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The influence of Industry 4.0 narratives on regional path development

Henrik Brynthe Lund ^a and Sigurd Sagen Vildåsen ^b

ABSTRACT

Industry 4.0 has become a key concept and buzzword in the global manufacturing industry. This paper argues that the concept has created an Industry 4.0 narrative that is having a decisive impact on the industry. The paper combines the literatures on the sociology of expectations and regional path development to develop an analytical framework which is employed in an analysis of the Raufoss region in Norway. We find that the expectations created by the global Industry 4.0 narrative have trickled down into national industry and innovation policies. This has resulted in the anchoring of innovation schemes, development of new educational provisions and generated technological capability building among manufacturers in the Raufoss region. In turn, we argue that these actions have enabled regional path extension.

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INTRODUCTION


Digitalization is the main driver in the development of 21st-century manufacturing, changing products, production processes and business models. The resulting societal debate, which most scholars would argue is based on buzzwords, frames industrial, political and academic efforts in the development of industries and economies.

Within the broad category of digitalization, Industry 4.0 (I4) (Schwab, 2016a) has become an established concept amongst policymakers, business leaders and academics. In this paper, we argue that the I4 concept has created a distinct narrative, which has permeated industry and innovation policy and in turn resulted in regional development in the Raufoss region of Norway. In our analysis of the I4 narrative, we draw on insights from the sociology of expectations (SOE) literature (Berkhout, 2006; Borup et al., 2006; Van Lente, 2012), which provides an emphasis on the influence of expectations in policymaking (Havas

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et al., 2010), technological innovation and sustainability transitions (Bakker et al., 2011), and regional path development (Steen, 2016).

To analyse the regional effects of the I4 narrative, we combine insights from the SOE literature with recent – more agency-sensitive – path-development literature (Grillitsch & Sotarauta, 2020; Hassink et al., 2019; MacKinnon et al., 2021). Our analysis is guided by the research question: *How can the Industry 4.0 narrative influence regional path development?* Through a qualitative case study of the Raufoss region, the paper analyses how expectations created by the I4 narrative have provided momentum for research and development within manufacturing. We argue that development in the region has been influenced by the I4 narrative, which has permeated national and regional industrial and innovation policy, resulting in innovation schemes, educational provisions and company capability upgrading, which ultimately has enabled regional path extension (Isaksen, 2015). By combining the SOE and path-dependence literatures, the paper provides a novel approach to understanding the influence of narratives for regional path development.

In the following theory section we develop our analytical framework drawing on SOE and path-development literature. We then present the Raufoss case and methodology before presenting the I4 narrative and discussing its influence on regional path development. Finally, we conclude and consider avenues for future research.

THEORY

Sociology of expectations (SOE)

The SOE explores the dynamics of expectations related to science, technology and society (Borup et al., 2006). Konrad et al. (2017, p. 466) define expectations ‘as statements about future conditions or developments that imply assumptions about how likely these are supposed to be and that travel in a community of public space’. By doing so, the authors take economic and cultural aspects into account, in addition to the technological. Expectations and visions are important in mobilizing resources on the macro- (e.g., national policy and research funding), meso- (e.g., industry sector and innovation networks) and micro-levels (e.g., individual or groups of engineers or researchers). Expectations also develop a direction for development, producing a shared agenda for the different actors involved, thus they are performative (Borup et al., 2006; Konrad et al., 2017). Therefore, analysing expectations is important to understand industrial, technological and – as in this paper – regional (industrial) development (Borup et al., 2006). We argue that expectations play an important role in regional industrial development, as expectations towards technologies related to the I40 concept (e.g., big data, cloud computing and cyber-physical systems – CPS) generate actions such as investment in new technologies amongst business leaders. Expectations and visions link technical and social issues as they create images of futures where technology and social issues are intertwined (Borup et al., 2006). Particularly relevant for the I4 narrative, because it concerns a range of different technologies that to a varying degree have been implemented in production lines, are technological expectations, which can ‘be described as real-life representations of future technological situations and capabilities’ (p. 286).

