

Advanced Manufacturing and Jobs in South Africa: An Examination of Perceptions and Trends

**Paper presented at the International Conference on
Manufacturing-Led Growth for Employment and Equality**

Johannesburg, 20 & 21 May 2014

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This paper is part of an emerging body of work on advanced manufacturing in South Africa. Other ongoing work includes

- The ***Implementation and Outcomes Evaluation of the National Advanced Manufacturing Technology Strategy***, an evaluation undertaken jointly by the Department of Science and Technology and the Department of Performance Monitoring and Evaluation in The Presidency, and
- The ***Advanced Manufacturing Research, Development and Innovation Roadmap Project***, a project led by the Department of Science and Technology in collaboration with the Department of Trade and Industry.

Kindly contact the corresponding author for more information on this paper and the other projects.

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The opinions expressed by the authors may not reflect those of their respective employers.

Abstract

Advanced manufacturing has been recognised globally as important to reverse de-industrialisation and to create decent, well-paying jobs. However, lingering perceptions regarding the negative correlation of advanced manufacturing and technological advancement on employment creates resistance to the adoption of advanced manufacturing practices by industry. These perceptions are particularly evident in South Africa against the backdrop of declining employment and falling manufacturing growth as a proportion of national growth, where adversarial management-worker labour relations are contributing to current and projected job reductions through mechanisation.

Combinations of new and old knowledge and technologies (components of advanced manufacturing) are increasingly being recognised as advanced and specialised factors of production to compliment traditional factors in the manufacturing sector. Evidence of this can be found in international private sector studies and in the global government manufacturing policy discourse which recognises talent-driven innovation and advanced technologies as the most important drivers of manufacturing competitiveness.

In this paper we show that the effects of advanced manufacturing, technological advancement and innovation on employment are far from simple and causal. From a theoretical perspective there is no consensus in academia on the effects on employment, with multiple factors contributing to job creation and job destruction in relation to different types of innovation. The literature also indicates that the effect on jobs varies depending on whether one examines the effects at a firm, industry or sector level. Results also seem to vary depending on the industry or services sector selected.

However, we do find empirical evidence that there is a strong and positive correlation between product innovation and direct job creation in the manufacturing sector, although there seems to be a slightly negative correlation between process innovation and direct jobs. In addition, we find that the proportion of indirect jobs to direct manufacturing jobs increases dramatically as manufacturing becomes more high-tech and advanced due to forward and backward (extensive supply chains) linkages and a sophisticated manufacturing service sector.

Making use of two examples we dispel several entrenched notions regarding advanced manufacturing and jobs. In the first example we illustrate how advanced manufacturing could revitalise a low-tech sector characterised by a large number of low-skilled jobs. In the second example we present a high-tech firm that is also labour-intensive.

It is imperative for the country to embrace and adopt advanced manufacturing approaches alongside conventional manufacturing methods for economic growth, employment and international competitiveness. Talent-driven innovation and advanced technologies need to become more important from the perspective of South African manufacturing stakeholders. The advanced manufacturing of today will become the conventional manufacturing of tomorrow, hence the South African manufacturing sector needs to rapidly embrace and adopt advanced manufacturing approaches in order to improve competitiveness and stave off further job losses and de-industrialisation.

The country has an established manufacturing base and good public-funded science and technology capabilities. What is required is for the public sector, the private sector and labour to work together for the manufacturing sector to become more competitive and thereby grow and create more jobs. We conclude by making several policy recommendations in this regard.

1 Introduction

South Africa is plagued by persistently high unemployment, growing inequality and poverty. To ameliorate these challenges the South African government has identified employment-intensive growth as a priority as per the New Growth Path, the National Development Plan, and the National Industrial Policy Framework and associated Industrial Policy Action Plans. Furthermore, government has identified manufacturing as a key sector to not only drive economic growth but also to create jobs.

It is well known that the South African manufacturing sector's contribution to growth and employment has been in decline for decades, which indicates that the sector is becoming progressively less competitive. The competitiveness of local manufacturers has historically been based primarily on the traditional factors of production such as cheap electricity, low-cost labour and plentiful raw material as well as industry protection such as incentives and trade barriers. This historical competitive edge has largely been eroded as manufacturers' cost base has risen due to rising administered prices and wages, without concomitant increases in productivity. South Africa's economy has also been affected by increased globalisation through being exposed to cheaper imported goods on the open market, with the country's industrial and trade policy instruments having to be amended in order to be compliant with World Trade Organisation rules.

Locally, government (specifically the Department of Science and Technology and the Department of Trade and Industry) has recognised the importance of developing the country's advanced manufacturing capabilities alongside conventional manufacturing, and for the economy to transition from being a resource-based economy to becoming a knowledge-based economy through technological innovation (DST 2002, DST 2003, DTI 2002, DTI 2007). The importance of advanced manufacturing and a competitive manufacturing sector underpinned by talent-driven innovation and advanced technologies is also acknowledged by the governments and private sector companies in countries and regions such as the United States of America, the United Kingdom, the European Union and the People's Republic of China.

However, there are perceptions that the adoption of advanced manufacturing approaches and the use of advanced technologies in the manufacturing sector are associated not only with low employment-intensive growth but also leads to job destruction. In this paper we will scrutinise these perceptions and examine the links between advanced manufacturing approaches and job creation.

2 Global manufacturing trends

2.1 Historical trends and the effects of off-shoring

Manufacturing in the last century was characterised by labour-intensive production and heavy engineering, with workers having a narrowly defined skill set and fixed job responsibilities, and such workers easily obtainable (DBIS 2009, p. 3 and Pietrantonio, Snyder & Stanlick 2013). This mode of manufacturing was dominated by input factors of production (labour, materials, capital equipment and energy) together with achieving greater efficiencies and productivity.

The emergence of globalisation naturally led to the gradual relocation of production to developing countries where lower wages could be paid, raw materials were cheaper and/or electricity costs were lower (Deloitte 2013b, p. 15 and Pietrantonio, Snyder & Stanlick 2013). This trend started with

the 'off-shoring' of the assembly of low technology ('low-tech') commoditised goods such as furniture, clothing and textiles, but has subsequently expanded into medium technology ('medium-tech') and even high technology ('high-tech') goods like computers and mobile phones as the manufacturing capacity of these regions matured and became more sophisticated (OSTP 2011, pp. 1-2). In many cases the design, research and development (R&D), logistics and distribution remained in the industrialised countries, while the assembly and component manufacturing were outsourced to the lowest-cost producers.

Off-shoring of production has had a significant effect both for developed and developing countries. With regards developed countries, off-shoring has led to job losses and shrinkage of manufacturing contribution to gross domestic product (GDP). For example, in the United States of America (USA) the contribution of manufacturing to GDP dropped from 27% in 1957 to 11% in 2009, and manufacturing employment shrank from 17.6 million jobs in 1998 to 11.6 million jobs in 2010 (OSTP 2011, p. 1). In addition, the USA's share of high-tech exports declined from 20% in the late 1990s to 11% in 2008, and the country's trade balance in advanced technology manufactured products moved from a surplus to a deficit in 2001, with trade deficits of \$17 billion and then \$81 billion in 2003 and 2010, respectively (OSTP 2011, p. 2).

Off-shoring to developing countries has enabled these countries to not only industrialise and grow, but also to develop high-tech industries of their own. For example, China's share of world high-tech manufacturing increased from 3% in 1995 to 19% in 2010, with a 50% share in computers, 26% in communications and 17% in pharmaceuticals and semiconductors (Pouris 2012). The country's trade balance in high-tech products transitioned from a deficit to a surplus position in 2001 followed by a trade surplus of about \$13 billion in 2003 and then approximately \$130 billion in 2008 (OSTP 2011, p. 3).

Developed countries have also discovered that off-shoring has had un-intended consequences. In addition to the loss of low-value jobs in the USA high-tech sector (e.g. in assembly), in certain sectors the country has also seen the loss of more sophisticated engineering and advanced manufacturing activities; the loss of knowledge, skilled people and supplier infrastructure; and the loss of investment and employment in manufacturing R&D (OSTP 2011, pp. 3-5). The short-term gains associated with off-shoring of low-tech, labour-intensive manufacturing activities have therefore had a profound long-term impact on the USA's manufacturing sector from a synergistic and systemic perspective.

Companies are now realising that the historical comparative advantage of cheap labour and materials does not translate into a strategy for sustained and long-term manufacturing competitiveness (Deloitte 2013b, p. 15). In addition, companies have observed rising labour costs in rapidly-developing countries like China, higher logistics and transportation costs (due to elevated global oil prices) and increasing risks (stock in transit on ocean-going vessels taking several months to get to market). They have also identified the need for production operations to be closer to the market, realised the advantages of co-locating production with R&D and expressed concerns regarding product quality (Deloitte 2013b, p. 15 and GOS 2013, p. 25).

These factors, together with the availability of low-cost shale gas in the USA have led some manufacturing companies to gradually 're-shore'¹ high-tech production back to the USA (Deloitte 2013b, p. 6). Global brands such as General Electric, Motorola, Texas Instruments, Intel and Apple have either announced plans to invest in state of the art manufacturing facilities in the USA, or are

¹ Re-shoring or on-shoring "involves the repatriation of production from low-cost locations; investment in onshore production to enhance capability; and sourcing of components from onshore, rather than from overseas" (GOS 2013, p. 25).

actively undertaking such activities. Additionally, firms in the USA are able to counteract high labour costs with high labour productivity (Deloitte 2013b, p. 15). The trend of re-shoring production has also been observed in the United Kingdom (UK) (GOS 2013, p. 25).

During the 2010 USA Congressional Elections both the Republican and Democratic parties attempted to attract voters by accusing their opponents of supporting policies that make it easier for companies to 'ship jobs overseas' (Wharton 2011). The Wall Street Journal reported on research conducted by the Massachusetts Institute of Technology in 2012 that showed that firms were under political as well as market pressures to move part of their production back to the USA (WSJ 2012). The USA government also realised that off-shoring had left the USA manufacturing sector vulnerable to the 2007/8 Global Financial Crisis, and that it was difficult to create manufacturing jobs in an environment of high unemployment and a de-industrialising economy.

The effects of rising labour costs in China has also led to China itself off-shoring its labour-intensive manufacturing activities to lower-cost developing countries in recent years (Davies 2012). This trend is set to continue with forecasts of job losses in labour-intensive manufacturing of up to 85 million jobs by 2022 as a result, together with predictions that China will continue to become a more efficient and higher-value manufacturing country (Ibid). This transition echoes the job losses, off-shoring of labour-intensive manufacturing and a move to advanced manufacturing which took place in Japan in the 1960s and South Korea in the 1980s.

