It's Coming Home Down Under – The Potential of Digital Work to Overcome Australia's Challenges in Reshoring Manufacturing

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Abstract. Over the past decades, the world has seen a continuous increase of globalisation and interconnectedness – in part supported by advances in digital communication and production technologies. In the case of industrial production, this trend has led to global, integrated supply chains in order to provide the most competitive and innovative products utilising the most competitive market conditions. In Australia, due to its remote geographic location and socioeconomic conditions, such as high labour costs and negative economics of scale, this has resulted in a loss of domestic manufacturing capabilities. With recent changes in the geopolitical environment (trade wars, actual wars, Covid-19, climate crisis etc.) calls to produce local are becoming louder again. In this article, we therefore explore the potential of digital technologies to overcome Australia's challenges in reshoring its manufacturing capabilities. Findings indicate that a highly skilled digital workforce is needed to leverage the country's potential in world-leading niche manufacturing. The Associate Degree of Advanced Manufacturing, developed and delivered by the Centre for Advanced Manufacturing at the University of Technology Sydney (UTS), is presented as an example of how to upskill the manufacturing workforce.

Keywords: Industry4.0 · Reshoring · Advanced manufacturing · Australia · University degree

1 The Tides Are Turning – From Offshoring to Reshoring

1.1 The Move to Globalisation and Integrated Supply Chains

Over the past decades, the world has seen a continuous increase of globalisation and interconnectedness – ranging from digital communication technology via cheap and fast travel to continent-spanning industrial production and supply chains. This led to a trend towards globally integrated supply chains, where high-wage countries are competing with low-wage ones in a highly competitive international environment. As a result, many high-wage countries, including Australia, outsourced parts of or often their entire production to offshore sites or suppliers (Adler and Breznitz 2020).

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1.2 Australia's Role

This trend was amplified in remote countries with small domestic markets, such as Australia. Importing became cheaper than local manufacturing, despite the long shipping distances. Especially in Australia, this has led to a severe loss of general manufacturing capabilities. A prominent case was the last Australian automotive manufacturer, GM Holden, to close down its production facilities and leave the country in 2020. While capabilities around commodities such as mining and agriculture are strong in the Australian economy, manufacturing capabilities are limited. As a consequence, Australia has a very low economic complexity compared to other countries of similar wealth (Wyeth 2022).

1.3 The World is Changing Again

In recent times, the world has started to change again. One of the most prominent challenges of global manufacturing and collaboration has been Covid-19. Lockdowns around the world have impacted all industries. Examples are the challenges in the distribution of surgical masks, or the shortage of microchips, jeopardising products from computers to cars and leading to increased prices and delivery times (Wu et al. 2021). In parallel, lockdowns in central container terminals have led to massive shipping delays and a heterogeneous geographic distribution of empty containers, further complicating logistics (Sheffi 2021). In addition, the ongoing trade war between Australia and China as well as new military conflicts, such as the Russian invasion of Ukraine, have further disrupted global supply chains. In parallel, a continuously growing awareness of sustainability has brought the reduction of e. g. energy consumption and CO_2 emission of logistics into public and government focus. More product-oriented trends include a growing demand for customised products that might even be adapted after an order was placed, which becomes more difficult with increasing shipping times (Kuhl and Krause 2019).

1.4 A Rethink Towards Reshoring

The resulting pressure on and uncertainties around global supply chains have led many to rethink the benefits of offshore manufacturing (Adler and Breznitz 2020). This has triggered increased attention to a counter-movement called "reshoring". It comprises both, "backshoring" into the original country and "nearshoring" to a nearby often neighbouring country (Éltető 2019). This does not necessarily mean a complete departure from the offshore manufacturing country and de-globalisation, but a strategic relocation (Éltető 2019). This trend has been supported by governments around the world. In line with the European Economic and Social Committee that sees reshoring as the foundation of re-industrialising the European Union, the Australian Government has launched several initiatives to drive local manufacturing, such as "Australian Made" and "Buy Local", as well as a general push for national sovereignty to overcome the current lack of qualified welders and other workers (Australian Government 2016; Crittenden 2022). In parallel, the political change towards reducing climate change is reflected in the industry. As an example, the mining mogul Andrew Forrest has committed to building 5.4 GWs of solar and wind energy capacity in the Pilbara region in Western Australia including the plan

of building a much larger site for substituting fossil energy sources through the onshore production of green hydrogen in the Nullarbor Plain in South Australia (Milne 2022; Waterworth 2021).

