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Göran Roos Allan O'Connor

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Göran Roos
Faculty of Design, Swinburne University of Technology, Melbourne, Victoria, Australia, and
Allan O'Connor
Entrepreneurship Commercialisation and Innovation Centre, The University of Adelaide, Adelaide, Australia

Abstract
Purpose – The purpose of this paper is to report on an industry policy implementation case involving around 30 manufacturing firms, where the intellectual capital (IC) lens, and especially the intellectual capital navigator (ICN) approach, was found to be very useful for evaluating alternative servitisation strategies. Servitisation is a form of business model innovation and as such involves restructuring the firm's resource deployment system including its IC resources.
Design/methodology/approach – The ICN was one of several methods and themes used by a sample of manufacturing firms during a 12 month period. Data capture were through video filming, observation, and formal interviewing during and after the interventions.
Findings – The ICN is considered to be the third most valuable theme in a strategic and operational servitisation programme for manufacturing firms, primarily in the domain of effectiveness evaluation of alternative resource deployment strategies and as such should be one of the key dimensions in a business model template for manufacturing firms that aim to servitize. This research also illustrates the usefulness of the intellectual capital lens in the policy implementation process.
Research limitations/implications – The findings of this study is limited to the servitization process of SME manufacturing firms in an Anglo-Saxon operating environment which very rapidly have gone from low to high cost.
Originality/value – The development of service-oriented business models for manufacturing firms suffers due to traditional business model frameworks not having a high relevance for servitising manufacturing firm. Consequently it is important to understand the potential contribution that the IC lens through the ICN can make in the servitisation process.

Keywords Public sector, Manufacturing, Intellectual capital, Industry policy, Servitisation
Paper type Research paper

Introduction
Given the importance of manufacturing for future economic wellbeing in Australia, and given the challenges facing many Australian manufacturing firms, a policy decision has been taken in South Australia to implement a number of industry policy actions (see, DMITRE, 2012) to enhance the managerial capabilities in manufacturing firms. One of the key strategy developments in manufacturing firms that was to be supported was servitisation. Given that the need to change the resource deployment system is a prerequisite for successful servitisation a competence development programme was identified as a suitable policy action in this area. It was decided to test the perceived importance of the intellectual capital navigator (ICN) as a tool to analyse the potential effectiveness of a given resource deployment structure as compared to other issues around the servitisation of manufacturing firms within the competence development programme for firms.

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There have been consecutive reviews attempting to map and structure the IC field (e.g. Brennan and Connell, 2000; Petty and Guthrie, 2000; Stewart, 2001; Pike *et al.*, 2006; Roos and Pike, 2007a, b). The recent literature divides the IC field into four temporal phases (e.g. Alcaniz *et al.*, 2011; Guthrie *et al.*, 2012; Dumay, 2013; Labra and Sánchez, 2013). The first temporal phase focuses on consciousness raising activities that strive to communicate the importance of recognising and understanding the potential for intellectual capital (IC) in creating and managing a sustainable competitive advantage. The second temporal phase focuses on conceptualising the organisation specific aspects of IC and its impact on capital and labour markets. This phase also contains the measurement focus of IC as well as the accounting, reporting and disclosure focus of IC. The third temporal phase focuses on analysis of IC practices in action. The fourth temporal phase focuses on IC eco-systems of cities and nations. The temporality of the phases refers to their initiation and their peak in terms of research articles. All phases are still ongoing but the emphasis, in terms of articles, has moved towards the latest phase – phase four.

IC reviews have identified two domains that are under-researched in addition to the four phases outlined above. The first is the interaction between technological development (not limited to ICT) and IC in action. Second, IC in the public sector including the relationship between IC and public policy. This is the domain in which this article aims to contribute. Articles that have contributed to this under-researched area are, for example, Dragonetti and Roos (1998), Roos and Jacobsen (1999), Burgman and Roos (2004), Bounfour and Edvinsson (2005), Dumay and Guthrie (2007) and Bronzetti and Sicoli (2011).

Government industry policy

Unless the politicians in a jurisdiction live in the fantasy world of perfect markets, industrial policy does not lack theoretical justifications (e.g. Dosi *et al.*, 1989; Chang, 1994; Stiglitz, 1996; Lall, 2004; Rodrik, 2004, 2008; Aiginger and Sieber, 2006; Bianchi and Labory, 2006; Cimoli *et al.*, 2009; Spence, 2008; Chang, 2011; Aghion *et al.*, 2012; Aiginger, 2014; Bailey *et al.*, 2014; Cirillo *et al.*, 2014; Crafts and Hughes, 2014; Clydesdale, 2014; Haar, 2014; Mason and Nathan, 2014; Nahtigal, 2014; Salazar-Xirinachs *et al.*, 2014; Warwick and Nolan, 2014; Bailey *et al.*, 2015; Gray, 2015), much of which has been developed during the period since the global financial crisis in 2008.

In order to understand what a policy aimed at increasing economic complexity to a level that matches the living standard of 2008 entails for Australia, an understanding of what activities contribute to economic complexity is needed. Product or service communities that entail complex supply chains at many levels increase economic complexity (e.g. machinery manufacturing with an economic complexity of 2.5 and automotive with a complexity of 2.3), whereas product or service communities that entail simple supply chains at few levels decrease economic complexity (e.g. mining with an economic complexity of −0.6) (Hausmann and Hidalgo, 2013).

Service complexity is strongly correlated with product complexity. That is, a country with a high economic complexity in products tends also to have a high economic complexity in services since most complex services[1] are either delivered by manufacturing firms, on behalf of manufacturing firms, or to manufacturing firms. The economic complexity of services is lower than the economic complexity of the correspondingly ranked products due to the need for fewer linkages and relationships in the production of the output. This mutually beneficial close relationship between the manufacturing and service sectors renders the traditional dichotomy and antagonism between manufacturing and services obsolete (Roos, 2010; Lichtblau *et al.*, 2013).