In addition to the emerging re-shoring corporate trends, governments of developed countries and regions such as the UK, the European Union (EU) and the USA have either begun developing policies or have developed policies to re-establish leadership in advanced manufacturing in order to reverse de-industrialisation and create decent, well-paying jobs (GOS 2013, p. 8 and OSTP 2011, p. ii). For example, recent policy recommendations to the President of the USA centre on enabling innovation, securing the talent pipeline and improving the business climate for advanced manufacturing firms (OSTP 2012, p. v). Notably, there is a realisation in the USA that low-cost, basic manufacturing will not regain its former prominence in the country's economy (Giffi 2012, p. 24). This sentiment is largely echoed in the policy discourse of other developed economies.

2.2 Advanced and specialised factors of production for manufacturing competitiveness

As stated in Section 2.1, manufacturing competitiveness has historically been achieved predominantly through achieving greater production factor efficiencies and higher productivity and efficiencies in an ongoing incremental effort within firms and global supply chains. Porter (1998) explains that for each economic activity, goods are produced with a combination of factors that reflect the factor endowments of the entity in question. Thus, goods that can be produced with a relatively high proportion of labour to capital tend to be manufactured in countries where labour is relatively abundant. Arrow (1999) adds that knowledge is increasingly becoming an important factor of production that is affecting the ability of firms to remain competitive. While capital and labour are considered private goods, growth is achieved through increases in knowledge.

Increasingly the importance of non-traditional factors of production are being recognised (Keeble & Nachum 2002, Porter 1998, p. 78 and Zack 1999). Competitive advantage is increasingly depended on combining new knowledge and improved technologies - the so-called advanced and specialised factors of production (Daniels & Bryson 2002, Di Cagno & Meliciana 2005, Florida 2002 and Powell & Snellman 2004) (see Table 2.1). These advanced and specialised factors must be integrated into existing industries. Florida (2002) argues that increasingly governments recognize that knowledge, creativity and other soft factors (such as quality of housing, diversity of social activities and the

overlaps between different knowledge bases) are becoming more important in driving innovation and the technological upgrading not of only industries, but whole regions. This is part of the reason why innovation seems to emerge disproportionately in urban areas where people from different backgrounds interact. These soft factors are especially relevant for innovation that depends on a talented and highly mobile workforce.

Table 2.1: Factors of production².

Factor type	Description
Factor conditions	Covers natural resources, climate, location, unskilled and semi-skilled labour, and debt capital
Generalised factors	Includes the transport system, debt capital and well-motivated and qualified employees who can be employed in a wide range of industries
Advanced factors	Includes modern communications infrastructure, highly educated personnel such as graduate engineers and computer scientists, and university research institutes in sophisticated disciplines
Specialised factors	Involves narrowly skilled personnel, infrastructure with specific properties, knowledge bases in particular fields, and other factors with relevance to a limited range or even just to a single industry

Contemporary manufacturing competitiveness is determined by factors such as an appropriately-skilled workforce and technological change which results in smarter products and production processes, and also creates jobs that are highly skilled and well paid (DBIS 2009, p. 3, Giffi 2012, p. 24, GOS 2013, p. 8 and OECD 2013). At the heart of contemporary manufacturing are technologies such as digital manufacturing, novel advanced materials, nanotechnology, biotechnology, additive manufacturing (AM) and information and communications technologies (ICTs) (Ibid). Technologies such as AM have the potential to disrupt traditional supply chains through customisable, on-demand and cost-effective single unit production manufacturing in the consumer’s home. Many of these new technologies are possible because of the way that physical technology is combined with deep knowledge in different fields.

Knowledge does not ‘hang in space’, and is often embodied through a diversely skilled workforce and carried by humans. The more knowledge is codified and becomes ubiquitous and thus easier to access from anywhere, the more tacit knowledge shaped by experience and unique combination of regional factors and the environment they interact in matters (Cooke & Memedovic 2006, Cunningham 2012, p. 64 and Fagerberg & Verspagen 2007). Asheim and Gertler argue that the more knowledge-intensive economic activities become, the more geographically concentrated the activities tend to be. This is due to tacit knowledge that is not easily articulated or recorded as it is best shared through face-to-face interaction between partners who already share some basic commonalities (Fagerberg et al. 2005, p. 293). Indeed, one of the true benefits and characteristics of clustering is a concentrated and common labour pool, with workers interacting and sharing knowledge and experience outside the bounds of the firm (e.g. in social or professional settings.)

A global chief executive officer-level survey revealed that talent-driven innovation³ is the most important driver for manufacturing competitiveness in countries (Deloitte 2013b, p. 6). Table 10.2

² Adapted from Porter (1998).

³ The two highest sub-components in the survey were ‘quality and availability of scientists, researchers and engineers’ (1st out of 40) and ‘quality and availability of labour’ (2nd). Other sub-components are ‘quality of primary and secondary schools to produce student population targeted in science, technology, engineering, and math’ (15th), ‘quality of college/university partnerships in research and innovation’ (28th) and ‘effective and efficient immigration policies and processes to attract and retain talent’ (40th). Source: Deloitte (2013b, p. 51).

reveals that the traditional direct factors of production are ranked 3rd (labour and materials) and 6th (energy). This is a sign that internationally, companies are moving away from making investment decisions based solely on cheap labour and materials, and that in the long term, strategies for manufacturing competitiveness need to be underpinned by skilled, talented and highly productive human capital and innovation (DBIS 2009, p. 1, Deloitte 2013b, p. 6, Giffi 2012, p. 10 and Kaplan 2007, p. 15).

Table 2.2: Ranking of global drivers of manufacturing competitiveness⁴.

Index	Rank	Index score
Talent-driven innovation	1	10.00
Economic, trade, financial and tax system	2	8.42
Cost and availability of labour and materials	3	8.07
Supplier network	4	7.76
Legal and regulatory system	5	7.60
Physical infrastructure	6	6.47
Energy cost and policies	7	6.25
Local market attractiveness	8	3.99
Healthcare system	9	2.48
Government investments in manufacturing and innovation	10	1.00

The above finding implies that nations cannot increase their growth without a talent supply that provides talent with the appropriate advanced skills and in the requisite quantities (Giffi 2012, p. 12). Hence a nation's ability to attract, develop and retain talent with advanced skills is not only important but will become an increasingly competitive arena in future.

The importance of talent-driven innovation reflects the changed skills requirements of manufacturing globally. In the past workers would be required to possess technical skills for narrowly defined duties, whereas in future workers need to have a far broader (multi-skilled) technical competency, undertake knowledge-based work and possess 'soft' skills (GOS 2013, p. 22 and Pietrantonio, Snyder & Stanlick 2013).

Manufacturing firms continue to update their equipment and introduce new technologies into the workplace requiring workers with more advanced skills, but there is a dire global shortage of appropriately skilled and qualified workers. The industry need for advanced skills is reportedly accelerating for workers across the spectrum from factory floor operators to 'white-collar' workers (university-educated), with workers needing not only to acquire advanced skills but to renew and maintain them continuously (Eggers & Hagel 2012).

Internationally on the supply side, lagging workforce development and the fact that the education sector experiences difficulty keeping pace with the skills demanded (i.e. skills rapidly becoming outdated) is contributing to the skills shortage (Eggers & Hagel 2012, IFC 2013, pp. 96-97 and McDougale & Furr 2013a). In South Africa a 2007 study revealed that manufacturing companies are concerned about a perceived decline in the quality of graduates from local higher education institutions, and that high-level graduate skills are in short supply (Kaplan 2007, p. 15).

In the USA, 6 million manufacturing jobs have been shed in the last decade, but a recent study revealed that 600 000 manufacturing jobs are unfilled due to companies not being able to secure workers with the required skills (Eggers & Hagel 2012). A shortage of sufficiently skilled labour also

⁴ Adapted from Deloitte (2013b, p. 7).

exists in the economic sectors connected with the EU's 6 key enabling technologies (KETs) due to the highly multi-disciplinary nature of KETs. In the area of nanotechnology and photonics there are estimates that 400 000 and 80 000 additional qualified experts will be needed in the EU by 2015 in the two fields respectively in order to meet the skills needs of the anticipated rapid industry growth together with the expected retirement of skilled workers (EC 2012, p. 6).

Internationally there are an estimated 45 million job seekers joining the labour force each year (IFC 2013, pp. 96-97). However, these job-seekers need to acquire the right skills to secure a job. The International Finance Corporation estimates that advanced economies will experience a surplus of 32 to 35 million workers without a university education by 2020, with estimates of approximately 58 million in developing countries (Ibid).

The above challenges (demand exceeding supply) in relation to meeting the skills needs of contemporary manufacturing demonstrate the strong correlation between technological advancement and employment in manufacturing. There is also some proof that KETs are facilitating the creation of high quality jobs in small and medium enterprises. In the photonics sector the bulk of the 5 000 European companies are SMEs (EC 2012, pp. 3-4). In the field of nanotechnology, estimates show that there has been a 25% increase in the number of workers globally to 160 000 between 2000 and 2008. And in the micro- and nanoelectronics industry (and associated downstream ICT industries) more than 700 000 jobs were created in the last decade in Europe (Ibid).

These priorities are reflected in government policy of key countries and regions. For example, the EU has committed €1.2 billion for a "Factories of the Future" research program to support the re-industrialisation of the region's manufacturing base (McDougle & Furr 2013b, p. 7). With a budget of nearly €80 billion available over 7 years (2014 to 2020), the EU's Horizon 2020 framework programme supports the systemic integration of research and innovation activities (but specifically focused on the KETs of micro-/nanoelectronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing technologies), thereby facilitating the conversion of knowledge into marketable goods and services (European Commission and EC 2012, pp. 8, 10).

In conclusion, this section underlines the rising importance of the so-called advanced and specialised factors of production (new knowledge and advanced technologies) over the more traditional factors of production (labour, materials, capital equipment and energy). Firms and governments are increasingly acknowledging the increased importance of knowledge (particularly tacit knowledge) and talent. More resources are being directed towards talent-driven innovation (innovation via a skilled workforce which can produce new knowledge and has the skills to work in a sophisticated manufacturing environment) and the deployment of advanced technologies within firms (with these technologies often brought about through R&D). The increased importance of the combination of new knowledge and advanced technologies are often more visible in the fast growth of hi-tech industries, products and solutions and is particularly visible in urban areas.

The provision of advanced factors of production places different pressures on governments and industries. For governments, the pressure is to create public goods that go beyond the basic factors, and conditions that support experimentation and ongoing learning. This affects issues such as publicly funded research, education policy, structural change and institutional reform. For industries, the challenge is to integrate new thinking, different knowledge domains and new technologies into existing organisations, markets and technologies.