1.5 Effects on Australian Manufacturing

Having moved away from manufacturing and towards a service-led economy over the past decades, reshoring poses a significant challenge to the Australian economy. Instead of pursuing mass manufacturing and global exports, a more viable path for Australia might be to focus on the manufacturing of customised quality products. Instead of global supply chains, global production networks based on digital data and knowledge can enable the export of Australian designs. An example is the joint Smart Global Brewery Network of the University of Technology Sydney in Australia and the Technical University of Dortmund in Germany, which allows to develop beer recipes that can be created on one brewery system, then transferred and automatically produce beer with the same quality on the other brewing system (itnews 2022).

1.6 Technology Enablers

To enable these use cases, digital technologies are required, which can range from CAD models for additive manufacturing via smart cobot controls to cyber-physical systems that combine the physical and the virtual worlds. Due to their complexity, these technologies and manufacturing systems cannot be developed in isolation, but need an interdisciplinary team of experts. This is not limited to system developers, but also includes its users, who need the expertise and skills to successfully install and use these systems. While skilled staff is reported as a key success factor of digitalisation and reshoring, they represent a key bottleneck at the moment (Adler and Breznitz 2020). Moving from manual to automated manufacturing activities, staff often needs completely new skills (an example being welders now programming welding robots rather than welding themselves). As technologies are usually not used in isolation, but as part of a bigger solution integrating different technologies, a diverse set of expertise is needed. This ranges from profound knowledge of basics, such as mathematical or engineering mechanics, programming and robotics as well as new collaboration and managerial skills to work in interdisciplinary teams.

Against this backdrop, the question addressed in this study is how to digitally enable Australia to successfully tackle its reshoring ambitions. For this purpose, Sect. 2 uses a literature review to analyse the potential of digital technologies as an enabler for reshoring. Section 3 focuses on the specific reshoring situation in Australia, and how necessary digital expertise and skills could be built in the workforce. Section 4 concludes this study with implications beyond the Australian context and provides an outlook on the near- to medium-term future.

2 Digital Technologies to the Rescue – Are They a Game Changer for Reshoring

2.1 The Emergence of Digital Capabilities

While the trend towards reshoring of manufacturing is driven by external factors such as increased supply chain costs and uncertainties, there are technological drivers that allow to reduce manufacturing costs to a competitive level. This specifically includes digital, often called Industry 4.0 (I4.0), technologies, enabling advanced manufacturing and robotisation, which can be used to substitute expensive labour activities (Éltető 2019).

Digitalisation is becoming a decisive competitive factor, presenting engineers and technicians with new challenges as innovations and new business models emerge at the interfaces between traditional engineering disciplines. For industrial production and engineering, I4.0 is transforming manufacturing throughout the world by bringing real-time data, automation, data analytics and intelligence to operations. The I4.0 era is defined by an exceptional technology push around automation and digitalisation (Lasi et al. 2014). Technologies applied under the umbrella of I4.0, such as additive manufacturing, digital automation, big data, or cloud services are shaping modern manufacturing operations and contribute to performance improvements (Dalenogare et al. 2018). Industry 4.0 has been spreading across the world in all industrial sectors, from mining to food.

So can digital technologies support a movement to bring home manufacturing jobs? As enabler for solving complex problems across global supply chains and production, digital technologies can play a role (Treven 2022). There is, however, an argument that the digitalisation of manufacturing could lead to both stronger geographical integration and fragmentation and that any specific effects will emerge in a sector-specific manner (Butollo 2021). Others question the causalities between backshoring movements and I4.0 technology adoption altogether (Kamp and Gibaja 2021). In the following, current literature is reviewed to clarify if and how I4.0 could help with reshoring ambitions.

2.2 Does I4.0 Help with Reshoring Ambitions?

The search term developed by Fratocchi and Di Stefano (2020) was used in Web of Science to identify the relevant literature on reshoring in general: “reshor*” OR “re-shor*” OR “backshore*” OR “back-shor*” OR “back-reshor*” OR “back-sourc*”. We find that research output on reshoring has steadily grown over the last 20 years, with a very prominent uptick in 2016 (see Fig. 1). This trend started even before recent geopolitical shifts (such as Covid-19) might have further accelerated this.

But what about research at the intersection of reshoring and digital technologies? To analyse the cross-section of these two areas, we added a search string relevant to digital production and I4.0 following Moeuf et al. (2018) and, to widen the search, added technology as an additional term: (“reshor*” OR “re-shor*” OR “backshore*” OR “back-shor*” OR “back-reshor*” OR “back-sourc*”) AND (“Industry 4.0” OR “Digital production” OR “Digital manufacturing” OR “Internet of things” OR “Cyber Physical System” OR “Cyber Factory” OR “technology”).

