2014; Saslavsky & Shepherd, 2014). The importance of productivity improvements in enabling services for the sake of increasing manufacturing output is shown in many studies (see e.g. Office of the Chief Economist, 2015), and this link appears to have strengthened over time (Lind, 2010).

2.4. Manufacturing is the largest driver of high value services meaning it is critical for the high-end of the service economy

As outlined above, due to the mutually dependent inter-sectoral relationship between manufacturing and services, a country's capacity to develop its services sector is dependent on the specific structure of its manufacturing sector, given that different manufacturing sub-sectors require different service input and have different levels of service usage intensity (Roos & O'Connor, 2015). Lichtblau *et al.* (2012) illustrate that the manufacturing sector drives jobs in other sectors through this interconnectedness by the fact that in the EU, 100 manufacturing jobs generate on average 64 jobs in the rest of the economy (an employment multiplier of 1.64). These 64 jobs are distributed as: 20.3 jobs in private and public services; 13.6 jobs in logistics; 12.8 jobs in business services; 11.7 jobs in agriculture; 1.6 jobs in utilities; 1.3 jobs in financial services; 1.1 jobs in communications; 0.9 jobs in construction; and 0.6 jobs in mining.

Manufacturing is, through its R&D activities, the dominant source of new technologies for the service sector (Tassey, 2010). Most services in advanced economies are either delivered by manufacturing firms (servitization), on behalf of manufacturing firms and/or to manufacturing firms (input services). This can be exemplified by Sweden where 77% of all service exports are related to manufacturing activities and would not exist without manufacturing. Generally, the three largest service categories procured in manufacturing are: other business services; transport, storage and communication, excl. post and telecommunications; and wholesale and retail trade. R&D constitutes a minor share of services in manufacturing (Lodefalk, 2013).

The servitization of manufacturing is an ongoing process that alters the borders between manufacturing and services. Manufacturing firms are increasingly offering services to achieve a higher perceived value for their offerings from the customer's point of view and, as a consequence, an increasing proportion of sales volumes and profit margins are being generated by services (Fang *et al.*, 2008). It has been shown that services are a key contributor to the competitive advantage of manufacturing firms (Matthyssens *et al.*, 2006). The driving force to extend the manufacturing firm's offering to include services, can be expressed as a move from an incomplete offering in a product-focused transaction-based customer relationship to a complete offering (i.e. the bundling of products and services to better meet defined customer needs) in a relational-based long-term customer relationship (Stremersch & Tellis, 2002; Penttinen & Palmer, 2007; Kowalkowski & Kindström, 2009).

This increasing interrelationship between services and manufacturing has a number of consequences. One is that it is no longer possible to separate between manufacturing firms and service firms, only between manufacturing activities and service activities. This means public statistics are becoming increasingly unreliable in their statements around the reduction in manufacturing and increase in services as sectors (Roos, 2012a; 2013; 2014a; 2014b).

This problem of blurring boundaries between services and manufacturing was pointed out by The Royal Society (The Royal Society, 2009): "*The technical inadequacies of the official statistics pose significant methodological complications. ... For example, the diversification of firms' business models and the blurring of boundaries between services and manufacturing sectors limits the usefulness of current official statistics as aids to policy.*"

Another report (Department for Trade and Industry, 2007) states: "*It is preferable to look at service activities as opposed to service sectors ... but in practice this is difficult to do as most statistics are based on sectors as defined by the standard industrial classification.*"

The conclusion is that we cannot trust the official statistics when it comes to reporting on the decline in manufacturing since it is likely that it will miss the rapidly servitizing part of manufacturing, which means that the presence (and importance) of manufacturing is likely to be substantially higher than it appears. These statistics become even more unreliable as we move, through the deployment of Key Enabling Technologies, towards Everything-as-a-Service practices in the manufacturing domain. If this is combined with the fact that the demand for manufactured goods is increasing, albeit more slowly than the associated productivity improvements in the manufacturing industry providing these goods – resulting in higher output but lower employment, it is clear that the importance of the manufacturing industry will become increasingly underestimated as its statistical share in the average economy will decrease.

