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Manufacturing and Innovation

SUBMISSION TO SENATE STANDING COMMITTEE ON ECONOMICS

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Australia's Innovation System

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The Australian Workplace Innovation and Social Research Centre (WISeR) *focuses on work and socio-economic change. WISeR is particularly interested in how organisational structure and practices, technology and economic systems, policy and institutions, environment and culture interact to influence the performance of workplaces and the wellbeing of individuals, households and communities.*

WISeR also specialises in socio-economic impact assessment including the distributional impacts and human dimensions of change on different population groups and localities. Our research plays a key role in informing policy and strategy development at a national, local and international level.

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KEY FINDINGS AT A GLANCE

- Manufacturing is central to 'economic complexity' or 'network richness' (how societies amass and utilise productive knowledge). Products embody knowledge, so we can say: *"what a country makes is what it knows".* Sophisticated products reflect high and diverse capabilities in local value chains – 'economic complexity'.
- Complexity is the key driver of differences of income per capita between countries, predictive of a country's future growth, and the complexity of its exports.
- Australia's economic complexity has fallen dramatically:
    - 2008 ranking is 79, below Trinidad and Tobago, Mauritius, and Chile, and ahead of Zimbabwe, Jamaica, and Pakistan. Australia's complexity rating is -0.321, compared to Japan (2.316), Germany (1.985) at the top of the list, Singapore at number seven (1.639), and the USA at 13 (1.447), China at 29 (0.894), Thailand at 31 (0.814), and Malaysia at 34 (0.759).
    - Australia's 'economic complexity' has deteriorated since the middle 1960s, with a dramatic deterioration of -0.50 over the 1998-2008 decade, the period during which our exports came to be dominated by coal, iron ore, other minerals and liquefied hydrocarbons and manufacturing's GDP share fell dramatically.
- In advanced economies, manufacturing
    - Drives innovation and productivity growth
    - Is the biggest spender on R&D
    - Drives high value services
    - Has high multipliers through linkages to other sectors, and
    - As the largest component of world trade, drives ever -increasing specialisation and sophistication.
- Unless Australia takes action to diversify and transform its manufacturing, the Nation faces the permanent loss of essential economic capabilities and, with that, reduced capacity to develop new ones in the future. The consequences would include:
    - Dependence on fewer, and lower value adding, industries
    - Greater vulnerability to external shocks
    - A weaker, more narrowly-based and exposed Australia economy,

  with unacceptable transition costs for Australia society.
- Innovative organisation and leadership, together with changes in technology and global supply chains make this diversification possible and feasible on an internationally competitive basis.
- Australia must build complexity, innovation and non-price competitive advantage. It must aim for medium to high complexity, low volume, high variability (customisation) and high value adding activities – the characteristics of 'new manufacturing'. It must aim for agility across multiple value chains, and rapidity to market. It must aim for industry opportunities where being small is not a disadvantage.
- In new manufacturing particularly, competiveness is a function not of technology alone, but of a structured and purposeful interaction of strategy, leadership, technological excellence, and enterprise and value chain organisation and culture. Hence an integrated approach to competiveness is vital.
- Australia must aim for accelerated diversification into new high growth value chains, using and translating existing capabilities, building on existing strengths, including those involved in the automotive industry.
- Value chain mapping and technology fore sighting are fundamental to the identification of opportunities.
- Not only individual firms, but also nations, regions and governments compete to capture and localise the benefits of dynamic innovation.

- A brief survey of current programs and approaches of other advanced economies to accelerate the transformation of their manufacturing sectors suggests that Australia has more to do to become competitive in policy and strategic terms.

1 INTRODUCTION

Manufacturing and Innovation has been prepared by the Australian Workplace Innovation and Social Research Centre for the consideration of the Senate Standing Committee on Economics on the Australian Innovation System.

It describes the importance of 'economic complexity' as the primary driver of a nation's prosperity and performance, and the centrality of manufacturing to economic complexity, productivity, innovation and having a place in the international knowledge economy. The paper argues that whilst post-resources boom Australia, having become a small high cost economy, will struggle to compete in manufacturing activities where scale and unit cost are the bases of competition, the nation cannot afford to lose key manufacturing capabilities.

Rather, the strategic focus now needs to turn to 'new manufacturing' opportunities opened up by changes in technology, international supply chains of increasingly complexity and innovative new forms of business organisation. New manufacturing is characterised by combinations of short production runs, medium to high complexity, high value, high variability and customisation. In many new manufacturing activities, being small need not be a disadvantage.

