Why does technology policy around Industry 4.0 continue to draw on technology change approaches developed in the 1960s?

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Abstract

In this article we argue that technology policy thinking around the slow adoption of industry 4.0 amongst manufacturing SMEs in the North Sea Region requires reflection, re-formulation and re-focusing. Underpinning the rationale for European funded research and knowledge exchange, consultancy and support is the diffusion model of technology change. The article argues that this model encourages those interested in addressing slow rates of adoption to understand lack of adoption as an individual failing of the firm. Instead, we argue that adoption/non-adoption decisions must be contextualised in the social and material realities facing decision makers within the firm. We argue that non-adoption can be a perfectly legitimate strategic choice. The article highlights, three potential contextual components that may better explain low industry 4.0 adoption rates amongst SMEs: interpretative flexibility; continued technology change and lack of growth in other parts of the economy.

Introduction

The article is based on what we have learned over a three-year Interreg project (2017-2020). Over this period the project developed and tested tools including a state of readiness questionnaire, benefits identification and organizational change workshops and process that helped firms identify future staff needs. The consistent problem faced by all partners in the project was encouraging firms to engage with the testing and development of support tools. To be blunt, firms did not seem to be struggling with barriers to adoption, rather they seemed uninterested in industry 4.0. This joint experience triggered discussion and the search for alternative approaches to technology change that might explain why firms were not motivated to engage in the project. The article presents the results of that search for new ideas and uses them to re-think both the work we have been doing and the broader policy narrative that we have been a part of.

UK Industrial Digitalization Review Interim Report (UK Industrial Digitisation, 2017) defines Industrial Digitalisation as:

“the application of digital tools and technologies, in all their forms, to the value chains of businesses who make things (e.g. automotive and construction) or that are operationally asset intensive (e.g. power grids, wind farms etc.): it is the merging between the physical and digital worlds”. Industry 4.0 is a general-purpose technology, one with applicability in a wide

variety of settings. It can, therefore, be expected to diffuse widely across all sectors of industry with positive consequences for whole economies.

Nevertheless, the uptake of digital technology, particularly by Manufacturing SMEs is regarded as being too slow, leading to policy interventions, such as Made Smarter and our own funded activities in Grow In 4.0. These knowledge exchange programmes are aimed at supporting industry 4.0 uptake amongst manufacturing firms. However, embedded in the form of these interventions is a particular set of believes about how and why technology change occurs. Primarily, the 'support' approach assumes that an industry 4.0 future is a foregone conclusion – that Industry 4.0 will eventually diffuse to all corners of industry and that the only question is how quickly it will do so. This techno-determinist view of technology has been widely criticised (Shove, 1993; Pinch and Bijker, 1984) and we argue in light of this that the dogged reliance of policy makers an implicit 'diffusion' model of innovation (see both UK Industrial Digitisation, 2017 and Made Smarter, 2017) unhelpfully plays down the complex and dynamic social, technological, organizational and economic contexts in which adoption decisions actually take place. We argue that adoption is better understood as 'demand' for technology change, in which high or low demand for digital technology by SMEs reflects the complex interweaving of various contextual factors that shape strategic decision making.

The benefits of Industry 4.0

That there is a strong relationship between technology change and economic growth is undisputed. As Mokyr (1990) notes, technology change has become a "...*seemingly perpetual mechanism of continual expansion"* – a lesson not lost on promoters of industry 4.0. Technology innovation, in this understanding, is a driver of economic growth, firm competitiveness and higher living standards. Digital technology is a general-purpose technology, meaning it is applicable to all industries – hence it has been hailed as a driver of the 3rd Industrial revolution.

The many demonstrable benefits of industry 4.0 make this view difficult to argue with. Digital technology through sensors, connectivity and data processing offers more refined, extensive and remote control over processes and costless real-time connectivity between elements of the production process (Wang et al 2015, Wang et al., 2016). The ability to access manufacturing process data in real-time improves strategic and operational decision making (Porter and Heppelmann, 2014, Schwab, 2016) and so allows production to run more flexibly, reliably and efficiently (Shrouf et al 2014; Hozdić 2015). Thus, adopting firms are able to lower maintenance costs (predictive maintenance based on wear data), reduce down time, are able to run processes at higher capacity with fewer staff and better respond to consumer demands for product customisation (Zawadzk and Żywick 2016). Manufactures can themselves manufacture goods with integrated digital capability (Ayala et al., 2017, Coreynen et al., 2017) which then subsequently yield user data that enable new services (such as charging for functionality that can be turned off and on remotely).