The statistics and discussion presented above raise the question of what we mean by manufacturing. The intuitive understanding that the word tends to engender in the minds of people (the noisy, dirty and dangerous transformation of raw materials into finished products, preferably by bending metals and with sparks) is more and more misleading and will soon become totally outdated. Manufacturing includes the whole chain of activities from research and innovation through to recycling of the provided object. Physical fabrication is only one small part of the whole manufacturing process, and is today mostly silent, clean, safe and very advanced in terms of material, processes and equipment, and as a consequence the macroeconomic importance of manufacturing is normally, as stated above, substantially underestimated (Roos, 2012b).

Regulatory reform and trade liberalisation can also accelerate growth in the manufacturing sector and as a consequence increase incomes and shift relative prices. This, in turn, produces a net increase in the demand for non-traded services such as passenger travel, tourism, restaurant food, and real estate activity (Dehejia & Panagariya, 2012).

2.5. Manufacturing generates job growth and economic activity in the rest of the economy

Each job in manufacturing generates on average between 1 and 15 jobs in the rest of the economy. The highest numbers can be found in knowledge-intensive manufacturing jobs in firms that also have knowledge intensive service activities and are located in a cluster of associated activities in a region with high economic complexity. The Milken Institute estimates that every computer manufacturing job in California creates an additional 15 jobs elsewhere in the economy (DeVol *et al.*, 2009). In a more recent study Moretti & Thulin (2012) looked at the employment multipliers in more detail and compared Sweden with the US, taking into account the structure of the two economies. The authors found that low skilled manufacturing jobs have an employment multiplier of around 1 in both economies whereas high skilled manufacturing jobs on average have an employment multiplier of close to 5 in the US and around 3 in Sweden.

The US Manufacturing Institute has estimated the average economic multiplier effect across different sectors and finds that manufacturing has a higher economic multiplier effect than any other sector: for every $1 in manufacturing value added, $1.4 in additional value is created in other sectors. (DeRocco *et al.*, 2009).

Evidence shows that areas with strong clusters perform better economically than areas without these clusters: they have higher job growth, higher wage growth, more businesses, and a higher rate of patenting (Delgado *et al.*, 2014). This means that manufacturing clusters are critical for both employment and direct economic prosperity. On the firm level the key benefits of clusters and their embodied proximities are best articulated as (Döring & Schnellenbach, 2006): "*Networks of regionally clustered businesses and institutions, therefore, offer two broad opportunities: formal exchanges of knowledge through market relationships, where proximity allows the establishment of closer ties; and the informal exchange of knowledge in social networks of individuals.*"

The economic terminology for this is agglomeration economics while a policy-driven operationalisation of this is known as cluster policy or smart specialization (Roos, 2014a). The research in this domain shows that firms that are members of agglomerations have higher productivity as well as higher productivity improvements than firms that are not members of any agglomeration (Jaenicke *et al.*, 2009; Garanti & Zvirbule-Berzina, 2013). Typical benefits are fourteen percentage points higher value added growth, seven percentage points higher profitability growth and two percentage points higher wages per employee (a proxy for productivity) to the advantage of firms in clusters vs. those not in clusters (extracted from Sölvell & Williams, 2013, table 2, p. 30).

Emerging technologies, including automation, will, over time likely create a substantial number of new jobs in the same way they have in previous technological shifts (Cyert & Mowery, 1987; Wadhwa, 2012; Miller & Atkinson, 2013). It is expected, however, that for the first time in history, the speed of knowledge development will exceed the speed at which humans will be able to absorb this new knowledge. It may be impossible, therefore, to bridge the skills gap between what was required in old jobs and what is required for new jobs, for a large proportion of the population, making it necessary to replace them with capital equipment to retain the pace of productivity improvements necessary for the firm to survive. This inability to bridge the skills gap will generate an increasing level of systemic unemployment and even in the best scenarios, there will be a substantial net decline of jobs before there is a net increase. The duration of this net decline can be substantially impacted by government policies (Marchant *et al.*, 2014). Irrespective of this, the nature of jobs is changing and will continue to change as illustrated by Donofrio & Whitefoot (2015): "*The number of employees in manufacturing without a high school degree declined from 10 million to less than 2 million in 1960–2010, and manufacturing employment requiring a college or more advanced degree increased by more than 2 million jobs.*"