3 Trends in South African Manufacturing

It is well-known that the manufacturing sector's contribution to South Africa's GDP and direct employment has been in a slow decline for decades. Industry lobby organisations such as the Manufacturing Circle (MC) predict that the situation is likely to persist into the future unless the situation is addressed to improve the sector's competitiveness (MC 2012, p. 2). In fact, a leading financial newspaper goes so far as to venture that the economy will de-industrialise within the next decade if growth remains slow and the stubbornly high unemployment rate persists ('Service economy is not enough' 2013). South Africa's manufacturing sector can be described as diverse, but the scale of production is low and declining. Many South African manufacturers now depend on supply chains from Asia. South African manufacturers have also been affected by increased import competition and the volatility of the Rand exchange rate.

Rodrik (2006, p. 14) argues that the relative profitability of the South African manufacturing sector decreased by around 30% between 1980 and 2004. It can be argued that the relatively lower profit margins in the domestic manufacturing sector could explain why the sector has struggled to attract widespread foreign direct investment. Elsewhere, Rodrik (2006, p. 9) argues that the manufacturing sector's inability to create low and semi-skilled jobs was at the centre of South Africa's unemployment and insufficient growth problems. For instance, Rodrik argues that a strong decline in the relative price of manufactured goods was the predominant cause for the decrease in manufacturing employment (2006, p. 20).

A poll of MC members revealed that overall, manufacturing firms would be reducing their employment levels during the course of 2014 (MC 2013b). Furthermore, a growing portion of the MC member firms that indicated future job cuts expect such cuts to constitute 15% or more of their workforce (ibid). Reasons cited for this trend included a lack of workforce skills, the inability to fill vacancies due to high labour costs, production scale-backs due to "non-competitive pricing", plant shutdowns due to high fixed costs and subdued demand. Many multinational companies operating in South Africa also bemoan the onerous administrative burden regarding international expert immigration, which makes it difficult to compensate for local skills gaps using mobile international expertise.

Most telling, however, is a self-reported growing trend by manufacturers to mechanise and automate (MC 2013b). This is reportedly due to a volatile and destabilised labour force environment combined with manufacturers' perceptions that their workers "had a poor attitude to productivity and work in general" together with high wage increase expectations and the resultant response by manufacturers to protect and maintain their levels of production (Greve 2013). The knock-on effect of the automation trend is job redundancy; but at the same time skills shortages in automation and robotics are being observed and some companies are having to train their staff to manage automated systems (MC 2013a).

The MC maintains that an average manufacturing growth rate of 10% or more is the solution for sustainable long-term and job-inclusive growth (Abedian et al 2011, p. 6). The MC has set four goals in order to achieve such a growth rate and to become more globally competitive, specifically

- A supportive and investor-friendly business environment;
- Being the gateway for exports to Sub-Saharan Africa but competing with imports on an equal footing domestically;
- Beneficiation of natural resources; and
- Locally-manufactured products being highly-regarded and preferred by South Africans⁵.

⁵ Adapted from MC (2012, p. 3).

The actions recommended in support of these four goals appears to make no mention of improving or enhancing the innovative capacity of the local manufacturing sector through the adoption of advanced manufacturing practices, apart from aiming to “Promote and maintain a skills pipeline”. This is in contrast to the global trends of embracing new knowledge and advanced technologies (advanced and specialised factors of production as per Section 2) in order to create new solutions for old and new problems. These four goals implies that the MC, representing many leading domestic manufacturers appears to have a traditional perspective that sees jobs being created through higher growth, but does not elaborate how this will be brought about.

To illustrate the differences between South African and global manufacturing, a study by Deloitte revealed that South African manufacturers ranked cost and availability of labour and materials, and energy cost and policies 1st and 3rd respectively as determinants of manufacturing competitiveness (Deloitte 2013a, p. 10) (Table 3.1). Internationally manufacturers rank talent-driven innovation as the most important determinant of manufacturing competitiveness, with cost and availability of labour and materials in third place (Deloitte 2013b, p. 6). South Africans rank talent-driven innovation as the 7th-most important driver of competitiveness in stark contrast to their international counterparts.

This reveals that the historical, low-cost paradigm within South African manufacturers of focusing on the traditional factors of production persists into the current day. It appears as though local manufacturers have by and large not made the necessary transition to a new paradigm to deal with the effects of globalisation and the removal of protectionist barriers through the inclusion of advanced and specialised factors of production (new knowledge and advanced technology). In order to become globally competitive South Africa’s manufacturers need to focus on being innovative through the adoption of advanced manufacturing practices in addition to being focused on costs.

Table 3.1: Comparing the South African manufacturing firm perspective on competitiveness drivers with that of global manufacturing⁶.

Index	Global Rank	South African Rank
Talent-driven innovation	1	7
Economic, trade, financial and tax system	2	4
Cost and availability of labour and materials	3	1
Supplier network	4	6
Legal and regulatory system	5	9
Physical infrastructure	6	5
Energy cost and policies	7	3
Local market attractiveness	8	2
Healthcare system	9	10
Government investments in manufacturing and innovation	10	8

In response to the steady decline in manufacturing activity, the Industrial Policy Action Plan (IPAP) of the Department of Trade and Industry (**the dti**) has a target of 2 447 000 additional indirect and direct jobs by 2020 (Davies 2010). Out of this figure, 350 000 direct jobs are projected to emanate from the manufacturing sector (EDD 2011). The IPAP, as well as the Department of Economic Development’s New Growth Path sees an expanded manufacturing sector as the primary and central driver of the economy (DTI 2013) not only for the direct employment-intensive nature of

⁶ Adapted from Deloitte (2013a, p. 10).

manufacturing, but also because of the sector's multiplier effects and potential to create a more equitable economy (Coleman 2013).

4 What is advanced manufacturing?

There is no internationally-accepted definition of advanced manufacturing according to a 2010 situational analysis of the South African advanced manufacturing industry commissioned by **the dti**. The report proposed a definition for advanced manufacturing as a "collection of high value adding manufacturing processes, management techniques, technologies and knowledge capital that occupy the top-tier in manufacturing industries and drive competitiveness in the local and global economies" (Frost 2010). The report furthermore associates a combination of sophisticated computer controls; concentrated bodies of expertise; advanced processes; high value products; processes, products and technologies that are not easily replicable; focused R&D and being industry leading/industry changing with advanced manufacturing.

the dti subsequently adopted the above definition of advanced manufacturing, which is reflected in the Department's 2013 IPAP (DTI 2013). The IPAP furthermore states that high-value goods and services require a minimum set of features, namely "advanced manufacturing technologies, the development and exploitation of intellectual property (IP), a sufficient IP protection regime and globally competitive financial and support instruments", and that advanced manufacturing integrates other advanced technologies such as high-performance computing, automation and control systems, high-precision manufacturing linked to intelligent production systems, and sustainable and environmentally friendly processes and technologies (ibid).

In the USA, the President's Council of Advisors on Science and Technology defines advanced manufacturing as a group of activities that depend on the use and coordination of information, automation, computation, software, sensing and networking, and/or makes use of cutting edge materials and emerging physical or biological scientific capabilities (OSTP 2011, p. ii). Examples of these capabilities include nanotechnology, chemistry and biology. Furthermore, the USA's definition of advanced manufacturing includes new methods of making existing products or making new products emerging out of new advanced technologies (ibid). This definition also makes it clear that advanced manufacturing is not a sub-sector of an economy; it describes a cross cutting activity in the economy.

The Department for Business Innovation and Skills in the UK has a similar description of advanced manufacturing. It categorises businesses that use R&D, new technologies, state of the art equipment, a high degree of design and highly skilled people (including scientific skills) to make technologically complex products, processes and associated services of high value as advanced manufacturing firms (DBIS 2009, p. 1). Furthermore, the Department states that advanced manufacturing is often based on new industrial platform technologies that have multiple commercial applications such as composite materials to replace metals in the shipbuilding, aerospace, car manufacturing and construction sectors, spanning the spectrum from large aerospace companies all the way to small companies created through the spin-out of university research (ibid). This definition makes it clear that more advanced manufacturing approaches will displace or substitute more traditional manufacturing activities.

The Chinese Academy of Sciences views market analysis, product design, machining, assembly, sales, maintenance, services and recycling as important for advanced manufacturing alongside conventional manufacturing processes (Wang et al. 2010). Furthermore, it believed that future technology development for advanced manufacturing will be determined primarily by

“informationisation” (ubiquitous information) and “greening” (green manufacturing), but also by globalisation, “intelligentisation” and integration of multi-disciplines. The ubiquitous information theme would be underpinned by technologies such as industrial wireless networks, sensor networks, radio frequency identification and micro-electromechanical systems, whereas the green manufacturing theme entails resource- and energy-efficient manufacturing through pollution reduction and within the entire product life cycle (from design through to recycling).

Elements of the above definitions and descriptions of advanced manufacturing are evident in the Advanced Manufacturing Technology Strategy (AMTS) of the Department of Science and Technology (DST). The innovation pillar of the 2002 National Research and development Strategy (NRDS) entailed the creation of five technology missions to promote economic and social development, including an Advanced Manufacturing Technologies and Logistics Strategy in support of **the dti’s** Integrated Manufacturing Strategy (IMS) (DST 2002, p. 42). Importantly, the IMS recognised the need to move from raw material-intensive manufactured goods towards increasingly knowledge-intensive goods and services, supported by the provision of the necessary human capital and appropriate technology strategies to improve the manufacturing sector’s competitiveness (DST 2002, p. 5 and DTI 2002, pp. 28, 30). The IMS also states that South Africa’s future competitiveness will in part hinge on the ability of the manufacturing sector to innovate and to master advanced manufacturing technology domains (ibid).

The AMTS focuses on the technology areas of advanced materials, product technologies, production technologies, logistics, cleaner production technologies and ICT in manufacturing (DST 2003, p. 11) across several industrial sectors⁷. The strategy entailed utilising the science base for human resource development (HRD) and knowledge generation together with industry-focused R&D and technological innovation.

The strategy recommends a focus on manufacturing to achieve higher growth rates to extract greater value from a move to higher value-added manufacturing activities, the export of manufactured goods, and downstream value-addition relating to South Africa’s finite natural resources (DST 2003, p. 6). The ultimate aim of the AMTS is to assist in improving the competitiveness of the South African manufacturing sector via targeted programmes that have an impact on industry development, world-class manufacturing, and innovation and R&D, all underpinned by HRD (DST 2003, p. 12).

For the purposes of this paper, we define advanced manufacturing as follows⁸.

Advanced manufacturing is an approach that

- Depends on the use and integration of information, knowledge, state of the art equipment, precision tooling, automation, computation, software, modelling and simulation, sensing and networking;
- Makes use of cutting edge materials, new industrial platform technologies⁹, emerging physical or biological scientific capabilities¹⁰ and green manufacturing philosophies; and/or
- Uses a high degree of design and highly skilled people (including scientific skills) from different disciplines and in a multi-disciplinary manner.