In addition to the emphasis on social, cultural and technological aspects, expectations have a collective character. Konrad et al. (2017, p. 466) argue that ‘the main performative roles of expectations in mobilizing, guiding, and coordinating diverse sets of different actors involved in technoscientific fields require expectations which are to some degree common, shared reference points’. These arguments support our emphasis on narratives, which Fløysand and Jakobsen (2017, p. 142) define as ‘the specific perceptions or modes of explanations promoted by an actor or group of actors located within the same discourse’. Thus, to understand expectations, we need to understand the narratives and the discourse that created them and untangle their

origins. In order for collective expectations to achieve a normative status, they have to be codified and spread (Berkhout, 2006). These expectations can be of both a positive and a negative character, the latter referring to how fear, for example, the fear of becoming uncompetitive, can generate actions amongst business leaders.

Expectations are inherently connected to the notion of agency, as narratives are created and reinforced by actors on different levels (Borup et al., 2006). Although the SOE literature most frequently is employed in analyses of particular technologies or technological fields (e.g., biogas, Geels & Raven, 2006; or gene therapy, Van Lente et al., 2013), we find that it, in combination with the literature on path development, provides analytical purchase when studying the regional outcomes of expectations generated by the I4 narrative.

Regional path development

The literature on path dependence has become a key theoretical approach within (evolutionary) economic geography in studies of regional industrial development (Hassink et al., 2019; Isaksen, 2015; Martin & Sunley, 2006). Based on the understanding that the potential for industrial development within a region is enabled or constrained by existing industrial and institutional structures, studies that employ the path-dependence approach aim to understand regional development processes and how regional paths are created, renewed, extended or exhausted (Isaksen, 2015). The literature on path development has generated key insights into how regions develop over time, and how these processes are influenced by both intra- and extra-regional conditions (Trippel et al., 2018). However, the influence of agency on path-development processes has largely been omitted (Hassink et al., 2019; Jolly et al., 2020). Following the recognition of the lack of agency in the path-development literature, several contributions have provided insights on, for example, change agency in path creation (Grillitsch & Sotarauta, 2020), institutional agency in path transformation (Miørner, 2020) and structural maintenance agency (Jolly et al., 2020). Furthermore, MacKinnon et al. (2021) highlight how agentic processes come into play with regard to legitimation of new path creation, underlining the importance of expectations in the creation of legitimation narratives that support path creation. Legitimation is in turn shaped by the agency of societal discourse (visions and expectations), government actors (policies and regulation), industry networks (developing standards), and organizations (aiming to improve their capabilities) (Yap & Truffer, 2019). We argue that the insights gained from the above studies of path creation/transformation are equally relevant for studying other path-development processes. Furthermore, we find that studies on how existing regional paths are continuously, yet non-radically, developed (e.g., through path extension) are key to understand the dynamic development processes in regions.

In our study of regional development of the Raufoss manufacturing region, we employ the notion of path extension, a development process where ‘incremental product and process innovations’ are conducted along prevailing technological paths. This entails making improvements in firm capabilities, for example, technological and/or knowledge upgrading (Kaplinsky & Morris, 2001), which ensures the continued competitive advantage within an industry. By drawing on the SOE literature and the notions of expectations and narratives, we introduce agentic aspects regarding path-development processes that opens for an analysis of multilevel agency, and how different levels of actors and policy translate into regional development (Grillitsch & Sotarauta, 2020; Hassink et al., 2019). By doing so, we contribute the literature on path development and its recent efforts to understand how agency influences path development.

METHODOLOGY AND CASE STUDY: THE RAUFOSS REGION

Raufoss is a manufacturing region with a long-standing tradition within Norwegian manufacturing. The region was one of two ‘locomotives for industrialization’ in the post-war era,

dominated by defence production centred around a state-owned ammunitions company (Wicken, 2009), which has given the region a leading role within the relatively small (5.7% of gross domestic product (GDP); World Bank, 2019) Norwegian manufacturing industry. Today, the majority of firms located in the region, which are both Norwegian and foreign owned, supply the automotive, aerospace and defence industry. In a Norwegian context, Raufoss is one of the most prominent regions for automated mass production, centred around the National Centre of Expertise (an Innovation Norway-funded cluster scheme) on automation and light-weight materials (NCE Raufoss) (Lund & Karlsen, 2020). The cluster constitutes the core of the region, and since 2017 has hosted the Norwegian Catapult Centre on Manufacturing Technologies, where four to six mini-*Industry 4.0* factories will be built (MTNC, n.d.).