2 'ECONOMIC COMPLEXITY'

Recent research has added important comparative and explanatory dimensions to existing insights into how and why nations succeed or fail to achieve or sustain high levels of prosperity. This approach provides insights and helps to order and explain regularities observed in high and lower performing economies, both those presently advanced and rapidly developing. It gives prominence to the importance of tacit knowledge and capabilities embedded in firms, organisations and markets, and has added evidence to existing perspectives that have emphasised the importance of knowledge, specialisation, and the role of broad based innovation in dynamic networks within successful nations.

It underlines the centrality of manufacturing to advanced knowledge economies.

Harvard researchers Cesar A. Hidalgo and Ricardo Hausmann et al have produced *The Atlas of Economic Complexity: Mapping Paths to Prosperity*[1]. The book relates differences in nations' economic performance to the 'complexity' of its economic networks that contain productive knowledge. In a broad context, the term 'complexity' could be substituted by such terms as 'density', 'thickness', 'interweaving' or 'network richness'. They emphasise the fact that modern societies are able not only to amass - but also to utilize effectively - large amounts of productive knowledge, is because of its being distributed in modules amongst members of society. This is an extension of Adam Smith's idea that economic progress is the result of an ever-deepening division of labour. This division of labour gives us all access to knowledge we would not be capable of holding individually.

To be able to be utilised fully, modules of knowledge need to come together in diverse combinations in teams, organisations and markets. It is these various teams, organisations and markets that allow the diffusion and use of this knowledge across society and the globe, and that provide the networks that allow greater and greater degrees of specialisation, on the one hand, whilst ensuring that the outputs of this specialisation are able to be absorbed and used, on the other. The networks allow both specialisation and sharing of outputs across society.

[1] Cambridge MA, Puritan Press, 2011.

In an advanced economy, there is diversity of knowledge which, in order to be useful and **productive,** must be held by many individuals. That means that to be utilised fully, knowledge needs to be organised through a social process into organisations, markets and institutions as modules.

The 'complexity' being spoken of here then consists of two broad things:

1. Increasing levels of specialisation and technical sophistication and organisation of knowledge into modules, and
2. Their complex combining and coming together in institutions, enterprises, markets and organisations.

This productive knowledge is not only formal but also tacit, residing in organisations, markets, enterprises and institutions as **capabilities.** Because much of this knowledge is tacit, it is hard simply to acquire it. It is not tradeable, nor can it be priced in the normal sense. It is clustered around and embedded within organisations, markets and institutions, and their networks. This means it is hard to acquire and for those who do acquire and hold it, it becomes a competitive strength. It provides a basis in superior organisation for competitive advantage distinct from standard price-based competition. It is therefore evident in those high cost manufacturing economies that succeed regardless of low cost competition, and is of vital importance to Australia, which has become a high-cost economy that is in clear danger of losing significant manufacturing capabilities, unless it undertakes an accelerated transition to advanced manufacturing activities.

Products embody knowledge: **"***what a country makes is what it knows".* For example, an advanced economy and society must be able to make products and services from the interaction and combination of the knowledge of specialist designers, marketers, finance specialists, engineers, technology experts from various disciplines, human resource managers, legal experts, environmental scientists, specialists from the social sciences, including branches of economics etc. Where these inputs are missing, it is not possible to make products of the same complexity.

We see through this example the extent to which making products involves interdependencies requiring cooperation between individual actors, particularly in making complex products. The more that these interdependences can be localised within a nation or region, the more a nation or region's economy has captured the benefits of the activity or sector in locally based complex value chains. Building these networks embodying key capabilities, including leveraging demand along high growth value chains, is a central task for policy.

2.1 MEASURING COMPLEXITY

Hidalgo and Hausmann et al have developed and Economic Complexity Index (ECI) for 128 countries. The ECI attempts to capture the total amount of productive knowledge embedded in society, through two terms: 'diversity' and 'ubiquity'. The authors state that their measures of complexity of available capabilities are

- Correlated to income per capita (not just as a symptom, but as a driver: the greater the complexity, the stronger the nation's growth and prosperity)
- Predictive of future growth (because the ability of a country to produce a new product is circumscribed by its existing capabilities and new ones it may acquire, and there is a close relation between the two)
- Predictive of the complexity of a country's future exports.

