The future of work – good for some bad for others[1]

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Executive Summary

The way we work, and the way organisations divide up the necessary tasks between technological artefacts and people is constantly evolving with the continuous technological development. This technological development is also continuously modifying the structures that emerges for holding and combining the distributed diversity of useful technical expertise, specialised capital equipment with its co-specialised relationships, processes, systems, information and knowledge (of which a large amount is tacit and therefore difficult to acquire) all of which contribute to higher efficiency, effectiveness as well as increased productivity of both the labour and capital that make use of it.

This technological development in combination with accelerating access to information and increasingly complex social networks drives an increase in the complexity of society. Managing this complexity increase in difficulty with the level of complexity as observed by Tainter (1988) and when the investments in efforts to manage this increasingly complex system result in diminishing marginal returns that over time leads to net negative returns the result is that this society rapidly reverts to a lower level of complexity or in normal terms it collapses. The biologist E. O. Wilson in an open discussion stated (Whitney, 2009): "We have Paleolithic emotions, Middle Age institutions, and god-like technologies and we will be facing a point of crisis in the coming decades". The above aspects indicates the basis for many challenges that society will face over the coming decades.

Over the coming decades this rate of change will accelerate exponentially, leading to fundamental challenges for individuals, organisations and society. This development is leading to an increasing mismatch between the skills existing in the workforce with the skills needed for the work opportunities of the future. One of the clear trends is the elimination of the "middle skilled part" of the workforce simultaneous with increasing productivity and insufficient supply at the high skilled end of the workforce resulting in increased real incomes at this end. At the low-skilled end of the workforce we will see some increase in demand in sectors where the underpinning market demand is growing faster then (a frequently low) productivity improvement (e.g. in health and age care) but there will still be oversupply combined with low productivity improvements in many sectors at this end resulting in decreasing real incomes for individuals employed in these latter sectors of the economy. The largest change in impact will be for the service sector, a sector traditionally spared this type of productivity improvement driven reduction in number of jobs.

In some specific industries e.g. thermal coal and parts of the agricultural value chain (meat), there will be further job losses due to a combination of technology obsolescence, changing consumer preferences and regulatory changes resulting in stranded assets with a very high negative impact on both firm value and firm cash generation.

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[1] This document draws heavily on: Roos, G. (2015). Technology-driven Productivity Improvements in the Professional Services Industry. Chapter 3 in Part A: Global Drivers and Digital Disruptors in Evans, E., Burritt, R. & Guthrie, J. (eds.). (2015). Future Proofing the Profession: Preparing Business Leaders and Finance Professionals for 2025. Chartered Accountants Australia and New Zealand & School of Accounting, RMIT University, Melbourne, Australia. ISSN: 2200-2820. pp. 41-50; Roos, G. (2017). Technology-Driven Productivity Improvements and the Future of Work: Emerging Research and Opportunities. Hershey, PA: IGI Global; Roos, G., & Shroff, Z. (2017). What will happen to the jobs? Technology-enabled productivity improvement–good for some, bad for others. Labour & Industry: a journal of the social and economic relations of work, 27(3), 165-192. References to claims made can be found in these sources if not found in the text.

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The required skills for the future labour market will be around interpersonal skills, creative problem solving and deep domain expertise combined with sufficient knowledge in adjacent domains to take a systemic view on issues. The challenge here is that the development of the knowledge domains that underpin the domain expertise will be so fast that there is a need for continuous learning to stay relevant and employable (and in some domains this speed may over time outpace human ability to learn making it imperative to complement the individual with artificial intelligence type systems). The responsibility to ensure this employability through relevance rests equally on the individual, the employer and government. This requirement of relevant skills is equally if not more critical on the managerial level in firms. In terms of life-long learning it is imperative that the mutuality of rights and obligations is balanced on every scale i.e. individual, organisation, sector and economy-wide.

It is worth noting that the lower the economic complexity of the country or region the larger these challenges will be.

Organisations are responding to this by developing ways to manage internal (full- and part-time) staff simultaneously with orchestrating relationships with external actors to guarantee access to the right capability at the right time whilst simultaneously aiming for a lower risk exposure in an increasingly dynamic and unpredictable operating environment by making labour a variable cost which is changing the contractual relationships between employers and the providers of labour (individuals or organisations). This is resulting in a drastic increase in part-time and temporary work and as a consequence many low-wage earners become dependent on government assistance to sustain an acceptable standard of living. It is also normal that low hourly wages go hand in hand with insecure working models.

High and sustained levels of inequality, especially inequality of opportunity can entail large social costs. If this inequality rests on rents and hence does not generate appropriate incentives it can result in unproductive behaviour with the resulting adverse social and economic consequences, including a loss of confidence in institutions, eroding social cohesion and confidence in the future. The IMF has found that income inequality negatively affects both growth and the sustainability of growth. Again increasing economic complexity goes hand in hand with decreasing income inequality.

This development requires changes by individuals, organisations and government to ensure a positive outcome for society. On the national level a policy aiming at increased economic complexity combined with policies to address the skills mismatch in the present and future workforce, as well as a policy for providing dignity to those that will be left behind through smart social programs (some of which are already operating in other countries).

On the firm level there must be an increased focus on productivity improvement and non-price-based competition.

On the individual level there will have to be a substantially increased focus on and responsibility for continuous competence development as well as a high flexibility and acceptance for change.

In spite of all these developments the fundamental problem is not that we are running out of tasks that need to be done but rather that we have too many things that need to be done but that not enough of them are defined as jobs and hence are being paid or that we have sufficient capabilities to execute that tasks for which someone is willing to pay. This means that we must find ways of identifying and creating the jobs that will help us address the increasing complexity of society and for which there is enough wealth created in society to enable these jobs to be paid. This means that we are, in job terms, facing two challenges: Firstly, to match the capability in the labour force with the ever-evolving tasks that needs to be executed and secondly to match the tasks to those needed to manage an increasingly complex society. This dramatic shift that we are presently living through put a time pressure on society to act on the above not to lose a whole generation out of the labour market. As a society we are moving towards a time when we will need as many human-tool pairs as

we can generate to manage the ever-increasing complexity of society but the requires that both the human and the tool component of the pair are appropriate for the task.

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Introduction

The way we work and the way organisations divide up the necessary tasks between technological artefacts and people is constantly evolving with the continuous technological development. Over the coming decades this rate of change will accelerate exponentially, leading to fundamental challenges for individuals, organisations and society. This change will be most felt in the services industry, which has previously largely been spared this type of experience. Hence, I will initially discuss this domain using examples from the legal domain but will conclude with a generalisation of impact across the board.

Every 50-70 years there's a major shift in how value is created in society, thanks to emerging technology. Throughout our industrial history, five major shifts in technology paradigms has restructured the scaffold of society (Perez, 2010):

1. The industrial revolution (commenced around 1770) that revolutionised textile production through mechanisation and created a canal and waterway infrastructure leading to the emergence of UK as a key industrial state benefiting from an unprecedented increase in living standards and national prosperity. The key resource that was viewed in a new light as a low and declining cost inexhaustible all-pervasive raw material that also acted as a multiplier of human capability was water.
2. The steam engine paradigm (commenced around 1830) included also the development of machine tools and had an emphasis on railway infrastructure but also a telegraph, city gas, port and universal postal system infrastructure. This paradigm shift resulted in the UK being challenged by the US. The key resource that was viewed in a new light as a low and declining cost inexhaustible all-pervasive raw material that also acted as a multiplier of human capability was coal.
3. The steel, chemistry and electricity based heavy engineering paradigm (commenced around 1870) with its focus on mega-structures, such as bridges, tunnels and ships and with an infrastructure focus on cables for electricity and telecommunications. Both the US and Germany embraced this paradigm and overtook the UK. The key resource that was viewed in a new light as a low and declining cost inexhaustible all-pervasive raw material that also acted as a multiplier of human capability was steel.
4. The combustion engine paradigm (commenced around 1910), emphasising mass production and with a heavy dependence on oil and minerals and with an infrastructure focus on roads, airports, ports and pipelines. US vying with Germany for leadership with China emerging towards the latter part. The key resource that was viewed in a new light as a low and declining cost inexhaustible all-pervasive raw material that also acted as a multiplier of human capability was oil.
5. The digital paradigm (commenced around 1970) and its emphasis on information (sensors of different types, software and hardware) and with a focus on the associated cable, fibre optics, radio and satellite digital telecommunications as well as high speed multimodal transport infrastructure. China is presently challenging the US for leadership in this paradigm. The key resource that is viewed in a new light as a low and declining cost inexhaustible all-pervasive raw material that also acted as a multiplier of human capability is the silicon chip.

It is worth noting that infrastructure development continues throughout several paradigms but changes scale from local via national to global. Capacity and throughput also increase whilst simultaneously there is a reduction in the cost of use. This is done by putting to use the technologies developed in each of the paradigms.

Each of these paradigms all incorporated changes in relative costs, in the perceived space for innovation, and how value creating activities are organised. In other words, they change the scaffolding of society.

Each of these paradigms have gone through the same pattern to the order of: emergence followed by one or more bubbles; a recession (which is also the turning point where the new ways of creating value is accepted as the future with the associated deep transformation of the institutional framework in and across economies); then a long era of prosperity; and finally, a reduction in productivity improvement laying the foundation for the next paradigm to emerge. Presently, we're at the end of the recession period of the Digital paradigm (Figure 1).

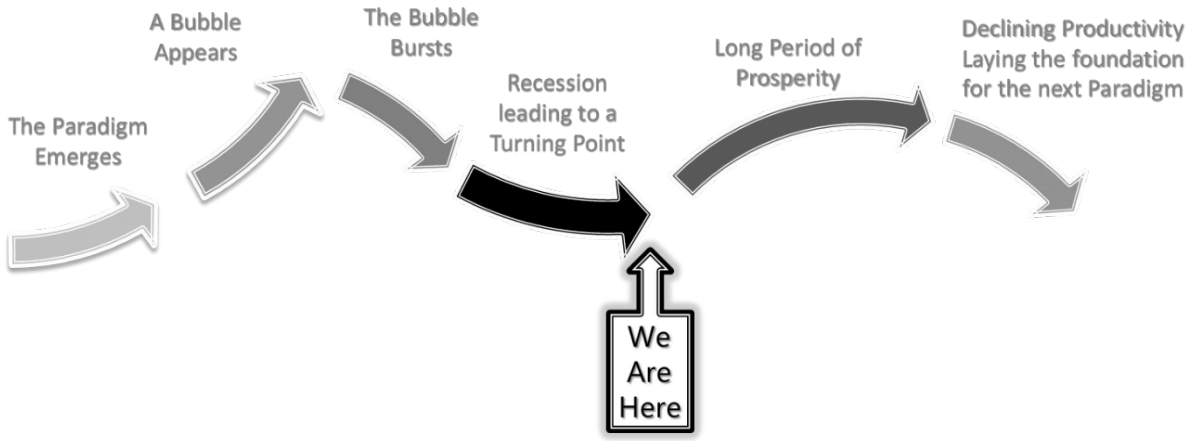

Figure 1: The phases of a paradigm

It takes between 20 and 40 years from its first visibility to when new technology begins to have major structural impact on the economy. An example is 3D printing that emerged already in the early 1980s but that has not until now started to have major impact. This is not only due to the inherent complexity of converting new technology into new capital equipment but also due to these new technologies enabling a dynamic and non-linear diffusion and assimilation process. This process will result in many major incumbent growth engine sectors being replaced by emerging sectors with the associated obsolescence of traditional task skills on all levels in the organisation. For obvious reasons this puts a strain on the economic and social fabric of society and for a period leads to strong income polarisation (Perez, 2010; Roos, 2017). This also explains why it is the young generation (that does not need any relearning or retraining) that is most adept at developing, absorbing and deploying these new ways of working.

The adoption speed of new technologies is limited by:

- The availability on the market or availability from in-house development of the necessary technology. It must also be embodied, integrated and adapted for a specific use.
- The cost of implementing and deploying a technology even if it is available.
- The cost and availability of labour to complement the technology to be implemented or deployed and the cost of retraining, redeploying or dismissing existing labour that is being made surplus by the implemented or deployed technology.
- The economic or other benefits that can be extracted from the implemented or deployed technology.
- Regulatory, social, political and other barriers to adoption of new technology

In the early phases of a paradigm shift, we tend to overestimate the short-term impact of new technologies while underestimating their long-term impact – an effect well known in technology forecasting, sometimes labelled macro-myopia (Saffo, 1992). This is one of the reasons that bubbles appear in the early phases of a new value creating paradigm.

From the above we see that during each of these paradigm shifts there will a dramatic increase in the creative destruction that takes place across an economy. This means that individual firms as well as other types of organisations must choose to adopt these new technologies and change the way they create value, or be expelled from the market they operate in. Perez (2010) notes that public institutions that are not exposed to competitive pressure normally lags the competitively exposed sectors in these necessary transformations by between 20 and 40 years.

The shifts each also have a new and different relationship between how innovation takes place and how it diffuses. As an example, some of the major drivers for innovation in the preceding value creating paradigm was the post war reconstruction and the cold war whereas in the new paradigm they are clean low resource footprint economic growth and ageing.