⁷ The automotive and transport, cultural and craft, clothing and textiles, metals and minerals, chemicals, aerospace and the capital goods sectors were deemed to hold the greatest potential for growth and impact on the overall SA manufacturing sector at the time (DTI 2002 and DST 2003, p. 11)

⁸ Primarily an amalgamation of the definitions of Advanced Manufacturing in OSTP (2011) and DBIS (2009), but also incorporating elements of Wang et al. (2010).

⁹ Such platforms have multiple commercial applications, e.g. composite materials, and exhibit high spill-over effects.

¹⁰ E.g. nanotechnology, biotechnology, chemistry and biology.

Advanced Manufacturing includes a combination of the following.

- Product innovation: Making new products emerging out of new advanced technologies (including processing technologies).
- Process innovation: New methods of making existing products (goods or services).
- Organisational innovation or business model innovation: Combining new or old knowledge and technologies with traditional factors of production¹¹ in non-traditional fields or disciplines in unique configurations.

Although some sub-sectors such as biotechnology or genetic engineering are by their very nature more advanced, we do not see advanced manufacturing as a sub-sector of the economy, but rather as a cross cutting approach. It can be foreseen that more advanced manufacturing approaches will eventually affect all sub-sectors.

The implication of this definition is that the emphasis should be on ensuring that more of South Africa's traditional manufacturers embrace advanced manufacturing approaches proactively, or that new more advanced manufacturers emerge that will challenge traditional incumbents. For government, the priority should be to support the creation of more advanced and specialised factors of production (viz. new knowledge and advanced technologies) (see Section 2), while the private sector should search and exploit opportunities to combine new and old knowledge and technologies to solve existing problems, take advantage of emerging opportunities and fill the gaps that are unique to the regional context. In Section 9 we will elaborate on the policy recommendations.

5 Perception of the negative impact of advanced manufacturing on jobs

When the importance of advanced manufacturing is mentioned in public, some commentators impulsively respond that the increased use of advanced manufacturing approaches is undesirable because it displaces labour. We also believe that part of the sensitivity of this topic relates to the incorrect, colloquial (and often interchangeable) use of the terms 'technology' and 'advanced'. While it cannot be denied that new technology often substitutes for labour, we believe that this matter is far more nuanced and should be explored in more detail.

5.1 'Promoting advanced manufacturing will replace people with technology'

Intuitively one is inclined to equate technological advances and associated increases in productivity with a concomitant decrease in employment because fewer workers are required for the same production outputs (IFC 2013, p. 18).

In addition, the conventional view is that the benefits of innovation accrue disproportionately to stakeholders that control the distribution channels of inputs and outputs, shareholders, managers and highly skilled workers in technically sophisticated enterprises, with the broader labour pool not benefiting fairly in the benefits (Dutz et al. 2011, p. 3). This view is echoed in local media reports ('SA's workers in a parlous state' 2013 and Gleason 2013) of an Organisation for Economic Co-operation and Development (OECD) study which reportedly concluded that rapid advances in technology¹² are primarily responsible for the steady fall of labour's share of income since the 1980s

¹¹ Labour, materials, capital goods, energy, etc.

¹² 'Technology' in this context includes advances in materials, robotics, communication and computing.

in contrast to the increasing gains enjoyed by the owners of capital from productivity gains over the same period.

However, an examination of the primary material (OECD 2012) that the journalists above are reporting on reveals that the report in fact ascribes as much as 80% of the decline in the labour share to total factor productivity (TFP) growth and capital deepening. The authors of the relevant chapter of the OECD report then casually links TFP growth and capital deepening to the replacement of workers with machines brought on by innovation through the spread of ICTs without providing any referenced in support of this opinion, nor explaining the rationale behind the supposed linkages between cause and effect.

In this particular instance, not only have the authors of the OECD report tenuously linked worker substitution directly with the spread of ICTs, but the local media has misinterpreted this link further and substituted “the spread of ICTs” with “rapid advances in technology”. Such reporting reinforces the simplistic misperception that technological advancement leads directly to job destruction.

The fears that technological change will lead to mass job losses and unemployment have been in evidence since the dawn of the Industrial Revolution. A famous example occurred in the early 19th Century when textile artisans protested against the deployment of stocking frames, spinning frames and power looms, all labour-saving machinery in England¹³. The main objection of these ‘Luddites’ was that the machinery could be operated by less-skilled (and therefore cheaper) labourers, leading to job losses amongst skilled workers.

In South Africa there are persistent perceptions that the introduction of advanced technologies in the manufacturing sector either does not create jobs¹⁴ or actually leads to job losses through automation (Burger 2012 and Wild 2012). In Wild (2012), Laubscher states that while it is imperative that South Africa develops advanced technologies for the manufacturing sector to be internationally competitive, that these same technologies will lead to job redundancies and would thereby undermine the country’s strategies to address the over-supply of unskilled labour. Even the Minister of Science and Technology, the Honourable Derek Hanekom (MP) (2013) has expressed concerns that technological advancement and innovation may result in job losses and contribute to widening inequality, particularly in light of the high costs of tertiary education.

However, Cunningham, Jacobs and Vorster (2010) found that in the electronics sector there is a strong positive relationship between the use of advanced technologies (and especially highly qualified people) and employment for low-skilled workers. A firm that develops an electronics product with a few engineers could easily create several dozens of jobs for lower skilled workers in a production environment that combines state of the art equipment with more traditional jobs such as assembly, packaging and distribution (see Section 6.2 on multipliers).

It is also important to recognise that manufacturing is not homogeneous with regards the proportion of capital- and labour-intensiveness. Zalk (2014, pp. 4-5) describes three categories of manufacturing that inherently have varying potential for direct employment creation in relation to capital investment, as follows.

- Primary manufacturing which is inherently capital- and energy-intensive: These manufacturing operations reside within the ‘Minerals-Energy Complex’ sector and offer little scope to substitute labour for capital. Production entails converting primary resources into

¹³ Source: Wikipedia.org.

¹⁴ In Wild (2012) Dr Paul Potgieter, the Aerosud Group Managing Director states that high-tech industries cannot be mass employers due to high quality and repeatability requirements which are assured through mechanisation and automation.

semi-processed goods, e.g. steel, chemicals and aluminium. However, the role of such operations is to foster greater employment in sectors that are medium to highly labour-intensive through the supply of intermediate goods.

- Manufacturing in which capital and labour are complimentary. These operations typically exhibit a concomitant rise in employment with capital investment. Examples include the fabrication of metals and plastics; capital and transport equipment; and parts of agro-processing and the automotive value chain.
- Manufacturing which is intrinsically labour-intensive. Examples include the South African clothing and footwear sectors which often experience severe distress as they bear the brunt of increased competition from imported, low-priced, labour-intensive goods due to a massive global increase in unskilled labour. However, employment declines can be arrested and employment gains through a strategic focus on achieving higher quality, reliability and shorter delivery times.

5.2 Inconsistent use of terminology, conflation of concepts and incorrect use of terms

In Section 4 we sought to clarify what we meant by ‘advanced manufacturing’ through proposing a definition for the concept. This section highlights the interrelatedness of the concepts of innovation, technology, knowledge and high-, medium- and low-tech products or sectors, and how they differ from and contribute to an advanced manufacturing approach. While these concepts are interrelated, they are not interchangeable. It is therefore important to take note of this when examining how these factors impact on jobs.

Technology

The commonly-held understanding of technology narrowly refers to technical artefacts (typically consumer electronics such as smartphones or tablet computers), hardware or computer software. However, this does not reflect the complexity of how a technical artefact is used, specifically the need for knowledgeable people to use artefacts to make a product, and the necessary organisational methods to configure the knowledgeable people and the artefacts to make a product (Cunningham 2012).

In Cunningham (2012), Enos (1991) defines technology broadly to include four components, viz. technical hardware (machines and equipment in a specific configuration make goods or provide a service), know-how or knowledge (comprising scientific, technical and codified knowledge, and formal qualifications), organisation (specifically the managerial methods that links the ‘hardware’ and ‘know-how’ components and that integrates the other elements into a firm or organisation) and the product or process (goods or services produced). These components are depicted graphically below in Figure 5.1.

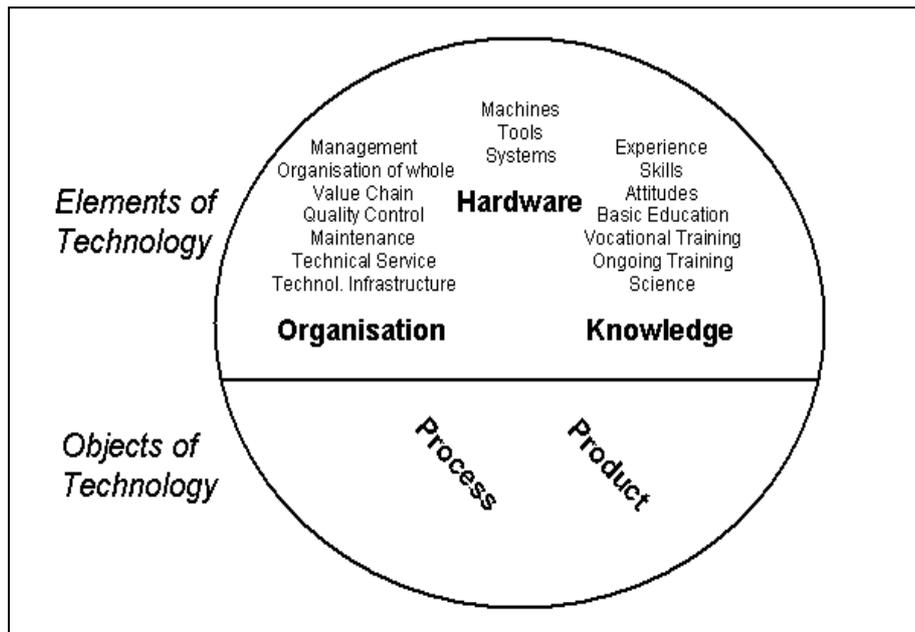


Figure 5.1. Graphical depiction of the four components of technology¹⁵.

The knowledge-based economy

The concept of technology and the role of technological innovation need to be viewed in the context of the knowledge-based economy¹⁶. The concept of a knowledge-based economy was introduced to South African in the NRDS within the context of transitioning the South African economy from being reliant on natural resources towards becoming a knowledge-based economy in order to accelerate economic growth, create wealth on a sustainable basis and improve the quality of life of South Africans (DST 2002).

The effect of the increasing knowledge intensity on the economy has been discussed in Section 2 (as part of the advanced and specialised factors of production), and again as an element of technology in the above sub-section. However, it is worth addressing the concept of a knowledge-based economy briefly.