This expected increase in unemployment generates two problems. The first was articulated well by Ford (2009, p. 5): "*Jobs are the primary mechanism through which income –and hence purchasing power– is distributed to the people who consume everything the economy produces. If at some point, machines are likely to permanently take over a great deal of the work now performed by human beings, then that will be a threat to the very foundation of our economic system.*" In other words, if enough people, through unemployment, cannot participate in the economic system whilst being a drain on the resources from this system, it will create a negative feed-back effect in this system, driving it into decline. This will be the primary problem to address if most of the unemployment effects created by technology-generated productivity-improvement hit middle-aged or older employees. The second problem was articulated well by Kass (2012, p. 6): "*Unemployment, even if compensated, is demoralizing, degrading and dehumanizing ... We need to consider work, as Dorothy Sayers put it, as 'not, primarily, a thing one does to live, but the thing one lives to do'.*" This means that even if society provides the economic input enabling these unemployed individuals to pay for what they need, being productive is essential to human well-being and the social and psychological effect of unemployment: stigmatization, depression, anxiety, poor self-esteem, divorce, substance abuse, crime, increased chronic diseases, suicide and mortality will be present. (Baker & Hassett, 2012; American Psychological Association, 2013) (Vardi, 2012).

3. INDUSTRIAL RENAISSANCE

Success in achieving a high economic complexity commences a positive feed-back loop. This means that high economic complexity provides the necessary foundation for building new industries with even higher economic complexity and so on. This positive feedback loop is normally grounded in a positive interaction between research intensive firms, research intensive universities, and public and private research organizations. In the best of worlds this will lead to increasing marginal returns on investments in increasing the economic complexity: something that can be seen over periods of time in e.g. Singapore, Switzerland and Sweden. As a consequence the industrial future of a country is more positive the higher its economic complexity. This will not stop the two-thirds of all manufacturing activity that needs to take place in close proximity to its key market to migrate its production activities to these markets as the industry and its associated demand matures. Nor will it stop the remaining one-third of all manufacturing that needs to be close to the key knowledge development centres of its core capabilities to migrate to these knowledge development locations. What it will mean is that countries with high economic complexity will be able to generate new industrial activities at a higher pace than it loses industrial activities of the first type and that these countries will be the recipient of foreign direct investment in the form of co-location by non-domestic firms that need to locate close to the world leading knowledge development centres that, by definition, exist in countries with high economic complexity.

Over the coming decades we will have an unprecedented speed of technological development with dramatic implications for the way value is created and captured in society, and for those who will be winners and losers both on the national (macro) level, the industry (meso) level, the firm (micro) level and also on the individual level. In addition, the scarcity of many natural resources (such as petroleum, rare earths, readily-accessible metals), calls for greater environmental sustainability and the growing importance of a low carbon economy are driving new innovations, e.g. biomimicry, green chemistry and green nanotechnology, whole system design, industrial ecology, greater resource productivity, sustainable energy and satellite technologies (Future Manufacturing Industry Innovation Council, 2011).

The manufacturing sector is incredibly diverse and hence it is very difficult to draw general conclusions as relates to the strategic developments of the sector as a whole. The strategic context of an individual firm will vary on many dimensions e.g. capital intensity, cyclicality, type of customer, supply chain structure, type of competitors and level of competition.