Research shows that successful industry policy requires a considerable degree of flexibility in ideological terms from government. If the guiding ideology is too rigid – like the free-market ideology in the UK from the 1980s until the 2008 financial crisis – the research shows that a country will implement the wrong type of industrial policy in the wrong way (Chang *et al.*, 2013), Chang *et al.* (2013) further points out that the success of industrial policy depends critically on the country's political economy (i.e. if there is no political base for industrial policy, it will fail in the face of policies that undermine it). In order to be effective in its industry policy intervention, government needs to be both embedded in society and have sufficient autonomy to choose effective interventions (Evans, 1995). Finally it is, of course, necessary for the policy implementing organisations to be structurally (e.g. routines, decision processes, organisational structure and coordination), relationally (e.g. interconnected and interlinked) and capability-wise (e.g. organisational memory) competent as well as being staffed by capable individuals (Chang *et al.*, 2013).

Public policy should aim at guiding the processes leading regions to diversify into new growth paths, based on sectoral structural changes into "related" sectors (Frenken *et al.*, 2007; Asheim *et al.*, 2011). What is important from a policy perspective is the ability to build on a region's existing specialisation, ensure technological rejuvenation of traditional sectors and move towards knowledge-related sectors, which in turn enhance knowledge spillovers and reinforce the innovation ecosystem. Within this context, an appropriate mix of innovation and industrial policy might favour such technological rejuvenation of "old manufacturing" and rural areas, which would entail an increasing demand for knowledge-based services and an "up-grading" of existing sectoral specialisation toward innovative related activities (Meliciani and Savona, 2014).

Industry policy must match the capability of both the targeted agents as well as the implementing agents. Industry policy must also change when environmental conditions change, the most important of which are frequently world market conditions and the state of the cumulative development of technological capabilities. Industry policy needs to contain policies for both developing and growing emerging industries as well as industrial euthanasia policies for the phasing-out of dying or superseded industries (e.g. of these policies see, e.g. DMITRE, 2012).

Chang *et al.*'s (2013) review of industrial policy highlights the importance of the national vision. For instance, if Finland, with its population of 4.5 million and one of the largest endowments of timber per capita in the world, did not aspire to compete in the most difficult industries with the best nations in the world, it would have maintained its specialisation in logging. Successful industry policy makers have to shape the world by moving beyond the rationalist framework of many economists – a framework that has become a hindrance in understanding the economic world, a world that is not a probabilistically predictable response to structurally given incentives, and come up with an alternative vision that most of the electorate probably will initially think will fail (Chang *et al.*, 2013).

The alternative is to build a policy to increase economic complexity to a level that matches the living standard of 2008 in Australia. This requires implementing four key policies. First, policies that will increase the presence of highly complex manufacturing activities within the country (e.g. chemicals, pharmaceuticals, electronics, aerospace, mechanical and electric machinery, automotive, synthetic fibres, alloys, medical devices, etc.; most sophisticated defence systems falls in this category as well and are frequently used by countries with sophisticated defence-industry policies to also enhance domestic economic complexity). Second, policies that will increase the in-country share of global value chain activities related to complex manufacturing or complex services. Third, policies that will increase the value added through increased complexity in the processing of endowment resources (e.g. produce gluten free bread for export instead of exporting wheat; produce metallic particles for use in additive manufacturing instead of exporting unprocessed ore etc). Fourth, policies that will reduce the presence of industrial activities with low economic complexity and without linkages to more sophisticated domestic value chains.

Unfortunately the present trajectory in Australia seems to be the opposite with a preference for complex manufacturing activities to be located outside the country (e.g. automotive, supply ships and submarines). Decreasing the in-country share of global value chain activities related to complex manufacturing (e.g. migrating automotive and other machinery supply chain participants to, for example, Thailand, migrating petroleum refining activities to, for example, Singapore; lack of incentives to increase the value adding of food, minerals and oil and gas). This deindustrialisation will be difficult to turn around if allowed to continue for too long since rebuilding an industrial commons once lost is almost impossible and will likely relegate Australia to the lower end of the OECD living standards rankings.

Unfortunately this development cannot be compensated through increased service activities: first, most highly complex, and hence highly value adding, service activities are intimately linked to manufacturing and cannot be provided in the absence of manufacturing (i.e. it is likely that the presence of automotive design capability and activities in the absence of automotive manufacturing will be a short lived phenomena). Second, service activities have lower economic complexity than the manufacturing activities to which they are linked hence will not have the same impact on increasing national economic complexity. Third, most non-manufacturing linked service activities cannot increase their productivity (known as Baumol's cost disease) and will hence have to compensate for the increase in productivity in the surrounding economy by lowering the wages paid. Fourth, most service professions that do not require in the same individual the three capabilities of domain expertise, creative problem solving ability, and interpersonal skills on a continuous basis will be automated over the coming ten years or so, removing most back-office type operations (e.g. in law firms and accounting firms). This will likely result, from an employment point of view, in a very small high value added and complex service sub-sector with high productivity and high wages, and a very large low value added and simple service sub-sector with low productivity and low wages. This means that the challenge cannot be solved through some form of service economy.

Servitisation of manufacturing

Manufacturing, like all economic activities, is in a constant state of flux, which requires reactive or proactive adaptation by firms if they are to retain their ability to grow and prosper (Roos, 2014a). The constantly reducing value creating potential in the production phase of manufacturing requires the extension of activities into the pre- and post-production phase, normally in the form of services and hence the increasing importance of servitisation. This and other drivers for the structural change in manufacturing towards servitisation are discussed more in detail below; see also Appendix 2 with its Figure A2 and Appendix 1 with its Figure A1.

The embodiment of developing technologies in the form of capital equipment used in the production process and the combination of this equipment into complex cyber-physical systems becomes tomorrow's production systems (see, Brecher, 2012) and will change the way manufacturing firms operate as well as increasing the speed with which the share of service activities increases in the manufacturing firm.

This blurring between services and manufacturing should be better reflected in industrial development policies. It is necessary to avoid the risk of underestimating the importance of the manufacturing sector, while it is fundamental to assess its structural relationships with the services sector (Ciriaci and Palma, 2012).

A weakening manufacturing base will eventually lead to a decline in the quality, and exportability, of services where manufacturing firms are the clients (Tassey, 2010; Fuchs and Kirchain, 2010; Pisano and Shih, 2012), illustrating the strong mutual links between the manufacturing sector and the service sector.