The notion of the knowledge-based economy seeks to integrate knowledge into traditional (neo-classical) economics. Classical input-output economic theory was viewed as not being sufficient able to explain long-term growth over and above the production factors of labour, capital, materials and energy, and the resulting outputs of the economy (OECD 1995 in Godin 2003).

This new economic growth theory recognises the knowledge base as an additional factor of production (ibid). Knowledge-based economies are characterised by a high degree of investment in innovation (including R&D); in the production, distribution and use of new knowledge; and in the enhancement and/or acquisition and diffusion of existing knowledge, intensive use of acquired technology and a highly educated workforce (Foray & Lundvall 1996, OECD 1996, OECD 2001 and Webb 2001 all in Godin 2003, pp. 11-12). This does not imply that industrialised countries no longer manufacture basic products, but that they typically do so by combining new knowledge and advanced technologies.

¹⁵ Source: Enos (1991) in Cunningham (2012).

¹⁶ It would be a mistake to treat the knowledge-based economy as a new separate economy. The knowledge-based economy is a concept that is infiltrating all aspects of our lives.

Some commentators are of the opinion that knowledge (human capital and structural capital) is the prime determinant of economic development (Edquist 2001 and Lundvall 1992). Therefore knowledge may conceivably be seen as a far more important resource in the modern economy than physical capital (machinery and buildings), and hence the most important process in the world today is learning (ibid). Furthermore, if knowledge and learning are the primary determinants of economic growth and development then the best strategy for economic growth is one that strengthens the knowledge base of a country (Johnson & Lundvall 2001 and Edquist 2001). Indeed, Lundvall asserts that the success of individuals, firms and national systems is determined by the capacity to learn and adapt within a context of an accelerating rate of change (Lundvall 1996).

Innovation

According to the OECD, an innovation is the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organization or external relations (OECD 2005). Product innovation takes place when the new or improved product is introduced into the market; whereas processes innovation, marketing method innovation or organisational method innovation takes place when they are brought into actual use in the firm's operations (ibid). Innovation can at the lowest level be new to the firm, new to the market, new to the world, etc., but innovation can only take place at the firm level. An innovation can be brought about through R&D or without R&D.

Low-tech, medium-tech and high-tech

The United Nations Industrial Development Organisation (UNIDO) makes use of the classifications developed by Sanjaya Lall for categorising manufactured goods according to their International Standard Trade Classification (ISIC) description and code, and the OECD technology classification method^{17, 18} (UNIDO 2013, p. 60). Table 5.1 shows the classification of various goods into low-tech, medium-tech and high-tech categories.

Table 5.1: Product categories and associated technology groupings¹⁹.

International Standard Industrial Classification (ISIC)	ISIC code (Revision 3)	Technology group
Food and beverages	15	Low-tech
Tobacco products	16	Low-tech
Textiles	17	Low-tech
Wearing apparel, fur, leather products and footwear	18, 19	Low-tech
Wood products (excluding furniture)	20	Low-tech
Paper and paper products	21	Low-tech
Printing and publishing	22	Low-tech
Furniture; manufacturing, not elsewhere classified	36	Low-tech
Coke, refined petroleum products and nuclear fuel	23	Medium-tech
Rubber and plastic products	25	Medium-tech
Non-metallic mineral products	26	Medium-tech

¹⁷ The OECD's technology classification method is based on R&D intensity relative to value added and gross production statistics.

¹⁸ UNIDO's high-tech product category is a combination of the OECD's high-tech and medium- to high-tech product definitions; UNIDO's medium-tech product category uses the OECD's medium- to low-tech product definition; and UNIDO's low-tech product category uses the OECD's low-tech product definition.

¹⁹ Source: UNIDO (2013, p. 60).

International Standard Industrial Classification (ISIC)	ISIC code (Revision 3)	Technology group
Basic metals	27	Medium-tech
Fabricated metal products	28	Medium-tech
Chemicals and chemical products	24	High-tech
Machinery and equipment, not elsewhere classified; office, accounting and computing machinery	29, 30	High-tech
Electrical machinery and apparatus; radio, television and communication equipment	31, 32	High-tech
Medical, precision and optical instruments	33	High-tech
Motor vehicles, trailers, semi-trailers and other transport equipment	34, 35	High-tech

Summary

Section 4 proposes a definition for advanced manufacturing. The definition includes the elements (organisation, hardware and knowledge) and objects (products and processes) of technology, combinations of new and old knowledge and technology as additional advanced and specialised factors of production through organisational and/or business model innovation, product innovation and process innovation. It is also clear from the information presented above that the categories of low-tech, medium-tech and high-tech apply to products (and also to firms or sectors), primarily for import-export trade data purposes.

A firm that makes high-tech goods may not necessarily employ advanced manufacturing approaches. For example, an electronics firm which imports components and merely assembles them may well be classified as a high-tech firm, but due to the absence of new technologies and innovation, the production that takes place within such a firm would not be classed as advanced manufacturing.

On the other hand, firms may well make low- or medium-tech products, but their production operations may well be described as advanced manufacturing. For example, a company in the food and beverages sector may make use of biotechnology platform technologies, use highly-skilled workers and undertake product, process and organisational/business model innovation, in which case this 'low-tech' firm does truly undertake advanced manufacturing. Another example is in the medium-tech foundry industry. A foundry using an AM platform combined with computer aided design and simulation software can make production moulds to test a new product which is subsequently cast using traditional approaches. In this instance advanced manufacturing is used to make medium-tech products.

With regards to inclusive job creation, high-tech companies that use advanced manufacturing approaches can create jobs for workers at all skills levels, i.e. not only for high-skilled university graduates. This may entail low-skilled workers using sophisticated tools or production methods in operations. Equally, low-tech companies that use advanced manufacturing approaches can contribute not only to job preservation but also to job creation. We will illustrate the positive correlation of the use of advanced manufacturing in a low-tech sector and a high-tech firm using two examples in Section 7, specifically the use of AM in the footwear sector and high-tech composite products in the aerospace sector.

A counter-factual argument would be that if South Africa does not invest in innovation and the increased use of more advanced manufacturing approaches, the result would be a less competitive manufacturing sector leading to even more local job losses.

6 Arguments in support of advanced manufacturing

Arguments can be made in support of advanced manufacturing as being critical for the wealth and prosperity of a country. For instance, many low-skilled workers have found work in hi-tech sectors due to the high multiplier effects of the manufacturing sector. Innovation in new products or new markets also directly creates new jobs, new career options, and more opportunities for economic diversification. Lastly, advances in manufacturing will also better use finite resources in the country, thus increasing productivity, wages and thus wealth.

6.1 *The observed effect of innovation on jobs*

The fears of significant job losses as outlined in Section 5.1 have not come to pass. Commentators such as Rogoff have suggested that the flexible nature of market economies have absorbed the effects of technological changes (Rogoff 2012). In WEF (2014), Shibulal states that “Technology is often blamed for unemployment, but jobs are not disappearing. They’re evolving. Losses in one sector often mean gains in another.”

Section 5.1 examined the often unfavourable perceptions of technological advancement on jobs. Now that the concepts of technology, innovation, the knowledge-based economy, low-tech, medium-tech, high-tech and advanced manufacturing have been elaborated on in Sections 4 and 5.2, this section will examine the theoretical basis of how technological advancement could affect employment, and will also refer to empirical studies undertaken in industry, primarily in relation to the manufacturing sector.

Firstly, the issue of how technological advancement affects employment is long-running and has been the subject not only of robust public debate but also of research at a theoretical and an empirical level (Freeman & Soete 1997 in Peters 2005, p. 1). In fact, there is no consensus amongst academia regarding the effects of innovation on employment (IFC 2013, p. 19).

From a theoretical perspective there are several ways in which innovations and higher productivity can destroy existing jobs (displacement effects) or create new jobs (compensation effects). Product and process innovations also influence employment differently (Freeman & Soete 1997 in Peters 2005, p. 1 and IFC 2013, p. 19). The nett effect on employment ultimately depends on several firm-, sector- and country-specific factors, and also whether employment is measured at a firm, industry or country level (IFC 2013, p. 19).

The OECD (2013, pp. 94-96) posits a causal link between the inputs of product and process innovation and the resulting mix of job destruction (displacement effect) and job creation (compensation effects) (Figure 6.1). The report maintains that complex product innovation is determined primarily by formal R&D, while process innovation relates primarily to embodied technological change²⁰ (ETC), with a combination of R&D and ETC resulting in both product and process innovation.

²⁰ The OECD states that ETC refers to innovation embodied in new equipment, and that process innovation relates to ETC “acquired by investment in new machinery and equipment and by purchasing external technology incorporated in licences, consultancies and know-how” (2013, p. 94).

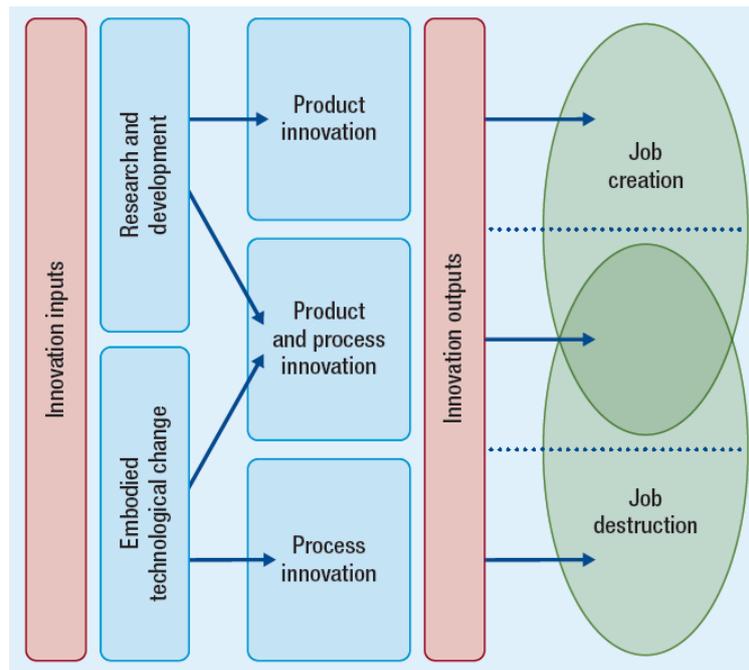


Figure 6.1. Graphic illustrating the linkages between the inputs of product and process innovation and the resulting job creation and job destruction²¹.

Simplistically, product innovation is seen to create new jobs due to the creation of new markets, whereas process innovation leads to job losses due to fewer workers required to produce the same output using new machinery (Ibid). However, in reality the effects are not that simple. Product innovation may also cause job losses in the sector that produces the ‘old’ products which are displaced by the ‘new’ products. In addition, process innovation is also associated with several compensating mechanisms (see below) which may offset job losses brought about through mechanised labour savings.

In OECD (2013, p. 95) Vivarelli (2013) describes several labour-compensating mechanisms²² of technological change as follows.