Thus, the application of Industry 4.0 technologies will, it is claimed, continue to disrupt companies giving rise to new business models, enhanced products and enhanced services

(Made Smarter, 2017) with the potential to transform industry (Langley, et al. 2020; Brynjolfsson and Mcafee, 2016). From the perspective of policy makers, the rapid adoption of industry 4.0 is itself essential for future growth and competitiveness (see, for example, European Commission, 2016; UK Industrial Digitisation, 2017).

Consequently, from this perspective, it is paradoxical that SME's would be reticent to make the investments necessary to yield these benefits. Framed in the logic of paradox, Delotte's 2019 industry survey found that many CEOs were still reticent to commit to industry 4.0. Made Smarter (2017), McKinsey Digital (2016) and UK Industrial Digitisation (2017) make the same complaint, suggesting that low adoption rates are caused by a variety of factors: firms lacking the right leadership, lacking in the skills needed to enact organizational change, over-cautious with regards R&D investments, failing to prioritise organizational change or simply lacking in confidence. Other reports note a general conservatism and lack of ambition pervading whole regions (e.g. Stentoft, Rajkamur and Madsen (2017) with respect to Danish Industry). The problem, as these reports understand it, is one of individual firm's failure to grasp the opportunities presented by industry 4.0. We were not able to find a report which broke the isomorphism of this this logic. The 'contextual' factors that did gain any traction were skills shortages, lack of standards and, perhaps unsurprisingly, lack of support from regional and nation government agencies.

Policy narratives and assumptions

The 'technology adoption' model made famous by Rogers (1962) is a useful . Rogers uses a diffusion metaphor and characterises new technology as moving steadily through populations of individuals and firms – the metaphor has stuck. In Roger's model the population itself is characterised by different categories of individual actors with differing propensities to adopt new innovations. Limited numbers of 'early adopters' lead the way, followed by the bulk of 'adopters', followed by another smaller group of resistant 'laggards'. The rate of adoption can be mapped onto the classic and now famous 'S' curve – with slow but accelerating initial uptake, rapid uptake and then taping off again as the market becomes saturated with only the laggards still resisting adoption. The adopting populations themselves, defined in this way, map onto the normal distribution we would expect to see of any single population characteristic.

The model is alive and well and unchanged in its application in the 2000s. Deloitte' s industry 4.0 2019 survey reports, for example, that overall, just 20.7 percent of manufacturing organizations surveyed rated themselves as "highly prepared" to address the emerging business models the Fourth Industrial Revolution. Their summary then goes on to identify Frontrunners, Followers and Stragglers. Frontrunners, which comprise 26 percent of the respondents, indicated that they strongly believe in the business value of adopting new technology solutions for digital transformation and are ready to use the new technologies. Followers (51 percent) generally believe in the business value of new technology solutions, but lag on readiness. Stragglers (23 percent) are not yet on board with the business value of new technology solutions and are behind on adoption readiness. Clearly these categories are taken directly from Roger's categories of early adopters, adopters and laggards and reproduces the logic underpinning the diffusion model.

The model, it should be noted is not without its problems. Firstly, it is historical, it looks back at what has happened, it is not a predictive model or a theory of technology change. Secondly, and relatedly, it individualises explanations for adoption (early adopter, adopter, laggard), paying no attention to context (Shove, 1993). In so doing it creates a circular argument, a late adopter, for example, is a label given to an observed behaviour, but it is not an explanation of it. The model offers a what, but not a why. The model also provides and inherently linear metaphor – diffusion is a metaphoric understanding of technology change that encourages the idea that technology change happens in one direction. Diffusion does not occur, for example, in reverse and it does not change direction.