These innovations as they diffuse and are adopted are both a response to and a driver of change in individual behaviour, societal norms, structure and activities of firms and other organisations as well as in legal and structural underpinnings of nation states. In the transition phase this is a major challenge for the political leadership (look at the 1930s for an understanding of analogue challenges during the last transition period)

This interplay of diffusion and adoption of technology has major impact on productivity. The number and structure of firms and thereby the number of employees needed in different sectors and for different tasks will change, for instance the move towards the digital mine of the future can increase the Gross Value Added (GVA) in a mining company by 25% over 10 years with capital investments of only between 10¢-15¢/$ increased GVA.

Shifts in value creation means the structure of the economy will be fundamentally adjusted. As always, there will be winners and losers. Looking at shifts in specific new technologies from the old ways of creating value to the new, we can see some interesting patterns:

Distribution of new technology causes major resource reallocation between sectors in the economy. Growth will primarily take place in sectors relating to the provision of new technology-enabled offers and the major beneficiaries will be the first mover sectors and firms.

Sectors providing input to the first movers, as well as sectors and firms that provide products and services complementing the products and services from the first mover sectors and firms will also experience growth.

More divergence between sectors of the economy linked to the new ways of creating value will accelerate their growth. For those linked to the old way of creating value, growth will slow down and eventually turn into a decline. This means resource allocation by the market from low growth sectors to the high growth sectors will change rapidly.

New skills in labour will be in demand and can command high earnings. There will also be a slow, 10-year shift in the structure of existing organisations as well as the regulatory environment that when it takes place lays the foundation for continuous growth. As the new technologies in the paradigm matures, we see it disseminated across the economy, facilitated by more competence and by reduced risk due to standardisation.

The market allocates resources to the most productive firms within the sectors that embrace changes to value creation. For these firms, the focus moves over time towards efficiency in their activities leading to increased competition. This is further facilitated by a stabilising regulatory environment as regulations catch up with the new way of creating value

Growth drivers of the economy from sectors linked to the old way of creating value to the new way will also see a shift, and an increasing share of firms clinging to the old way will either die or embrace the new paradigm.

Each paradigm exhibits its own unique causality between innovation, diffusion, institutional change, productivity change, change in number of firms and employees and relative factor prices (Lundquist

et al. 2008). The present transition to the digital value creating paradigm will impact the composition of jobs. The number of jobs will decrease in some domains and increase in others as jobs linked to the preceding paradigm disappear and jobs linked to the new paradigm appear.

Historically, time lags between job destruction, job creation and delays in any adjustment process have resulted in a net decline in job numbers before a net increase becomes visible (Roos & Shroff, 2017). The complexities around job creation, job destruction, labour market churn and other characteristics are reviewed and discussed in Mamede (2009). Martynovich (2016) notes that emerging technology-enabled sectors tend to exhibit a spatial distribution that changes over time which also contributes to the imbalance in net jobs at a given location at a given time.

There is a positive correlation between growth in value-added and employment in digitally related sectors and this correlation is stronger for supply-driven sectors than demand-driven sectors (Lundquist et al. 2008). A stronger regional presence of leading industries, associated with digitally induced structural change, positively affects the ability of regions to attract and retain employees (Martynovich & Lundquist 2016). Manufacturing sectors linked to digital technologies act as stabilising factors, helping economies to retain workers whereas service sectors related to digital technologies help to attract workers (Martynovich & Lundquist 2016).

Technology-Driven Productivity Improvements with a focus on ICT enabled Automation

The biggest factor in increasing economic growth and improving living standards is the economy's ability to continuously produce more out of less, also known as productivity (Fox, 2002) or in the words of Krugman (1990): Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per employee.

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 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[2], technical services[3] and operational services[4]) has been much lower than that of manufacturing. Thelle & Ellersgaard Nielsen (2013) identify 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 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 increasing speed and capacity of computer hardware; the increasing availability of data due to digitisation and 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

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[2] For example, lawyers, accountants, advertising firms and consulting firms.

[3] For example, engineers, architects and land surveyors.

[4] For example, leasing office equipment, security firms and employment agencies.

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 positive effects of these developments will be higher productivity for the remaining highly skilled staff. The overall effect for professional services firms is outlined in Figure 2.

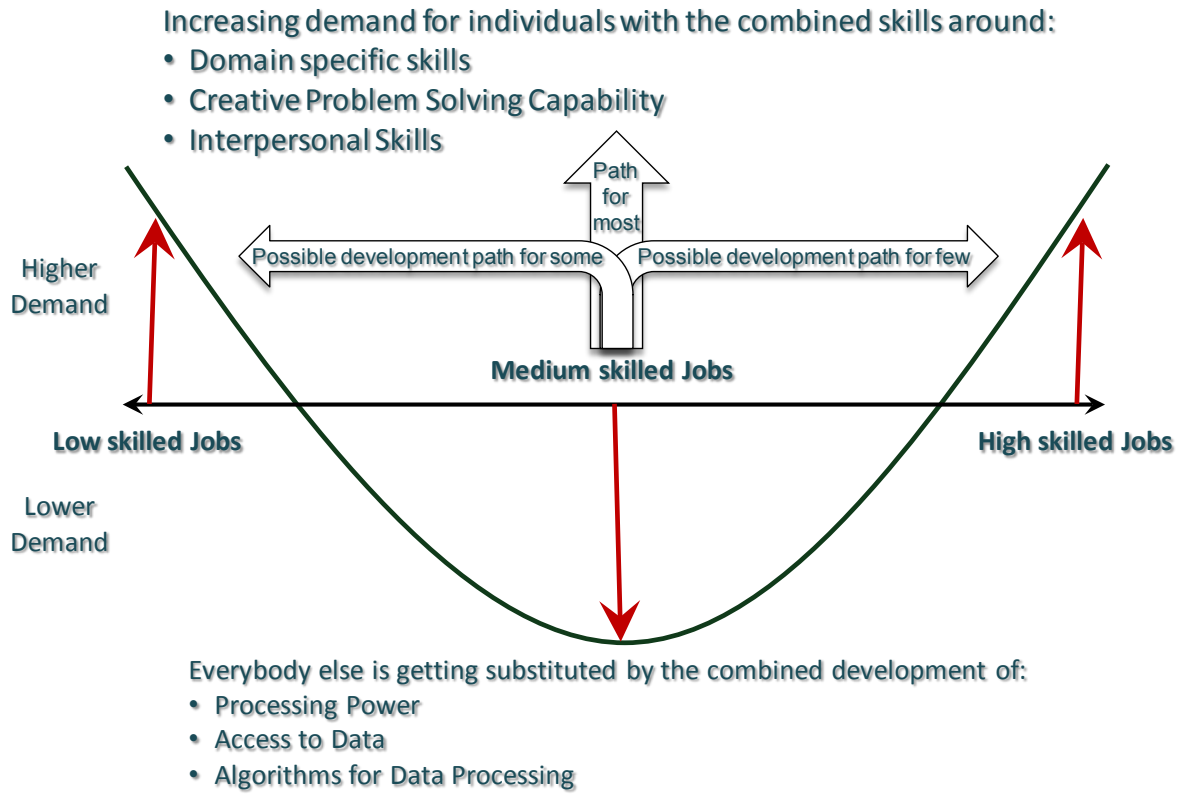

Figure 2: Around half of all service jobs will disappear over the coming 10-20 years and many of them over the coming 5-10 years (Roos, 2014a)

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[5]) 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.

It is worth reflecting on the dynamics of the change identified in Figure 2. The medium-skilled staff being made redundant during this change will on paper have three choices if they are to stay in the professional services firm domain. First, they can try to increase their skills to make themselves eligible to enter the high-skill domain. In the past this would have required a high level of domain-specific expertise as well as the skills to function well within the company environment and being proficient in using the appropriate tools for the job. Today this requires: ICT and other relevant technology skills; basic skills achieved through normal education; company-specific skills; task-specific skills; task-process skills; task-specific expertise; general sectoral knowledge; company-

[5] In retail service robots that can identify you through face recognition on entering the retail outlet and remember your personal preferences to provide you with your preferred personalised beverage on reaching the counter are already on trial with chains selling coffee and other beverages.

specific knowledge; product or offering knowledge; financial knowledge; an appropriate attitude; appropriate values; customer service skills; communication skills; sales skills; problem-solving skills.

In the future the focus on domain-specific expertise, creative problem-solving skills and interpersonal skills will increase even further. Some specific competencies required for tomorrow's world have been identified by the European Commission (2014) as: the ability to create and modify new services, that is, service design encompassing the technology aspect, the service aspect and the business model aspect; understanding customer business needs and processes; and the ability and resources for service development, that is, the creation and deployment of intellectual capital resources (for more on this see, e.g., Roos et al., 2012). This means that a significant share of the medium-skilled employees will no longer be needed and will not have the ability to move into the high-skilled domain either.

Interestingly, the skill requirement shown on the left-hand side of Figure 2 is also increasing so if you are a cleaner you will be expected to have a high understanding of what clean looks like and how to achieve it, you will be expected to adapt quickly to different layouts and contexts for the cleaning activity, and you will be expected to have a high level of interpersonal skills so that you are perceived by other individuals as a positive contributor to the environment instead of a disturbance. This also means that there will be a sizeable group of medium-skilled employees no longer needed who will not be able to move into the low-skilled domain.

This situation will give rise to the following pressures on wages for the three groups. First, the scarcity of suitable staff for the high-skilled employee domain combined with dramatic productivity improvements benefiting this group will provide a double upward pressure on the earnings in this area. Second, the surplus of suitable staff in the low-skilled employee domain combined with the inability to increase productivity in large swathes of this domain resulting in Baumol's cost disease[6] (Baumol & Bowen, 1966), unless acted upon, will provide a double downward pressure on the earnings in this domain (due to supply exceeding demand and the need to reduce salaries to match the overarching productivity improvements in the economy). Third, the individuals in the medium-skilled domain 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 or part-time employment (with salaries far below what they used to earn) due to the lack of fit between the knowledge, skills and experience that they possess and what is demanded in the growing sectors of the economy. Even if we experience the normal Schumpeterian effect of a growth in jobs and sectors that presently do not exist, this is still a likely outcome because: (a) there will be a mismatch between the initial speed of growth of 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 technology enabled productivity improvement 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 between 45 and 55 percent for most economies. An estimate of NZ numbers can be done using the correlation between economic complexity and share of jobs at risk (higher economic complexity means lower share of jobs at risk[7]) and would arrive at a number around 55 percent compared to 57 percent in Australia and e.g. 47 percent in

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[6] Baumol's cost disease is a rise in wages without productivity gains.

[7] The dynamic model (with a central positive feed-back loop) linking the two variables can be summarised as: Economic complexity means that the economy have many Highly competitive firms that remain competitive through Constant productivity gains which mean that they are likely to be early users of productivity enhancing technologies like e.g. automation leading to a high probability of competitive advantage leading to demand growth outstripping the productivity growth and as a result they need not only to retain (although with continuous retraining) existing employees but also to hire new employees.

Sweden illustrating the high economic complexity of Sweden and the low economic complexity of Australia. These numbers are almost certainly an overestimation since the technological development will not eliminate jobs but instead tasks in jobs and hence these numbers are likely the share of the workforce that will have a large share of its constituent tasks removed which opens up for either getting new tasks to perform or merging several jobs with reduced tasks into one thereby generating redundancies. An example might help here: There is a recent trend in developing machine learning based tools that can be used by individuals for personalised language learning. In studies it is shown that these tools replace two out of the three task groups that are performed by language teachers i.e. administrative tasks and language learning tasks but not motivational tasks. These former two tasks make up around 70% of what a language teacher does. This means that the productivity of a language teacher now has increased by over 200%. As a consequence, we can now provide new tasks to fill these free 70% or we can replace three teachers with one leaving two unemployed.

There are several studies aiming at finding the specific share of tasks in specific jobs that are at risk of being substituted by technology.

Not only will the above destroy any hope of many existing types of professional services firms with the existing types of jobs being large employers that provide decent salaries, it will also generate major social problems. Many countries have in place a policy to increase the number of people with university education, but most universities are currently educating in only one of the three required skills domains, that is, domain expertise. Historically 'high-status' professions[8] like law and accounting will be low-volume employers in tomorrow's world. The few who succeed will be at the top of their class with an innate ability and capability in the areas of creative problem-solving and interpersonal skills providing them with a potential to reach the top of their chosen profession.

This domain-expertise focus in universities is likely to generate a large number of graduates with no jobs and large study debts. Some of them may be able to migrate into the lower end of the skill scale but the corresponding oversupply of individuals will generate an increasing downward pressure on the salaries of those who do secure a part-time job, say, serving coffee to visiting tourists before their job is replaced by a service robot or automated in other ways.

The impact on the primary industry and manufacturing domains will be less, owing to their already lean operations with high productivity. However, there will still be some impact in terms of reduction in domains that have not previously focussed on productivity improvements due to either historically very high operating margins (hence low pressure to improve productivity), very high demand growth in the markets served (frequently leading to demand exceeding supply and hence low pressure to improve productivity) , or lack of suitable mature technologies embodied in productivity enhancing offerings or approaches (hence the traditional productivity improvement approaches of complementing or substituting labour with capital equipment is not possible). An example of the first is mining, of the second is production of "free-from"[9] food, and of the third is automation in meat production. Much of manufacturing is likely to continue to exist in a space where constant reduction of employees per unit of output will continue in most firms due to technology driven productivity increase outpacing demand growth in the markets served. This will be exacerbated by the replacement of labour by capital equipment, leading to most scale-intensive industries moving towards becoming lights-out or people-less 24/7 production operations[10]. The scale requirement will also reduce due the ability to create multi-mode production facilities.