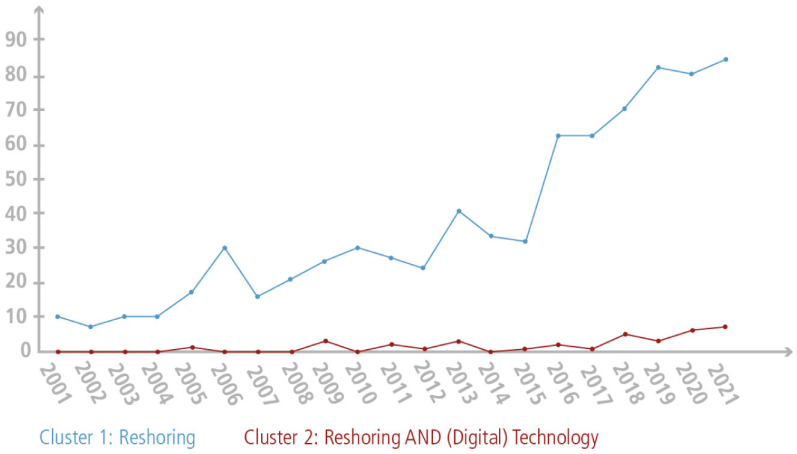

Fig. 1. Publication numbers over time (according to web of science).

It can be observed that research on digital technologies as an enabler for reshoring ambitions is still emerging (see Fig. 1). While empirical research at this cross-section is rare, some recent studies have highlighted the potential of digital work and technologies for successful reshoring ambitions.

In high-cost countries in the Americas and Europe, there is a persistent focus on cost reduction, which led to initial offshoring initiatives and now remains a core reason for reshoring. The limited adoption of new technologies does not seem to change that focus (Ancarani and Di Mauro 2018). At the same time, I4.0 technology is most likely adopted by highly innovative firms competing on quality (Ancarani et al. 2019). As key enablers for cost-effective reshoring, digital technologies have some way to go. In the context of Denmark, the perceived relevance of I4.0 technologies has a high impact on companies that have moved manufacturing back compared to companies that have moved manufacturing out. "The objective of Industry 4.0 in Denmark is to bring manufacturing home or remain domestic" (Stentoft and Rajkumar 2020). In Germany, however, I4.0 seems to remain of lower importance regarding corporate reshoring ambitions (Müller et al. 2017).

So how, specifically, can digital technologies under the I4.0 umbrella contribute to reshoring ambitions? Enabling the manufacturing of High-Mix Low-Volume (HMLV) products is a strength of I4.0 and its pool of digital technologies (Johansen et al. 2021). This allows companies and countries with a low level of automation to quasi-skip Industry 3.0 and directly set up a state-of-the-art manufacturing system. In this respect, technologies like additive manufacturing ("3D printing") allow for complex custom-made designs that can be flexibly post-processed and combined with other products using intelligent robots, such as collaborative robots ("cobots") (Mehrpouya et al. 2019). Additive manufacturing has also been found to play a contributing role through enabling shorter lead-times, lower transportation costs and inventories, more customisation options, fewer supplier miscommunications and increased responsiveness to product

and market changes (Moradlou and Tate 2018). The Internet of Things can further support the creation of smart, flexible and transparent domestic supply chains (Ghadge et al. 2020). These can help with predicting process bottlenecks as well as showing customers the origin of all product resources.

So how can the implications of these new I4.0 technologies on Australian manufacturing workplaces and workers be assessed and possibly serve as an enabler for reshoring and reindustrialisation? Australia, being a geographically remote country with high labour costs, could benefit from those technologies in unique ways.

3 The Australian Case – Building a Digital Foundation to Bring Back Manufacturing

3.1 The Unique Manufacturing Landscape in Australia

Dean and Spoehr (2018) provide a comprehensive analysis of Australia's set of manufacturing challenges and opportunities arising from the fourth industrial revolution. Some key findings are that:

- "little attention has been paid to the social and economic implications of Industry 4.0 for Australian workplaces, workers and society – specifically in the context of manufacturing",
- "insufficient attention has been paid to the importance of building Industry 4.0 technological and organisational capability and capacity amongst manufacturing SMEs and preparing larger firms for digital transformation",
- "Australia lags behind many of its competitor nations in the adoption and diffusion of advanced technologies and skills", and
- "given Australia's relatively low economic complexity, there is a risk that a lack of collaboratively determined policy for Industry 4.0-driven industrial transformation leaves Australia insufficiently prepared to take full advantage of the opportunities flowing from Industry 4.0."