The paper draws on both primary and secondary data. The primary data build on insights gained from 19 semi-structured interviews with industrial actors and public and private organizations (Table 1) in the Raufoss region (from December 2016 to December 2018), and observations at national industry conferences (in 2016 and 2018). The interviews were structured around a set of topics, such as implementation of advanced (I4) manufacturing technologies,

Table 1. List of informants.

Interview	Firm/organization	Informant(s) position(s)	Period
1	University	Professor	December 2016
2	Automotive manufacturer 1	Head of development and operations manager	December 2016
3	Automotive manufacturer 2	R&D manager	January 2017
4	Aerospace and defence manufacturer	Chief human resource officer	January 2017
5	Vocational college	Department manager	January 2017
6	Automotive manufacturer 3	Chief human resource officer and hr consultant	January 2017
7	Apprenticeship organization	General manager and operations manager	January 2017
8	Norwegian Confederation of Trade Unions (Landsorganisasjonen)	Leader, vice-chairman and business manager of the local labour union	January 2017
9	Regional industrial network	General manager	November 2017
10	Cluster organization/research institute	Project leader/senior consultant	November 2017
11	Regional high school	Principal	January 2018
12	Automotive manufacturer 1	Former chief executive officer	March 2018
13	Wooden building solutions manufacturer	Chief executive officer	April 2018
14	The Federation of Norwegian Industries (Norsk Industri)	Executive manager and head of research and innovation	September 2018
15	Telecommunication hardware manufacturer	Chief technology officer	September 2018
16	Norwegian Confederation of Trade Unions	Secretary	September 2018
17	Aerospace and defence manufacturer	Factory manager	November 2018
18	Composite LPG cylinder manufacturer	Head of engineering	December 2018
19	Automotive manufacturer 3	Customer line manager	December 2018

knowledge demands following technology implementation, how technologies were identified, and who the manufacturers' key collaboration partners were regarding technology and knowledge development. In line with the characteristics of semi-structured interviews, the conversations with our informants developed around some predefined questions which ensured a structure for the interview, while also being flexible enough to pursue topics that arose during the interview (Longhurst, 2010). The interview data were analysed using NVivo software to uncover how informants talked about the I4 concept, technological upgrading and the outcomes of this upgrading. We did not create codes to group the different sources of data in NVivo, rather, we used the software to search for information regarding, for example, I4, technology, funding and policies, across the different data sources. The interviews were conducted while studying historic and contemporary developments (both technological and knowledge related) within the region and were thus not solely focused on gathering information on the I4 narrative. Rather, the interviews and insights gained from talking to manufactures in the region spurred our interest for the I4 narrative and was the starting point for this paper.

The secondary data are drawn from national and international reports regarding I4 (Blanchet et al., 2014; Geissbauer et al., 2016; Kagermann et al., 2013; KPMG, 2018; Myklebust et al., 2021), policy documents (Ministry of Trade Industry and Fisheries, 2017), and academic and media articles. Furthermore, to trace the application of the concept and how manufacturers within the Raufoss region participated in innovation projects where technological upgrading and I4.0 was central, an analysis of the Research Council Norway's (RCN) database on innovation projects located in the Raufoss region that received funding in the period 2000–20 was conducted. In total, 40 innovation projects were analysed.