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[8] This is high status professions in the Anglo-Saxon countries whereas in the Germanic countries these would be replaced by engineers and medical doctors as high-status professions

[9] Food where a naturally exiting component have been removed e.g. lactose, gluten, fat, sugars, etc.

[10] It is the journey towards this endpoint that is important not reaching it – in fact most production operation will either not be able to reach it in practice or will not desire to reach it for many reasons.

All is not doom and gloom though for several reasons. Firstly, there will be growth in new firms enabled by the development of these technologies, including technology-based start-ups, but the existing skill levels of the individuals released out of e.g. the professional service industry may not be suitable for these newly created jobs but will instead likely be suitable primarily for the service activities of servitising[11] manufacturing firms (Roos, 2015a), in the experience economy (including the visitor economy) and as a basis for jobs in the health and care sector. Unfortunately, however, the earnings potential will only be on the same or at a higher level than it was in the professional services industry from which they have departed, in the manufacturing domain and there will still be the same requirements for creative problem-solving and interpersonal skills limiting the opportunities. Secondly, there will be a demographic driven declining supply of labour resulting in labour shortage in the world unless technology driven productivity improvements outpace demand growth in the underlying markets (as we have stated that it will) or unless the immigration of labour is dramatically increased, as illustrated by Figure 3. Thirdly, like in all previous paradigm shifts there will be a need to put in place new enabling infrastructure. The building of the new digital and low resource footprint infrastructure will both "upgrade" our existing world and lay the foundations for the new jobs of the future. This will produce next-generation jobs across the spectrum; from civil engineering (digging up roads to put fibre optical cables in place or building towers an equipment for 5G base stations) to structural engineering (keeping skyscrapers standing or replacing concrete buildings with wood based buildings) to manufacturing (making the digitally enabled products and the low resource footprint products) to the provision of digital or digitally enabled services which also have a low resource footprint. Making spaces and physical things smart and connected is going to produce lots of jobs and so is the transitioning of products and processes into low resource footprint products and processes. Fourthly, technology will indeed replace some jobs, but it will also enhance human performance in many jobs and enable the creation of totally new jobs. So, although 30-50 per cent of all work tasks are replaceable by technology new job opportunities will surface. As most everything around us becomes tech-enabled and connected, we will start applying the ideas behind this "Internet-of-Things" to mission-critical parts of the economy, such as health care, transportation, and defence. Such a development will begin to radically change – and improve – work that matters and lay the foundation for jobs that we cannot imagine today. Making this digital and low resource footprint build-out come to fruition is the entrepreneurial opportunity of a lifetime. Our current industrial-age inefficiencies are business opportunities for next generation business leaders. Machine learning based solutions provided across virtually every aspect of life will address myriad (but not all) societal problems, in the process generating enormous economic value. Rather than foreshadowing the end of the middle class, new technology can help drive its growth – IF WE GET THE POLICY SETTINGS RIGHT.

Combining these developments, we will see that the workforce volume problem seems to even out (although we will likely see a decline on jobs before an increase in the OECD world at least) due to the opposite direction of the drivers above whereas the skill shortage problem is exacerbated by all the drivers.

[11] This term is used to describe manufacturing firms that complement their manufacturing activities with service activities to maintain the same value adding potential given that the value adding potential in the production phase of manufacturing is declining simultaneously with the value adding potential in pre- and post-production-phase activities increasing.

Figure 3: Global Workforce Crisis (Strack, 2014)

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

In the manufacturing sector there will be further transformational impacts from the so called key enabling technologies normally defined as: Information and Communication Technologies including Big Data & Big Data Analytics, Artificial Intelligence as well as internet-of-things; Advanced Manufacturing Technologies including additive manufacturing and industrial robotics; Industrial Biotechnology with specific focus on microbial consortia engineering and synthetic biology; Photonics; Advanced Materials; Nanotechnology; Micro- and Nano-electronics. These technologies are characterised by the fact that they impact most industrial activities and that they form industries in their own right. These key enabling technologies will also drive the development of new production systems that will change the way humans interact with the manufacturing process and the continuously changing semi-permeable boundary between virtual space – where all operations are digital – and physical space. These key enabling technologies are estimated (Roos, 2014b) to have the following impact on industrial activities by 2025 (Table 1):

Key Enabling Technology Domain	Examples of Estimated Impact By 2025
Information and Communication Technologies including Big Data & Big Data Analytics, Artificial Intelligence as well as internet-of-things	• Mobile Internet: 10–30% productivity gain for transaction labour. • Automation of knowledge work: US$35,000 – US$65,000 of additional productivity per full time employee in customer service, sales, IT, legal, finance, science, engineering and management • Cloud technology: 20–30% productivity gains through reduced infrastructure and facilities footprint together with higher task standardisation and automation; 10–15% productivity gains through standardisation of application environment and packages together with faster experimentation and testing. • Internet-of-things: 2.5–5.0% saving in operating costs, including maintenance and input efficiencies
Advanced Manufacturing Technologies including additive manufacturing and industrial robotics	• Additive manufacturing: 60–80% value increase per product produced and 35–60% cost savings to consumers plus 10% added value from customisation from consumer use; 40–55% cost savings to buyers from direct product manufacturing; 30% production cost reduction using superior moulds. • Advanced Robotics: USD$240,000–390,000 per person for extended/ improved quality of life from robotic human

	augmentation; 75% potential improvement in productivity per unit of work automated through industrial robots; 35–55% potential improvement in productivity per unit of work automated for commercial service robots. • Autonomous and Near-Autonomous Vehicles: US$2–8 per hour in value of time saved as well as 70–90% fewer accidents together with 15–20% gain in fuel efficiency from autonomous cars; 70–90% fewer accidents and 10–40% greater fuel efficiency plus 1–2 drivers per 10 trucks (for monitoring) from autonomous trucks.
Industrial Biotechnology with specific focus on microbial consortia engineering and synthetic biology	Will have transformational impact on value chains in the chemical, food, recycling and will impact many other value chains.
Photonics	Will have transformational impact on value chains in the medical devices, scientific and measurement instruments value chains plus will dramatically improve process efficiency and effectiveness in all process industries.
Advanced Materials	Will impact most industries – the impact will accelerate into transformational across all physical manufacturing once the technologies reach maturity which will likely happen after 2025
Nanotechnology	Will impact most industries – the impact will accelerate into transformational across all physical manufacturing once the technologies reach maturity which will likely happen after 2025
Micro- and Nano-electronics	Will impact most industries – the impact will accelerate into transformational across all physical manufacturing once the technologies reach maturity which will likely happen after 2025

Table 1: Examples of Impact on industrial activities from Key Enabling Technologies by 2025 (Extracted from Table 2, pages 11-21, in Roos, 2014b):

A less discussed but critical issue is the stranded asset problem that will accelerate in industries impacted by any combination of technological obsolescence or shift in consumer preference or regulatory environment. Examples of industries impacted are in the thermal coal value chain, the pesticide production value chain, the energy distribution value chain, the agricultural value chain, and many more. Some interesting work in this area is done at the Stranded Assets Programme at the University of Oxford's Smith School of Enterprise and the Environment. With every stranded asset there is of course an employment impact.

Competencies and Work hours in Manufacturing[12] [13]

Much of manufacturing is likely to continue to exist in a space where constant reduction of employees per unit of output will continue in most firms due to technology enabled productivity increase outpacing demand growth in the markets served. Given that there is a correlation between the age and size of the firm on the one hand and the maturity of the markets they serve on the other one would expect that larger and older firms would have a net loss in employment whereas smaller and younger firms would have a net gain in employment – this is also borne out by statistics..

[12] This section draws heavily on: Roos, G. (2014). The constantly changing manufacturing context. Chapter 1 in Advanced Manufacturing - Beyond the Production Line. Committee for Economic Development of Australia (CEDA). April, pp. 31-56; Roos, G. (2017). Technology-Driven Productivity Improvements and the Future of Work: Emerging Research and Opportunities. Hershey, PA: IGI Global

[13] For a similar discussion around the agriculture, aquaculture, forestry and mining sectors see Roos, G. (2017). Technology-Driven Productivity Improvements and the Future of Work: Emerging Research and Opportunities. Hershey, PA: IGI Global

It is important to realise the rapidly increasing skill requirements in manufacturing: "*Modern manufacturing requires teamwork, planning skills, communication skills, improvisation, agility of the mind, and a large foundation of knowledge*" Mitchell (2012).

The key skills required in the manufacturing sector have been identified by Osterman & Weaver (2014). Based on a large empirical study in the US they have found the results outlined in Table 2.

Share of manufacturing establishments requiring the skill	Skill required
81.20%	Interpersonal skills: Cooperation with other employees
75.60%	Basic reading skills (ability to read basic manuals)
74.00%	Basic math skills (ability to add, subtract, multiply, divide, and handle fractions)
64.20%	Interpersonal skills: Ability to work in teams
62.30%	Computer skills (required to use a computer at least several times a week)
60.50%	Basic writing skills (ability to write short notes)
52.60%	Extended reading skills (ability to read either complex technical documents; any document longer than five pages; or articles in trade journals, newspapers, and magazines)
42.40%	Basic reading, writing, and math skills
41.90%	Extended computer skills (any one of Use CAD/CAM; Use other engineering or manufacturing software; Write computer programs (e.g., programming a CNC machine for a new piece))
38.00%	Extended math skills (any one of Algebra, geometry, or trigonometry; Probability or statistics; Calculus or other advanced mathematics
31.50%	Algebra, geometry, or trigonometry
29.20%	Use other engineering or manufacturing software
28.40%	Use CAD/CAM
24.50%	Two or more extended reading skills
23.00%	Two or more extended computer skills
22.10%	Extended writing skills (ability to write at least one page)
18.60%	Write computer programs (e.g., programming a CNC machine for a new piece)
13.60%	Probability or statistics
11.60%	Two or more extended math skills
7.40%	Calculus or other advanced mathematics
4.20%	Two or more extended writing skills

Table 2: Present Manufacturing skills requirements (Osterman & Weaver, 2014, Table 1, p. 4 - based on MIT's Production in the Innovation Economy (PIE) Manufacturing Survey (2012–2013); Table 2, p. 5 - based on MIT's Production in the Innovation Economy (PIE) Manufacturing Survey (2012–2013); Table 3, p. 6 - based on MIT's Production in the Innovation Economy (PIE) Manufacturing Survey (2012–2013); Table 4, p. 6 - based on MIT's Production in the Innovation Economy (PIE) Manufacturing Survey (2012–2013))

Davis et al. (2012) found that the principal challenge facing the advanced manufacturing sector is the rapid pace of global technological development and the associated challenge of capturing and retaining a large share of the high value added segment of the global market in manufacturing which will require research and development (R&D) of new products and processes (the annual increase in R&D spending in the manufacturing sector is around 8-9% per year), design for manufacture, and the manufacture of relatively complex products. This requires a high level of management skill but the specifics of this skill will vary depending on the specific product market strategies and the stage in the product market lifecycle of the firm's principal product-service-system offering and will have to continuously change at the same pace as new technologies and new knowledge are adopted in the firm (Davis et al., 2012).

On the employee side higher levels of responsibility, autonomy and managerial delegation will be required at all levels in the organisation, and the sector and will continue to have a strong demand for people with Science Technology Engineering and Mathematics (STEM) skills (Davis et al., 2012)

including also IT skills. Giffi et al. (2015) found that the areas most impacted by the skill shortage in the US, according to a survey of CEOs, where:

- Maintaining or increasing production levels with growing customer demand (82% judged this to be negatively impacted)
- Implementing new technologies and achieving productivity targets (78% judged this to be negatively impacted)
- Achieving customer service post-sales service (69% judged this to be negatively impacted)
- New product development and innovation (62% judged this to be negatively impacted)
- International expansion: ability to import, export, or expand globally (48% judged this to be negatively impacted)

Hausmann et al. (2011) articulated the unique manufacturing challenge as "*People who know about design, marketing, finance, technology, human resource management, operations and trade law must be able to interact and combine their knowledge to make products. These same products cannot be made in societies that are missing parts of this capability set*". This aligns well with the statement of Pisano & Shih (2009) that "*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*".

The importance of education and its deployment in entrepreneurial endeavours is underscored in studies by e.g. Gennaioli et al. (2011); Roys & Seshadri (2013); Millan et al. (2014); Prettner & Strulik (2014); Hanushek & Woessmann, 2015). There has also been a long understanding that education as a rule translates into higher earnings (Psacharopoulos, 1994; Psacharopoulos & Patrinos, 2004; Dickerson & Vignoles, 2007; Hanushek & Woessmann, 2008; Greenwood et al., 2011; Autor, 2014). On average, compared to those with an upper secondary education, tertiary-educated adults earn about 1.6 times more than their peers, while individuals without an upper secondary education earn 24% less and the difference in earnings from employment between these two groups increased from 75 percentage points in 2008 to 79 percentage points in 2012. (OECD, 2014a).