The model uses 'diversity' and 'ubiquity' as crude approximations for complexity and hence, for the variety of capabilities present in a nation or required to make a product. A country exhibiting diversity in its products has a large amount of embedded knowledge

and a sophisticated array of capabilities: it can do many things. Less diversity indicates the reverse.

Ubiquity is about the number of countries that make the same or similar product, given that sophisticated products are made in relatively fewer places. The more ubiquitous a product the less sophisticated it is likely to be. In short, the knowledge-intensity of a nation is expressed in the (higher) diversity of the products it makes and the (lesser) ubiquity of its products.

Hidalgo and Hausmann et al use international trade data to bring out these concepts and make comparisons. These data are rich because they are longitudinal, and provide a standardised set of classifications to describe cross-country information on what nations produce[2].

2.2 Australia's Position and Performance

The top 10 ratings for complexity are:

1. Japan
2. Germany
3. Switzerland
4. Sweden
5. Austria
6. Finland
7. Singapore
8. Czech republic
9. UK
10. Slovenia.

The bottom 10 is comprised of Libya, Gabon, Cameroon, Nigeria, Guinea, PNG, the Congo, Sudan, Angola, Mauritania (119-128).

Australia's 2008 ranking is 79, below Trinidad and Tobago, Mauritius, and Chile (76,77,78), and ahead of Zimbabwe, Jamaica, and Pakistan (80, 81, 82). Australia's complexity rating is -0.321, compared to Japan (2.316), Germany (1.985) at the top of the list, Singapore at number seven (1.639), and the USA at 13 (1.447), China at 29 (0.894), Thailand at 31 (0.814), and Malaysia at 34 (0.759).

Australia is expected to perform poorly by comparison with other countries in the East Asia and Pacific region in GDP growth per capita to 2020 (p 69) and overall GDP growth over the period, being described as a "laggard" (p 75).

Moreover, Australia's performance in 'economic complexity' terms has deteriorated since the middle 1960s. In 1964 Australia had an ECI rating of 0.41. By 1998 this had fallen to 0.18, before falling further to -0.32, a deterioration of -0.73 over the 44 year observation, but with a dramatic deterioration of -0.50 over the 1998-2008 decade, the period during which our exports came to be dominated by coal, iron ore, other minerals and liquefied hydrocarbons and manufacturing's GDP share dropped dramatically.

This deterioration is not due solely to the dramatic growth of Australia's extractive industries relative to other sectors. It is also attributable to

- The relatively small set of minerals and energy commodities that dominate our export profile, together with the fact that these are produced by a significant number of other nations, and

[2] The limitations of this are acknowledged. First, the data are only for exports. Nations do produce things they do not export. But exports reveal the pattern of specialisation and dependency. Second, the usual limitation of the data to products not products and services applies here. Third, non-tradable activities are not included.

- The pronounced decline in manufacturing's GDP share over that time, from just under 12 per cent to below 10 per cent by 2008, with a further dramatic fall to just above eight per cent by 2012[3]. This pronounced manufacturing decline is of course closely related to the 'crowding out' effects of the previous resources boom, transmitted principally through a higher exchange rate, causing a loss of manufacturing competiveness.

3 Australia Needs to Lower its Risk Exposure – Portfolio Approach

Australia is a small trade-exposed economy. Rather than over-reliance on a small number of export commodities, Australia needs to take a portfolio approach to the future. It needs to diversify and expand its portfolio of economic capabilities. Changes in technology and global supply chains make this diversification possible and feasible on an internationally competitive basis.

For a country with a large resources sector, manufacturing offers vital diversification and a hedge against economic disruption. Resources is a notoriously cyclical business, with booms turning to busts as global capacity increases in response to high prices. Manufacturing increases Australia's economic diversity, providing the Nation with increased security against adverse movements in commodity prices and minerals demand.

Without targeted action Australia faces the permanent loss of essential economic capabilities and, with that, reduced capacity to develop new ones in the future. The consequences would include:

- Dependence on fewer, and lower value adding, industries
- Greater vulnerability to external shocks
- A weaker, more narrowly-based and exposed Australia economy,

with unacceptable transition costs on Australia society.

4 Manufacturing's Role

Manufacturing is critical to achieving 'complexity' within a national economy; it is the biggest contributor to complexity. It is obvious that taking a raw material and transforming it into a manufactured product tailored for use by a demanding end user involves complexity, both of a technical and organisational nature. Taking titanium and using it to design and then produce lightweight, safe and highly functional enabling devices for the aged and disabled is clearly complex, to take just one example.