Changing consumer and customer preferences

What consumers value is continuously changing. One driver of this change is increasing living standards, which result in preferences moving from products to services and onwards to experiences. This journey increases the requirement on product providers also to provide services. This requires an understanding of the three components of value (Pike and Roos, 2004, 2007):

(1) Instrumental: the value derived from the deployment and use of the offering. This is the value component on which most focus is placed to the exclusion of the other two. In its simplest form this component can be easily expressed in direct monetary terms.

(2) Intrinsic: the value derived from the possession of the offering. This is the value that a coin collector assigns to his coins or the value we assign to things for what they are in themselves, like aesthetics or knowledge. This is the reason why one may be willing to pay for features in a product that one will never use – it feels good to possess it.

(3) Extrinsic: the value derived from the appreciation of the offering by others. This is most easily visible in "show-off" goods (see, e.g. Veblen, 1899), for example, a brand suit with the label visible on the sleeve when worn.

This servitisation means that manufacturing firms must broaden the value attributes on which they focus, providing from primarily instrumental to more balanced across instrumental, intrinsic and extrinsic.

Other drivers in the global value chain with implications for the servitisation strategy

These drivers can be grouped as follows. First, increasing wage cost drives the move towards replacing labour with capital equipment, which in turns drive the share of inputs being service inputs and hence the servitisation of capital equipment producers and providers. Second, the declining wage differential is reducing the technology complexity domain where international outsourcing is an appropriate response. This reduction is both from the low-tech and from the high-tech domain direction resulting in a small and shrinking area of medium tech being the only domain where international outsourcing remains feasible whereas in the increasing low-tech and high-tech areas domestic outsourcing tends to be the appropriate response. This results in decreasing demand for manufacturing as an outsourced service from existing providers (Grover, 2008). Third, increase or decrease in the presence of industrial commons (and hence in the economic complexity of the region or nation). An industrial commons (Richardson, 1972; Abramovitz, 1986) is normally defined as the embedded knowledge, technology capabilities, specialised equipment and specific co-specialised assets that enhance the efficiency, effectiveness and productivity of the proprietary capital and labour that use it (Roos, 2014a). This industrial commons does not reside in one organisation but is spread out over a large group of organisations and individuals but normally within a limited geographic domain (Pisano and Shih, 2009). A broad base of industrial commons with different domain expertise provides a basis for a high level of economic complexity, which is a prerequisite for sophisticated servitisation so an increase in the presence of industrial commons increases the potential for servitisation. To maintain an existing industrial commons it is necessary not only to maintain a manufacturing base of a certain size and diversity but also to maintain a diversity of contributing intermediary institutions that contribute to maintaining and developing the industrial commons through relevant both product and process R&D and innovation (Andreoni, 2011; O'Sullivan, 2011; Best, 2014).

The combination of the above with the continuing migration of maturing medium technology activities to lower cost jurisdictions requires manufacturing firms in both the low-tech and high-tech activity domains to compete on the basis of value for money and not on the basis of cost alone. This need for migration towards higher value for money through services is driven by increasing competitive intensity resulting in product-based competitive advantage being increasingly difficult to maintain (Kinnunen, 2011). Given the reduction of value adding potential in the production activities of manufacturing, servitisation is the way for firms to monetise the increasing value adding potential in the pre- and post-production activities (see, Figure A1). For a discussion of the structural shift in manufacturing, see Roos (2014a).

Visnjic and Van Looy (2011) identified two service paradoxes. First, a growth paradox that may unfold when a manufacturer neglects the feedback effect from products to services, allowing substitution effects to prevail (i.e. service sales reduces product sales due to extending the life-cycle of the installed product). Second, a profitability paradox that occurs when a manufacturing firm either does not recognise the importance of scaling up service activities or simply fails to scale up. Fang *et al.* (2008) have studied this scale effect and found that the impact of a servitisation strategy on firm value (as measured by Tobin's q) remains relatively flat or slightly negative until the firm reaches a critical mass of service sales (20-30 per cent of turnover), after which point it has an increasingly positive effect. As expected, the effect of service sales on firm value depends on both firm and industry factors. Service transition strategies are more effective at enhancing value when the service offerings have high relatedness to the firm's core business and when the firm has available resources (i.e. resource slack and/or strategic resource re-deployment ability). The impact on firm value by adding services to core products increases as industry turbulence increases but decreases when the firm's core products are in high-growth industries (Fang *et al.*, 2008).

The literature identifies a set of key drivers for manufacturing firms to move into services and they are synthesised by Roos (2015) and summarised in Appendix 2.

Gebauer *et al.* (2005), in their study of German and Swiss equipment manufacturing firms that had extended their service business, found that many manufacturing companies have difficulty in successfully exploiting the financial potential of services. They identified that the expected higher returns from an investment in broadening and deepening the service business frequently does not materialise. As a consequence the servitization objectives are not met and the manufacturing firm abandons or reduces the focus on its servitization strategy. They call this the "service paradox".

This fits with the findings of Kowalkowski (2008).

Neely (2008) found that in smaller firms servitisation appears to pay off while in larger firms it proves more problematic. Benedettini and Neely (2010) focused on the set of bankrupt firms indentified in Neely's (2008) study with findings that could be interpreted as: those firms that had servitised by offering services unrelated to their core offering were those that had gone out of business, while those that had offered closely related and integrated services had not been as badly affected, which is aligned with the findings of Fang *et al.* (2008).

Visnjic and Van Looy (2011) suggest that firms need an integrated service business model in order to benefit from a servitisation strategy and avoid the "service paradox" presented by Gebauer *et al.* (2005). The development of service-oriented business models for manufacturing firms suffers from the traditional business model frameworks not having a high relevance for servitising manufacturing firms (Zolnowski and Böhmann, 2011). This problem is addressed in Roos (2013) where the 21 dimensions relevant for manufacturing firms are identified and by Salkari *et al.* (2007) where key business model dimensions for servitising manufacturing firms are identified.