- Through new machines. The same process innovations that displace workers in the product industries where the new machines are introduced create new jobs in the capital industries where the new machines are produced.
- Through decreases in prices. Although innovations involve the displacement of workers, these innovations lead to a decrease in the unit costs of production, and in a competitive market this effect leads to decreasing prices; in turn, decreasing prices stimulate new demand for products and so additional production and employment.
- Through new investments. In cases where the competitive convergence is not direct, during the gap between the decrease in costs – due to technological progress – and the consequent fall in prices, extra-profits may be accumulated by innovative entrepreneurs. These profits are invested, creating new output and new jobs.
- Through declines in wages. Where there is demand for labour, the direct effect of job-destructive technologies may be compensated within the labour market. Assuming free competition and full substitutability between labour and capital, technological unemployment implies a decrease in wages and this should induce a reverse shift back to more labour-intensive technologies.

²¹ Source: Vivarelli (2013) in OECD (2013, p. 95).

²² This bulleted list is a direct quotation from OECD (2013).

- Through increases in incomes. Trade unions may redistribute part of the innovation rent back to the workforce and thus a portion of the cost savings due to innovation can be translated into higher wage income and hence higher consumption. This increase in demand leads to an increase in employment, which may compensate for the initial job losses due to process innovations.

An example of the ‘decreases in price’ labour-compensating mechanism of technological change relates to the development and introduction of automotive assembly lines by Henry Ford (IFC 2013, pp. 17-19). As a radically disruptive process innovation, the assembly line rendered automotive production much less labour-intensive compared with the craftsmanship-based single unit or batch production of the day where only the affluent were able to afford to purchase automobiles. However, cheaper cars created a strong market demand over time and therefore substantially increased the market size. This innovation essentially laid the foundation for a global automobile industry, which led to significant direct job growth in automotive production, in supply chains and in support services.

Concerning the level at which employment effects are measured; jobs might be lost in some firms due to productivity improvements, but there may be gains at the industry or country level (IFC 2013, pp. 17-19). In IFC (2013, p. 19), Nordhaus (2005) reported that more rapid productivity growth in manufacturing led to higher rather than lower employment at the industry level, although some job losses may occur in individual companies or sub-sectors. He concluded that the displacement effects are more than offset by the compensation effects of lower prices and an improved global competitiveness of the industry. For instance, a manufacturing firm that decreases its production workforce due to efficiency improvements often in effect creates indirect jobs in packaging, transport and logistics.

A large and international manufacturing firm study²³ found that there was higher employment growth in firms which innovate in products or processes and have achieved higher productivity compared with non-innovative firms (Dutz et al. 2011). The results support the notion that not only is innovation a strong driver of employment growth, but that innovation-driven growth is inclusive (i.e. it also absorbs unskilled workers).

Another study²⁴ concluded that product innovation²⁵ in manufacturing firms is linked to increases in employment in a 1:1 ratio with sales growth, whether the firm adopts a ‘first product to market’ approach or a product imitation strategy (Peters 2005). However, the study also concluded that process innovations are associated with a slight employment reduction for manufacturing firms.

Several studies have also shown that product innovation is positively correlated with employment growth irrespective of the type of industry (Alvarez et al. 2011, Harrison et al. 2008, Mairesse, Zhao & Zhen 2009 and Peters 2005 all in IFC 2013, p. 19).

6.2 Multipliers and wages in the manufacturing sector

This section examines the multiplier effects associated with the manufacturing sector. The focus is primarily on jobs multipliers, although other economic multipliers will also be discussed. The wage rates of average and high-tech manufacturing are also discussed.

²³ The study involved 26 000 firms across 71 countries including OECD and developing countries.

²⁴ The study involved 2 200 German manufacturing and services firms between 1998 and 2002.

²⁵ In this instance product innovation included the introduction of a new product to a market and also firms that pursue product imitation strategies, i.e. new to the firm but not new to the market.

Countries that have appreciable advanced manufacturing capabilities exhibit good economic multipliers in the manufacturing sector (Deloitte 2013b, p. 29). The higher economic multipliers of the manufacturing sector compared to other sectors are attributed to substantially larger supply chains (COC 2011a and McDougle & Furr 2013b, p. 3). For instance, in the USA an additional value add of \$1.40 is created in other sectors for every dollar of value created in manufacturing (Ibid). (The next closest sectors are Information and Agriculture at approximately \$1.15 additional value added.)

In research commissioned by the MC, Abedian et al. claim that the manufacturing sector can create significant economic spillovers and is amongst the top-three sectors in the country with the highest multiplier effects²⁶ (2011, p. 5). They estimate that R1 invested in the South African manufacturing sector will create an additional value add of R1.13 (Table 6.1) (Abedian et al., p. 15). Furthermore they argue that the close relation between agriculture and manufacturing (especially in the agro-processing sector) will lead to strong indirect benefits as well (Ibid).

Table 6.1: Output multipliers of a R1 investment in selected South African sectors²⁷.

Sector	Multiplier (output)
Agriculture	R1.79
Manufacturing	R1.13
Construction	R0.81
Wholesale and Retail	R0.72
Mining	R0.60
Finance	R0.49
Transport & Communication	R0.03
Electricity	R0.03

Abedian et al. estimates that approximately three decent and sustainable jobs will be created as a result of a R1 million additional investment in the manufacturing sector (Abedian et al. 2011, p. 15). This is in contrast with estimates of almost 11 jobs in the labour-intensive agricultural sector and 0.1 jobs in the capital-intensive transport and communication sector and the electricity sector for the same level of additional investment (Ibid). Table 6.2 shows the employment effects as a result of an additional R1 million investment in selected South African sectors.

Table 6.2: Number of jobs created for a R1 million investment in selected South African sectors²⁸.

Sector	Multiplier (no. of jobs)
Agriculture	10.5
Wholesale and Retail	3.3
Manufacturing	3.0
Construction	2.5
Finance	1.0
Mining	0.5
Transport & Communication	0.1
Electricity	0.1

²⁶ These are output, employment, export earnings and fiscal revenue multipliers.

²⁷ Source: Abedian et al. (2011, p. 15).

²⁸ Source: Abedian et al. (2011, p. 15).

A country with a strong manufacturing base exhibits high jobs multiplier effect on the supporting services sector²⁹ (COC 2011b and Zalk 2014, p. 6). In fact it is believed that the manufacturing sector has a higher jobs multiplier than any other economic sector, and that the manufacturing sector jobs multiplier is rising primarily due to smarter and more advanced manufacturing (Bernaden pp. 3, 7).

The reason for the rise in jobs multiplier effects in advanced manufacturing is because such manufacturing entails investments in R&D and HRD which results in the development of product and process technologies and associated increased productivity and innovation, thereby creating a similar high skills demand in sectors which support manufacturing (Bernaden p. 1 and Deloitte 2013b, p. 29).

Table 6.3 below shows a range of manufacturing activities and their associated multiplier effects, showing that as manufacturing becomes more sophisticated the jobs multiplier rises. It reveals that in general manufacturing, for every one direct manufacturing job created there are approximately 1.6-2.5 indirect jobs created. However, as manufacturing becomes more sophisticated, the number of indirect jobs created rises to between 4 and 15 for every one direct manufacturing job. This is largely in line with a statement by Majaja³⁰ (in Wild 2012) that advanced manufacturing activities typically create 7 indirect jobs in associated supply chains and service industries for every direct manufacturing job.

Table 6.3: Types of manufacturing and associated jobs multiplier³¹.

Type of manufacturing	Jobs multiplier
General manufacturing ^{32, 33}	1.58-2.5
High-tech manufacturing ³⁴	3.5
Microprocessor electronics manufacturing ³⁵	4.1
Jet engines ³⁶	7-8
Electronic computer manufacturing ³⁷	15

The rider in this instance is that the above high-tech manufacturing firms need to exhibit advanced manufacturing characteristics, have strong and extensive supply chains (implying a well-established supply base) and forward linkages, and a network of sophisticated service providers which provide the necessary support. Without an advanced manufacturing approach, extensive supply chains and sophisticated service providers the indirect jobs multipliers will never be realised. For example, a high-tech electronics manufacturer that who merely imports sub-components and assembles the inputs into products, and is supported by overseas service providers will not create many indirect jobs, even though the firm would be classified as a high-tech company.

In addition to the advantageous jobs multipliers of manufacturing generally and combinations of high-tech manufacturing specifically, wages in high-tech manufacturing are much higher than

²⁹ These sectors include banking, logistics, education, call centres and healthcare (Deloitte 2013b, p. 29).

³⁰ Chief Director: Advanced Manufacturing at **the dti**.

³¹ Cautionary disclaimer: "Studies highlight that multipliers are highly dependent on the regional, local and industry context. Furthermore, they vary with the maturity of the company, the distribution channel model used by a specific client as well as the cost and availability of labor." (IFC 2013, p. 30).

³² In the USA. Source: Bernaden (p. 7).

³³ In the USA. Source: Giffi (2012, p. 5).

³⁴ Specifically regions like California. Source: DeVol et al. (2009) in Bernaden (p. 7).

³⁵ Specifically Intel Corporation, USA. Source: Josephson (2011) in Bernaden (p. 6).

³⁶ Specifically General Electric Aviation, USA. Source: Bernaden (p. 5).

³⁷ Source: DeVol et al. (2009) in Bernaden (p. 7).

conventional manufacturing, which in turn are still higher than wages in sectors such as the services industry (COC 2011b, McDougle & Furr 2013a and OSTP 2011, pp. 9). A career in manufacturing historically translated into low wages for low-skilled workers, but this is no longer necessarily the case.

In the USA, manufacturing wages are approximately 22% higher than wages in services (OSTP 2011, p. 9). Additionally, workers in high-tech manufacturing industries in the USA earn 50-100% more than the average wage rates in all other fields (OSTP 2011, p. 9), and in the UK high-tech manufacturing workers earn 27% higher wages than the average of all manufacturing and approximately 47% higher wages than low-tech manufacturing (DBIS 2009, p. 4).

7 Selected case studies illustrating job creation in advanced manufacturing firms

In this section we will use two different examples that illustrate how advanced manufacturing may be useful to a low-tech sector, and how low-skilled people might participate in an industry that is generally labelled as being advanced or high-tech.

7.1 Applying advanced manufacturing in a low-tech sector: Footwear

The footwear sector is estimated to be the third-most labour-intensive sector³⁸ in South Africa, only exceeded by the clothing and furniture sectors (DTI 2012 in De Beer & Emslie 2012). Global footwear industries have restructured significantly, with a geographic shift of production towards developing countries that have lower production costs - more specifically labour costs. The most significant growth has been shown by Chinese footwear companies, and as a consequence, most developed countries have reduced local footwear manufacturing in volume terms. Globally the manufacturing of footwear for exports has quadrupled (Ibid).