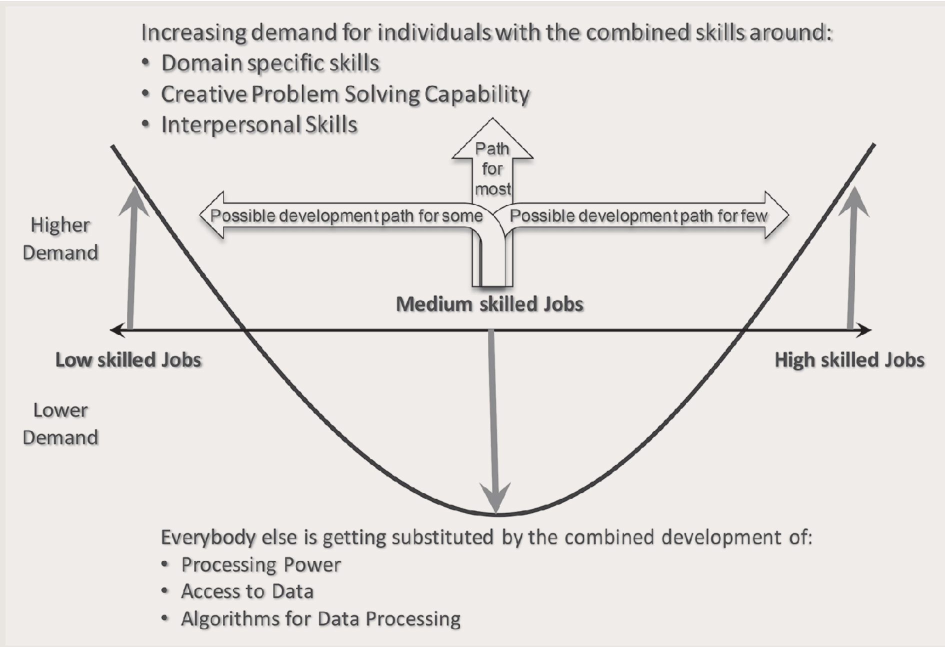
The way this industrial renaissance plays out in reality is also a function of the industry policies adopted by different countries, and by supra-national and sub-national regions (for an interesting discussion of this from an EU perspective, see Ambroziak (2014; 2015). But the conclusion is that increasing the economic complexity will increase the likelihood that benefits can be drawn from any form of industrial renaissance.

3.1. **Productivity improvements and implications for skills and jobs**

Technology-driven productivity improvement is nothing new; it has taken place in agriculture and manufacturing for a very long time. What is new is that the impact on the professional services industry will be great and will occur over a very short period of time. Historically, productivity growth in business services (made up of professional services, technical services and operational services) has been much lower than that of manufacturing. Thelle *et al.* (2013) identified the average productivity growth for business services for Germany, the Netherlands, the United States (US), the United Kingdom (UK) and Sweden to be 0.3% annually over the period 1995–2010. The average productivity growth for manufacturing in the same period is about 10 times higher. Based on these figures it is clear that if business services productivity improvements accelerate to a level similar to or, as is likely, higher than that of manufacturing, the impact on productivity will be dramatic.

Since this productivity improvement will exceed demand growth in many of the markets served, for example in legal services and accounting, (something that has not previously been the case) it will be possible to satisfy future demand with fewer employees. This type of dramatic technology-driven productivity improvement through automation is exemplified in the changes to the discovery phase in class action law suits where the thousands of hours previously used and invoiced can now be reduced to minutes owing to developments in: the speed and capacity of computer hardware; the availability of data due to digitisation and the development of sensors that can deliver just-in-time information; and the development of algorithms that enable this data to be turned into useful information. The implications for the number of back-office people needed in law firms to be engaged in this type of activity are obvious. As these technologies develop and disseminate, the number of individuals employed in accounting and law firms will be dramatically reduced over a time period probably shorter than 10 years. The overall effect for professional services firms is outlined in figure 2.

Figure 2. **AROUND HALF OF ALL SERVICE JOBS WILL DISAPPEAR OVER THE COMING 10-20 YEARS AND MANY OF THEM OVER THE COMING 5-10 YEARS**



Source: Roos, 2014a.

Figure 2 illustrates the effect on jobs across the different skill levels in a professional services firm from low-skilled (e.g., cleaning staff), to medium-skilled (e.g., back-office and some front-office staff) and high-skilled staff (e.g., a barrister arguing in front of a court). As can be seen, the impact is devastating in the middle-skilled domain where very few jobs will remain. This will happen whilst star lawyers arguing the case in front of the court will become even more productive and the concierge and cleaner that service them when they are in the office will still be sought after – an illustration of the demise of the middle and the growth of the two extremes.