Oliva and Kallenberg, (2003) identified three barriers for manufacturing firms servitising. First, firms are not able adequately to recognise the economic potential of the service component. Second, providing services is beyond the scope of their competencies. Third, firms fail to successfully deploy a service strategy during the transitioning-into-services phase.

While a thriving product business creates opportunities for service business development, providing services may imply drawbacks for product activities. On the one hand, some, but not all, services can become substitutes for products (Siggelkow, 2002), but, on the other hand, customers who are satisfied with the services delivered will be more likely to purchase product replacements from the same manufacturer, thereby increasing the product renewal rate (Heskett *et al.*, 2008) and by engaging in service activities, manufacturing firms become much more informed about customers' needs: this information can be used to enlarge the scope of the product offering, resulting in additional product sales (Visnjic and Van Looy, 2011) as well as providing input to the product and service innovation process (Ahonen *et al.*, 2011). Furthermore, additional product sales may accrue from extending the relationship into substituting product previously provided by competitors (Visnjic and Van Looy, 2011).

Given that several authors (e.g. Oliva and Kallenberg, 2003; Weeks, 2010) claim that organisations are likely to change their strategies, operations, value chains, technologies, expertise, culture, business model and system integration capabilities to achieve a successful servitisation strategy, therefore a successful servitisation strategy requires an understanding of the necessary changes in the resource portfolio and the resource deployment structure of the firm.

Contribution of IC

IC is an extension of the resource-based view, taking into account the dynamics of the firm and its environment. IC has both a resource perspective (i.e. what resources exist and how they behave) and a resource transformation perspective (introduced by Roos and Roos, 1997) capturing the value creation logic of the firm.

The IC perspective views resources as falling into five categories, and these resources can be both tangible and intangible. The five resource categories are: monetary resources defined as monetary or monetary equivalent resources; physical resources defined as all physical manifestations including plant, equipment, energy and electricity; relational resources defined as all relationships held by individuals as representatives of organisations; organisational resources defined as all results of human endeavours that remain in, and are owned by, the organisation when the employees have gone home and that you cannot find on the balance sheet (e.g. brands, processes, software, information, etc.); human resources, including concepts such as competence, skill, capability, and so on, residing in individuals. Tangible examples of these five resources are (in order): cash; building; energy; contract setting out the relationship; documented information; exam results. Intangible examples of these five resources are (in order): unutilised borrowing capacity; location, exergy; trust, preferred status; corporate culture; tacit knowledge (for a more detailed discussion see, chapter 2 in Roos *et al.* (2012)).

The IC perspective views the resource transformation system as the firm specific transformation of resources into each other with the use of other resources in a journey from lower to higher value in the eyes of the primary stakeholder (e.g. the customer). Examples of such unit-transformations are illustrated in Table AI.

When looking at firms with successful transitions along the goods-services continuum towards a higher presence of service (see, discussion of the literature in Roos, 2015), servitisation requires a manufacturing firm to both build new resources in the different resource categories and to deploy resources in a different way, in other words, the firm must change the way that it create value.

The IC perspective is strategically useful on the firm level (Roos *et al.*, 2001; Marr and Roos, 2005; Roos, 2005), especially if combined with the capability to analyse the potential effectiveness of a given resource deployment structure using sophisticated measurement and evaluation techniques (Burgman *et al.*, 2005; Pike *et al.*, 2005), and on the strategic level, especially the IC Navigator approach (ICN) (see, Roos *et al.*, 2012, Roos, 2014d), for examples of this application (see, e.g. Fernström *et al.*, 2004; Pike *et al.*, 2005).

The ICN used in this study is a numeric and visual representation of how management views the way in which resources are deployed to create value in the organisation and for its customers or stakeholders. The ICN helps identify resource transformations. It is important to note that all transformations are possible – it is just that in a given organisation they are not all relevant and Table AI provides a non-exhaustive example of transformations as an illustration.

The ICN is not a model that tries to map the real flows in the organisation. These "real flow" models are unable to capture what goes on in organisations since they can only capture well transformations of a physical, monetary or informational nature. This means that, due to the multidimensional and non-additive nature of transformations, not all transformations can be captured by "real flow" models. The ICN operates on a higher level of abstraction (the influence level, that is, to what extent does a real flow matter from a value creating point of view) than flow models but is simultaneously strategically more useful since it provides a total picture of all transformations and resources that contribute to the organisation's value creation (Roos, 2014d).

Roos *et al.* (2012) and Roos (2014d) describe the process used to create an ICN as a consensus process aimed at capturing the tacit knowledge in the management team as relates to how value is perceived to be created in the organisation. There are three steps in this process. First, identification of the resource deployed. Second, weighting of the resources as relates to their ability to influence value creation in the organisation. Third, evaluation of the identified resources as relates to their suitability to form the basis for competitive advantage and evaluation of the quality and quantity of each resource. This is especially useful when looking to set up a new business activity like a service business within a manufacturing firm.

Manufacturing importance

The importance of manufacturing for national wealth creation cannot be overestimated. Manufacturing drives up economic complexity through its large networks of suppliers across many industries, forms the basis for high value services, performance a disproportionate and large share of national industrial R&D, generates a considerable number of high paying jobs both directly and indirectly, is the key driver of productivity improvements across all sectors in the economy, and is a key generator of export earnings and government tax revenues. We will look closer at some of these contributions that are of relevance for this study.

Multiplier effects, jobs and wages

The manufacturing sector has larger multiplier effects than services as confirmed by studies (e.g. Park and Chan, 1989; Daniels and Bryson, 2002; Pilat and Wölfl, 2005; Guerrieri and Meliciani, 2005; Castellacci, 2008; Francois and Woerz, 2008; Nefussi and Schwellnus, 2010; Evangelista *et al.*, 2013; Zhang, 2014). This is explained by the denser backward and forward linkages formed within and around the manufacturing sector since manufacturing industries interact much more strongly with other industries, both as providers and users of intermediate inputs, and even though services now contribute as providers of intermediate input to the performance of other industries, their role remains more limited than that of the manufacturing sector. This mutually dependent inter-sectoral relationship between manufacturing and service means that a country's capacity to develop its services sector is dependent on the specific structure of its manufacturing sector since manufacturing industries require different producers' services and tend to use them with different degrees of intensity.