In advanced economies, manufacturing is central to higher GDP growth and economic well-being, because it

- Is central to driving productivity[4] and innovation across the economy. Manufacturing generates positive spill-over effects across the economy through,

[3] *Smarter Manufacturing for a Smarter Australia (*Report of the non-Government members of the Prime Minister's Task Force on Manufacturing), August 2012, p 13.

[4] Pilat, Cimper, Olsen and Webb, *The Changing Nature of Manufacturing in OECD Economies,* OECD STI Working Paper, 2006, pp. 22-23. Manufacturing is very important to the aggregate productivity performance of the whole economy. The current concern with deteriorating productivity performance nationally needs to recognise that a large part of this is due to compositional changes in the economy away from manufacturing to certain services has resulted in more people working in low productivity industries.

amongst other things, its research and development intensity, and involvement in developing future platforms or 'key enabling technologies' such as nanotechnology, photonics, advanced materials, etc. These platforms are keys to future competitive advantage.

- Is globally the biggest spender on research and development[5] and knowledge intensive services. To be part of the international knowledge economy, a nation needs strong and dynamic manufacturing.
- In Australia, manufacturing accounted for over a quarter of business expenditure on research and development (BERD) in 2009-10, second to 'services and other industries'.
    - The position of manufacturing in second place is symptomatic of Australia's poorer overall R&D performance, since countries with a smaller manufacturing sector will undertake less R&D.
- Is the largest driver of high value services (as distinct from R&D). Many have noted the increased blurring of lines between modern manufacturing and services. More and more services go into the production and marketing of manufactures; service occupations make up a higher proportion of the workforces of manufacturing companies[6]. The 'servitisation' of manufacturing is the process by which manufacturers use service offerings to build competitive advantage, sales and revenues. Servitisation builds value to the customer by going beyond offering a single transaction involving a discrete product to a longer term relationship geared to meeting evolving customer needs.
- Has strong backwards and forwards linkages to resources, agriculture and services (as instanced above), helping to drive demand and employment across the economy. Because of these strong linkages, manufacturing has a strong positive multiplier effect on the rest of the economy.
- Is the largest component of world trade (see below, 'Manufacturing and International Specialisation').

4.1 'NEW MANUFACTURING'

Events over the past decade particularly have reinforced that Australia will struggle to be competitive in forms of manufacturing where the bases of competition remains scale of production and unit cost. The impact of the resources boom and the high dollar, together with the rise of strong Asian competitors, mean that Australia has become a small high cost economy. The end of Australian automotive manufacturing attest to the difficulties Australia faces in being a competitive manufacturer where the bases of competition are scale and unit cost.

But changes in technology and international supply chains (greater and greater specialisation and complexity), together with innovative business organisation, have opened up new opportunities for internationally competitive manufacturing based on short run production, high variability, rapidity to market, and high value products exhibiting medium to high complexity. In so doing, it has opened up opportunities for small and medium enterprises (SMEs) and clusters of SMEs in increasingly specialised, interdependent, global supply chains. This is 'new manufacturing'.

Alignment to new manufacturing means that being small need not be a disadvantage.

Examples abound of small, high cost countries that have actively sought out and secured positions of international competitive advantage, moving up the value chain to compete less on cost – price factors and more on agility and 'new manufacturing' characteristics. These include Switzerland, the Scandinavian countries, Singapore and others. They sought to maintain and expand their involvement in manufacturing as central to their prosperity

[5] Ibid pp. 26-27.

[6] Ibid pp. 31-32. The authors state that in certain OECD countries in the mid-1990s the service industry input was 25-30 per cent of total manufacturing output.

and their ability to participate in the global knowledge economy, rather than allow de-skilling and deindustrialisation.

5 Manufacturing and International Specialisation

As the largest component of world trade, manufacturing drives ever increasing specialisation and deepening inter-dependencies. It deepens the division of labour. For example, trade in manufacturing grows at a faster rate than manufacturing output[7]. This reflects greater complexity, specialisation and interdependency in production within and between countries. Production of a final manufactured good will often be organised using intermediate goods and components produced in and sourced from many different countries, each specialising in a defined area. In the decade 1995-2005 intermediate goods represented 56 per cent of overall trade in goods. Over the past four decades, there has been a 10-fold increase in trade in intermediate goods[8].