THE I4 NARRATIVE: FROM GLOBAL TO REGIONAL

Developing a narrative

The concept 'Industry 4.0' (*Industrie 4.0* in its original language) first emerged at the 2011 Hanover Trade Fair, where it was presented as a vision for the future of manufacturing in Germany (Pfeiffer, 2017). In 2013, this resulted in the development the German industrial policy 'Platform Industrie 4.0' (Kagermann et al., 2013). Along with global consultancy firms such as McKenzie Global Institute (Manyika et al., 2012) and Roland Berger (Blanchet et al., 2014), the World Economic Forum (WEF) has been instrumental in developing the I4 narrative. In short, the I4 narrative centres on a fusion of technologies such as artificial intelligence (AI), advanced industrial robots, sensors, the Internet of Things (IoT), big data and cloud computing into cyber-physical systems (CPS) (Gilchrist, 2016; Schwab, 2016a), where fully autonomous production lines are remotely controlled. This was proposed to have vast impacts on both production, knowledge demands and business models. We regard the 2016 WEF Annual meeting in Davos, under the heading 'Mastering the Fourth Industrial Revolution', as the culmination of the I4 narrative. Together with the publication of WEF Executive Chairman Klaus Schwab's book *The Fourth Industrial Revolution* (2016a), we find that the 2016 meeting firmly put the I4 narrative into the global conscience, generating collectively held expectations among global policy and industry leaders. The I4 narrative quickly trickled down into industrial policies in other European countries (Reischauer, 2018).

In Norway, the concept was at the centre of attention at the annual industry conference *Industri Futurum* in October 2016, under the heading 'The Future Produced in Norway'. At the conference a top executive from Roland Berger, one of the leading consultancy agencies on I4.0 in Europe, delivered a keynote speech on the urgency of technological upgrading in the manufacturing industry and how Norwegian manufacturers should strive towards 'becoming Industry 4.0'. The notion of 'becoming' I4.0 was repeated several times by different speakers – playing into the fear of missing out (Berkhout, 2006) – conveying a plot where companies would

become uncompetitive on the global market if they did not put I4 strategies into place swiftly. In terms of policy, Roland Berger was also involved in advising the Norwegian Ministry of Industry and Fisheries which was at the time drafting the new industrial policy 'A Greener, Smarter and More Innovative Industry' (Ministry of Trade Industry and Fisheries, 2017).

The I4 narrative has, as demonstrated above, created a sense of urgency regarding technological upgrading in the manufacturing industry. This was evident at both the WEF annual meeting in 2016, where the disruptive impact of I4 was proposed as the Fourth Industrial Revolution (Schwab, 2016b), and at the Norwegian Industry conference the same year. The expectations generated by the I4 narrative in these globally and nationally impactful events with industrial and political leaders present create a sense of urgency. We argue that this results in a fear-of-missing-out logic (Van Lente, 2012) among industry leaders and politicians, which fuels actions towards a collectively shared future (Konrad et al., 2017). By portraying the technological upgrading that follows I4 as disruptive, actors such as WEF and Roland Berger create collectively held negative expectations, playing into manufacturers' fears of missing out and losing their competitive edge (Berkhout, 2006). Furthermore, we argue that these actors, through holding leading positions within the manufacturing industry, leverage their power to substantiate their narratives and (in the case of Roland Berger) position themselves as experts within the field. Ultimately, they were successful, as the narrative trickled down into national industry and innovation policies in Norway.

The I4.0 narrative in policy and funding

In March 2017, the Norwegian government launched its new industrial policy 'A Greener, Smarter and More Innovative Industry' (Ministry of Trade Industry and Fisheries, 2017). Leading up to the publication of the industrial policy, the Norwegian Ministry for Trade, Industry and Fisheries toured Germany for inspiration and input on the concept I4 and how this was reflected in industry and education. As part of this tour, the minister had meetings with Roland Berger (Ministry of Trade Industry and Fisheries, 2016a, 2016b). It is necessary to have a certain grasp on the main lines that are drawn up in the 2017 industrial policy because it frames and provides direction for regional industrial development and provides insights on the government's awareness of and ambitions for the I4 concept. As a key actor with the power to draft industry policies and innovation schemes (Yap & Truffer, 2019), the government expectations towards I4 and technological development is essential, as the drafting of industry and innovation policies that are in line with the I4 narrative provides legitimation for the narrative (MacKinnon et al., 2021). We regard the development of the Norwegian Catapult Programme as a concrete example of how expectations towards advanced manufacturing technologies (I4) have generated policy action that legitimizes the I4 narrative, which in turn has a direct impact on the Raufoss region.