This interconnectedness that manufacturing jobs drive jobs in other sectors can be illustrated by the numbers in the EU where 100 manufacturing jobs generate on average 64 jobs in the rest of the economy (a multiplier of 1.64) (Lichtblau *et al.*, 2013). These 64 jobs are distributed as: 20.3 jobs in private and public services; 13.6 jobs in logistics; 12.8 jobs in business services; 11.7 jobs in agriculture; 1.6 jobs in utilities; 1.3 jobs in financial services; 1.1 jobs in communications; 0.9 jobs in construction; and 0.6 jobs in mining.

The US manufacturing Institute has estimated the average multiplier effect across different economic sectors and finds that manufacturing has a higher multiplier effect on the economy than any other sector – for every $1 in manufacturing value added, $1.4 in additional value is created in other sectors (DeRocco *et al.*, 2009). Moretti and Thulin (2012) have looked at the multipliers more in detail and compared Sweden and the US on the manufacturing side, taking into account the structure of the two economies. The authors found that low skilled manufacturing jobs have a multiplier of around 1 in both economies whereas high skilled manufacturing jobs on average have a multiplier of close to 5 in the US economy and around 3 in the Swedish economy (Moretti and Thulin, 2012).

Tregenna (2009) demonstrates empirically that the decline in manufacturing employment that has been documented statistically is primarily associated with the falling labour intensity of manufacturing rather than an overall decline in the size or share of the manufacturing sector in most advanced countries. This follows from two simultaneous trends: first, the productivity growth in manufacturing is higher than in services (see, e.g. www.euklems.net) and is for most of the large companies higher than the demand growth for their products, enabling them to satisfy the demand with fewer employees. Second, much of the productivity improvements have been enabled by replacing labour with technology embodied in both software and hardware and this trend, which has been present for a long time in manufacturing, will, over the coming decade, also impact services in an unprecedented way, reducing the number of employees dramatically whilst simultaneously increasing productivity in the impacted service firms.

Research and development, innovation and productivity

Manufacturing is a main engine of economic growth, thanks to its higher productivity and scope for innovation (Andreoni and Gregory, 2013). The absolute majority of R&D spending in the world is geared towards manufacturing. This manufacturing research is not evenly spread and it is clear that countries with a high level of R&D in this domain have an advantage over those with lower R&D as can be seen from the findings of the 2009 ranking results of national innovation systems taking into account the innovation climate (Belitz *et al.*, 2011; Kovács, 2011).

Manufacturing's share of total R&D expenditure in the period 2008-2010 is calculated by Lichtblau *et al.* (2013) using OECD statistics (http://stats.oecd.org) and is shown to be 65.3 per cent for the European Union, 69.1 per cent for the US, 85.2 per cent for China, 87.1 per cent for Japan and 87.5 per cent for South Korea.

One of the key areas of research and innovation for securing tomorrows' successful manufacturing industries is the so-called key enabling technologies. Key enabling technologies have two specific characteristics that separate them from other "enabling technologies"; they are embedded at the core of innovative products and they underpin strategic value chains or in other words they underpin several other industries while also forming industries in their own right. Key enabling technologies are normally judged to include: information and communication technologies (including big data and big data analytics); nanotechnology; micro/nano-electronics; industrial biotechnology; photonics; advanced materials; and advanced manufacturing systems. Mastering of key enabling technologies is absolutely required to ensure that it is possible to produce future innovative products and is therefore a strategic priority to ensure the competitiveness of domestic industry.

Economies with a low share of manufacturing in the economy will have a relatively poor R&D performance and will suffer from the lack of associated spillover effects. Also, if there is a low relative volume and performance of research in key enabling technologies the future of any existing manufacturing sector is likely to decline with the associated negative effects for the economy.

Export earnings that pays for the cost of importing things

The largest share of exports is made up of manufactured goods, construction and agricultural goods. All of these, if any value is added to them, can be viewed as manufacturing in the broad sense of the word. This means that if any country is going to achieve a trade driven budget surplus (the normal way of achieving such a surplus), or even have the ability to import desirable goods and services without a negative budget impact, having a successful export driven manufacturing industry is a must. Australia's ranking in some relevant performance domains are as follows: manufacturing value added per capita – Australia ranks as number 22 with 33 per cent of the top ranking country's (Japan) performance (UNIDO, 2013, p. ix); economic complexity – Australia ranks as number 48 with 10 per cent of the top ranking country's (Japan) performance (http://atlas.cid.harvard.edu/rankings/country/); Net Export as per cent of GDP – Australia ranks low but positive with 12 per cent of the top ranking country's (Germany) performance[2].

At the root of the low tradability of services lies the fact that many services require their providers and consumers to be in the same location – no one has yet invented ways to provide haircuts long-distance that consumers desire. A rising share of services in the economy means that the jurisdiction, other things being equal, will have lower export earnings, meaning that unless the exports of manufactured goods rise disproportionately, the jurisdiction will not be able to pay for the same amount of imports as before. Also, the high tradability of manufacturing provides a crucial resilience to an economy with a strong manufacturing sector, as it can better protect itself from external shocks – exemplified by the resilience of the German economy following the 2008 financial crisis (Chang *et al.*, 2013).

The case study

A total of 32 sophisticated manufacturing firms that fitted the characteristics of technocrats, marketeers and Ikeas, as defined by Andersén (2012), were invited to join one of four programmes of business model innovation including a focus on servitisation. The firms were self-selected and on a first come first served basis. The assumption underpinning this approach is that this would generate a sample of firms that were willing to experiment (first mover behaviour), had a high problem understanding (goal oriented with clear problem identification) and were successful (could afford the time and money involved in participating). In addition the firms were demanding (know what good looks like in their mental view of the world and would provide immediate feedback if components of the programme where not valuable), were self-assured (did not mind the research process, e.g. video filming, questionnaire and discourse among peers and in private, did not mind sharing the outcomes with a wider audience) and had a high societal standing (hence high impact of judgemental statement regarding the programme process and outcome).