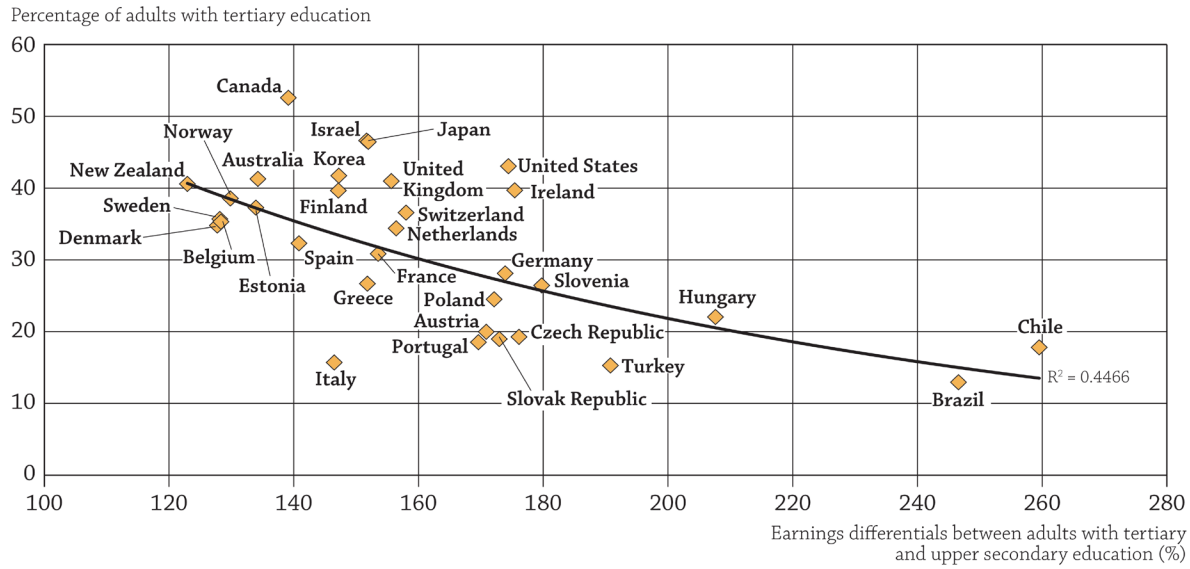

Figure 4:Percentage of 25-64 year-olds who have attained tertiary education and earnings differentials between adults with tertiary and upper secondary education 2012 (OECD, 2014a)

Several studies of firms from different countries and industries have all shown that workforce training is strongly linked to productivity (Wood et al., 2001; Tamkin et al., 2008) where the gains to employers are about twice the gains to the employees (Black & Lynch, 1996) and in addition the durability of the advantage to the employee is long lasting and transition resistant (Blundell et al., 1996). The American Society for Training and Development found a strong link between the level of a company's investments in formal training and their financial performance in the following year leading to improvements in the firm's stock performance as well as improved gross profit margin and market value per employee (Bassi & McMurrer, 2007) in addition investment in training increases firm survival (Collier et al., 2005). It has been shown that employee training generates increased firm productivity (Koike & Inoki, 1990; Mason & Wagner, 2002; Islam & Syed Shazali, 2011) and underpins the firm's ability to innovate (Mina et al., 2005) and to adapt to new rapidly changing requirements (Mason & Wagner, 2005; Ueshima et al., 2006; Jürgens & Krzywdzinski, 2015). A final point to be made is that there is a not insignificant time lag between the training taking place and the outcome being achieved since the training frequently needs to be complemented with investment in capital equipment and the development of co-specialised skills residing in the employee as relates to this capital equipment.

The above reasoning fits with the findings of Giffi et al. (2015) where the most common mitigation strategies used by firms to minimise the impact of skills shortages, as responded by US CEOs, are

Mitigation Strategy	Share of CEO's stating that the mitigation technique is important for using with the production workforce	Share of CEO's stating that the mitigation technique is important for using with engineers, researchers, and scientists
Internal employee training and development programs	94%	68%
Involvement with local schools and community colleges	72%	
External training and certification programs	64%	61%
Use of internship programs		60%
Partnering with universities		60%
Flexible work arrangements		58%
Use of overtime	58%	34%
Creation of new veteran hiring programs	49%	29%
Use of contingent labour (staffing agencies, etc.)	48%	41%
Flexible work arrangements	48%	
Outsourcing of certain functions	43%	36%
Focused recruiting on specific workforce segments, (i.e., gender and/or diversity initiatives)	33%	
Partnering with national laboratories and other research consortiums		24%
Considering a new geographic location (within the U.S) due to easier access to talent	22%	16%
Considering a new geographic location (cross-border to Mexico and/or Canada) due to easier access to talent	16%	11%
Considering a new geographic location (abroad to other parts of the world) due to easier access to talent	13%	11%
Involvement of labour unions	9%	

Table 3: US Skills Shortage Mitigation Strategies (extracted from Giffi et al., 2015, fig. 16 & fig. 17, p. 22-23)

Hence, it is possible to explain a significant share of cross-country labour productivity gaps through the level of national skill mismatch (McGowan & Andrews, 2015a) and this matters since closing a

national skills gap is a slow process (Braconier et al., 2014). McGowan & Andrews (2015b) conclude that:

- Cross-country estimates show that mismatch is more likely among the young and those with higher levels of educational attainment, suggesting that policies to increase educational levels may not be sufficient to address mismatch.
- A competitive and open business environment that favours the adoption of superior managerial practices is associated with lower skill mismatch.
- The positive effects of high managerial quality for reducing mismatch could be lowered by stringent employment protection legislation that imposes heavy or unpredictable costs on hiring and firing, slowing down the reallocation process[14].
- Framework policies that affect firm entry and exit and the efficiency of matching in labour markets are particularly important. For example, less cumbersome product market regulations and employment protection legislation and bankruptcy legislation that do not excessively punish business failure are associated with lower skill mismatch[15].
- Less stringent employment protection legislation is also associated with lower mismatch amongst youth, since it provides scope to improve the quality of job-worker matching, which is naturally lower amongst young people due to their lack of experience. This issue correlates strongly with the difference in unemployment rate between youth with low work experience and older workers with longer work experience.
- Policies that promote residential mobility– e.g. lower transaction costs on buying property and less stringent planning regulations and rental contracts – are associated with lower skill mismatch. High transaction costs and strict rental market regulations are associated with disproportionately higher mismatch amongst youth, who might be naturally more susceptible to mismatch if they have fewer resources to finance the higher moving costs that these policies imply. In addition, there are direct barriers like property purchase or rental cost making it difficult for low income individuals to take jobs in high cost locations e.g. this problem is highly visible in London where the present government is introducing new policies [including housing subsidies] to address this issue.
- A higher degree of flexibility to at least allow scope for wage bargaining around some centrally agreed standards to take place at the firm level, proxied by a lower coverage rate of collective bargaining agreements[16], is also associated with lower mismatch. Here it is important to point out that in e.g. Sweden there has been a long tradition, agreed between the trade unions and the private sector employers, to link salary increases with productivity improvements – something that is generally considered to have contributed substantially to productivity improvements.
- Higher participation in lifelong learning is associated with lower mismatch, as training beyond formal education can address changing labour market needs (e.g. due to technological advances).

From the above it is obvious that the half-life of technology-related competencies will become shorter, with a corresponding increase in the need for continuous professional development. The responsibility for this development will rest equally on the employee and employer, and organisational career paths will emerge where individuals change responsibilities to follow a product, service or system along its lifecycle. This path will be grounded in one generation or lifecycle of technology rather than in one responsibility that tries to keep pace with the ever-

[14] Note that New Zealand is not among those jurisdictions considered to impose heavy or unpredictable costs on hiring and firing

[15] Note that New Zealand is not among those jurisdictions considered to have cumbersome framework policies that affect firm entry and exit.

[16] This is measured by the percentage of workers who are covered by collective bargaining agreements, regardless of whether or not they belong to a trade union.

increasing development underpinning several sequential product generations, which for most individuals will be an impossible undertaking.

The effects of productivity growth and liberalised trade tend to be felt disproportionately by low-skilled workers (Berman et al., 1994) resulting in fewer employment opportunities for this category (Deitz & Orr, 2006). This means that continuous skill development is critical for everyone no matter the starting point.

There will also be a change in work-hour requirements: a reduction in absolute volume terms and an increase in the relative distribution across activities outside production. That increase will be seen at the front end of the manufacturing lifecycle (RD&I, Design, Virtual testing, Development of software tools and production processes, etc.) and at the back end of the manufacturing lifecycle, through increased service offerings to support physical outputs. This overall reduction will of course be driven by an increase in labour-saving advanced manufacturing systems and the migration to increasingly digital workflows. The impact of this on the individual will depend on whether that individual is a substitute or a complement to the technology that is being implemented in the workplace.

On the industry level, this means that the number of jobs in the economy created by one job in manufacturing will decrease from around 2.5 presently towards 0.7, which is more typical of the service industry, as manufacturing moves towards an everything-as-a-service model (Figure 5). This is on top of the dramatic productivity improvements that new technological development and new industry structure will drive. Productivity growth will, in many but not all sectors, far outstrip growth in demand, which will in turn lead to a rapid decrease in production-related and production-driven employment in the manufacturing industry. What remains of the industry will also have a much lower multiplier effect, which will have severe implications for employment levels and the tax base, with associated social and economic challenges. It is to be noted that this change is happening against a backdrop of ever increasing demand and consumption of manufactured goods.

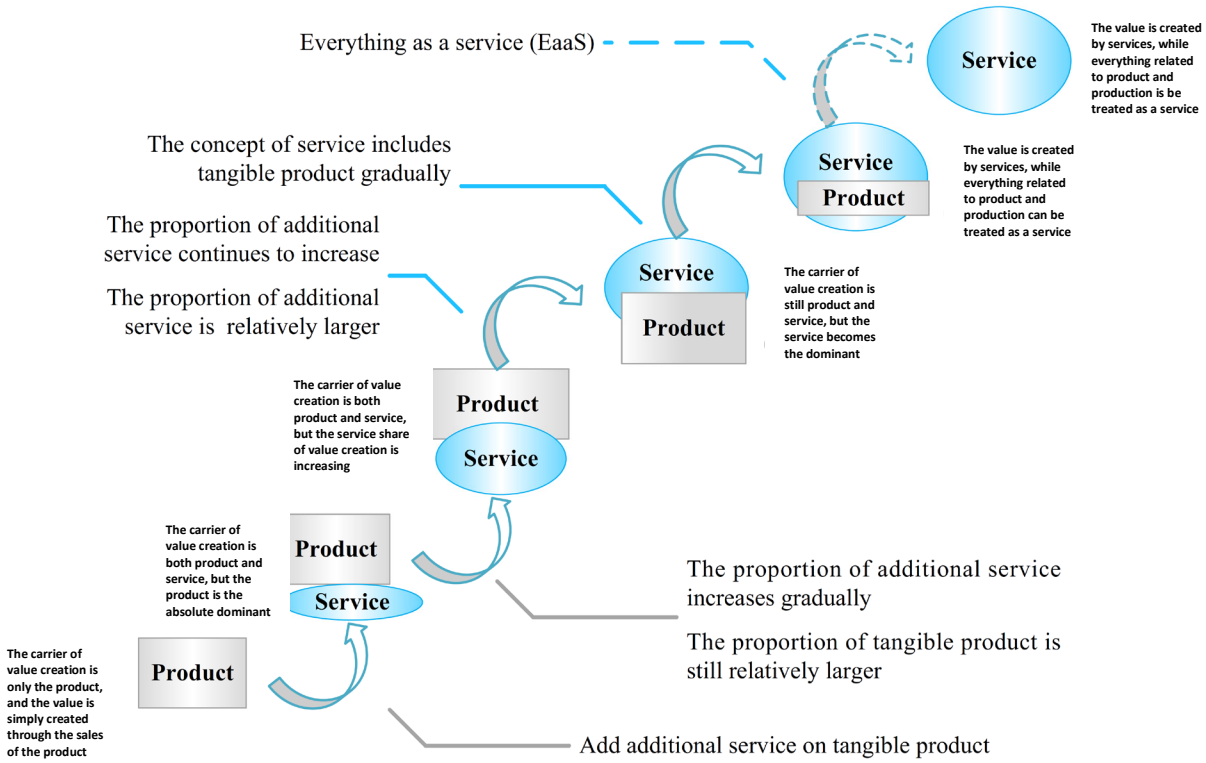

Figure 5: The move of manufacturing towards an everything-as-a-service model (synthesised from p. 7-8 and Figure 3 in Tao et al., 2015)

Countries with a highly functioning system of production-related service providers and firms anchored in Global Value Chains also tend to benefit in the areas of net employment, net output, productivity growth and knowledge production. Examples include Sweden, Switzerland and Germany. Highly prosperous countries are so because they either have high economic complexity or high export of endowment resources (or both as in the example of Norway). In the prosperous countries with high economic complexity exported services are to a high degree developed as a complement to exported manufactured goods (apart from being economically complex in their own right) and hence frequently benefit from non-price-base competition (e.g. predictive maintenance services) whereas in low economic complexity countries services are developed as a substitute to domestic non-exported manufacturing and these services have frequently low economic complexity like e.g. tourism.