The diffusion model is compelling, in part perhaps, because it sits so comfortably with entrenched rational-individual and market-economic ideas about how anonymous de-contextualised individuals make decisions – issues of relative power and conflicts within existing institutional arrangements are ignored (Shove, 1993). The consequence of this 'individualising', a sort of blame narrative, is that subsequent explanations for slow up-take are individualistic in nature:"…apathy, ignorance, traditionalism and lack of political will" are assumed to lie behind slow adoption, while, for example, the actual usefulness of the technology itself is never questioned (Shove, p. 1107).

This individualising is also neatly evident in Delotte's explanation for its survey findings. They report that while firms conceptually understood the profound business and societal changes that Industry 4.0 may bring, they were less certain how they could take action to benefit from Industry 4.0. There were too many options, not enough information meaning that many are finding it difficult to take the step toward investing. They also found that leaders continued to focus more on using advanced technologies to protect their positions rather than make bold investments to drive disruption.

Needless to say, the diffusion model also underpinned the rational for investment in projects such as ours, Grow-IN 4.0 aimed at supporting firms in adopting industry 4.0. Underling the rationale for these interventions was the idea, drawn from the diffusion model, that slow-adopters are failing or lacking in some way and this in turn makes sense of what we a term a 'narrative of support' – the rationale for the project. Indeed, the individualising and 'support' narrative is prevalent in much of the 2017 bid document for Grow-In 4.0. One beneficiary promised to "…provide our experiences in the *measurement of competencies*". (p.3, GI4.0 bid). Another promised to offer "...*counselling and facilitation*, as core instruments to enhance innovation and growth in manufacturing SMEs" (GI4.0 bid page 1).

It is also possible to discern what we refer to as the 'journey narrative'. For example, one beneficiary promised to "… learn from the partnership particularly in the created innovations thus allowing the XXXX to disseminate these to manufacturing SMEs *who are heading towards Industry 4.0* in Germany" (GI4.0 bid page 3) while another asserted their role as being to "….raise the level of innovation and to create more growth within manufacturing *SMEs who are heading for Industry 4.0*. (GI4.0 bid p.1). In our regular meetings, we used this language routinely and without reflection and indeed, used it to inform the 'support' tools we developed. The project developed its own 'state of readiness' tools to assess where SMEs where on their journey toward industry 4.0, while others were designed to create confidence

in decision making, identify future staff needs and increase the level of trust and confidence in staff needed to enact change. Together, these approaches all remained with the logical boundaries of the diffusion model's linearity (either as 'diffusion process' or as a 'journey toward')– that industry 4.0 was an unavoidable part of all firm's futures. The result of this was that we struggled to see beyond our own linear assumptions about technology change. No part of our thinking or analysis was shaped by the possibility that delaying adoption or not adopting where also reasonable strategies.

In this formulation the role for researchers such as ourselves is also clearly pre-scribed. As Shove (1993) wryly observes: "Sociologists, economists and market analysts are then charged with the secondary tasks of removing blockages and easing channels of communication so as to allow proven technologies to flow unhindered into everyday practice". (p.1108).

Consultants of course make their living from such work, clearing the way for technology diffusion by removing the blockages caused by reticent, incompetent or just ill-informed senior teams, but is this the right role for researchers? The Grow-In 4.0 deliverables where clear on this – engage with 150 firms, develop tools and business models to support the positive impact of industry 4.0.

RE-thinking our approach

Our narrow approach to the relationship between manufacturing SMEs and industry 4.0 technology perfectly matches Shove's concern that policy is underpinned by the linear, technology-centric logic of the diffusion model. An approach that wilfully individualises adoption decisions and so ignores the broader context in which those decisions are made and limits its focus to the individual shortcomings of non-and slow adopters.

We turn now to what a fuller consideration of those contexts might have looked like.
Contexts for action – that is the technological, institutional, economic and organisational regime that make sense of the adoption of industry 4.0.and non-adoption of industry 4.0 at any given moment in time.