This situation will give rise to the following pressures on wages for the three groups:

- The scarcity of suitable staff for the highly skilled employee domains combined with dramatic productivity improvements benefiting this group will provide a double upward pressure on the earnings in this area.
- The surplus of suitable staff in the lower-skilled employee domains combined with the inability to increase productivity in large swathes of this domain will provide a double downward pressure on the earnings in this domain originating in the effects of Baumol's cost disease (Baumol & Bowen, 1966).
- The individuals in the medium-skilled domains that cannot enter the low-or high-skilled domains will not be able to remain in the professional services industry and are likely to face long periods of unemployment due to the lack of fit between the knowledge, skills and experience they possess and what is demanded in the growing sectors of the economy.

This is a likely outcome even if we experience the normal Schumpeterian effect of a growth in jobs and sectors that presently do not exist because: (a) there will be a mismatch between the initial development speed and employment growth on these new sectors (low) and the speed of decline in employment in the existing sectors (high); and (b) the skill requirements for the jobs created in these new sectors are likely to be substantially different from the skills of the people losing their jobs due to automation in the existing sectors, hence making the transitional path possible for only a small number of these individuals.

Several studies identify the share of jobs at risk to be between 45 and 55 percent for most economies. An estimate of the Spanish number can be done using Frey & Osborne (2013) estimates, and by doing so, Bowles (2014) found that 55.3% of jobs in Spain are at risk from automation. Bowles (2014) also shows a reverse relationship between GDP per capita and share of employment at risk of being automated. Since GDP per capita is driven by economic complexity, we can conclude that the higher the economic complexity the lower the share of jobs at risk. The logic for this would be that in high economic complexity environments firms can stay competitive by constantly innovating and maximising productivity improvements. This means they will create new markets or serve existing markets better than others and hence will grow rapidly, leading to growth in the number of employees. It also means they will be early adopters of productivity increasing technologies such as automation. Given the lack of qualified external staff for operating these technologies they will have internal life-long learning strategies and apprenticeship structures, which mean that they will create the relevant workforce of tomorrow. Taken together, it means that in growing firms, the number of jobs at risk is fewer and the opportunity to migrate to new jobs is higher.

The impact on the primary industry and manufacturing domains will be less, owing to their existing lean operations and high productivity. There will also be a higher preparedness and acceptance of these types of productivity created job losses in these sectors since this is a pattern that has been common to these sectors for decades. However, there will still be some impact in terms of reduction in domains that have not previously focussed on productivity improvements due to either very high operating margins, very high demand growth in the markets that are served, or lack of suitable mature technologies embodied in productivity enhancing offerings or approaches. One example of the first is mining, one example of the second is production of "free-from" food, and one example of the third is meat production.

However, all is not doom and gloom. There will be growth in new firms enabled by the development of these technologies, including technology-based start-ups, while the existing skill levels of the individuals released out of e.g. the professional service industry will be suitable primarily in the service activities of servitizing manufacturing firms (Roos, 2015), in the experience economy (including the visitor economy) and in aspects of the health and age care-related sectors. It is important to realize the rapidly increasing skills requirements in manufacturing for creative problem solving and interpersonal skills: "*Modern manufacturing requires teamwork, planning skills, communication skills, improvisation, agility of the mind, and a large foundation of knowledge*" Mitchell (2012).

It is clear that although the impact is going to be highest in the professional service industry, primarily due to the very poor track record in productivity improvement, the impact will be substantial across the board.

3.2. **Implications for organizational forms**

Technological development will have dramatic implications for what we define as a firm and the way value will be created and captured in these firms.

A substantial and increasing share of an advanced economy's output is either in the form of information goods or digital goods (Eliasson *et al.*, 1990). This has implications for the way value creation and value capture will be organized, and hence how future "firms" and eco-systems will be structured and operate.

For manufacturing firms this means:

- Firstly, the products produced will have more components residing in digital space (e.g. software, manuals, status communications etc.);
- Secondly, manufacturing firms are increasingly adding pre and post-production phase services to their offerings (i.e. they servitize) and most of these services have a digital aspect to them (Roos, 2015);
- Thirdly, an increasing share of the manufacturing firm's inputs will be digital goods.

Using knowledge-intensive business services gives manufacturers an industry advantage when the depth of the market is taken into account (Bottini & Tajoli; 2010) and contributes to competitive advantage at the firm level (Matthyssens *et al.*, 2006).

