

Expanding Industry 4.0: Social science approaches to studies of technology change

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Bank 2018) and social science research (Lawrence et al. 2017). The latter have raised concerns regarding the potential implications of this change for the future of enterprises, the nature of work and broader society. As a consequence, there are calls for alternative visions of technological change that better address concerns of social change, justice and sustainability.

We acknowledge these critiques, however, taking Industry 4.0 as an emergent phenomenon we argue that the concept requires first a more detailed examination to ensure that alternative visions do not reflect similar limitations. In this paper, we do this by drawing on social science literature particularly ideas from innovation studies, social practice theories, development studies and sustainability transitions. The critical literature in these fields has remained largely disconnected from discussions regarding Industry 4.0, yet we suggest that they provide improved theoretical and analytical understanding.

2) Definitions: What's in a name?

Examining the terminology around Industry 4.0 reveals how research related to the reordering of society and the economy might inform our understanding of Industry 4.0. We reflect on three associated terms here: Industry 4.0 , the fourth industrial revolution and more broadly technological change

The Fourth Industrial Revolution

If one does agree with the view that the fourth industrial revolution is underway, then the literature on the history of technical change suggests further reflection is needed on this transition. Scholars exploring historic change have highlighted the cyclical nature of change.

Schumpeterian theories provide an account of how previous technology change typically happened. This occurs through the emergence of niches, which become adopted through the wider economy, eventually facilitating major change in industrial structure (Bernard et al. 2014, Köhler 2012). The source of disruptions in these accounts, however, rarely comes from incumbent actors who tend to be resistant to change. Rather it is entrepreneurs and new entrants who produce niche and new products (Hagedoorn 1996).

The important point here is that this account of radical change departs from common Industry 4.0 accounts. Disruptive change comes from *outside* rather than *inside* the existing system of production and is not associated with existing firms and supply chains. This account also questions the outcomes of disruptive change and whether it should be limited to current capitalist paradigms, as is typical in Industry 4.0 visions. Alternative outcomes have been suggested, including ones centred on abundance of digital goods and new types of post-capitalist production; or alternatively new hyper-capitalistic societies with capital increasingly intertwined with everyday lives (Mason 2016).

Technological change

The emphasis on technological change in the fourth industrial revolution is a key feature of the discourse. The emphasis on technological change is a key feature of the discourse. The emphasis on technological change is a key feature of the discourse.

and material changes associated with previous industrial revolutions have shaped institutions and everyday life; changes to labour and domestic life shifted the social contracts of urban provisioning, altered the moral geographies of mundane practices such as laundry, showering and commuting, and introduced new material elements to systems of resource provision (e.g. Kaika 2004, Kuijer & Watson 2017). There are many socio-technical theories (such as theories of social transitions, practice and innovation) that would provide insight to unravel the processes, outcomes and resistance to Industry 4.0 more broadly. Their contributions to the literature on Industry 4.0 are as yet fragmented however, and are yet to counter the prevailing

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developments, fo

research, with the potential for reciprocal methods which embed learning that might direct transition towards justice and sustainability benefits. However, case study research is inherently messy, with evolving research questions, methodological surprises and contentious findings compromising the validity and reproducibility of the research (Clark et al., 2007). Attempts to use such research outputs to inform policy and management may encounter resistance in a research landscape that celebrates universalism and generalisability (Sharmina et al. 2019).

Yet arguably it is messy research that is most needed to grapple with the critical questions being asked of Industry 4.0 and provide context-sensitive insights. There is considerable room for social science research which pushes the importance of heterogeneity of innovation processes, within and between sectors and locations allowing understanding of local needs and socio-cultural particularities to inform Industry 4.0 developments.

Integrating data and the digital into research

Industry 4.0 expands the sites and approaches to observe human-machine interactions. For example, smart meters and other devices enable flows of materials and resources to be traced with greater accuracy, specificity and granularity than ever before. Similarly, digitalisation of goods movement enable analysis of interactivity throughout the supply chain, with the potential to yield insights on governance, accountability and responsibility. In addition, advances in big data analysis, machine learning and other (non-AI) digital methods offers further potential for inquiry into a broad set research questions.

Yet questions regarding these methods, the skills needed to exploit them in the social sciences, and their ethical considerations are yet to mature. This is a challenge that has begun to be taken up by more critical data scientists, who through experiments, data extraction and analysis

Sustainability

There is increasing consensus that current modes of production and consumption are unsustainable. Rising demands for energy, water and land combined with increasing levels of emissions, growing inequality and volatile weather are of growing concern to businesses, policy makers and the public. Urgent and radical changes are required to address sustainability objectives. Unlike the literature on justice, Industry 4.0 has commonly been interpreted as an opportunity for sustainable transformation (e.g. Herweijer et al. 2018), promising vast improvements in operational efficiency, sensing and control over systems, the extended application of smart technologies, and demand management processes. Each has potential to contribute to sustainability objectives.