The countries likely to be least affected by this transformation are those with a high level of economic complexity and which:

- Produce much of the advanced manufacturing tools and systems used in the new industry, and also provide many of the services required to support them;
- Develop the necessary 'smart' materials that make up new, manufacturing processes (such as nanoparticles for additive manufacturing, microbial consortia engineering inputs for cellular factories, advanced materials for engineering applications, light conductors that enable photonic sensor development, etc);
- Provide pre-production services like R, D & I (from training to contract research and innovation) and Design as well as post-production services; and
- Deploy advanced manufacturing tools and systems used to create highly complex equipment requiring sophisticated assembly methods (few of which will be produced using additive manufacturing in the foreseeable future although automation through robotics and other means is going to be increasingly used).

Sweden, for example, has registered a simultaneous growth in its manufacturing and services industries. Sweden's manufacturers have successfully repositioned themselves in the value Chain (Roxburgh et al., 2012); in 2007, service-type jobs already made up 39 per cent of manufacturing employment in the country. In mature economies as a whole, the manufacturing share of total gross value added declined from 25 per cent in 1980 to 16 per cent in 2007. However, Sweden saw only a minimal decline from 21 to 20 per cent. Sweden's net manufacturing exports increased from 0.5 to 4.8 per cent of GDP over this period. The number of highly skilled workers increased by 1.7 per cent a year from 2001 to 2007, even as employment in assembly occupations declined by 2.6 per cent per year. Swedish companies invested, and continue to invest, double the average of the EU 15 in vocational training time. The imported content of manufacturing exports increased from 33 per cent in the mid-1990s to 39 per cent in the mid-2000s. The critical telecom sector had an import content of more than 45 per cent by the early 2000s. Overall, Swedish manufacturing employment still declined by 85,000 positions from 1993 to 2007, but there was a compensating 120,000 increase in employment in manufacturing-related business services.

A similar pattern is identified in a recent study by Lorenz et al. (2015) as relates to the foreseen workforce impact of the introduction of Industry 4.0 in German industry up until 2025. In this study they find that there will be a 610,000 decline of assembly line jobs whilst simultaneously there will be an increase of 960,000 jobs in ICT related domains netting out at a positive job creation of 350,000 jobs. Again, there will be a substantial skills mismatch between the jobs lost and the jobs created requiring competence development initiatives on individual, firm and national level to ensure the presence of sufficient number of people with these new demanded skills. From these two examples we can see that in countries with high economic complexity the impact of technology development is netting out to be positive whereas in countries with lower economic complexity it will net out to be negative.

One further effect of the rapid emergence of new technologies is that the largest threat to a company is perceived to come from firms that previously operated in domains different from the company (industry convergence is presently seen as the largest threat to the company that they manage by two thirds of all CEOs). This industry convergence is nothing new and is normal when the gale of creative destruction hits a specific sector and an example can be take from the digital revolution in the printing industry from the mid-1980s to the mid-1990s. In a report (Roos & Roos,

1993, p.8) it was stated: *The digitisation of all information has made it possible to manipulate it using computers and transferring from one computer to another using communications technology. This has resulted in disciplines and industries that previously were almost completely separated because of different tools, different knowledge, terminology and transferability, are becoming integrated through a common, open technology. For the printing industry and firms that have based their business on traditional adaptation and reproduction of page oriented printed information, these changes represent an important and decisive paradigm shift.*

The report went on to state that the printing industry had only seen the beginning of this impact and that more change was to be expected as further technological disruption impacted the industry and as a consequence the absorptive capacity of the firms as relates to understanding this new technology becomes critical as well as the ability to innovate in the way the technology was deployed and applied to ensure increased value creation for the customer and increased value appropriation for the firm as an indicator of continued competitiveness. The report also stated that in this process the printing industry firm participants would encounter new competitors including their existing customers. In its characterisation of the printing industry the report also states that the printing industry has changed from being a low risk industry to becoming a high-risk industry.

In a follow-up report (Roos & Albertsen, 1995) it is pointed out that investing in the new digital printing technology as a substitute for exiting technology without changing the production process, the offering or the business model is not advisable but instead firms should innovate around at least one of these three domains and in that way find new applications for this new technology that again will increase value creation and value appropriation simultaneously if relevant processes, business models and offerings are changed. As relates to the technology and the associated capital equipment the report states that the potential articulated around the technology is ahead of the actual reality primarily due to incomplete technological solutions, insufficient competence at suppliers and customers, teething problems, most offered machines are more prototypes then products in series production, a lack of software and a lack of standards, as well as unclear ability of suppliers to support the equipment provided as well as high risk around the survival of specific suppliers. The report states that whilst these problems will disappear over time the printing industry firms must start already now to build competence and to innovate for future deployment of this equipment which is likely to otherwise make the firm obsolete in the future.

The above paragraph could have been written about e.g. additive manufacturing not long ago, which means that the pattern is the same although there will be new challenges e.g. as relates to how to regulate new means of production e.g. additive manufacturing that enables copying of physical products or the illegal or undesirable production based on digitally provided information (e.g. the printing of fire-arms).

The speed with which different manufacturing sectors take in use new technologies varies but it is clear though, that with the increasing digitalisation of all processes (design, production, administration, and even R&D), the production system, the products themselves, and with the increasing presence of services both as inputs and part of the output (servitization), that manufacturing is moving towards “everything-as-a-service” with the associated massive productivity gains and dramatic increases in reliability as well as high levels of adaptation to customer needs and customer adapted clock speed. This is making the traditional sectorial divides between the service sector and the manufacturing sector increasingly irrelevant (and even misleading for policy makers).

Especially since domestic export-oriented manufacturing is the basis for most exported high-value services around the world.

Emerging Shifts in the Relationships between Providers of Labour and Users of Labour[17]

International research has found that three quarters of the fastest growing occupations require science, technology, engineering, and mathematics (STEM) skills and knowledge, with employment in these occupations growing at twice the pace of non-STEM (U.S. Department of Education (2007) as quoted in Becker & Park, 2011). Many of these STEM skills relate specifically to computer science and software engineering and hence points at the critical importance of digital literacy.

The increasing pace of technology development and the similarly increasing pace of new technology adoption (frequently in the form of new production tools), and the accompanying changes in business models, make the continuous adaptation of skill sets absolutely fundamental for successful participation in the labour market. More so than ever before, individuals that are not willing or able to do this will face being left behind. This change will also require a higher absorptive ability on the individual level which usually follows with a higher level of education and this is visible in the shift of the level of education among the existing workforce as illustrated in the US by Ruggles et al. (2010) and shown in Figure 6.

[17] This section relies heavily on: Z_punkt The Foresight Company & The Centre for Research in Futures and Innovation (CRI-FI), University of South-Wales. (2014). The Future of Work: Jobs and Skills in 2030. The UK Commission for Employment and Skills.

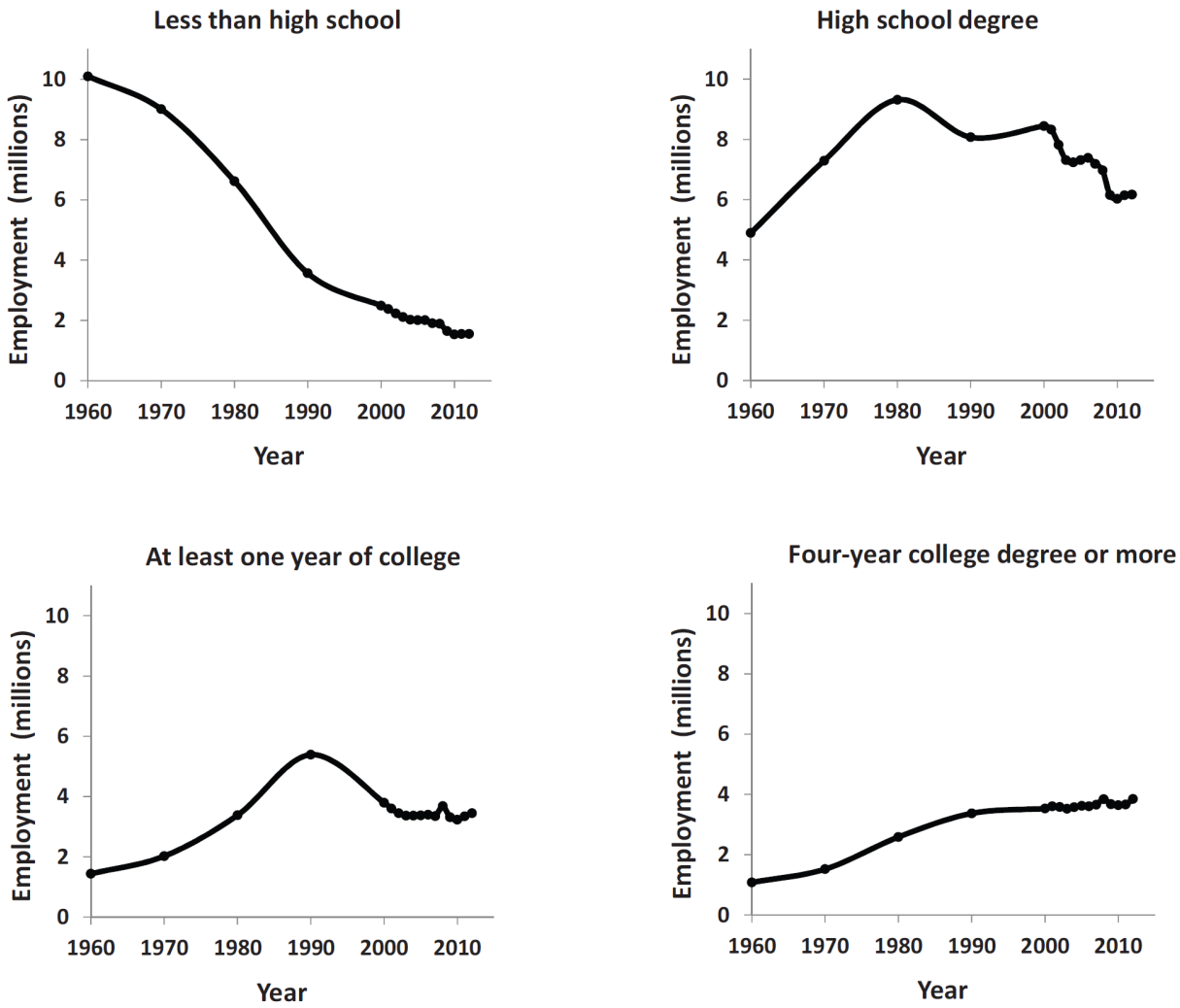

Figure 6: Trends in employment in the manufacturing sector by level of education, 1960–2012. (Data source: Integrated Public Use Microdata Series database) (Ruggles et al., 2010)

The digital development is ensuring that jobs will become more networked and more interconnected whilst also requiring higher levels of agility and flexibility. The growing availability of digital platforms is changing labour markets, organisational structures and the interrelationships between them – as can be seen e.g. through the growing share of peer-to-peer[18] activities in the economy.

[18] PSP activities have been discussed by Bauwens (2015): P2P processes occur in distributed networks in which autonomous agents can freely determine their behaviour and linkages without the intermediary of obligatory hubs (distributed networks are not the same as decentralized networks, for which hubs are obligatory). P2P is based on distributed power and distributed access to resources. P2P projects are characterized by a lack of a priori selection to participate. The capacity to cooperate is verified in the process of cooperation itself. Thus, projects are open to all comers provided they have the necessary skills to contribute to a project. These skills are verified, and communally validated, in the process of production itself. Reputation systems are used for communal validation. The filtering is a posteriori, not a priori and different to traditional peer review, where credentials are an essential prerequisite to participate. P2P projects are characterized by the implied capacity and design of peer to processes that allows participants free access to all the information about the other participants in terms of their existence and contributions (i.e. horizontal information) and access to the aims, metrics and documentation of the project as a whole (i.e. the vertical dimension). In P2P projects feedback is systemic, integrated in the protocol of the cooperative system.

At the same time the complexity of tasks to be addressed will increase as routine tasks are increasingly being automated. This will require that both employers and employees have the capability to work effectively in inter- and trans-disciplinary teams. This requires domain expertise combined with sufficient understanding of the other team members' domain expertise to interact effectively with them, ability to partake in virtual teams, interpersonal skills and cultural sensitivity, and finally creative problem-solving ability under time pressure (thinking on your feet). This means that the number of jobs that will be located in one and the same place only, will be fewer and so will the jobs that stick to a 9-5 schedule. Consequently, new practices and new contractual relationships will have to be developed by organisations to address trust, transparency and performance issues as well as how to execute continuous competence development of a largely virtual workforce to ensure their ability to contribute to the goals of the organisation. Employers' ability to secure and maintain their workforce supply in terms of both volume and competence will increase in criticality as the supply chain globalises and as the team work virtualises and this is further challenged by the demographics in some countries where we may well experience a workforce deficit within a 15-year period (depending in the balance between demographics and technology development and adoption of automation).

The organisation will also have to develop ways in which to manage internal (full- and part-time) staff simultaneously with orchestrating relationships with external actors to guarantee access to the right capability at the right time. This is changing the contractual relationships between employers and the providers of labour (individuals or organisations). Dolan et al. (2015) discuss 10 key dimensions that executives may use to assess their preparedness for the future of work in their organisations. This development has a synergistic relationship with the observed trend towards fewer hierarchical levels in organisations (Rajan & Wulf, 2006; Wulf, 2012; Castanheira & Leppämäki, 2013; Guadalupe et al., 2013).