Figure 7.1 shows that the long decline in local footwear unit production from 1988 to 2005 has only recently reversed. The South African footwear sector has not been able to take advantage of the substantial growth in the South African market over the last decade due to increased international competition (mainly from the East). Even though local production has grown since 2005, employment in the sector has been in decline since 2004. Had the industry been more competitive, production output may have grown more than it has done so, and the decline in employment may have been reversed (De Beer & Emslie 2012).

The global footwear sector follows a buyer-driven value chain, resulting in growing pressure on producers concerning buyer demands for price, variety and quality. As global production shifts to lower-cost locations, cost pressures are sustained on the industry as a whole. As a result, footwear manufacturers are not able to compete on the basis of price or gross margin (the pre-eminent tool used by most retailers), as new, lower-cost locations are continuously identified (De Beer & Emslie 2012).

However, retail chains around the world are seeking alternative supply chain models, due to a realisation that the 'price-first' model is misleading due to hidden costs and risks as alluded to in Section 2.1, namely rising logistics and transportation costs, risks associated with long lead times and large inventory holdings due to production being far from the market, and environmental

³⁸ As measured by number of jobs created per unit of capital invested.

considerations. This had led to several alternative avenues through which local firms can compete, including guaranteed quality, small-batch production runs and short lead times to market (Ibid).

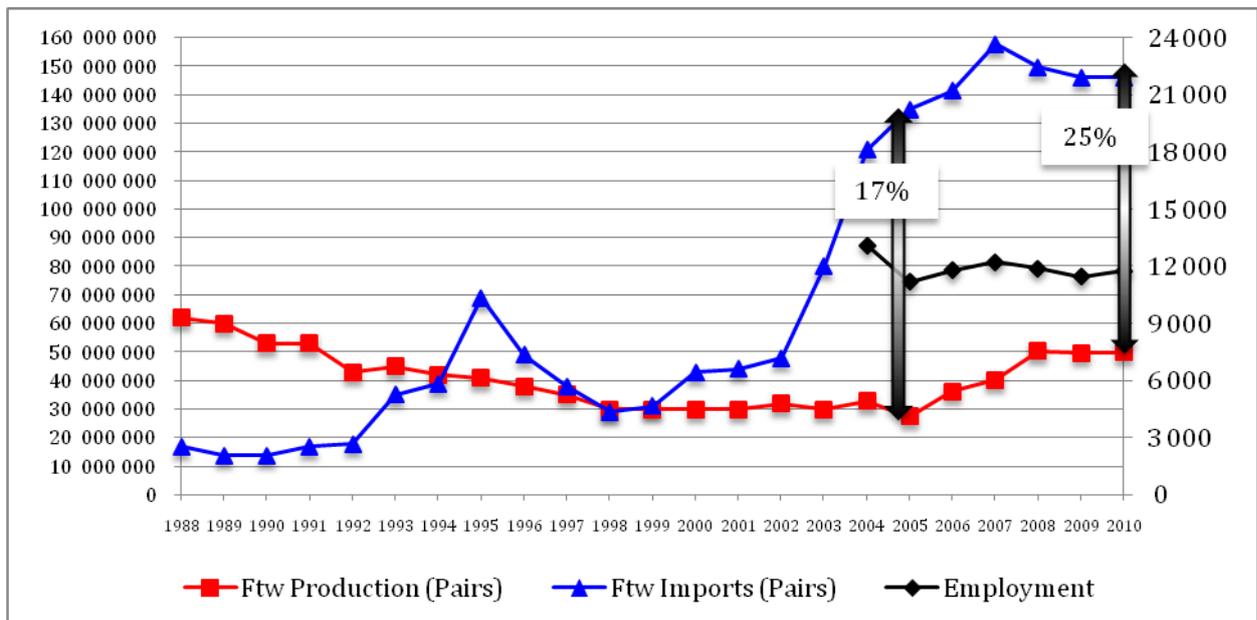


Figure 7.1: Footwear supply (local production and imports) to the South African market together with recent employment statistics³⁹.

Previous analyses showed that the South African footwear sector is uncompetitive with regards to a lack of skills, aging equipment, the development and application of technology and high labour costs relative to Asian competitors (Ibid). The sector is regarded as a low-tech industry that employs large numbers of low skilled workers. Many of the domestic footwear companies have old shoe designs and utilise outdated production methods.

With this in mind and to begin assist the industry to improve its competitiveness, the Vaal University of Technology (VUT) embarked on an applied research project. The work performed to date included demonstrating how advanced manufacturing techniques can be used for accelerated prototype development, rapid production tooling development and quick production of functional samples for prospective clients.

The VUT demonstrated to the local footwear industry that aesthetic product prototypes and repeatable samples could be delivered to buyers within 3-4 days of receiving a 2-dimensional design compared with the current turn-around time of 12-16 weeks. This was done by combining computer aided design (CAD) skills, virtual 3-dimensional (3D) modelling and 'growing' aesthetic (i.e. not functional) samples and functional tooling inserts on the VUT's AM equipment.

The VUT also assisted a footwear manufacturer to digitise one of its old designs so that the design could be modernised. This entailed digitising an original shoe using a 3D scanner. The 3D model was then restyled and improved according to contemporary shoe trends using virtual 3D modelling software. The redesigned shoe components were grown in Nylon Polyamide using VUT's AM equipment and then hand sewn together with the conventional components to create a functional prototype of the newly designed shoe.

³⁹ Source: Quantec in De Beer & Emslie (2012).

In addition to the much faster turn-around times for the development of prototypes and samples, the tooling inserts made by AM were designed to be compatible with the manufacturer's existing factory equipment. The use of 3D scanning, modelling and AM also shows the potential for footwear manufacturers to update their old product designs and also create totally new designs using these techniques.

Through this process the VUT showed several firms how advanced manufacturing approaches could be integrated into their current systems, tooling and manufacturing equipment for rapid product development and quick lead times to market. It shows the potential for a traditional and low-tech sector to become more competitive through the adoption of advanced manufacturing approaches, without the need to replace its existing production equipment and systems. In addition, this example illustrates how the adoption of advanced manufacturing practices need not displace traditional jobs; but how it can potentially contribute not only to job preservation but also to increasing volumes and employment opportunities.

7.2 Creating careers for low-skilled workers in an advanced manufacturing high-tech company: Advanced composite materials

AAT Composites Pty (Ltd) is an advanced composites manufacturing company that produces high-tech components and assemblies for the aerospace and top-end automotive sectors. It has a turnover in the region of R250 million per annum and 100% of its production is exported, indicating that the company is globally competitive.

The company has an in-house Engineering Division that undertakes product design and prototyping, development of product-specific manufacturing procedures as well as tooling development. The Engineering Division also provides engineering support to the Operations Division for production.

Even though advanced composites manufacturing is classified as a high-tech sub-sector, it is also very labour intensive, particularly with regards to semi-skilled labour. A key distinguishing feature of the advanced composites manufacturing within AAT Composites is that their production cannot be fully automated like other high-tech industries due to the diverse product mix made by the company. (Companies that manufacture large structures with large curvatures such as airplane wings make use of robotics to make such components, but it is more difficult to automate the production of a diverse range of smaller components that have tight curvatures.)

Out of the headcount of 425 at AAT Composites there are only 36 that have tertiary qualifications (20 engineers, 5 technologists and 11 artisans). Excluding the top management and administrative staff of 20 people, the rest of the staff in the Engineering Division, Operations Division and Quality Division are semi-skilled workers⁴⁰, constituting roughly 85% of the workforce.

AAT Composites recruits unskilled school-leavers from the community within close proximity to the company. These workers can progress through the ranks of the company and can choose from several career path options.

School leavers are screened for kinaesthetics/motor skills aptitude and placed on an internal formalised training programme before being deployed as operators, primarily within the Operations Division. The first level of training is to obtain basic skills in composites manufacturing specific to the above occupational job categories. Thereafter the workers receive product-specific training.

⁴⁰ At an operator or equivalent level, including team leaders and supervisors.

Operators within the Operations Division that show potential, initiative and aptitude are identified for career advancement and/or educational advancement. They may become Specialist Operators or move into a production line management role (Team Leader, Shift Manager or Section Manager). In terms of educational advancement, Operators may also register for an apprenticeship programme. After completing the required theoretical training and undertaking a trade test at an external college, they become in-house Artisans, and may then move on to supervisory and management positions within the company, or remain as Artisans.

Operations Division Operators may also move into the Engineering Division. The first step is to be promoted to a Technical Assistant, entailing work such as doing lay-ups for prototypes, configuration of operating procedures and engineering drawings. Technical Assistants who show an aptitude for 3D computer modelling may receive CAD/CAM⁴¹ training and be promoted to CAD/CAM Technicians which entails the implementation of product and tooling designs by Engineers and Technologists. The company is also considering a further step, wherein CAD/CAM Technicians may receive further training and become Designers who are responsible for the conceptualisation of new products and tooling.

During the period 2011-2013 there were a total of 145 Operators within the Operations Division who were promoted internally to higher positions within the production environment. Currently the Engineering Division has 3 Technical Assistants and 4 CAD/CAM Technicians who were once Operators. The majority of the CAD/CAM Technicians also have the potential to be developed into Designers.

The example of AAT Composites demonstrates that a high-tech company that makes use of advanced manufacturing approaches can also be labour-intensive. This disproves the notion that high-tech companies that adopt an advanced manufacturing approach are primarily capital-intensive, only employ highly-skilled workers and do not create low-skilled jobs. It is also important to note that this company is not only using sophisticated equipment and deep insight into composites, but that the way the company develops its internal knowledge and competency based itself is very innovative, thus the company's production activities fits the working definition of advanced manufacturing as proposed in Section 4.

In addition, the nature of employment creation within AAT Composites is truly inclusive. School-leavers with no tertiary qualification of any kind have several career path options within the company, either via a technical route in production or engineering, or the management route within production. School-leavers also have the opportunity to obtain an apprenticeship qualification and become an artisan.

8 Conclusions

Combinations of new and old knowledge and technologies are increasingly being recognised as advanced and specialised factors of production to compliment traditional factors in the manufacturing sector for high growth and the creation of decent, well-paying jobs. Evidence of this can be found in international private sector survey reports and in the global government manufacturing policy discourse which recognises talent-driven innovation (which is underpinned by multi-disciplinary skills and results in knowledge production) and advanced technologies as the most important drivers of manufacturing competitiveness.

⁴¹ Computer aided design and computer aided manufacturing.