It is obvious from this discussion that both value chains and the activities presently done within a given firm will become increasingly globalized. Location will be a function of ability to contribute to the value creation and could potentially change almost instantaneously.

4. THE FUTURE OF MANUFACTURING

The European Commission (2010) has stated: "*It is unquestionable that manufacturing remains vitally important for the EU economy. Manufacturing productivity is the motor driving EU wealth creation.*" From these quotes it can be seen that there has emerged an understanding that manufacturing today and tomorrow is critical for the prosperity of any nation.

From the above discussion it can be seen that manufacturing is set to change dramatically and there are four types of manufacturing emerging more rapidly than the rest:

- **Distributed smaller-scale local manufacturing** is primarily driven by developments in subtractive and additive manufacturing technologies, robotics and the general digitalisation of manufacturing, enabling simultaneous cost reduction and barriers-to-entry reduction. In some sectors this enables the local production of low-cost high-quality goods at increasing levels of customisation providing a potential competitive advantage in serving local markets.
- Some of the required qualities and characteristics identified for managing distributed manufacturing systems are (UNIDO, 2013): Dynamic collaboration across extremely complex, multi-level, reconfigurable supply chains; an agile supply chain; and transparent provision of information on products and processes. The tools needed to realize this will be (UNIDO, 2013): ICT solutions for distributed manufacturing; grid manufacturing to support col-

laborative planning; operation and management of manufacturing; and being able to respond to the emerging challenges such as innovation, speed and flexibility of computing systems, pervasive computing and embedded platforms (Jovane *et al.*, 2008).

- **Loosely coupled manufacturing ecosystems**. This is an example of the digitally enhanced agglomeration effects that can be seen in locations where strongly interconnected smaller manufacturing firms and individual experts compete on speed, agility and cost when it comes to low-volume high quality products and can outcompete large scale-based firms. These digitally enhanced agglomerations (or clusters) tend to be most successful when servicing consumer product providers that need to meet rapidly fluctuating demand in short life cycle goods or in goods that are adapted to consumer preferences through high frequency iterations. These agglomerations or clusters are also characterised by rapid collective learning that underpins a simultaneous cycle of increased quality, increased speed, increased capability and reduced production cost. The most successful manufacturing agglomerations of this type seem to encompass a substantial part of the complete value chain from raw material to finished product, including major specialized input providers, like: capital equipment suppliers and specialized business service providers. As such, they become difficult to imitate as a complete system and provide a basis for a competitive advantage as long as paradigm shifts in key underpinning technologies, key consumer demand patterns, key macroeconomic settings or critical regulatory settings do not occur.

- **Agile manufacturing methods implemented at larger operations**, specifically relating to products that have a high level of uncertainty around market acceptance, aiming to reduce the viable batch quantities through increased agility in both the supply chain and the manufacturing process itself. This includes moving to modular production lines and even multi-modal production facilities with the associated changes in production system. These changes will enable larger firms to compensate for diseconomies of scale as consumer demand fragments and pushes the need for shorter production runs back up the supply chain. This consumer demand fragmentation combined with reducing search costs for the end consumer, reduced shipping costs and increased shipping speed is shortening the front-end of the supply chain by removing intermediaries between the consumer and the producer (or brand owner).

In order to stay competitive, manufacturing companies must be able to react to unpredictable market changes, shorter timelines to launch new products into the market to attain first mover advantage and rising product development costs (UNIDO, 2013). Firms will have to manage volume changes of up to ± 70% (Gausemeier & Wiendahl, 2012) and hence must adapt their production systems to more rapidly respond to customer requirements and to better manage production capabilities (UNIDO, 2013). This increased demand volatility will also require faster supply chain related decisions that intrinsically have a higher level of flexibility (UNIDO, 2013). Shortening the time from idea or concept to full scale production is critical and the annual reduction should be at least 10% (using the finding from Teknikföretagen, 2009). This will require early adoption of emerging technologies that support the shortening of product development cycles as well as the ability to orchestrate the involvement and interaction of all actors along the transition from concept to finished product (UNIDO, 2013). Supply chains will need to be more flexible, easier to reconfigure and more responsive, to reflect the flexible and reconfigurable manufacturing systems and cost simulation systems (UNIDO, 2013).

