Editorial

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1 Introduction

Attention to the technological capabilities of manufacturing is a persistent contemporary theme for business and policy in advanced economies. Of course, technology has always played a central role in industrial development. However, with intensifying competition from lower wage yet increasingly capable manufacturers in developing and emerging economies, business and policy debate is growing about how high wage developed countries can create and deploy technology, innovation, and related knowledge assets to secure the future of their manufacturing sectors.

Traditionally, policy-makers have viewed manufacturing through the lens of jobs, production, and trade balances. Measures in these areas reflect a mixture of cyclical and structural trends. And while headline job numbers indicate that manufacturing sector employment has significantly declined in industrialised nations, the underlying story is more complex. Over the long run, manufacturing output and productivity have both increased tremendously – primarily because of enhancements in technological capabilities. Moreover, even though manufacturing's share of total output has declined due to the expansion of service sectors, it is also clear in the 21st century that standard statistical categories are less relevant now than they were in the middle of the 20th century. Manufacturing today involves significant contributions from activities counted in the services sector, including research, development, engineering, finance, advertising, maintenance, logistics, and other business-oriented functions. In short, while traditional manufacturing jobs have undoubtedly declined in developed countries (and will likely continue to do so), there is also another underlying and more promising story about the complex transformation of manufacturing capability. It is likely that the prospects for manufacturing in high wage economies will greatly depend upon abilities and trajectories of transformation to develop and acquire new knowledge and technological capabilities, to foster efficient and flexible networks of design, production and logistics, and to offer innovative products and associated services.

This editorial sets the context for, and provides an overview of, the articles in this special issue on the future of manufacturing in developed countries. As we will see, the articles highlight three paths for the future of manufacturing. The first focuses on the movement from centralised to distributed manufacturing capabilities and to the supply chain and knowledge management practices that result from this trend. The second path emphasises high value niche areas, exemplified by changes in the instruments industry. The third path examines the application of technological advances to manufacturing, for example, through the application of Radio Frequency Identification (RFID) devices to foster improved knowledge and control. Yet, as will also be shown, an examination of manufacturing technology forecasts over the last five decades relative to the realisation of these predictions suggests that manufacturing technology and operational enhancements must also be conjoined with broader management, workforce, and policy considerations in order to be successfully adopted.

2 Contents of the special issue

This special issue of the *International Journal of Foresight and Innovation Policy* is based on the proposition that the future of manufacturing in developed economies will hinge increasingly on capabilities to foster, deploy, and commercialise advanced

products, processes, organisational structures, human skills, and management practices. Strategies and policies to promote advanced capabilities seem to be one of the viable ways that developed economies can sustain manufacturing bases given globalisation and the growth of industrial development in low wage developing and emerging countries. All developed countries have established initiatives and policies along these lines. Yet, many questions remain about the prospects for manufacturing in developed economies and how quickly manufacturing can be transformed in order to retain as many jobs and as much productive capability as possible.

The articles in this issue suggest that the future of manufacturing may hinge on three paths. The first path has to do with the shift of manufacturing from centralised business control and production towards corporate collaboration between distributed production sites. Irene Petrick's article, 'Tipping the balance of power: the case of Large Scale Systems Integrators (LSSI) and their supply chains' offers a distinctive perspective on the relative position of Original Equipment Manufacturers (OEMs) and downstream suppliers in a distributed manufacturing chain. Traditional approaches place the OEM in the dominant position in a supply chain with the power to negotiate the extent to which downstream firms can take part. However, recent trends show evidence of inter-firm collaboration networks in which suppliers operate in shared roles. Petrick suggests a third alternative, that of LSSI. Under the LSSI model, competitive advantage accrues to firms with the most distinctive capabilities. OEMs may exert influence through their understanding of customer needs; suppliers may wield influence based on the value they add to the end product; and key collaborating partners may exercise influence through codevelopment of central features or architectures. Petrick projects that the LSSI model could result in a transitioning of the metrics used to gauge performance from cost/time/quality levels to innovation capabilities.

In this decentralised and distributed manufacturing environment, the need for advances in the management of information has the potential for stimulating a range of future technologies and capabilities. Armbruster, Erceg, Pandza, and Dreher's work 'Managing knowledge in manufacturing: results of a Delphi study in European manufacturing industry' addresses these opportunities in the context of how manufacturing can make the transition from an orientation around resources to a knowledge-based industry. The authors utilise a Delphi process to examine the extent to which industry experts, researchers, and policy-makers in Europe recognise the importance of knowledge management, forecast the timing by which knowledge management practices will be widely adopted, and perceive various barriers as limiting this adoption. Knowledge management is conceptualised as the ability to acquire, develop, and share knowledge within the enterprise and with external organisations. The article suggests that leading European experts place importance on inter-company cooperation, working with research institutions, building a workforce with diverse experiences and backgrounds, and fostering skill acquisition. However, tensions between cooperation and competition, pragmatic problem-solving vs. planning approaches, desire for reliable employees vs. flexibility in the labour force, in-depth skill development vs. cross-training, and short-term vs. long-term payoffs from learning are among the contradictions that arose in this effort to understand the institutional and political support for the future of manufacturing from a knowledge management perspective.