Despite advanced manufacturing being recognised globally as important to reverse de-industrialisation and to create decent, well-paying jobs, lingering perceptions regarding the negative correlation of advanced manufacturing and technological advancement on employment have created resistance to the adoption of advanced manufacturing practices by industry. These perceptions are particularly evident in South Africa against the backdrop of declining employment and a reducing manufacturing growth rate as a proportion of national growth, where adversarial management-worker labour relations are contributing to current and projected job reductions through mechanisation. However, it should also not be assumed that organised labour will resist the introduction of advanced manufacturing approaches, particularly in light of advantageous multiplier effects.

We find that the effects of advanced manufacturing, technological advancement and innovation on employment are far from simple and causal. From a theoretical perspective there is no consensus in academia on the effects on employment, with multiple factors contributing to job creation and job destruction in relation to different types of innovation. We also observe that the effect on jobs varies depending on whether one examines the effects on jobs at a firm, industry or sector level. Results also seem to vary depending on the industry or services sector selected. We also conclude that perceptions of advanced manufacturing, innovation and technological advancement are negatively influenced by inconsistent use of terminology, conflation of concepts and incorrect use of terms.

However, we do find empirical evidence that there is a strong and positive correlation between product innovation and job creation in the manufacturing sector, although there seems to be a slightly negative correlation between process innovation and jobs. In addition, we find that the proportion of indirect jobs to direct manufacturing jobs increases dramatically as manufacturing becomes more high-tech and advanced due to the extensive forward and backward (extensive supply chains) linkages and a sophisticated manufacturing service sector.

We have dispelled several entrenched notions regarding advanced manufacturing and jobs using actual examples. In the local low-tech and traditional footwear sector there is evidence that the adoption of advanced manufacturing practices would improve the industry's competitiveness through much faster product development compared with traditional methods, and that the use of advanced manufacturing methods in conjunction with existing production equipment would potentially lead not only to job preservation but also job growth.

In the instance of an advanced composites manufacturing company we show that a high-tech company is not only very labour-intensive, but that employment in the company is truly inclusive with most of the workforce being semi-skilled. The company hires unskilled school-leavers and offers various career path options to Operator-level workers to advance via promotion to senior levels and/or advance through obtaining a tertiary qualification. This disproves the myth that high-tech and advanced manufacturing companies only employ highly-skilled workers and not low-skilled workers.

Based on an international and national literature review our working definition of advanced manufacturing as follows.

Advanced manufacturing is an approach that

- Depends on the use and integration of information, knowledge, state of the art equipment, precision tooling, automation, computation, software, modelling and simulation, sensing and networking;

- Makes use of cutting edge materials, new industrial platform technologies⁴², emerging physical or biological scientific capabilities⁴³ and green manufacturing philosophies; and/or
- Uses a high degree of design and highly skilled people (including scientific skills) from different disciplines and in a multi-disciplinary manner.

Advanced Manufacturing includes a combination of the following.

- Product innovation: Making new products emerging out of new advanced technologies (including processing technologies).
- Process innovation: New methods of making existing products (goods or services).
- Organisational innovation or business model innovation: Combining new or old knowledge and technologies with traditional factors of production⁴⁴ in non-traditional fields or disciplines in unique configurations.

Our working definition of advanced manufacturing incorporates the above-mentioned advanced and specialised factors of production, namely new knowledge and advanced technologies, which are of utmost importance for economic competitiveness, economic growth and job creation. It also incorporates all forms of innovation as well as the imperatives of appropriate multi-skills development for talent-driven innovation and knowledge production. It should also be noted that advanced manufacturing is not an economic sub-sector. It is an approach that must be fostered across the entire manufacturing sector, irrespective of firm size or sub-sector.

9 Policy implications

Pouris (2012) reports that knowledge-intensive services industries and high-tech manufacturing industries have grown faster than other segments of the economy. He notes that their combined contribution to global economic output was approximately \$18.2 trillion in 2010, representing approximately 30% of world GDP (Ibid). As a result, governments are recognising that funding the development of complex and emerging technologies to support these industries through innovative products and services will not only result in high-value output and improved competitiveness but also generate well-paying jobs (Giffi 2012, pp. 12, 24, OECD 2013, OSTP 2011, p. ii and Pouris 2012).

Future value is seen to accrue through wholly unanticipated breakthroughs, but also via existing or emerging technologies, all of which will transform manufacturing as we know it (GOS 2013, pp. 20-21). For example, AM and other technologies such as new materials, computer-controlled tools, biotechnology and green chemistry together with direct customer input into product design will allow for cost-effective, fast and personalised production, which in turn will disrupt conventional manufacturing productions and supply chains (Ibid).

The EU has a focus on multidisciplinary and cross-cutting KETs⁴⁵ for a wide range of product (goods and services) and process innovation⁴⁶. It defines KETs as “knowledge-intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment” (EC 2012, pp. 2-3). Interestingly, studies have reportedly shown that public investments in KETs can produce returns four-fold that of the initial investment in the form of taxes and social security

⁴² Such platforms have multiple commercial applications, e.g. composite materials, and exhibit high spill-over effects.

⁴³ E.g. nanotechnology, biotechnology, chemistry and biology.

⁴⁴ Labour, materials, capital goods, energy, etc.

⁴⁵ The EU's KETs are micro-/nanoelectronics, nanotechnology, photonics, advanced materials, industrial biotechnology and advanced manufacturing technologies (recognised as a 'cross-cutting' KET) (EC 2012, p. 3).

⁴⁶ The main sectors where KETs find application include the automotive, food, chemicals, electronics, textiles, energy, environment, pharmaceuticals, construction, aerospace and telecommunication sectors (EC 2010 in EC 2012, p. 3).

contributions, and that the application of KETs contributes significantly to job creation (EC 2010 in EC 2012, p. 3). The UK has a similar approach, but has a broader focus with technologies for manufacturing categorised into pervasive and secondary technologies⁴⁷.

South Africa needs to embrace and adopt advanced manufacturing approaches alongside conventional manufacturing methods for economic growth, employment and international competitiveness. Talent-driven innovation and advanced technologies need to become more important from the perspective of South African manufacturing stakeholders. The advanced manufacturing of today will become the conventional manufacturing of tomorrow, and so the South African manufacturing sector needs to rapidly embrace and adopt advanced manufacturing approaches in order to improve competitiveness and stave off further job losses and de-industrialisation.

With regards to public sector policy implications, the state should support innovation and the creation of advanced and specialised factors of production in a coordinated and streamlined fashion. Specifically, the state needs to invest in appropriate multi-disciplinary skills (i.e. multi-skilled) development across the board for the manufacturing sector, from encouraging and supporting workplace training, to learnership and apprenticeship programmes, technician training, and all the way to postgraduate studies and post-Doctoral fellowships. Doing so will serve to increase the knowledge base of the country to improve South Africa's capacity for talent-driven innovation which, alongside advanced technologies, is seen by eminent economists and innovation policy practitioners as the most important determinants of economic success.

Public sector funding should be dedicated to the development of new and advanced technologies, including platform technologies for the manufacturing sector, as the private sector will initially tend to under-invest in technology development. These technologies should be developed in a prioritised fashion with due consideration given to existing public sector research and development capabilities, market needs and other 'top-down' considerations such as localisation and public sector procurement. Public sector investment in platform technologies must create positive externalities and spill-overs. Due regard also needs to be given to international technology trends and drivers.

A critical question is how the state can increase the absorptive capacity of the private sector to adapt and integrate advanced manufacturing technologies into their enterprises, taking advantage of pre-existing 'hidden' technology platforms already in place within public-funded institutions like science councils and higher education institutions.

The state needs to take stock of existing policy levers and implementation actors across departments in order to map the manufacturing-related instruments and institutions in order to identify gaps and opportunities for growth, jobs and enterprise creation. Opportunities need to be identified where the introduction of advanced manufacturing approaches has the greatest potential for preservation and creation of direct jobs together with high indirect job multipliers.

The indirect jobs multiplier potential associated with advanced manufacturing will only be realised if local supply chains and service providers are developed and strengthened. This has implications for supply chain development programmes, particularly in respect of South Africa's public procurement and technology localisation programmes, and the designation of local content levels.

⁴⁷ Pervasive technologies: ICT, sensors, advanced and functional materials, biotechnology and sustainable/green technologies. Secondary technologies: Big data and knowledge-based automation, the Internet of things, advanced and autonomous robotics, additive manufacturing (also known as 3D printing), cloud computing and the mobile internet. Source: GOS (2013, p. 21).

New science and technology, industrial and education policy instruments may need to be designed and created and existing instruments reviewed and re-focused if necessary. The existing and new instruments would certainly need to be supported through substantial fiscal allocations over and above the Medium Term Expenditure Framework allocation. While it would be advantageous for additional resources to be allocated to implementing such an approach, simply re-focusing existing efforts in a co-ordination fashion would make for a good start.

The USA government announced a \$1 billion Advanced Manufacturing Partnership (AMP) programme in July 2012 which proposed the creation of 15 innovation institutes covering a range of advanced manufacturing technologies to revitalise manufacturing in the USA (White House 2012a). The AMP seeks to bring industry, universities and government together to co-invest in emerging technologies and skills to support a vibrant domestic advanced manufacturing sector that would create high quality jobs.

The pilot phase of this initiative is a public-private institute for manufacturing innovation which entails a \$30 million investment by the USA government over 3 years, with industry co-funding of \$40 million (White House 2012b). The National Additive Manufacturing Innovation Institute (NAMII) was selected through a competitive process, and the winning consortium included manufacturing firms, universities, community colleges and non-profit organizations.

With regards to the private sector, manufacturers need to continuously search for and exploit opportunities based on combinations of new and old knowledge and technologies. This applies not only to product and process innovation, but especially to organisational and/or business model innovation. This is particularly important when introducing new knowledge in the form of skilled workers and sophisticated new equipment to traditional and/or distressed industries where the barriers to the adoption of change (which are needed for success or even survival) are high.

Investment in new technologies is prone to market failures related to coordination costs. When a new technology emerges, or a new competency is needed, firms typically find it costly to coordinate multiple investments which depend on investments by other economic actors. This is exacerbated by an uncoordinated public sector which at times has policy instruments with competing priorities. The state needs to work closely with the private sector to address coordination issues.

South Africa has an excellent platform for a new approach to manufacturing. The country has an established manufacturing base and good public-funded science and technology capabilities. What is required is for the public sector, the private sector and labour to work together for the manufacturing sector to become more competitive and thereby grow and create more jobs.

10 Acknowledgements

The authors would like to thank the staff of AAT Composites, the VUT Directorate of Technology Transfer and Innovation, and the Technology Innovation Agency (TIA) Technology Station for Materials Processing Technologies at the VUT for their time and inputs regarding this paper. We would also like to thank Mr. Beeuwen Gerrys and Ms. Helen Brown for their inputs. In addition, the National Research Foundation, the Technology and Human Resources for Industry Programme and TIA are acknowledged for funding support in relation to the footwear project in Section 7.2.

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