As the most heavily traded sector, manufacturing is at the forefront of international competition, driving both productivity growth and innovation as the bases for sustainable competitive advantage of nations and regions. This involves organisational as well as technical innovation. Manufacturing is known in advanced countries particularly, for organisational forms that use these interdependencies and interrelationships to build agility, alacrity and flexibility across an area or a supply chain.

Cluster organisations are critical platforms for innovation. Regional and sector based clustering exemplifies the critical role of complex non-price factors and of organisational superiority in sustaining competitive advantage. Clustering is an example of the attempt to utilise tacit knowledge and 'learning by doing' to embed unique advantages that are not traded and provide competitive advantage. A cluster is an example of 'network richness', 'interweaving' or 'complexity'.

Amongst a range of studies demonstrating the higher performance of firms involved in structured collaboration and clustering with other firms and non-firm organisations such as universities (as against those not so inter-connected), one instances 14 percentage points higher growth in value added, higher profitability growth of seven percentage points, and higher wages growth per employees of two percentage points[9].

Cluster organisations underline the tacit nature of much innovation and that, even in a globalised world, geography and propinquity matter.

Network richness and complexity are essential to competitiveness in a high cost environment. This includes co-production of applied research between universities and industry. This is an indispensable element of industry growth in a high cost environment requiring innovative capability, and an area in which Australia is a laggard [10].

Currently Australia rates poorly against other OECD countries for collaboration on innovation and 'state of cluster development' and 'value chain breadth'[11]. The World Economic Forum puts Australia in the fourth quartile for 'capacity for innovation'[12]. Australia compares unfavourably with countries such as Sweden and Germany, with respect to investment in 'intangibles' (as distinct from physical capital)[13]. 'Intangibles'

[7] Ibid, pp. 16-17.
[8] Cited in Roos, Australia Adjusting, November 2013, CEDA, p 106.
[9] Ibid, based on data provided in O. Solvell and M. Williams, *Building the Cluster Commons: An evaluation of 12 Cluster Organizations in Sweden 2005-2012*, Ivory Tower , 2013, Stockholm.
[10] Roos, Op. cit., p 108.
[11] Ibid., p 110.
[12] Ibid, p 111.
[13] Ibid, p 109.

investment covers organisational and human capital, R&D and investment in ICT – many of the things, in short, that enable a company to absorb and embed innovation.

Advanced capabilities are not evenly distributed across the globe. Globalisation does not signify a trend to economic homogeneity or convergence in the economic performance of nations (adjusted for differing factor endowments). Globalisation is about an ever-increasing division of labour across the globe. The world is not becoming 'flat' as some popular commentary has it, but 'spikey', where key high value production activities are concentrated in certain areas that possess the requisite capabilities.

Many companies that rushed to extensive outsourcing or off-shoring of their production have found that they reduced or lost opportunities for innovation and capabilities that had previously provided them with competitive advantage. Some have subsequently sought to in-source and consolidate key activities to defined centres.

This is also illustrative of the fact that manufacturing competiveness is a function not of technology alone, but of a structured interaction of strategy, leadership, technological excellence, and enterprise and value chain organisation and culture.

6 Policy and Strategic Implications

The policy and strategic implications, for high-cost economies seeking an accelerated transition of manufacturing as a basis for sustainable growth in living standards, are quite clear:

1. The focus needs to be on promoting competitive advantage based on innovation, organisational superiority, and agility. Cost-price based competition is not a sustainable basis for industry growth in a high cost advanced economy, such as Australia
2. A key objective is to create an environment conducive to the creation of a greater diversity of productive activities and capabilities, particularly network richness or complexity
3. This should be done by focussing on strengthening of tacit, embedded and networked, non-traded sources of competitive advantage, combining the technical with the organisational and strategic. The idea is to foment connectedness and density to cope with complexity. This provides a platform of competitive advantage less likely to be able to be replicated by competitors
4. In building new capabilities and moving up the value chain, a nation or region needs to build on what capacities and abilities it has. This means targeting products close to the current set ('near-by' products), and targeting capability gaps to move up the value chain progressively. Because productive knowledge is embedded
    a. It is generally not realistic to envisage making things at a large distance from the existing set of capabilities, but
    b. Expanding productive knowledge and industry capability by building on existing strengths can make a transition from old to new viable. A nation or region must translate and transform what it has. This is important for Australia, which needs to find replacement industry opportunities for declining industries, and is in danger of permanent loss of significant capability.