3.2 New Skills Are Needed

In light of these challenges, organisations need to close existing knowledge gaps within their business domains in order to leverage opportunities emerging from digital technologies. According to the Australia Institute's Centre for Future Work, "the reorientation of manufacturing production around more specialised and skills-intensive production strategies reinforces the need for more highly trained and technology-capable manufacturing workers" (Stanford 2020). Hence, the Australian Government Department of Education and others have identified an urgent need for training in this area as a part of the Australian Government's Job-ready Graduate Package (2021). To bolster manufacturing expertise and capabilities domestically, the Department of Education sponsors the advanced apprenticeship-style Digital Technologies (Industry 4.0) pilot at six Australian universities (Tehan 2020). This includes funding for the development of the program plus substantial tuition fees for up to 20 students as a pilot cohort. Students need to be

employed by local small or medium-sized businesses. Another requirement for students to enrol in this program is commitment from their employer to the study required, e.g. through flexible working arrangements.

3.3 A New Degree

The University of Technology Sydney (UTS) participates in this program by creating and delivering the Associate Degree of Advanced Manufacturing (ADAM) (UTS 2021). ADAM is a 2-year degree if undertaken full-time and aiming at.

- boosting the capability of local value chains and strengthening university-industry collaboration in teaching and research,
- embedding industry partnerships with participating universities, deepening links with local businesses, encouraging the culture of collaboration between higher education and industry, and.
- delivering additional higher-level technical skills that directly articulate into a Bachelor's degree on completion if desired.

To bring the latest research directly into the classroom, the UTS Centre for Advanced Manufacturing (CAM) leads curriculum development and course design for ADAM (UTS 2021). The ADAM curriculum is designed around four streams, representing the interdisciplinary nature and unique combination of future skills needed to bring advanced manufacturing to the workplace: Industrial and Manufacturing Engineering, Data Management and Analysis, Automation and Robotics and Complex Systems Management.

Within these streams, a range of new courses has been specifically designed for ADAM. For instance, the stream Industrial and Manufacturing Engineering includes the course Production System Design to introduce lean manufacturing as a prerequisite for digitalisation and the course Factory Modelling and Simulation to familiarise students with digital twinning. Data Management and Analysis builds on the Industrial Internet of Things Studio as well as Machine Learning and Industrial Data Science. Automation and Robotics has a focus on collaborative robots, e.g. via the Collaborative Robotics Studio, where students get to experience advantages and limitations of the technology as well as use cases in different domains. Complex Systems Management includes e.g. Product Development for Industry 4.0, where students apply product development methodologies to systematically develop new technical products in the advanced manufacturing context.

The courses focus on providing students with the skills and tools required to apply advanced manufacturing in their workplaces. While all courses are project-based, a number of courses are offered in a studio environment, taking hands-on and applied learning to an advanced level. The equipment provided by our industry partners helps in providing the latest technology and hardware used by leading firms in the advanced manufacturing arena such as Balluff, Bosch, and Siemens. Assessments are designed in a way that students' workplaces can serve as a case study for current state analyses and, more importantly, improvement and optimisation. Exams play a minor role, the focus is on demonstrations, reports and presentations, individually and in groups. This allows immediate translation of learnings to the workplace.

ADAM is making a start to tackle Australia's challenges in using I4.0 technologies to reshore manufacturing. The new degree develops technological and organisational I4.0 capabilities for SMEs based on a state-of-the-art curriculum targeted at upskilling the manufacturing workforce. Critical to success was the UTS CAM global partner network. In addition to Australian companies from the manufacturing sector, we have particularly involved German companies that are both lead providers and lead users of Industry 4.0 technology. Since industrial data science plays a significant role in the context of advanced manufacturing, our corporate partners have been selected accordingly. In addition, we have involved Australian national and German industry associations representing a large number of SMEs. Social and economic implications have also been included, e.g. via the Complex Systems Management stream or built-in into other courses such as safely introducing collaborative robots into the workplace, taking into consideration not only physical but also psychological and ethical risks (Guertler, forthcoming).

4 Conclusion

The authors of this paper have no doubt that the availability of academics well-trained in STEM subjects will be a key factor in the competitiveness of manufacturing industries worldwide. However, a highly skilled workforce alone will not help Australia achieve a manufacturing renaissance. The development of global supply chains, which is difficult to predict, will be decisive in determining whether manufacturing in Australia will once again be more strongly geared towards the local market. Current and future global crises, but also the need to drastically reduce CO_2 emissions, could have a positive impact on the competitiveness of Australian factories in the local market. However, it is very likely that Australia will not become an export country for industrial goods based on the German model due to its geopolitical situation, geographic location and the high labour costs in global comparison. Therefore, Australia must also find its own way with regard to the digitalisation of the manufacturing industry and cannot simply copy approaches from leading industrial nations.

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