To date this body of research focuses on the direct, upstream sustainability benefits of technical innovation. Wider sustainability implications of Industry 4.0 are less commonly discussed. Given the potential wider reaching effects of Industry 4.0 on society, the indirect impacts are worthy of more extensive consideration. For example what potential do Industry 4.0 technologies, platforms and business models have for unsettling unsustainable systems of provision commons today (or reaffirming them) (Carolan 2018). Alternatively, how do new objects and configurations in homes interact with the emergence of new routines and/or norms and expectations regarding everyday consumption?

It is therefore vital to understand how Industry 4.0 might most effectively contribute to realizing global sustainable development objectives. With global sustainable development commitments such as the Paris Agreement framing the current discourse on climate change adaptation it is important to understand what a fit-for-purpose Industry 4.0 might look like with consideration of the appropriate modes of governance, equitable access and adoption. Questions need to also be situated in a broader discussion concerning responsible digital transformation: What are the implications of Industry 4.0 for everyday geographies of lifestyle and labour? How does the automation and digitization of industry spill-over into domestic practices? and; What are the associated impacts for the ways in which resources used and wastes produced?

Summary

In sum, the acknowledgement of justice and sustainability issues emerging with Industry 4.0 suggest that better linkages between social sciences and engineering/business research would be beneficial. At present, social science research has strongly focussed on the challenges of

automation and begun to formulate approaches for potential mitigation. Such work needs to be more strongly integrated with the practices and requirements for engineers to consider, and needs to increasingly challenge the overarching visions of what Industry 4.0 should be. Future visions of ways by which Industry 4.0 will transform society and might be pushed to improve justice and sustainability outcomes has been explored by social scientists but this has often been fairly speculative. It is here that demonstrators and prototypes built by engineers can offer more ground considerations and visions that can be supported by social scientists.

5) Conclusion

The social science literature has yielded a number of important discussions

Bijker, W.E. (1995) *Of Bicycles, Bakelites and Bulbs: Toward a Theory of Sociotechnical Change*. MIT Press, Cambridge, MA.

Bors, D. (2018) *Data Analysis for the Social Sciences: Integrating Theory and Practice*. SAGE, Thousand Oaks, CA.

Brynjolfsson, E. & McAfee, A. (2014) *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*. First Edition. W. W. Norton & Company, New York.

Butollo, F., Jürgens, U. & Krzywdzinski, M. (2018) *From Lean Production to Industrie 4.0. More Autonomy for Employees?*, Working Paper, SP III 2018-303, WZB Discussion Paper, Berlin, Germany.

Carolan, M. (2018) Big Data and Food Retail: Nudging out Citizens by Creating Dependent Consumers. *Geoforum*, 90, pp. 142 150.

Chandy, E. ed. (2016) *The Future of Work in the Developing World*. Brookings Institution, Washington D.C.

Clark, C., Brody, M. & Dillon, J. (2016) The Messy Process of Research: Dilemmas, Process, and Critique, in *Towards a Convergence Between Science and Environmental Education*, Routledge, pp. 81 96.

Edwards, P. & Ramirez, P. (2016) When Should Workers Embrace or Resist New Technology? *New Technology, Work and Employment*, 31(2), pp. 99 113.

Glover, A., Strengers, Y. & Lewis, T. (2018) Sustainability and Academic Air Travel in Australian Universities. *International Journal of Sustainability in Higher Education*, 19(4), pp. 756 772.

Graham, M. & Woodcock, J. (2018) Towards a Fairer Platform Economy: Introducing the Fairwork Foundation. *Alternate Routes*, 29, pp. 242 253.

Hagedoorn, J. (1996) Innovation and Entrepreneurship: Schumpeter Revisited. *Industrial and Corporate Change*, 5(3), pp. 883 896.

Herweijer, C., Combes, B., Johnson, L., et al. (2018) *Enabling a Sustainable Fourth Industrial Revolution: How G20 Countries Can Create the Conditions for Emerging Technologies to Benefit People and the Planet*, Economics Discussion Papers.

- Sen, A.K. (1999) *Development as Freedom*. Oxford University Press, Oxford, UK.
- Sharmina, M., Abi Ghanem, D., Browne, A.L., et al. (2019) Envisioning Surprises: How Social Demand. *Energy Research & Social Science*, 50, pp. 18–28.
- Susskind, R.E. & Susskind, D. (2015) *The Future of the Professions: How Technology Will Transform the Work of Human Experts*. Oxford University Press, Oxford, UK.
- UNCTAD (2017) Robots, Industrialization and Inclusive Growth, in *Trade and Development Report 2017*, United Nations Conference on Trade and Development, Geneva, Switzerland, pp. 37–66.
- WEF (2017) *Digital Transformation Initiative*, World Economic Forum, Geneva, Switzerland.
- Williams, A. & Srnicek, N. (2015) *Inventing the Future: Postcapitalism and a World without Work*. London: Verso.
- World Bank (2018) *World Development Report 2019: The Changing Nature of Work*, World Bank, Washington D.C.