In the Raufoss region, industrial policy has been particularly important in setting out goals and providing funding for the establishment of the Norwegian Catapult Programme. The programme is founded on the Norwegian industrial policy from 2017 (Ministry of Trade Industry and Fisheries, 2017) and aims to develop a national infrastructure that will improve Norwegian companies' access to, and the quality of, research and development (R&D) and technology infrastructures that will 'accelerate the process from concept to market' (Norwegian Catapult, 2019). One of the established catapults, on manufacturing technologies, has been located at Raufoss. We argue that the Catapult can be regarded as a result of policymakers' expectations towards I4.0 technologies and their effect on Norwegian manufacturing. The vision (Berkhout, 2006) to create 'a world class technology centre, consisting of several mini-factories, with industry 4.0 standard' (SINTEF Manufacturing, 2018), underpins this argument. Furthermore, the Catapult reinforces the specialization of the Raufoss region as a key region for automation and light-weight materials, taking over for the NCE funding (2006–16). The effect of the Catapult

has not, at present (2021), resulted in the development or exploration of new industrial opportunities for the region. Rather, it contributes to enhancing the competitive advantages of the region within manufacturing, thus enabling path extension (Isaksen, 2015).

According to a project leader in the cluster organization, the establishment of the Catapult in the Raufoss region is the result of years of strategic development, where cluster and innovation funding schemes have been used as steppingstones to develop the core manufacturing capabilities (both technological and human resources) of the Raufoss region (interview 10). We argue that the Catapult demonstrates essential multilevel interaction and agency and can be seen as a regional manifestation of the national ambitions regarding I4. Our informant's reflection on successfully attracting the Catapult to the region also demonstrates how the location was anything but coincidental, and how a regional actor (cluster organization) consciously plays into the narrative of I4, which was legitimized by the state through both policy and funding, to enable continued development of the regional industrial path. The Raufoss region emerged as the most suitable candidate for anchoring such a national catapult in terms of the regional industry's characteristics (predominantly manufacturing), mode of production (mass production), and globally competitive (in many cases foreign owned) manufacturing companies.

As a provider of public research funding, where the emphasis on I4 also has risen within the last decade, the Norwegian government provides further legitimation for the I4 narrative within the Raufoss region. One expression of this was the establishment of the Centre for Research Based Innovation on Manufacturing (SFI Manufacturing). The core activities of the centre are anchored within the Raufoss industrial park with SINTEF Manufacturing as its host. The annual reports show a clear development on how I4 is used as conceptual framing, in both the core activities and spin-off innovation projects. The year 2018 was a highlight in this regard with several explicit references and examples of activities (SFI Manufacturing, n.a.). An analysis of 40 successful innovation research project applications (from 2000 to 2020) within the Raufoss region (RCN, 2020), which have been granted funding from the RCN, shows that the I4 concept explicitly and I4 related technologies are apparent in several projects. In the period 2009–20, two (of 28) projects explicitly relate to I4, while nine (of 28) projects focus on I4 related technologies such as three-dimensional (3D) printing, big data, AI, simulation technology and sensor detection. Examples of this are the projects CPS Plant (2017–21) and DataVar (2020–23), which both encompass research topics such as big data, use of AI and complex (cyber-physical) production systems. The rising number of innovation projects receiving funding for developing I4 (-related) technologies further underscores how the I4 narrative contributes to industrial development within the region. These research activities contribute to improving regional manufacturers' capabilities (Kaplinsky & Morris, 2001), resulting in incremental innovation within products and processes and enabling path extension (Isaksen, 2015).

I4 and technology upgrading in companies

The I4 narrative has created a momentum for technological upgrading within companies located in the Raufoss region. This is also the case among those companies that already were technological frontrunners. According to a factory manager at a defence and aerospace manufacturer, the attention that the narrative has gathered has resulted in participation in discussions with European business leaders on what to make of the I4 concept and how to understand it and inviting technology providers into their factory at Raufoss to see how it can be further developed (interview 17). Other manufacturers see I4 as something that legitimizes technology upgrading to improve the companies' capabilities (Yap & Truffer, 2019). For example, the chief executive officer (CEO) of an automotive manufacturer explains that when it comes to 'the Industry 4.0 concept ... we just have to be there ... we have to think next generation in terms of removing

assembly lines and steps and use more robots'. The I4 narrative has evidently encouraged the company to buy new manufacturing technology and upgrade their production and assembly lines.