6.1 After Cars

What does this mean for the national and regional responses, for example, to closure of the automotive industry? As stated above, industrial development is path-dependent. Hence the emphasis on targeting 'near-by' products as key to the diversification strategy,

and on 'translating' the stock of competencies presently held to new product and market segments and opportunities.

It must be emphasised, a further implication of path-dependency is that unless diversification opportunities are found rapidly, essential skills, capabilities and complexity will be lost permanently. The principle of 'use it or lose it' applies here.

Automotive manufacturing is complex manufacturing par excellence. Some of the enabling competences and technologies inherent in automotive manufacturing and engineering include: systems integration, materials science and engineering, process engineering, automation and control technologies, electronics and miniaturisation, digital content, sensing and simulation, high tooling skills, injection moulding, etc. The objective is to identify applications for these capabilities outside automotive, in high growth local and global value chains in new manufacturing.

6.2 VALUE CHAIN MAPPING AND TECHNOLOGY FORE SIGHTING

This requires intensive value chain and opportunities mapping, to identify iteratively current and prospective opportunities, aligned to existing or achievable new capabilities of Australian manufacturers. It requires also technology fore sighting, not only to understand what production technologies will be in use, but also to understand how technology will further fragment international value chains, and create new demand. The resulting 'demand/supply/capability matrix' should isolate high value and credible industry diversification opportunities for Australian firms.

Note that this approach sees the most powerful approach as being on the demand side; although technology is vital, it is not a technology-push model. It has application broadly, and not only to the challenges of companies currently dependent on exiting automotive majors. WISeR is currently using this approach to identify and analyse potential in assistive technologies for the aged and disabled in a major project being undertaken with the SA Department of State Development and Germany's Fraunhofer Gesellschaft. It is also intended to extend and apply the approach to prime facie opportunities for SA in:

- selected defence (armed vehicles fit-out and through-life support; the Future Submarine project, amongst others)
- sophisticated manufacturing inputs to selected resources and energy areas (copper and complex combined ore bodies; unconventional gas)
- assistive technologies for the aged and disabled
- medical devices, and
- clean technologies[14].

7 INTERNATIONAL CONTEXT

The foregoing has emphasised the centrality of manufacturing to complexity and Australia's future ability to participate in the global knowledge economy. It has emphasised the importance to Australia of rapid transition to opportunities in 'new

[14] The approach is elaborated in three documents attached to this submission:

1. Spoehr, J., Worrall, L., Sandercock, P., Eyre, J., & Molloy, S., *Assisting Transition: Assistive technologies opportunities and industrial transformation in South Australia,* April 2014. Adelaide: Australian Workplace Innovation and Social Research Centre (WISeR).
2. Spoehr, J., Worrall, L., *Strength in Diversity: Diversification, Innovation and Jobs. Commonwealth Review of SA Economy and Impact of GMH Closure,* January 2014. Adelaide: Australian Workplace Innovation and Social Research Centre (WISeR).
3. Spoehr, J., *Foundations for Industrial Rejuvenation. Lessons from International and National Experience*, January 2014. Adelaide: Australian Workplace Innovation and Social Research Centre (WISeR).

manufacturing', and that building and sustaining positions of competitive advantage is more than technology (vital though this is), and includes a rigorous understanding of demand and global market and value chain opportunities, and recognition of the critical role of complex non-price factors and organisation and strategy.

If so, a policy based on the model of atomistic competition between firms producing homogenous products will serve us poorly. Currently, Australia has a policy and strategic approach which is uncompetitive with other high cost advanced countries.

Not only individual firms, but also nations, regions and governments compete to capture and localise the benefits of dynamic innovation that come from having a strong knowledge-based manufacturing sector. Competition at these levels, beyond the individual firm, is ubiquitous in advanced economies. As stated above, Australia is presently internationally uncompetitive at this level.

A brief survey of latest approaches internationally confirms the relevance and currency of the above analysis, including the salience of 'intermediate' organisations to deliver 21st century industry extension services on a properly strategic basis.

7.1 COMMON APPROACHES

The approaches typically combine the following key elements:

- Accelerated diffusion of Key Enabling Technologies (KET) along target value chains[15] including a technology and future demand foresight function
- Production systems, encompassing areas such as high performance workplaces, business model innovation, design, intelligent factories, smart specialization, technology and opportunity mapping, and cluster organization
- Leveraging new global market and value chain opportunities.

There is recognition that the most powerful levers/forces are on the demand side, and in having a sophisticated understanding of present and future drivers (complexity, increasing interdependencies, etc.)