Malone et al. (2011) finds that across the OECD part-time and temporary employment among prime-age workers has risen 1.5 to 2 times as fast as total employment since 1990. From 2000 to 2010, the number of temporary jobs in France rose by more than 66 percent, while the number of permanent jobs increased by just 7 percent. In Germany temporary work has grown from a very low number to around 1 million during the decade 2000-2010 and there has also been a parallel increase in part-time work. This means that the total work need has not grown but instead been distributed among more people, including more part-time workers and so-called "mini-jobbers" (Dauderstädt, 2013). Manyika et al. (2011) in their own surveys of US employers, found that more than one third say they plan to increase use of contingent labour and part-time workers in the years ahead and that a range of new intermediaries emerge to supply high-skill talent for short-term assignments. This supports the statistics that close to one third of Americans work as independent workers (Berland, 2014; Matthews, 2015). Fischer & Bergstermann (2015) found that many low-wage earners (that predominantly exist in the private service sector) have become dependent on government assistance to sustain an acceptable standard of living. It is also normal that low hourly wages go hand in hand with insecure working models. One effect of this can be seen in the changing wealth inequality where e.g. Stierli et al. (2015) found that the bottom half of adults collectively own less than 1% of total wealth, the richest decile holds 87.7% of assets, and the top percentile alone accounts for half of total household wealth.

Manyika et al. (2012) found that companies are using technology and flexible work arrangements to be more precise in when and how they engage labour—moving closer to making labour a variable cost, rather than a fixed one. Companies can now choose to employ workers on a spectrum of work arrangements—from traditional full-time workers who come to the workplace every day to contingent remote workers, who are enlisted to meet spikes in demand. This allows companies to bring in talent as needed and to acquire the services of people with highly specialized expertise that many companies could not afford to hire full time. With new software tools for managing a variety of workers and contractors, companies can now reduce total labour costs and offer employment

opportunities to people in untapped pools of talent who might not want to work full-time, whether they are parents of young children, post-secondary students, or people nearing or in retirement who want to supplement their income.

Amuedo-Dorantes & Serrano-Padial (2010) identified that the existing research suggests that, relative to permanent employment, fixed-term work may increase temporary workers' exposure to poverty through low wages and high turnover rates. However, fixed-term jobs could help lower temporary workers' poverty likelihood if they provide inexperienced and unskilled workers with a stepping-stone to more promising placements or if they help individuals earn a second household income. They also found, using Spanish data, that women, particularly older women, as well as older men holding temporary jobs are more likely to live in poverty than their permanent counterparts. Much of the contemporaneous negative impact of temporary employment is due to short-lived temporary work contracts, which appear more harmful than longer temporary contracts. Specifically, temporary work contracts lasting up to six months are linked to a 4 to 9 percentage point higher poverty exposure among all men and women relative to permanent work contracts. As a result, the predicted contemporaneous poverty rate of temporary workers reaches 13% among older males, 10% among younger women, and up to 16% among older women. The link between temporary employment and poverty is further emphasized among older men and younger women holding one-year contracts, who endure a three percentage point higher contemporaneous likelihood of life in poverty than their permanent counterparts. As such, the predicted contemporaneous poverty rates among temporary workers with one-year contracts reach 10% among older men and 6% among younger women.

This Spanish study aligns well with Otterbach & Sousa-Poza (2014) study, using German data, where they found that being unemployed has a strong negative effect on life satisfaction and health. They also, however, highlight the fact that this effect is most prominent among individuals over the age of 40. A second observation is that job insecurity is also associated with lower levels of life satisfaction and health, and this association is quite strong. This negative effect of job insecurity is, in many cases, exacerbated by poor employability.

Moriceau et al. (2015) identified some key dimensions on which the emotional state of freelance or temporary workers differ from full time employees as shown in this summary:

Dimension	On the one hand	On the other hand
Time	Permanent guilt, lack of time for the project and for other activities, risk of no project in the future	Joyful, self-motivating, choice and control
Emotional state	Doing what you love, Self-determination of how to do things, freedom and autonomy	Frustration and fear
Social involvement	Loneliness, lack of stable relationships with colleagues, lack of security and protection, too much responsibility, lack of support	Master of your own destiny, greater openness to meet with and work with others
Separation between work and non-work	No separation and work is life	No separation and work takes precedence all the time and everywhere at the expense of everything else, High social cost, worry about health
Recognition	Pride in accomplishments	Lack of recognition and appreciation, Social perception of failure due to lack of employment

A tentative conclusion is that those that voluntarily chose a career as freelance workers are more satisfied and would overwhelmingly like to continue in this role, whereas those that are forced to choose this career path are experiencing a dramatic fall in quality of life and would overwhelmingly prefer to find or return to stable employment.

An increasing share of innovation takes place at the intersection of disciplines and sectors. This underpins the criticality of mastering not only science, technology, engineering, and mathematics (STEM) in general and specifically key enabling technologies but also areas like design and HASS (humanities, arts, and the social sciences). The distribution of jobs and disciplines across sectors will of course both be a consequence of and stimulate the hybridisation of skills which will provide some individuals with a strong position to compete within an increasingly demanding workplace. As companies respond to the increasing speed of knowledge development (presently human knowledge is estimated to double every 13 months moving to every 12 hours over a 10-year horizon) by embracing increasingly semi-permeable organisational boundaries through e.g. open innovation, cross-sectoral and cross-discipline collaboration with customers, suppliers, experts and others, there will be a requirement for changing the way work is done.

Increasing globalisation and the increasing competitive pressure that follows from it combined with the unprecedented speed of knowledge development is likely to continue to increase the flexibility that employers demand from their employees. As the world of work become more flexible, employees are expected to shoulder more and more responsibility for skills development. Self-management, alongside core business skills, such as project management expertise, and the ability to promote your personal brand, will become increasingly vital. Personal agility and resilience, such as the ability to adapt to or embrace change is important within this context, particularly for young people who may in the future be competing for jobs with those that stay in employment longer (Tha latest data from Sweden shows that 28% of the workforce older than 70 are still in work and 10% over 77 are still in work – two-thirds because they enjoy it and one-third because they need the money) although at the moment there is now evidence that increasing the employment of older persons reduces the job opportunities or wage rates of younger persons (Banks et al., 2010; Munnell & Wu, 2012). The hierarchical structures of companies are changing towards leaner management with more responsibility for tasks and processes. The responsibility to uphold the organisation's brand when dealing with customers, rests more and more on the shoulders of individuals. New technology enabled work modes, making it possible to work wherever and whenever, further drive this.

As discussed above, the shrinking middle will challenge the workforce. The high-skilled minority (characterised by their creativity, analytical and problem-solving capabilities and communication skills) will have strong bargaining power in the labour market, whilst the low-skilled will bear the brunt of the drive for flexibility and cost reduction, resulting in growing inequality.

Jobs which have traditionally occupied the middle of the skills hierarchy and earnings range, such as white-collar administrative roles and skilled / semi-skilled blue-collar roles, are declining at a significant rate due to changes in work organisation driven by technology and globalisation. There is evidence that new types of jobs are emerging to fill the middle ground, but these have markedly different entry routes.

The future workplace will be multi-generational, with four generations working side-by-side. Traditional notions of hierarchy and seniority will become less important. The skills for leading and managing the four generational workforces, and for facilitating collaboration across multiple generations and their values, will be in increasing demand.

The complex values of this multigenerational workforce will impact upon employers' ability to attract talent, at all skill levels. Attitudes to corporate social and environmental responsibility, or expectations of flexible working conditions, will alter the ways employers recruit.

Cross-generational skills acquisition will be important. While the speed of technological change may place younger cohorts at a perceived advantage, especially those who have grown up entirely in a digital age or within a given technological paradigm, all age cohorts will need to invest in continual up-skilling to keep pace with accelerating development. Workers in older age groups will need to embrace technology fully in order to compete in the labour market. By 2020, over 50 per cent of the workforce are expected to be Generation Y members who have grown up connected, collaborative and mobile. A similar requirement is developing as relates to gender and cultural background.

In this dynamic environment it is essential that firms are able to ensure that the firm becomes a high performance workplace. This is not an easy thing to implement since the implementation road to achieving such a high performance work place will incur short term costs that may, in the absence of institutional support, initially disadvantage the firm compared to firms that adopt a labour cost minimisation strategy (Rubinstein & Kochan, 2001; Dobbins & Gunnigle, 2009) and hence the high performance work place implementation may be abandoned before any positive effects have been realised and hence a short term success may lead to a long term failure by performing on the effectiveness dimension whilst failing on the efficiency dimension.[19] Robin et al. (2014) have summarised international policies promoting the adoption of high performance workplace practices as shown in table 4.

	Name	Country	Type of high performance work place practice	Period of operation	Link

[19] Robin, M., van Wanrooy, B., Good, L, & Gahan, P. (2014). High Performance Manufacturing Workplaces. A Report Prepared for the Department of Industry. Centre for Workplace Leadership. The University of Melbourne. have the following illustration of legal framework and their effectiveness as relates to high performing manufacturing workplaces (references excluded):

In the 1990s and 2000s the UK adopted legislation to introduce minimum wages and working time regulation, which helped to promote partnership between managers and employees by limiting managerial control and building employee trust. The UK also legislated consultative and information sharing arrangements consistent with EU Directive 2002/14/EC giving employees the right to be informed and consulted about certain work changes. In organisations with 50 or more employees, negotiation about establishing an information and consultation scheme can be initiated by 10 per cent of employees or instigated by employers. The schemes must meet certain basic standards, including participation by employee representatives or employees directly. If the parties cannot agree on the type of scheme they would like, then a standard scheme is implemented. In conjunction with other measures introduced to promote opportunities for employees to contribute in the workplace, this helped shape a discourse about partnership at the workplace level. However, research has found that the legislation has been disappointing in terms affecting the prevalence of information and consultation schemes or managers' attitudes to consultation since its introduction. When schemes have been introduced, many have focused on the minimum standard in the legislation and on communication rather than consultation. However, some have suggested that the legislation has had an impact in encouraging employers to initiate schemes before it was introduced and by providing legal mechanisms to enforce information and consultation rights. In providing these avenues, this legislation seems better than the absence of any formal regulation.

Germany has institutionalised opportunities for employees to contribute in their workplaces through its Works Constitution Act, which drives the structure and powers of workplace information and consultation bodies. In organisations with five or more employees, at least one union member or three employees are needed to initiate a works council with elected employee representatives. As such, while the majority of workplaces across Germany have a works council or are covered by a collective agreement, not all workplaces are covered. These works councils function as information and consultation bodies with a veto over management decision making and the right to co-create workplace policy on some issues, particularly the allocation of working hours, the payment system and the introduction of monitoring technology. In institutionalising works councils as a common feature of German workplaces, legislation has helped encourage the adoption of opportunities to contribute, though there are some concerns about the need to strengthen enforcement rights and broaden the scope of works councils' powers.

Legislation	Works Council Act	Germany	Opportunities to Contribute	1952-present (amended most recently in 2001)	http://www.worker-participation.eu/National-Industrial-Relations/Countries/Germany/Workplace-Representation
Legislation	Information and Consultation of Employees Regulations	UK	Opportunities to Contribute	2005-present	http://www.acas.org.uk/index.aspx?articleid=1598
Government Programs	Value Creation 2010	Norway	Opportunities to Contribute	2001-2010	http://www.forskningsradet.no/prognett-vs2010/Home_page/1233558293538
Government Programs	Leadership 4 Growth	Ireland	Knowledge Skills and Abilities	2006-present	Programme http://www.enterprise-ireland.com/en/funding-supports/Company/Esetablish-SME-Funding/Leadership-4-Growth-Programme.html
Information Provision	Investors in People	UK	Knowledge Skills and Abilities	1991-present	http://www.investorsinpeople.co.uk/
Other Government Policy Levers	National Partnership for Reinventing Government	USA	Knowledge Skills and Abilities; Motivation and Effort	1990s	http://govinfo.library.unt.edu/npr/whoweare/historyofnpr.html
Industry and Stakeholder Policies	Partnership Institute	UK	Opportunities to Contribute	2001-present	http://www.partnership-institute.co.uk/
Industry and Stakeholder Policies	Involvement and Partnership Association	UK	Opportunities to Contribute	1884-present (current name adopted in 1989)	http://www.ipa-involve.com/

Table 4: Examples of international policies promoting the adoption of high performance workplace (Robin et al., 2014)

It is worth discussing here the increasing inequality in most western societies where the gap between the rich and poor is at its highest level in decades (Dabla-Norris et al., 2015). Some degree of inequality may not be a problem insofar as it provides the incentives for people to excel, compete, save, and invest to move ahead in life and it can also influence growth positively by providing incentives for innovation and entrepreneurship (Lazear & Rosen 1981). High and sustained levels of inequality, especially inequality of opportunity can entail large social costs. If this inequality rests on rents and hence does not generate appropriate incentives (Stiglitz 2012) it can result in unproductive behaviour with the resulting adverse social and economic consequences, including a loss of confidence in institutions, eroding social cohesion and confidence in the future (Dabla-Norris et al., 2015). Several IMF studies (e.g. Berg & Ostry, 2011; Ostry et al., 2014; Dabla-Norris et al., 2015) have found that income inequality (as measured by the Gini coefficient, which is 0 when everybody has the same income and 1 when one person has all the income) negatively affects growth as well as the sustainability of growth. Dabla-Norris et al. (2015) find in their study some interesting and robust results: an inverse relationship between the income share accruing to the top 20 percent and economic growth such that if the income share of the top 20 percent increases by 1 percentage point, GDP growth is 0.08 percentage point lower during the subsequent five years, suggesting that the benefits do not trickle down. This is to be compared with their finding that a similar increase in the income share of the bottom 20 percent is associated with 0.38 percentage point higher growth. They found that this positive relationship between disposable income shares and higher growth continues to hold for the second and third quintiles (the middle class). These results are in line with findings by the OECD (OECD, 2008; Cingano, 2014; OECD, 2014b) and the World Economic Forum (Mohammed, 2015). The public interest around these issues has been heightened by the publication of the book *Capital in the Twenty-First Century* by Piketty with its discussion of income and wealth dynamics. The effects of increasing income inequality can be summarised as:

- It lowers growth by reducing the ability of lower-income households to stay healthy and accumulate physical and human capital (Aghion et al., 1999; Galor & Moav 2004; Dabla-Norris et al., 2015).