1. Interperatative flexibility and decision-making uncertainty

Slow technology uptake is not unusual, even in times of rapid technological change and economic growth. It took firms 25 years for the manufacturing firms of the industrial revolution to fully exploit the benefits of electrically-powered machinery. Brynjolfsson and Mcafee (2016), interestingly, provide a very individualising explanation for this, arguing that that this is how long it took for older owners to retire and younger more entrepreneurial managers to take over. A better explanation, in our view, lies in the disruption and confusion caused by young technologies – what has been termed interpretative flexibility (Pinch and Bijker, 1987) - periods in which there is uncertainty as to how a technology should be understood and used. It is not surprising perhaps, that Delotte found that managers were

unsure how to act. The issue perhaps was not a lack of information but conflicting and shifting information, not really information at all. Arguably, system providers and policy makers contribute to the confusion with claims for benefits which are always positive in the extreme. Hubris from academics, policy makers and consultants, which potential adopters are right to be suspicious of, may well be itself acting to supress adoption.

2. Rapid technology change

A related issue concerns the rate of improvement in the technology itself. As ever more providers emerge offering new solutions, and while this does cause confusion, it is also the case that those solutions tend to get better over time. They become more usable, better adapted to specific contexts and have reliability problems and usability issues ironed out – they settle, in other words, into stable 'dominant designs' (Utterback, 1994). If digital technologies are still emergent, which they appear to be, then delaying adoption makes strategic sense. Allowing your competitors to go first means you can learn from their mistakes, what Porter (1985) calls this the 'follower advantage'. Put another way, being a laggard is a problem in the diffusion model, but a respectable strategic position from another perspective or put yet another way, today's early adopters may turn out to be tomorrows bankrupts.

3. Economic realism

Unfortunately, Western economic growth has been stagnating since the 1970s (Gordon, 2016; Benavav, 2020); in part, ironically, because of entrenched over-capacity in production (Benavav, 2020). It is for this reason, Benavav argues, that investment has fled industry leading to global de-industrialisation and into services, real-estate and finance. Any decision to adopt a technology is of course also an investment decision and investors tend to keep their hands firmly in their pockets when they do not have the sense that demand for products is growing (Benavav, 2020). This is precisely what we see with Apple inc at the moment, they are sitting on over 4bn dollars, with no incentive to invest and other large technology firms, such as Boeing, who are using profits not to re-invest in new technology, but to buy back their own shares. Given that returns to investment in R&D have fallen from 2.7% (1970-1979) to 1.2% (2012-2019) avoiding big technology investments is perhaps a sensible survival strategy.

The support-based policy intervention is of course based implicitly on the idea that investment in innovation leads to economic growth. This may be true in areas where there remains growth potential, such as those firms increasing their share of existing markets (this has been the case where the retreat of the state has ceded service provision to the private sector) or where new products are created to replace old ones (such as the smart phone) but this remains a zero-sum gain in terms of growth and job creation.

It follows that active and risky investment in greater productive efficiency industry 4.0 may not be a sensible option for the majority of firms – indeed, at the level of the economy, it may simply lead to more over-capacity that is already causing manufacturing its' woes. Seen from the perspective of the individual firm, projects like GI4.0 are in effect pressuring individual firms to take the risks of innovation, at a time when the returns on this investment are questionable.

4. Appropriateness

Foxconn, the Apple Iphone assembly giant, has its workers sitting around tables assembling Iphones by hand from piles of components lying on the table. The automation technologies that could do this work are well established – and would barely count as innovation, but they are not adopted. The reason for this is partly low-wages, but it is also the specific context in which the firm operates. To keep its products up-to date and allow last-minute changes Apple prefers on-tap human hands. In one instance, for example, Apple decided last minute, that it wanted to use glass instead of plastic screens in its Iphone 5. The workers, who live in dormitories at the factory, were woken up, given a cup of tea and a biscuit, and sent down to the cavernous assembly rooms where they set about stripping out the already installed plastic screens and replacing them with glass ones (Freeman, 2018). In our own ongoing research, we have seen digital technologies, in one case a boiler repair diagnostic system, maintained for a decade and then abandoned. Large commercial aircraft can, in theory, pilot themselves from airport to airport - they don't need even one pilot. Yet two pilots remain in every aircraft – held in place by powerful unions and public opinion – it would be difficult to argue that automation has been a good investment for this repair company or for airlines.