- Technology is crucial, but the strategy and approach are not supply- or technology-push

They also recognize the critical role of complex non-price factors and of organizational superiority in sustaining competitive advantage

- Hence they are multi-disciplinary in their approach

The focus is on multi-faceted innovation and experimental development and diffusion

- Tacit knowledge, networks and organization are as important as technical excellence and formal knowledge. The point is to combine the technical with the strategic and organizational.

7.2 INTERNATIONAL EXAMPLES

7.2.1 INDUSTRY 4.0

This is the technology policy of the German government to achieve the fourth industrial revolution over the coming 10-20 years. The Smart Factory is characterized by high adaptability through electronics and IT applications, particularly the Internet of Things, as the basis for networked production. Industry 4.0 continues the German tradition of 'diversified quality production', increasing the emphasis on customization in the context of flexible, integrated production, where self-optimization, self-diagnosis of problems, and highly intelligent support of workers in undertaking complex tasks are vital. These

[15] KET include nanotechnology, micro- and Nano-electronics, industrial biotechnology, photonics, advanced materials and advanced manufacturing technologies.

include machines that anticipate failures and trigger maintenance, or self-organizing logistics. Projects under Industry 4.0 include 'Intelligent Technical Systems', 'Cognition for Intelligent Systems' and 'Integrated Production Technology for High Wage Countries'.

7.2.2 NATIONAL NETWORK FOR MANUFACTURING INNOVATION

The US President has announced a series of regional hubs funded as public – private partnerships involving the federal administration, states, businesses and universities. They are called Institutes for Manufacturing Innovation (IMIs) and the establishment of 45 IMIs over the next decade is targeted. The Institutes seek to leverage industry, academia and government to address industry-defined problems and opportunities. They seek to build networks and collaboration between these, implicitly recognizing that the US has deficiencies in this area. IMIs are understood to cover "*the full innovation process, including technology roadmapping, applied research, operation of demonstration facilities and testbeds that benefit small and medium-sized manufacturing enterprises (SMEs), education and training at all levels, and development of standards and credentials*"[16].

The Institutes are intended to articulate with the Manufacturing Extension Partnership, the collaborative state-federal program that focuses on the productivity, competiveness and innovative potential of SMEs. The MEP consists of field staff numbering over 1300 technical experts in every state charged with translating research results to new products and innovations.

IMIs now exist in additive manufacturing, digital manufacturing and design innovation, lightweight and modern metals innovation, and energy.

7.2.3 FACTORIES OF THE FUTURE

Also known as MANUFUTURE, this was launched under the EC as part of the European Economic Recovery Plan, and delivers projects as components of a strategic roadmap for "*re-useable, flexible, modular, intelligent, digital, virtual, affordable, easy –to-adapt, easy-to-operate, easy-to-maintain and highly reliable 'Factories of the Future'".* There are four key project areas:

- Sustainable manufacturing: new eco-factory model, green products manufacturing, high efficiency and near-to-zero emissions, reuse and recycling, adaptive and responsive human machine interface, etc.
- ICT-enabled intelligent manufacturing: smart factories (agility and customization), virtual factories (globally networked manufacturing and logistics), digital factories (modeling, simulation and evaluation), etc.
- High performance manufacturing: flexible adaptive plant, equipment and systems for rapid (re)configurations, high precision micro-machines and systems, integrated shop-floor simulation, etc.
- Exploiting new materials through manufacturing: shaping, handling and assembling structures of increasing complexity, including Nano particles.

7.2.4 SMART SPECIALISATION AND CLUSTERING

Although not exclusive to the EU, both are explicit policy and strategic aims of the Union's manufacturing approach, with smart specialization criteria the condition for European Structural and Investment Funds for research and innovation under the Europe 2020 jobs and growth agenda.

The present EU policy is RIS3 (Research and Innovation Strategies for Smart Specialisation). The objectives relating to specialization are based on the view that encouraging regions to build on existing competitive strengths and deepening the division of labour will promote innovation and sustainable competitive advantage. It will also prevent scarce resources from being wasted or duplicated. It seeks to concentrate knowledge and resources to maximum

[16] Hart, Ezell and Atkinson, Why America Needs a National Network for Manufacturing Innovation, December 2012.

impact and involves developing a vision and identifying competitive advantage for the region, centred on knowledge-based economic activity. It includes alignment of stakeholders and setting strategic priorities. Building strengths in a limited number of activities, regions can take advantage of economies of scale and scope and positive externalities[17].