Other manufacturer in the region do not have a conscious attitude towards the I4 concept, yet their investment decisions are in line with that of those manufacturers who do. The CEO of a building solutions manufacturer explained that:

We want to be the best within digitalization, robotization and automation. I feel like someone started to call that I4. It might be that other people call this I4, but we are more concerned with investing in the best equipment available. If that is I4, that's okay. (interview 15)

This illustrates how the I4 concept might not be something that manufacturers explicitly use themselves as part of their everyday language. Furthermore, it shows how a company make strategic decisions concerning technology investments that are in line with the I4 narrative, without necessarily labelling it as I4. We argue that this taps into the issue of agency, and how narratives are created on a higher level, e.g., national (in policy) and global (in higher level meetings such as the WEF's Annual Meeting), and manifest in regions and places. Companies and practitioners themselves have had no part in developing the narrative yet act in line with it.

I4 and education

Recent contributions have found that vocational education institutions in the Raufoss regions have developed new educational programmes to accommodate knowledge needs that follow implementation of more advanced (I4) manufacturing technologies (Lund & Karlsen, 2020). In collaboration with regional industry, the regional vocational college, has upgraded their education programmes to 'comply with [Industry] 4.0' (interview 5). In 2021, the vocational college introduced programme called Manufacturing 4.0, to prepare students for the 'extensive change and automation of industrial production and planning' that follows the Fourth Industrial Revolution (Fagskolen Innlandet, 2021). Similarly, the Raufoss high school and the vocational college have moved parts of their education into the new Learning Factory to access new technologies, more in tune with I4 demands, and industry knowledge and competence (interview 11). The Learning Factory is a partly industry-funded educational arena located within the Catapult Centre at Raufoss (Raufoss Industripark, 2020). These changes in educational provisions illustrate how the I4 narrative has influenced vocational education in the region. Furthermore, it demonstrates how key components in the regional innovation system change in line with the narrative, providing workers with the skills required for manufacturing in an I4.0 context, and thus enabling path extension (Isaksen, 2015; Lund & Karlsen, 2020).

CONCLUSIONS

The paper demonstrates the influence of narratives on technological expectations, and how these result in decisions that fit into the predominant narrative. By doing so, we tap into a wider debate on how agendas, both technological and political, are set, and how they are reinforced by key actors (and agency) within the knowledge system. As such, the paper contributes to increasing the awareness of both policymakers and industry leaders on how dominant narratives, which create future visions (Berkhout, 2006), might shape their actions and decisions, and how this has played out in the Raufoss region.

The implementation of advanced (I4) manufacturing technologies in Raufoss companies has not resulted in the development of new regional industrial pathways. Rather, the technological expectations generated by the I4 narrative has resulted in technology upgrading among Raufoss companies, enabling the region to continue its developmental path within the manufacturing

industry. These developments are legitimized by institutional development financed by the state that support path extensions, such as the establishment of the Catapult centre, which can be seen as a continuation of previous smart specialization strategies (e.g., the NCE programme). We argue that the global I4 narrative has resulted in regional path extension (Isaksen, 2015) in the Raufoss region due to multilevel agency. Expectations amongst national policymakers, related to increased competitiveness among Norwegian manufacturers caused by technological upgrading, led to the development of industrial policy and innovation schemes that were anchored in the Raufoss region due to industrial preconditions and strategic actions of the regional cluster organization. The narrative has in turn influenced regional manufacturing leaders to invest in new technologies that are in line with the I4 narrative. Our findings demonstrate that the I4 narrative has generated changes within the greater regional innovation system that combined ensures the extension of manufacturing industry in the region, avoiding a lock-in where the regional industry would lag behind in a global industry.

There are few studies within economic geography addressing the influence of narratives on regional path development. As such, by combining the SOE and recent – agency sensitive – path-development literatures, this study contributes to the academic debate by introducing a novel approach to investigate regional path development. We believe that further investigations into how policies and industrial decisions are shaped by dominant narratives and associated expectations are called for, as they can provide insights on key agency aspects related to path development.

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