- It lowers the growth in labour productivity as it reduces the educational attainment of children from poor families in an environment where higher and/or good quality education carries a tuition fee (Stiglitz 2012).
- It lowers the income mobility between generations as a consequence of increased path dependency between parent's earnings and children's earnings Corak (2013).
- It reduces aggregate demand and undermines growth, because the wealthy spend a lower fraction of their incomes than middle- and lower-income groups (Carvalho & Rezai, 2015).
- It enables investors to increase their holding of financial assets backed by loans to low- and middle-income earners, resulting in rising debt-to-income ratios and thus financial fragility which hurts short- and long-term growth (Kumhof & Rancière, 2010; Kumhof et al., 2012; 2013; 2015).
- If existing for prolonged periods it can intensify leverage, overextend credits, and relax mortgage-underwriting standards (Rajan,2010), which together with an associated push for financial deregulation (Acemoglu, 2011), provide the basis for a financial crisis which has a sharp negative impact on short- and long-term growth.
- It contributes to larger external deficits (Kumhof et al., 2012) hence potentially threatening macroeconomic and/or financial stability, and thus growth (Bernanke, 2011).
- If extreme over a prolonged time it affects the economics of conflict, as it may intensify the grievances felt by certain groups or can reduce the opportunity costs of initiating and joining a violent conflict (Lichbach, 1989; Schock, 1996; Esteban & Ray, 2011; Koubi & Boehmelt, 2012; Kuhn & Weidmann, 2013; Ghatak, 2014).
- It has the potential of leading to poor public policy choices as can be seen in the protests against growth-enhancing economic liberalisation and against free trade, globalisation and other market-oriented reforms (Claessens & Perotti, 2007).
- It leads to a higher concentration of power in the high-income group which may result in a decrease in the provision of public goods that boost productivity and growth, and which would disproportionately benefit the poor (Putnam, 2000; Bourguignon & Dessus 2009).

It is worth noting that a strong correlation is found between economic complexity and inequality in such a way that as economic complexity increases, income inequality decreases (Hartmann et al., 2015). These results are found to be robust when controlling for measures of income, institutions, and human capital. The key insight from this is that social policies alone might lack the strength required to fully modify income inequality in absence of changes to a country's productive structure and as a consequence one of the key objectives of industry policy must be to increase a country's economic complexity.

How Should Society Respond to these Challenges[20]?

On the Macro or National level there needs to be an economic/innovation/education/industrial policy with a consistent, sustained and long-term focus on increasing the economic complexity of the economy. The key policies are outlined in figure 7.

[20] This section draws heavily on: Roos, G. (2014). Manufacturing in a High Cost Environment – Basis for Future Success on the National Level. Chapter 1 in Roos, G., & Kennedy, N. (eds.). (2014). Global Perspectives on Achieving Success in High and Low Cost Operating Environments. Hershey, PA: IGI Global. doi:10.4018/978-1-4666-5828-8. pp 1-51; Roos, G. (2014). Manufacturing in a High Cost Environment – Basis for success on the firm level. Chapter 13 in Roos, G., & Kennedy, N. (eds.). (2014). Global Perspectives on Achieving Success in High and Low Cost Operating Environments. Hershey, PA: IGI Global. doi:10.4018/978-1-4666-5828-8. pp 393-480. Roos, G. (2017). Technology-Driven Productivity Improvements and the Future of Work: Emerging Research and Opportunities. Hershey, PA: IGI Global.

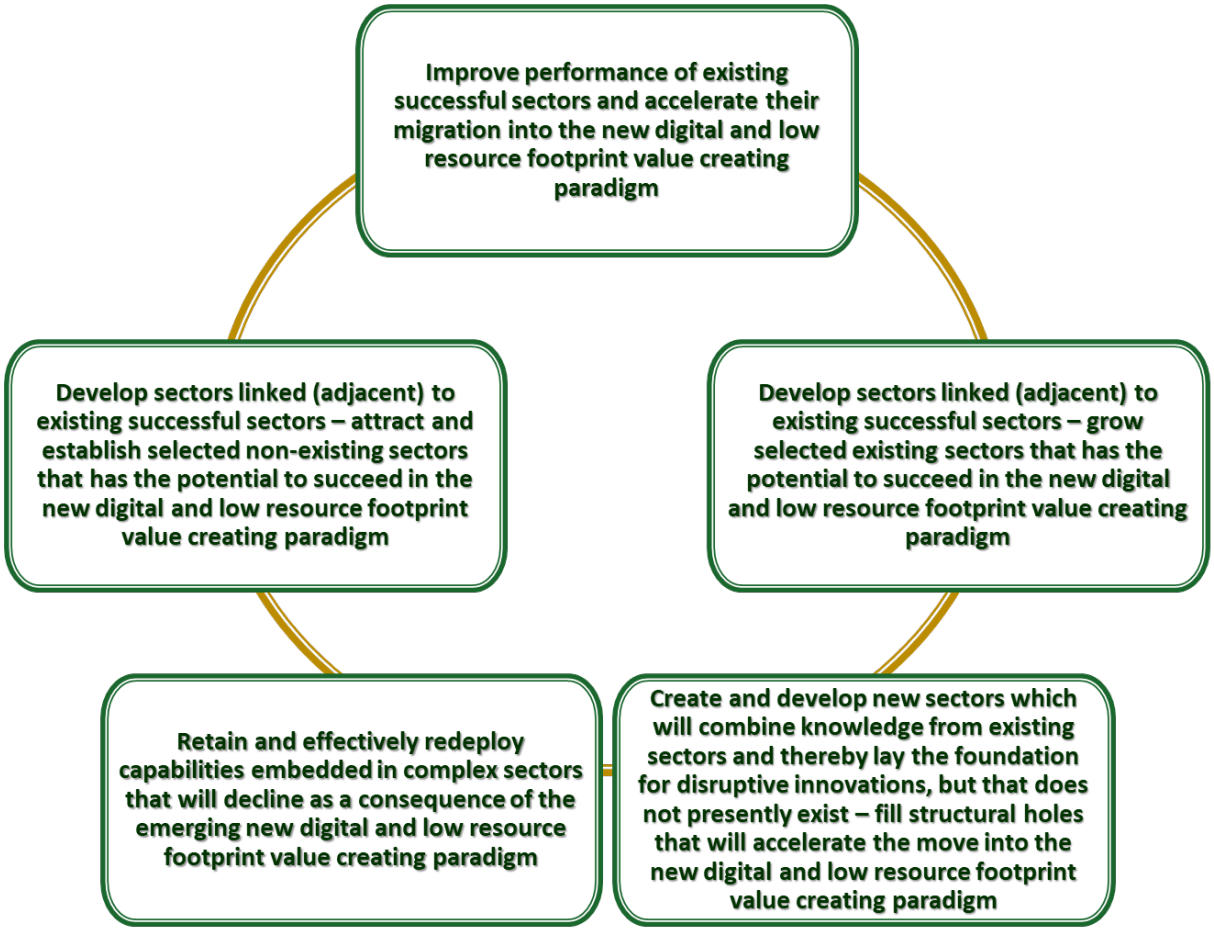

Figure 7: Policies for pursuing an increase in economic complexity (Roos et al., 2018)

The price of not pursuing this policy direction is a reduction in national prosperity with all its consequences.

It can here be worth remembering that a small economy does not have the opportunity of a large economy to spontaneously generate optimal responses to change. Left to its own devices, compared to a large economy, the small economy as a whole has a higher risk of decline unless there is outside intervention. To express it in neo-classical economic terminology: The smaller the economy the more pervasive market failure is, as an attribute of the economy as a whole (Roos, 2012). This means that the responsibility and need of Government to intervene is larger the smaller the economy.

This means that government must move away from its focus on not picking winners [which means that it normally focuses on picking losers instead by giving handouts to businesses that are failing or businesses that have strong influencing abilities on government's decision making]. Instead government must focus on creating an environment in which winners can emerge and then get in behind and support them to scale-up and grow. This normally means changing the focus from supply side financial tools to supply side information tools (e.g. roadmaps and market information enabling better decision making on the firm level but normally outside the financial reach of smaller firms) but primarily to demand side tools like procurement (e.g. analogues to the US SBIR program), regulation (the way Scandinavia and California have forced innovation resulting in world leading enterprises through e.g. environmental regulation), and smart specialisation or cluster formation to ensure agglomeration benefits. The above policy tools normally need to be complemented by clear direction setting leadership from government to become maximally effective. Government must also partner with the private sector around innovation since government has the ability to take higher risks and engage in project with longer times to profit than the private sector has. By doing this government can create new markets and transformative innovations resulting in a crowding-in

effect (i.e. the stimulation of private investment and the growing of national output) opposed to the frequently and erroneously touted crowding-out effect. This requires empowering government to envision directions for technological and other change and invest in that direction and it will require changing the way public sector spending is traditionally evaluated and finding ways in which governments (and the taxpayer) can reap the rewards of this public spending commensurate to some extent to the risk that are assumed. This will mean that governments will frequently fail but as long as there are learning, and the same mistake is not repeated this is OK. An interesting and enlightening discussion of associated topics can be found in Mazzucato (2015) and can be illustrated by the quote: *Tomorrow's growth or long term economic growth is determined by todays investments in R&D, infrastructure projects, human capital, technical change and innovation. But innovation requires decisions on directionality and capabilities to understand and engage dynamically with future technological and market opportunities*.

A drastic approach would be to implement a corporate tax system reversely proportional to the economic complexity of the firm. The base rate for firms with very high economic complexity like e.g. medical devices or pharmaceuticals could be around 10% whereas the tax rate for low economic complexity activities like log export could have a tax rate of 50%.

Policy tools must also be deployed to increase the share of SME's that both desire and have the ability to grow to the international benchmark of 15% or higher. This will normally require the provision of sectoral specific support like e.g. the capability to go from batch production to continuous production in the food sector – a capability not normally found in universities. Hence the establishment of catapult type centres modelled on the Norwegian variety instead of on the UK one would address this.

To address the skills mismatch and the workforce volume government needs to develop a workforce strategy made up of four key components: A rolling 20 year forecast of supply and demand by skill level in the workforce (this will of course be wrong since we do not know what jobs may exist in the future but it will be better than having no forecast to work from); An immigration policy focussed on how to attract the people having the skills that will be in short supply; An education and upskilling (including life-long learning) policy; a policy focussed on retaining the people with the skills that will be in short supply.

On the Meso or Sectoral level there needs to be a focus on both the building of rich industrial commons and on ensuring strong agglomeration economic benefits. The consequences of not pursuing this will be a reduction in the number of sectors present in the economy as well as a reduction in competitiveness of remaining sectors. The end result is likely to be low value-added commodity export grounded in comparative advantages only, combined with a potentially large visitor economy i.e. a typical third world economy with low economic complexity.

On the Micro or Firm level there needs to be a focus on continuously enhancing the performance on all productivity drivers:

- Managerial competence and capability together with managerial practices
- High-performance work systems
- Higher-Quality General Labour and Capital Inputs
- Integrated Innovation
- Appropriate Firm Structure in combination with absolute and relative firm size
- Participating in Global Value Chains or a high export level to end consumers
- Clustering
- Coopetition
- Demand generation
- Production Systems targeted at high cost technology intensive operating environments including implementing and mastering an appropriate Cyber-physical Interface that is changing dynamically to maximise the benefits to the firm of rapid market and technology changes

- Mastering Relevant Key Enabling Technologies (presently deemed to include[21]):
  - ICT including Big Data & Big Data Analytics, Artificial Intelligence as well as internet-of-things
  - Advanced Manufacturing Technologies including additive manufacturing and industrial robotics.
  - Industrial Biotechnology with specific focus on microbial consortia engineering and synthetic biology
  - Photonics
  - Advanced Materials.
  - Nanotechnology
  - Micro- and Nano-electronics.

Firms will also have to maintain two simultaneous strategic capabilities: the first will be a continuous focus on efficiency through cost reductions (using the principles of lean and other similar approaches) and productivity improvements (defined as getting more for less); the second will be a continuous focus on effectiveness through innovation (using the principles of integrated innovation to both create and capture value) and productivity improvements (defined as doing smarter things in smarter ways). (For further discussion of this see Roos, 2014c.) This increased dynamic will likely result in both increased entrepreneurial activities and a shorter average life span for a given organisation.