A second path is focused on the prospects for high value niche areas. In 'Feeling for the future: strategic responses to industrial, economic and technological change in the European instruments and sensors sector', Green and Malick draw on the European

Commission-sponsored Future of Manufacturing project to assess future prospects for this industry. The instruments sector is defined as dealing with devices that monitor and control production processes. Drivers for prospective expansion of the sector include the need for more sophisticated monitoring and simulation, the rise of the pharmaceuticals industry, environmental regulation, and increasing technological miniaturisation. Strategic responses of the industry are likely to include greater cooperation with colleges and universities, client industries, and other firms in the value chain. This level of partnership offers an opportunity for some instruments firms to be positioned as 'total managed solution providers.' It is expected that more multifaceted segments of the industry (e.g. metrology and control) may retain R&D locally, whereas commoditised segments (e.g. some sensor-related functions) are likely to migrate to lower cost sites. Much depends upon the ability of the industry to address anticipated skill shortages in the workforce.

A third path places attention toward opportunities generated by advances in technology. Weissenberger-Eibl and Koch discuss the potential contribution of RFID technologies in advancing manufacturing in 'RFID and its influence on manufacturing'. RFID uses radio waves to identify items that are tagged with a microchip. RFID is envisioned to be integrated in the production processes within a supply chain for the provision of real-time information. Reduced cycle times, greater speed and flexibility, materials and inventory savings, reduced downtime, improved demand management with less volatility in customer forecasts, and new capabilities in monitoring maintenance needs for product lifecycle management are among the potential benefits from widespread adoption of RFID. Realising these benefits is not limited simply by the lack of tags, but even more by the lack of connections to internal production and information systems. There may be technological or resource considerations for this lack of integration, such as companies without the capabilities or capital to implement this level of integration and limits in software systems to handle this volume of information. Alternatively, there may be qualitative considerations, such as strategic considerations that internal information is central to competitive positioning, concerns about the risk of privacy breaches, or lack of skilled workers to effect implementation. The authors point out that leadership and support from top management as well as a commitment to change are required to broaden RFID's prevalence across manufacturing operations and supply chains.

In reviewing technological opportunities anticipated in these three paths, it must be remembered that technological predictions about the manufacturing are not always realised. In 'A brief history of the future of manufacturing: US manufacturing technology forecasts in retrospective, 1950-present,' Youtie, Shapira, Urmanbetova, and Wang reviewed past manufacturing technology forecasts over the last five decades. The article observes that new technology has frequently been seen as both a remedy and a threat: in the manufacturing sector, it has aided substantial improvements in manufacturing productivity and quality, yet at the same time it has generated concerns about impacts on the number, type, skill requirements, and location of manufacturing jobs. Currently, the technologies anticipated to be influential in the future of manufacturing include molecular and nanomanufacturing, biomaterials and bio-processing, microelectromechanical systems, and free-form fabrication. However, it was noted that predictions as to how technology will evolve in future periods have had mixed records of fulfilment. Some manufacturing technologies have not fulfilled expectations (e.g. integration technologies in the 1980s) whereas others have greatly exceeded expected

adoption rates (e.g. the internet in the 1990s). Moreover, technology forecasts did not occur in a vacuum; they were always conjoined with projections about how to manage these technologies, global responses to these technologies, and the impact they will have on employment and skill. Here, the authors note the emphasis on innovation, knowledge management, customer relationships, and life-cycle waste reduction as among the organising concepts expected to be prominent in the future period.

This issue suggests that there are a set of next generation supply chain and knowledge management practices, value-added industries, and technologies that have the potential to sustain and advance manufacturing in developing countries in the future. But there is an important risk in that lower wage global competitors are also working in these same areas. Innovation and discovery alone are not sufficient to implement next generation manufacturing technologies and techniques. This collection continues to reference the need for organisational strategies, structures, leadership, and workforce training to make the interconnections necessary to commercialise and upgrade these technologies. Policies and programmes are essential to transferring new soft practices, as well as relevant next generation technologies, to ensure that next generation manufacturing technologies are not only developed but effectively deployed in industrialised countries.

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