Similarly, policies to encourage, augment or accelerate industry clustering are widespread and involve recognition of the importance of organizational (as well as technological) innovation to manufacturing competiveness. Such policies use interdependencies and inter-relationships to build agility, flexibility and accelerated diffusion and learning across an area or supply chain.

7.2.5 The 'Catapult' UK Technology and Innovation Centres Program

The UK 'Catapult' Technology and Innovation Centres Program commenced in 2013. There are presently seven centres focusing on Satellite Applications, Future Cities, Connected Digital Economy, Offshore Renewable Energy, Cell Therapy, Transport Systems and High Value Manufacturing.

By linking high end research with businesses large and small in the seven focus areas the centres aim to close the 'gap between concept and commercialisation', and gaps in the national innovation system itself.

The activities of the innovation centre are described as being to:

- enhance businesses access to leading-edge technology and expertise
- reach into the research base for world-leading science and engineering
- undertake collaborative applied research projects with business
- undertake contract research for business
- be strongly business-focused with a highly professional delivery ethos
- create a critical mass of activity between business and research institutions
- provide skills development at all levels.

Funding for research projects is a mixture of public and private, with core public funding for long-term investment in infrastructure, expertise and skills development (expected public funding support of at least 10 years), combined with variously configured business funded, and joint publicly and privately funded applied research and development projects.

8 South Australian Approaches

South Australia's *Manufacturing Works* strategy was launched in 2012 and augmented in 2014 in response to the impending end of automotive manufacturing in Australia[18]. *Manufacturing Works* is considered the most advanced policy of its kind in the nation, embodying many of the policy approaches described above, including: a focus on leveraging demand through value chain mapping and technology fore sighting, smart procurement, alignment to high growth value chains and market opportunities, etc.; combining the technical with the organisational and strategic, high performance workplaces, business model innovation, design-led innovation, etc.; and accelerated diffusion of Key Enabling Technologies.

Further complementing these strategic directions in South Australia will be establishment of the Stretton Centre from 2015 in the City of Playford, in northern Adelaide. The Stretton Centre aims to be a leader in industry diversification and economic rejuvenation

[17] See EC, Guide to Guide to Research and Innovation Strategies for Smart Specialisation (RIS 3) May 2012

[18] *Manufacturing Works: A Strategy for Driving High-Value Manufacturing in South Australia*, October 2012, and *Our Jobs Plan*, February 2014.

in northern Adelaide, drawing upon local, national and international expertise, to build a world class economic and industry development facility in South Australia

The Stretton Centre will focus purposeful collaboration between governments, industry and the university sector in the areas of economic and industry development, as well as in program delivery to businesses in the region. Stretton will become the vehicle for delivery of practical, effective, and high quality industry extension services close to end users, in line with international best practice.

The Stretton Centre will target industry transformation, aiming to:

- be an expert industry and workplace innovation body relevant to the modern manufacturing and knowledge economies;
- be an integrative, leading and coordinating entity, learning from the best of breed internationally (e.g., Fraunhofer Gesellschaft in Germany);
- combine practical local knowledge with understanding of international best practice in industry strategy, building a team of highly capable practitioners, networked to key decision makers and influencers at state and national levels;
- specialise in helping to build high performance workplaces that align with the new industrial opportunities – short runs, high variability, and high value products, and medium to high complexity;
- provide value chain expertise, business extension services, and highly valuable approaches to effective local industry participation practices; and
- be an advanced business extension agency for manufacturing and knowledge-intensive service industries.

Stretton has been funded by the state Government to operate as a node of the proposed Innovative Manufacturing CRC to work on industry transformation.

In Adelaide's south, the former Mitsubishi automotive plant at Tonsley Park is being redeveloped as an education, clean technology and manufacturing precinct. Flinders University is investing $120 million in a new facility for Computer Science, Engineering and Mathematics at Tonsley Park, from which initiatives such as the Medical Devices Partnering Program and the Centre for Nanoscale Science and Technology will be delivered.

The state has invested $125 million in a new Sustainable Industries Education Centre, to train more than 8000 people a year in the building, construction and water industries. Amongst the companies attracted to the site to date, Siemens has entered into an MOU to as act a strategic partner in the site's future development.

Together, Stretton and Tonsley provide opportunity for complementary development as north – south nodes of a comprehensive and dynamic regional innovation system.