The consequences of not pursuing this will be a business failure rate that far outstrips the creation of new enterprises and hence will reduce the number of jobs available as well as the level of prosperity in the economy.

On the Individual level there needs to be a focus on continuous competence development as well as a high flexibility and acceptance for change. The consequences of not pursuing this will be a need for society to deal with the normal fallout of unemployment and reduced self-worth (Köper et al., 2013):

- Impairment in self-rated health state.
- Increase in certified sickness absence.
- Impaired sleep.
- Impaired 'recuperativeness'.
- Increased self-reported stress.
- Cardiovascular impairment and increased rates of related mortality.
- Increased drug addiction.
- Increased number of medical prescriptions / uses of psychotropic drugs.
- Increase in smoking and alcohol consumption.

Smart Social Programs

When it comes to addressing the increasing level of job-insecurity and flexibility of contractual relationships between employer and employee there is a need for "*Smart" Social Programs*. Simply providing disadvantaged individuals with a monthly check does not usually help those people to get back on their feet and become self-supporting, rather, such handouts tend to create cycles of dependency, lethargy, and lack of self-respect as well as external respect (Marchant et al., 2014). One model (Ford, 2009) proposes incentives that, if fulfilled, would have a positive effect on the income: the greater the response to the incentives, the greater the income the individual will receive. Such incentives might include participation in environmental stewardship, continuing education, child-care, art, music, volunteer work and other laudable activities. This proposal might eliminate the often negative effects of having "idle hands," low self-esteem associated with job loss, social stigma and lack of productive activities. Under this incentive model, the individual incomes

[21] The rapid development in science and technology will mean that the group of key enabling technologies will be in constant flux as some move out (a slow process) and others get added (a faster process).

received, while unequal, would not be unfair. The Danish Flexicurity model (http://denmark.dk/en/society/welfare/flexicurity/) which benefits employer, employee, unemployed and the taxpayer by combining high unemployment benefits with low job protection and high participation rate (Viebrock & Clasen, 2009). The pros and cons of the Flexicurity model as evaluated post the global financial crisis by Andersen (2015) are found to be:

Pros	Cons
• High rates of flows into and out of jobs enable firms to more readily adjust labour inputs to the business cycle and structural changes. • High job turnover rates make it easy for most unemployed workers to find jobs, implying that most unemployment spells are short. • In the wake of the global financial crisis, there has been no steep increase in long-term unemployment and no signs of increased structural unemployment. • It is fairly easy for youth to enter the labour market, and the youth unemployment rate is relatively low.	• Reconciling unemployment support with job-search incentives is challenging and places a heavy burden on active labour market policies. • The flexicurity model risks encouraging excess turnover of labour. • The system reduces incentives for firm-specific training. • Public finances are sensitive to the employment level, and for the system to function in a crisis, governments must ensure adequate fiscal space. • There is a high risk that low-educated workers will be marginalized in the labour market.

Given that any consideration of flexicure arrangements need to be empirically grounded in time and space, and carefully contextualised (Sultana, 2013) it is clear that there is a debate around the pros and cons as well as the contextual applications of this model and that modifications are both possible and in some contexts desirable. In both the Dutch and Danish approaches social dialogue is a central feature of any effort to design and legitimise flexicurity policies. Atkinson (1984) suggest that, in searching for their own context-specific pathways to flexicurity, jurisdictions need to consider four kinds of flexibility: Numerical/contractual flexibility—referring to employment status, and hence to the types of contract that can increase flexibility, such as fixed-term contracts, temporary employment, work on call, etc.; Temporal/financial flexibility—referring to atypical working hours and time account schemes, and hence to overtime, part-time, weekend working, irregular and/or variable hours, as well as to the variation in base and additional pay according to the individual or firm performance.; Productive/geographical flexibility—referring to production systems, and hence to subcontracting, use of freelance labour, etc.; Functional/organisational flexibility—organising flexibility within the firm by means of training, job-rotation, worker involvement, multi-tasking, and so on, based on the ability of employees to perform various tasks and activities. This calls for continuous updating of skills which makes workers more flexible with regard to their own skills. These different types of flexibility arrangements are counterbalanced by different forms of security arrangements: Job security - referring to security that is based on employment protection legislation, which constrains employers from easily dismissing workers; Employment security (also referred to as „transitional employment security") - referring to adequate employment opportunities through high levels of employability ensured by e.g. education and training. Income security - referring to the protection of adequate and stable levels of income. Combination security - referring to the security that comes from a worker being able to combine his or her job with other responsibilities or commitments than paid work. The success of the Danish and the Dutch models have inspired many jurisdictions to contemplate or launch modified versions of these models (Šidová & Vallušová, 2013). Looking at these contemplations and modifications it is possible to contruct a modified version that would aim to address the barriers identified (by e.g. Algan & Cahuc, 2006) for the inability of countries that lack public-spiritedness of their citizens

resulting in moral hazard issues which hinder the implementation of efficient public unemployment insurance models like the Flexicurity model. The modified model would work as follows: The employer is required to keep a competence profile of each employee with a plan to continuously develop the employee's competence that has to be adhered to (i.e. links to life-long learning). This plan is continuously updated to ensure that the employee, if having all the competences stated in the plan, is fully qualified for existing and new jobs in the company. There will be a minimum number of training days required every year to improve the employee's competence aligned with the competence profile. In addition, the employer will have to pay a small annual amount per employee towards a training fund. In return, when the market circumstances so dictate, the employer can lay off the employee with 24 hours' notice. The employee when laid off will be eligible for a government funded 70% of previous salary level [or the minimum legal salary if higher] as long as they participate in training to reach the targets set in the competence profile – this training will be funded by the training fund and provided by approved training providers [that are frequently audited]. The employee is obliged to be registered as a job seeker from day one of unemployment [will be registered automatically by the employer on lay-off] and will be required to accept any job offered on a salary level equal to the present 70% level or higher. If such a job offer is rejected the governmentally provided salary will drop to 70% of the previous 70% i.e. 49% of the original salary and so on down to the minimum legal salary. If the job-seeker is offered a job back in the original firm or a firm associated with the original firm or any of its equity holder's other firms in which they hold equity interest the job-seeker goes back on the original 100% salary plus a small premium due to now holding higher competence [the premium is a function of how much training has been received].

A further model is the Universal basic income. This concept has been around for some time and has gained, for different reasons, support across a wide range of the political spectrum but normally defined in different ways by different proponents (see e.g. De Wispelaere & Stirton, 2004; Petersen, 2014). The concept is deceptively simple in theory and very complex indeed in practice. The debate has been ongoing at least since 1905 in Scandinavia when Wicksell argued the case for a universal basic income (Wicksell, 1905). A good review of this debate can be found in Birnbaum (2005). Some practical alternative suggestions for designing a universal basic income for the UK context can be found in Torry (2015) and some interesting case studies in Koistinen & Perkiö (2014). In 2016 there was a referendum in Switzerland on whether or not to implement a version of universal basic income in which the proposal was rejected. De Wispelaere (2015) examines political strategies to build robust enabling coalitions in favour of universal basic income and identify the many principle problems.[22]

A variety of this is the German Hartz initiative commenced in 2003. This approach provides a source of income at or above the subsistence level for those currently out of the labour force and can be seen as short-term salaried employment that is possible to combine with social security support in order to provide a foothold in the labour market for those currently on the outside, but avoids the problem of high reservation wages for those currently receiving social security benefits. The initiative includes support for further vocational education from the German Federal Labour Agency, subsistence payments by the Federal Labour Agency, and job administration provided by public Staff Services agencies and this was later expanded for new types of employment exempt from, or covered by a gradually rising social security tax. The initiative also included a grant for people outside the labour market seeking to move into self-employment and was further expanded in 2004 when the unemployment benefits for the long-term unemployed were amalgamated with welfare benefits resulting in a somewhat lower level of social assistance. Eligibility is a function of savings,

[22] The universal basic income approach is built on the assumption that having an income is the same as being included which of course is not true, so this approach does not provide a solution to the permanent exclusion problem generated by technology driven structural unemployment.

life insurance and spouse income and the claimants must enter into a legally binding contract obliging them to improve their employment situation including accepting any kind of legal job. After the initiative was implemented German unemployment rate fell from almost 11% in 2005 to 5.5% by the end of 2012. There is still much debate on whether this reduction can be attributed to the Hartz reforms or to other factors. (Wennberg et al., 2014). Hertweck & Sigrist (2012), Krebs & Scheffel (2013) and Launov & Wälde (2013) argue that these reforms have had a very positive effect on the German labour market and on the unemployment rate although the later study is more critical. Wennberg et al. (2014) argue that since there was resistance and critique due to the Hartz initiative creating winners and losers the learning from the German experience are that even well-implemented reforms are likely to meet resistance when most people are risk-averse and gains and losses are unevenly distributed on the labour market.

The debate is not over and arguments can be made both for and against the three alternative ways forward presented above. These arguments need to be made in a given context and hence the author is unable to argue which of these (or any other newly created approach) is the right one for New Zealand[23].

Donofrio & Whitefoot (2015) have summarised the actions that the different actors need to take in the present environment from a US perspective. Translating this to a NZ environment and adding from the above key insights generates Table 4.

Actor	Recommended Actions
Businesses	• Companies should examine their business models to search for missed opportunities to leverage distributed tools and coordinate manufacturing and product lifecycle services. • Businesses should establish training programs to prepare employees for modernised operations (including increased levels of automation) and invest in advancing the education of their low- and middle-skilled workforce. • Manufacturers should implement principles and practices such as LEAN manufacturing that enable employees to improve productivity and achieve continuous improvement. • Businesses should work with local educational institutions on all levels to form partnerships to help students graduate with relevant skills and help them to take part in continuing education in the workplace. • Businesses should work with industry associations and higher education institutions to (1) establish national skills certifications that are widely recognized by employers and count toward degree programs, and (2) improve access for students and employees to gain these certifications. • Businesses should attract and implement programs to retain diverse employees, including along gender, race, and socio-economic background.
National Government	• Should convene stakeholders to identify and spread best practices for value creation across all sectors of the economy but with a specific focus on those that contributes to increased economic complexity. • Should establish incentives for businesses to invest and be involved in education programs. • Should reform immigration policy to welcome and retain high-skilled individuals with advanced science, technology, engineering, and mathematics (STEM) degrees, especially those educated by institutions with a high international standing among leading international businesses. • Should implement SBIR type programs with a focus on helping young businesses with both the desire and ability to grow to become globally competitive. • Should apply research funding towards understanding economy-wide barriers to increasing the economic complexity of the nation.

[23] Many of these arguments will boil down to the two-step process of: Firstly, society having a need for an increasing number of firms – all of which are increasingly profitable as a foundation for national prosperity. Secondly, the argument around how the generated surplus should be divided between the providers of capital and the providers of labour and other members of society using government as a distribution mechanism. There is normally agreement between the different stakeholders around the first step and then there is normally a sound disagreement around the optimal distribution in the second step. As has been shown in this paper, it is not a desirable direction to have an increasing Gini coefficient if long term prosperity is to be both grown and sustained. An example of ways to address this is the linking of productivity improvements and salary increases seen in Sweden between employers and unions.

	• Should emphasise programs that supports innovations grounded in all key enabling technologies as well as innovations in the associated business models. • Should incentivise the holding of equity for a minimum of seven years. • Should evaluate the use of soft loans (e.g. income contingent loans) as opposed to grants in the industry policy domain • Should facilitate industry and government cooperation to identify shared opportunities to invest in precompetitive research in long-term, capital-intensive fields. • Should support investment in world-leading infrastructure enabling the deployment of key enabling technologies • Should update the statistical data collection system to account for the irrelevance of service and manufacturing sectors when increasing number of firms partake in both service and manufacturing activities and when the mutual dependency of multiple sectors increase and when the basis for national prosperity is increased economic complexity. • Should establish incentives for businesses to invest and be involved in education programs. • Should partner with local governments, industry, higher education, investors, and economic development organizations to create local innovation networks (clusters, smart specialisation, etc.) • Should work with local governments to optimize the decision-making process for urban development investments and locations to facilitate the creation of innovation networks (clusters, smart specialisation, etc.). • Should work with businesses and local educational institutions on all levels to form partnerships to help students graduate with relevant skills and help them to take part in continuing education in the workplace.
Education Institutions	• Should work with businesses, government and local educational institutions on all levels to form partnerships to help students graduate with relevant skills and help them to take part in continuing education in the workplace. • Should provide opportunities for students to participate in team-based engineering design experiences and learn how to use emerging tools that enable new business creation (including design thinking and other complementary innovation skills). • Should improve the cost effectiveness of higher education. • Should work together with businesses and industry associations to (1) establish national skills certifications that are widely recognized by employers and count toward degree programs, and (2) improve access for students and workers to gain these certifications. • Should act to improve the inclusion of traditionally underrepresented groups in science, technology, engineering, and mathematics (STEM) fields as well as other disciplines required for value creation, such as market analysis and design. • Should continuously and simultaneously pursue excellence and relevance in both education and research
Other actors	• Researchers should further investigate and codify best practices for innovation and develop effective methods of teaching them. • University rating organizations should track and make transparent the cost-effectiveness of degrees at higher education institutions.

Table 5: Recommendations organized by actor for prosperous path forward in the US (Modified based on Donofrio & Whitefoot, 2015, pp. 7-9.)

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