To verify the value of the ICN approach it was provided as one of several themes in the programmes (the themes are outlined in Table AII in alphabetic order). For each group of firms these themes were covered during a total of ten full interaction days over a 12 month calendar time period[3].

Each theme was covered through theory dissemination, examples and exercises relating to the individual firm. In-between modules the individual firm worked with implementing the insights into their own organisation (averaging 30 man-hours per firm per module). The average duration between modules was four weeks.

In addition, each firm had access to one of the authors for one meeting lasting between two hours and one day for any module related purpose the firm felt useful to address. Each firm sent their CEO plus between two and four other senior executives to the modules. The agreement was that the participants would only return to the next module, if they got value out of the present module. All firms participated in all modules.

Some modules were video filmed and all had external observers in the form of researchers taking notes and collecting group exercise output as well as circulating and capturing spontaneous comments and quotes during breaks. All the video material was reviewed and it provided valuable input for modifying the understanding of the relative value of the themes. In addition the programme was followed up with formal evaluations by module and as a whole immediately after, six month after and 12 months after the programme, executed by an independent researcher.

Findings and conclusions

This is the first theoretically grounded empirical testing of the usefulness of the IC lens in a servitisation context. The study shows some interesting findings.

Finding 1: The ICN with the associated effector plot evaluation is considered to be the third most valuable theme in a strategic and operational servitisation programme.

Finding 2: The usefulness of the ICN is primarily around evaluating different alternative resource deployment strategies, (i.e. different servitisation strategies in terms of resource deployment), for their relative effectiveness.

Finding 3: The ICN with the associated effector plot evaluation allowed the firms to understand the difference between an effective product production resource deployment system and an effective service production resource deployment system.

Finding 4: The ICN with the associated effector plot evaluation allowed the firms to understand the difference between a product-service-system resource deployment system and a solutions resource deployment system.

Finding 5: The ICN with the associated effector plot evaluation allowed the firms to clarify the appropriate interaction between the service part of the business and the manufacturing part. This includes designing and engineering the product and the services for achieving monopoly service rents through unique non-imitable integration between service and product.

Finding 6: The ICN with the associated effector plot evaluation allowed the firms to identify the changing relative importance of different resources as one moves from a product to a service focus.

Finding 7: The ICN with the associated effector plot evaluation allowed the firms to identify potential additional revenue streams.

The conclusion is that the importance of the IC Lens in a servitisation process is found to be high and it provides inputs to this process that are difficult to provide in other ways.

A further conclusion is that the ICN should be one of the key dimensions in a business model template for manufacturing firms that aim to servitised.

However, more research is needed on categorising different resource deployment structures and their impact on firm performance.

Finding 8: IC as a lens can contribute in both policy implementation and policy formulation. The policy formulation use can be illustrated by the Case of Manufacturing Works in South Australia where this lens was used throughout the policy formulation process. Aspects of this have been covered in other publications (e.g. Ahlqvist *et al.*, 2013, 2014, 2015; Dufva *et al.*, 2013; Roos, 2014e; Roos *et al.*, 2014; O'Connor *et al.*, 2015). The case above illustrates the use of the IC lens in the policy implementation process.

The empirical data underpinning this study and the other studies above highlight that the IC lens is exceedingly useful in policy formulation and implementation in manufacturing firms when understanding and evaluating alternative resource deployment systems for a servitisation strategy. Both these findings are critical in terms of underpinning the increased complexity of the South Australian economy, a policy objective, as a prerequisite for minimising any period of declining living standard and for laying the ground work for future living standard growth.

Notes

1. The most complex service categories are in descending order: royalties and license fees; financial services; insurance services; and other business services.
2. Calculated based on data from http://en.wikipedia.org/wiki/List_of_countries_by_net_exports.
3. The program was funded by Australian Industry Group in South Australia, Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) in South Australia and was executed as part of the evaluation process executed by the Entrepreneurship, Commercialisation and Innovation Centre (ECIC) at University of Adelaide.

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Further reading

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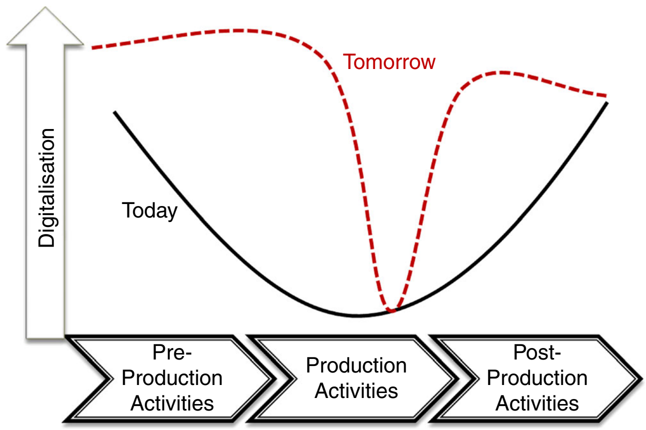
Appendix 1. Impact of technology development

The dominating technological development at the moment is the digitalisation of manufacturing which is resulting in a move of activities, executed by the manufacturing firm, from the physical space to the digital space (Figure A1).

As can be seen from Figure A1, this means that the firm will have an increasing amount of digital activities in its value chain. If these activities are outsourced or purchased they will be outsourced or purchased in the form of services. This means that even if they are executed within the firm they are executed as a service, whether charged for or not, and consequently the share of services purchased or executed by the firm is, and will continue to, increase. The main technologies that will impact manufacturing and the servitisation decisions of manufacturing firms over the coming decade are summarised and outlined in Table AI (summarised from pages 11-21 in Roos, 2014b).