- **Complex manufacturing systems operating in an environment of increasing fragmentation of manufacturing activity.** An increasing number of product dimensions with performance requirements and increasing technology-based innovation will result in increasingly complex manufacturing designs, products, processes and operations. These complex manufacturing systems entail (UNIDO, 2013): affordable high-performance production tools; interdisciplinary cooperation between the engineering, material, natural and computer sciences; improvements in the usability of advanced technology; and rapid engineering and production of integrated high-confidence cyber-physical products and systems combined with modern manufacturing control systems.

5. CONCLUSIONS

Economic complexity is the key driver of economic prosperity since it enables the production and export of things not possible to produce and export by others. This drives prosperity directly through export revenues and profitable firms, and indirectly through employment and high salaries with the associated consumption, all of which provides revenues for government. Since economic complexity is primarily driven by the type of manufacturing sector a country has it is clear that the present and future shape of the national manufacturing sector is critical for what level of future prosperity a nation will have.

The future shape of the manufacturing sector is path dependent i.e. it is driven by the present shape of this manufacturing sector and sector changes initiated by technology development. The strongest technology impact on the manufacturing sector will come from what is known as key enabling technologies. Government policy will also impact the future shape of the manufacturing sector. The sector is also impacted by the firms that make up this sector. Examples of firm internal factors are: managerial competence and capability together with managerial practices within the firm; R&D and innovation intensity across technical and non-technical domains. The sectoral structure is also impacted by firm structure in combination with industry structure and ecosystem in which the firm operates as well as the firm's absolute and relative size. Other factors impacting the sectoral structure are: productivity spill-overs; competitive intensity; regulatory environment; flexibility of input markets; quality of general labour and capital inputs; speed and level of upgrading of capital equipment; demand volume and demand sophistication; firm level absorptive capacity; firm's growth intent, etc.

Given the foreseen changes that have been outlined in the present paper, manufacturing activities will likewise change in many dimensions. The implications of these changes will be that:

- The difference between service firms and manufacturing firms will continue to be blurred and it will be more relevant to talk about service activities and manufacturing activities and both will frequently be executed within the same firm.
- Productivity improvements will, for most firms, exceed the demand growth in the underlying markets, hence enabling the delivery of tomorrow's demand with less than today's number of employees. This will be more visible the higher the service content delivered by processes and people that can be automated using emerging automation technologies – and the highest impact is likely to occur among professional services.
- Without a corresponding increase in the complexity of combined digital and physical systems delivered, the economic complexity of a given firm and a given jurisdiction will decrease. Increasing this complexity will be easier for already economically complex jurisdictions. Hence the challenges relating to maintain national prosperity will increase in a non-linear fashion with the distance to the economic complexity frontier.
- At the economic complexity frontier, the reduction in workforce will be more than compensated for in the growth of employment following from demand growth exceeding productivity growth. Instead, the largest challenge will be to ensure sufficient volume of competent employees and to manage the share of the workforce that does not manage to bridge the skills gap between the old jobs and the new jobs.
- The further away from the economic complexity frontier, the larger the net negative impact of more jobs being lost than created. This negative impact will further be exacerbated by the large number of unemployed that will become a burden on the national economy. This will result in a decline in con-

tribution to national prosperity simultaneously with an increased drain of whatever prosperity is created and as a result rapidly declining living standards.

- Without a clear and long term policy to increase economic complexity the gap between the prosperity of a nation not at the economic complexity frontier and a nation at the frontier will increase at an accelerating rate. Such a policy will have as one of its key focus areas a large export-oriented, advanced manufacturing sector. This policy would have to take both a short-term and a long-term view on the technological impacts on both firms and society in terms of productivity improvements, skills and jobs, organizational forms, global dispersion and the concentration of value creating activities in order to ensure that these changes are net positive to the country as a whole.

Manufacturing, which will look substantially different tomorrow as compared to day, will continue to be the foundation for prosperous economies and will, in complex and mutually reinforcing linkages with services, continue to be a cornerstone for new knowledge development and an ever increasing potential to create even more prosperity for the citizens in the countries where these firms are located.

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