Conclusion

The models used by policy makers and consultants create simple and compelling narratives (diffusion, support, developmental journeys) that provide simple and plausible problem-solution couplings (Kuhn, 1962) and these provide clear rationales for investment in support and knowledge exchange. However, these narratives also trap us into asking a limited number of questions. As academics we need to rise above hype, technological hubris and given problem-solution couplings. We need to focus first and foremost on the contextual factors which shape SME decision making. In so doing, we must allow that not acting in a way that fits with policy makers' economic and social models may also make sense – not adopting industry 4.0 must be seen as a legitimate rather than a luddite act. We must also look to the bigger picture of that context, how, for example, are the economic conditions experienced by SMEs and how does this shape their decision making? Finally, we must understand SMEs as consumers of technology and seek to understand how that consumption is constructed. SMEs are not getting in the way of diffusion, they are displaying consumption patterns that reflect lived-realities – complex realities that policy makers and consultants seem presently unwilling to try and access.

References

Brynjolfsson, E., & McAfee, A. (2014). The second machine age: Work, progress, and prosperity in a time of brilliant echnologies: WW Norton & Company.

Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics, 204, 383-394.

Deloitte (2019) Industry 4.0: Global's annual survey on business's preparedness for a connected era. https://www2.deloitte.com/insights/us/en/deloitte-review/issue-22/industry-4-0-technology-manufacturing-revolution.html

Freeman, J. (2018) Behemoth: A History of the Factory and the Making of the Modern World, WW Norton and Company, NY.

Gordon, R. (2016) The Rise and Fall of American Growth Princeton University Press, NJ.

Hozdić, E. (2015). Smart factory for industry 4.0: A review. International Journal of Modern Manufacturing Technologies, 7(1), 28-35.

Industrial Digitalisation Review (2017) Industrial Digitalisation Review: Interim Report. https://www.tpdegrees.com/globalassets/pdfs/research-2017/idr_interimreport_july17.pdf

Made Smarter (2017), Made Smarter Review (2017), Department for Business, Energy & Industrial Strategy
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/655570/20171027_MadeSmarter_FINAL_DIGITAL.pdf

McKinsey Digital (2016) Industry 4.0 after the initial hype: Where manufacturers are finding value and how they can best capture it.
https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/getting%20the%20most%20out%20of%20industry%204%200/mckinsey_industry_40_2016.ashx

Nascimento, D. L. M., Alencastro, V., Quelhas, O. L. G., Caiado, R. G. G., Garza-Reyes, J. A., Rocha-Lona, L., & Tortorella, G. (2019). Exploring Industry 4.0 technologies to enable circular economy practices in a manufacturing context. Journal of Manufacturing Technology Management.

Pinch, T. and Wiebe, B. (1984) "The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." Social Studies of Science 14(3): 399-441.

Porter, M. (1985) Competitive Advantage: Creating and Sustaining Superior Performance, New York: Free Press.

Porter, M. and Heppelmann, J. E. (2014). How smart, connected products are transforming competition. Harvard business review, 92(11), 64-88.

Schwab, K. (2017). The fourth industrial revolution. Currency.

Shrouf, F., Ordieres, J., & Miragliotta, G. (2014, December). Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm. In 2014 IEEE international conference on industrial engineering and engineering management (pp. 697-701). IEEE.

Rogers, E. M. (1962) Diffusion of Innovations, Glencoe: Free Press, New York.

Shove, E. (1993) Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings, Energy Policy. Vol. 26(15): 1105-1112.

Stentoft, J., Rajkamur and Madsen, E (2017) Industry 4.0 in Danish Industry: An empricial investigation of the degree of knowledge, perceived relevance and current practice (2017), University of Southern Denmark.

Utterback, J.M. (1994) Mastering the Dynamics of Innovation, Boston, Mass.: Harvard Business School Press.

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of industrie 4.0: an outlook. International journal of distributed sensor networks, 12(1), 3159805.

Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of industrie 4.0: an outlook. International journal of distributed sensor networks, 12(1), 3159805.

Zawadzki, P., & Żywicki, K. (2016). Smart product design and production control for effective mass