Source: Roos (2014a)

Figure A1. The increased digitalisation in the manufacturing activities

Technology domain	Impact on servitisation
Information and communication technologies including big data and big data analytics	*Will increase the servitisation potential through* Increased efficiency of people interactions through social technologies on mobile devices Increased productivity through more efficient information access using mobile devices Increased productivity of administrative, service, sales, technical, financial, legal and managerial work through automation Increased productivity through a reduction in the infrastructure and facilities needed following on from task standardisation, application standardisation, automation and the use of cloud technology Faster experimentation and testing through the use of cloud technology Faster decisions and higher quality decisions through the use of big data analytics that can be automated into service processes
Internet-of-things	*Will increase the servitisation potential through* Sensors to track machinery and provide real-time updates on equipment status which decreases downtime Sensors to improve supply chain monitoring, tracking and management as well as the flow of inventory around factory floors or between different workstations, reducing work-in-progress inventory levels, decreasing waiting times, and enabling flow optimisation Sensors and actuators enable position change of work-in-progress objects ensuring arrival at processing capital equipment in perfect position avoiding jams and damages to the capital equipment Enabling saving in operating costs, including maintenance and input efficiencies
Additive manufacturing	*Will increase the servitisation potential through* Will enable on-demand production of e.g., tools and parts at the user facility when needed with the benefits of little to no production waste, short changeover times, and little to no direct labour required. Key benefits will lie in value increase in the produced item, cost savings, customisation and reduced distribution cost
Industrial biotechnology	*Will increase the servitisation potential through* Will change the structure and participants in value chains like e.g., chemical, pharmaceutical, food, energy, waste, mining etc. and thereby enabling new ways of doing things with the associated services
Photonics	*Will increase the servitisation potential in many ways relating to* Information gathering Information transmission Energy transmission Energy projection
Advanced materials	*Will increase the servitisation potential through developments in* Lightweight and ultra-strong materials Materials capable to resist aggressive environments Surface materials and coatings Electronic and photonic materials Smart, multifunctional devices and structures Biomaterials Specific industrial and other materials
Nanotechnology	Given the definitional challenges of nanotechnology i.e. the area is very broad since it is defined by size only and the consequential challenges posed by its

(*continued*)

Table AI.
Impact on servitisation from emerging key technology domains

Technology domain	Impact on servitisation
	multipurpose nature, determining the impact of the field is very difficult. Nanotechnology can be fundamental to a product and give it its key functionality, or it can be ancillary to the value chain and constitute a small percentage of a final product; or it may not even be present in the final product, only affecting the process leading to its production (Gadekar and Kadam, 2014). It suffices to say that this technology domain will impact servitisation
Advanced manufacturing equipment with special focus on industrial robotics	*Will increase the servitisation potential in many ways relating to* The continuously lowering barriers to deploy industrial robotics The introduction of self-optimising smart driver-less vehicles Automation of manufacturing activities using self-configuring and adapting robots combining the flexibility of a skilled human with the precision and speed of a robot Broader benefits derivable from robotic human augmentation Development and implementation of commercial service robots
Micro- and nano-electronics	Will increase the servitisation potential in many ways due to the extended collaboration required throughout the nano-electronics ecosystem, addressing the entire value and innovation chain

Source: Extracted from Table AII in Roos (2014b)

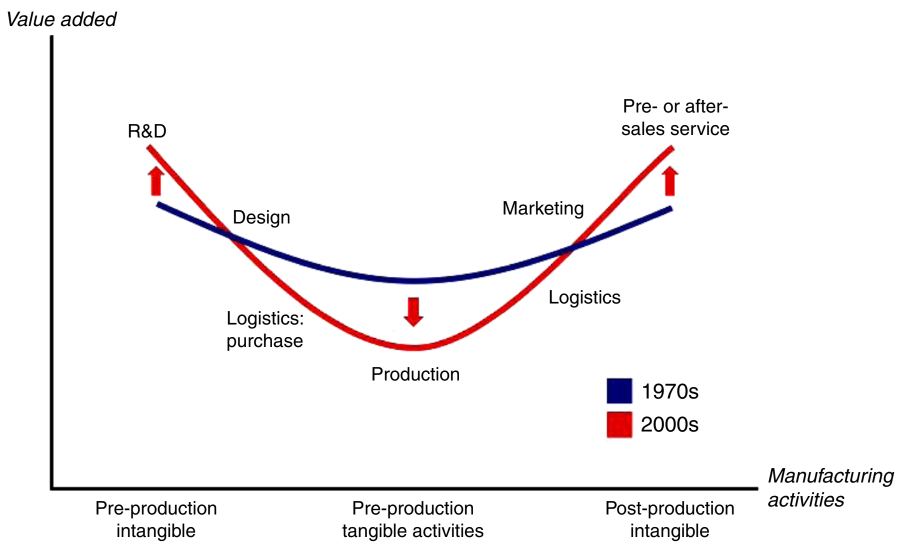
Table AI.

Appendix 2. Key drivers for manufacturing firms to move into services

The many different drivers for manufacturing firms, expressed as observations by management, to servitised are summarised in Table A1, based on a review of the literature in Roos (2015). (Figure AII, Tables AII and AIII).

Programme themes in alphabetic order:

- Allocating resources for service business.
- An Integrated view of Servitisation.



Source: Veugelers (2013, p. 27 after original concept by Shih, 1992)

Figure A2.
The shift in value-adding over time across the key value chain steps

Tactical observation by management	Desired outcome through servitisation
Increased volatility in product sales (e.g. reduction of customer capital equipment spend in the mining industry)	Lower volatility in cash flows due to a balance of product sales revenues and after sales service revenues
Missing out on the revenue potential in the large installed base	Increase the revenue stream from the installed base and contribute to a reduction in cash flow volatility for the manufacturing firm
Loyal customers are easier to serve and hence cost less to serve and consequently are more profitable to serve	Increase profitability by leveraging economies of loyalty
Loyal customers have lower price sensitivity	Increase profitability by leveraging economies of loyalty
Loyal customers use more complex services that frequently are more profitable	Increase profitability by leveraging economies of loyalty
Loyal customers provide positive referrals and references to potential new customers	Reduce selling costs by leveraging economies of loyalty
Services are more difficult for competitors to imitate	Increased profitability due to the creation of competitive advantage, the duration of which can be extended through barriers to entry inherent in the difficulty to imitate
Services provision requires a closer relationship between producer and customer and may result in customer lock-in	This increases customer loyalty as well as providing a basis for competitive advantage and hence increase profitability
The product as a vehicle for service delivery, offers a potential for monopoly in some co-created services	Increased profitability through monopoly rent, economies of loyalty and in-depth learning which reduces the cost and risk around the development of both new products and new services
Continuous customer interaction speeds up the acquisition, volume and relevance of customer knowledge	Volume of innovation ideas increases and their market acceptance risk is reduced. Probability of co-developing new offerings with a lead customer is increasing thereby reducing market acceptance risk
Decreased interest in the product matched by increased interest in the outcome of the use of the product	The ability to partake in business operations that do not involve product sales but instead product use e.g., car sales replaced by car rental or car sharing
Service delivery with high customer satisfaction drives replacement product sales	Increased profitability due to repeat purchase
Some outcomes demanded by customers requires service delivery	Retain market relevance, frequently combined with increased customisation of the complete offering
Some products require continuous service deliver over extended periods of time	Retain customer relationship
Offshoring or outsourcing of production	Substitute lost cash flow and earnings
Increasing regulatory requirements in the through-life and end-of life product responsibility domain	Services ensure regulatory compliance
Services can contribute to reduced environmental and resource footprint	Respond to market trends and reduce operating costs

Table AII. Tactical reasons and objectives driving servitisation in manufacturing firms

(*continued*)

Tactical observation by management	Desired outcome through servitisation
Service provision adds another business	Increased turnover and (frequently) operating margin sometimes through increased opportunities for cross-selling
Services can differentiate the product offering	Increased competitive advantage resulting in increased profitability
Services can extend product life	On the one hand this increases the net present value of the earnings from a given product sale but on the other hand it reduces the net present value of new product sales so this needs to be managed very carefully

Source: Roos (2015)

Table AII.

- Art base of the Product-Service-System/Solutions offering.
- Committing managers to service business.
- Cost structure due to strategic choices and identification and management objectives for associated economic value added drivers as well as bankruptcy predicting indicators.
- Creating a vision and communicating the need of renewal throughout the organisation.
- Creating positive attitude towards continuous renewal.
- Creating shared understanding and commitment to service business.
- Creating trust and developing mutually beneficial long-term relationships.
- Dedication to the creation of service innovations.
- Description how the target customer segments, target consumer segments and other definitive stakeholders capture value from the offering.
- Description of how the product-service-system/solutions offering should be implemented at the target customer segments, target consumer segments and other definitive stakeholders to ensure the targeted benefits (value).
- Description of the product-service-system/solutions offering.
- Design base of the product-service-system/solutions offering.
- Developing a customer-oriented mind-set.
- Developing and managing a dynamic value network to access resources and technologies.
- Developing innovative ways to share revenue and risk.
- Developing service-oriented capabilities.
- Emotional state base of the product-service-system/solutions offering.
- Empowering everybody to be innovators.
- Empowering people to manage and implement renewal.
- Fostering service-orientation through the whole value network.
- Grounding the changes of organisational culture.
- Identification of target customer segments, target consumer segments and other definitive stakeholders.
- Incoming Logistics and Supply Chain Choice.
- Linking service-orientation to business strategy.

Table AIII. Examples of resource transformations

		Transformation into the following resource				
		Monetary	Physical	Relational	Organisational	Human
Transformation Originating in the following resource	Monetary	Putting money on the bank to gain interest	Procurement of raw material or equipment	Investing in relationship building	Investing in software, brand building, information, etc	Investing in competence development or in people with higher or more appropriate competence
	Physical	Selling products	Mixing chemical A with chemical B to get chemical C	Strengthening relationships through superior aesthetic design or through chemical dependency e.g., tobacco	Developing new products requiring new production processes	Taking into use new equipment requiring new competence to operate
	Relational	Monetising relationships like in e.g., shopping TV where the good seller pays the TV channel to get access to the viewers	The power exerted by big customers to get free sample products developed by tier one suppliers	Word of mouth	The quality system that is implemented for free by the large customer into the valuable small supplier to assist them reduce quality variability	Co-learning in e.g., joint research projects
	Organisational	The additional price you can charge because of brand or IP	Process drive production in e.g., the process industry (the recipe that if followed generates the product)	A customer relationship management system that increases customer loyalty when put to use	Automated software development	Automated training
	Human	Monetising competence (frequently through man-hours as a proxy)	The creation of a prototype or a work of art	The conversion of a non-relationship into a relationship by e.g., a salesperson	Documenting a process so that it can be repeated by others	Apprenticeship or personal training

Source: Extracted and synthesised from chapter 3 in Roos *et al.*, 2012 and Roos, 2014d

- Organisational culture in servitisation.
- Outgoing Logistics and Distribution Channel choice for each of the target customer segments, target consumer segments and other definitive stakeholders.
- Place, role and strategy of THIS business in the business ecosystem of which it is part.
- Positioning and coordinating networks.
- Positioning of THIS business within the company's strategy.
- Promoting flexible risk management.
- Pursuing systemic change.
- Relationship width, depth and frequency for each of the target customer segments and other definitive stakeholders.
- Resources, competitive advantage and resource deployment structure (IC navigator).
- Revenue models with focus on accessing multiple profit pools and maximising the number of revenue streams/pricing logic combinations aimed at achieving an economic value added for the business exceeding the revenue stream from its primary offering.
- Success factors for entering and developing a servitisation strategy.
- Technology base of the product-service-system/solutions offering.
- The acquisition and development of talented employees.
- The service business model.
- The service value network perspective.
- The strategic perspective of servitisation.
- Understanding the business practices and processes of other key actors.
- Understanding the customers' strategic options.
- Utilising different ways of renewal.
- Value attribute, attribute preference and attribute performance for each of the target customer segments, target consumer segments and other definitive stakeholders.
- Value configuration (value chain, value shop, value network) and associated transaction and coordination cost issues.
- Value proposition for each of the target customer segments, target consumer segments and other definitive stakeholders.
- What competitive advantage does the offering enable or contribute to within the target customer segments, target consumer segments and other definitive stakeholders.
- What requirements must be fulfilled by the target customer segments, target consumer segments and other definitive stakeholders in order to be able to benefit from the offering.

Corresponding author
Professor Göran Roos can be contacted at: goran@roos.org.uk

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