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Policy to support digitalisation of industries in various regional settings: A conceptual discussion

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ABSTRACT
The purpose of the article is to analyse regions' varying preconditions for digitalisation of industry and, on that basis, discuss regionally tailored policy strategies to stimulate digitalisation. Building on both regional innovation system and asset modification approaches, the authors suggest a theoretical framework that identifies regions' potential for digitalisation from their stock of relevant assets at the firm and innovation system level. The analysis identifies four types of regions with different preconditions for supporting digitalisation of industries. This in turn provides the foundation for a discussion of the role of actor-based and system-based policy strategies to support digitalisation in each type of region. From the existing literature, the authors discuss empirical examples of digitalisation within each of the four types of regions but also highlight that individual regions need to tailor the portfolio of policy support within the identified strategy, as each region is structurally and institutionally unique.

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Introduction

In this article, we reflect upon and mobilise theoretical approaches and empirical examples in existing literature to discuss what types of policy strategies can stimulate digitalisation of industries in different regional settings. We understand digitalisation as the development and utilisation of a wide range of digital tools and infrastructures that have the potential to change firms and industries substantially through innovation (Nambisan et al. 2017; 2019; Isaksen et al. 2020). Digitalisation is the core of Industry 4.0, which expands the productivity focus and opens entirely new possibilities in both product and service manufacturing from the integration of digital tools (Bai et al. 2020). Examples of such digital tools are smart sensors, big-data processing, artificial intelligence, and 3D printing. These path-breaking digital technologies allow for cross-product and architectural combinations (Yoo et al. 2010), which are becoming increasingly important in efforts to tackle grand societal challenges through 'greener' production processes and value chains (Perez 2017), and the implementation of new welfare technology (Bodenhagen et al. 2019).

The digital tools can be 'big bang' generic technologies that initiate a technological revolution and a new techno-economic paradigm in the world economy (Perez 2010), which make studies of digitalisation and its effect on industrial (and societal) development of high relevance. Digitalisation affects industries and societies worldwide but is adopted and developed differently in different industries and regional contexts, partly depending on the absorptive capacity of firms and regions. Therefore, policies to strengthen industries' use of digital tools must consider the conditions in particular regions. Research has analysed how industries in different types of regions vary in their innovation capacity and based on the findings researchers have discussed regionally adapted policy approaches (Tödtling & Trippl 2005;

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Isaksen & Trippl 2016). Researchers have also discussed policy implications on regional levels as a result of the creation and adoption of Industry 4.0 technologies (Baily & De Propis 2020). Such policy strategies 'require tailor-made actions embedded in and linked to the specific needs and available resources of regions' (Baily & De Propis 2020, 249). While this argument of place-based policy is well established in the literature, it is also general. Our contribution includes a more detailed discussion of conditions in firms and on the regional level of how digital technologies can be adopted, used, and devloped, and on that basis we analyse what can be adequate policy strategies for digitalisation in different types of regions, and we provide illustrative examples.

We argue that digitalisation of industries in a region may require that firms modify their existing assets. Such assets are developed over time to support prevailing activities and therefore the existing assets may not necessarily support firms' digitalisation undertakings (Isaksen et al. 2020). Based on the regional innovation system (RIS) approach, we argue that digitalisation (and other considerable changes) in firms often do not depend only on the modification of assets at the firm level. Firm-level changes will also often require support from assets, and subsequently modification of assets, at the innovation system level (Trippl et al. 2020). The RIS approach demonstrates that firms obtain information, expertise, and knowledge from a varied set of external actors in innovation processes, and that innovation processes are supported by an institutional infrastructure (Asheim et al. 2019). Thus, digitalisation of firms may need new types of support and modification of assets at the RIS level (as well as from national and international levels).

The main research question addressed in this article is what policy strategies can stimulate digitalisation of industries in different regional settings. Building on the argument that digitalisation in firms and industries is based on existing and modified assets in firms and RISs, we explore the potential of different types of regions to support digitalisation of industries. We distinguish between four types of regions. Regions that at the outset have a low stock of assets of relevance for digitalisation in both firms and the RIS are denoted as low-potential regions. Regions that have high stock of assets relevant for digitalisation in firms while the RIS is not supportive in that matter are seen to have firm-driven potential for digitalisation. By contrast, regions that have a significant volume of assets relevant for digitalisation at the RIS level but not at the firm level are seen to have a system-driven potential for digitalisation. Lastly, regions that hold a large stock of relevant assets in firms and RISs are denoted as high-potential regions.

To discuss which type of policy for supporting digitalisation may be most relevant to each of the four types of regions, we apply the distinction between actor-based and system-based policy approaches (Isaksen et al. 2018). Actor-based policy approaches include equipping actors in RISs, such as firms, universities, and vocational schools, with the required capabilities to adopt or develop digital technologies. System-based policy approaches consist of adapting the working of RISs in such a way that they provide better support for innovation activity in the form of digitalisation in existing and new firms. Such adaption includes strengthening the relevant knowledge flow between firms and with knowledge organisations within and beyond the RIS, and ensuring that formal and informal institutions support rather than hamper digitalisation activities – that is, they contribute to resolving potential innovation system failures (Klein Woolthuis et al. 2005). Moreover, the idea is that policy is most efficient if policies to support firms' innovation activity and policies to strengthen RISs are coordinated and heading in the same direction.

The article contributes to the literature on regional policy designed to stimulate digitalisation of industries in various regional settings, firstly, by linking the notions of regional innovation systems, asset modification, and actor-based and system-based policy in a theoretical framework, and secondly, by applying the framework to empirical examples. The remaining part of the article is structured as follows. The next section ('Asset modification for digitalisation of regional industries') develops a conceptual framework of four types of regions that differ in their potential to stimulate the digitalisation of industry and the type of actor-based and/or system-based policies that are most appropriate in each case. The third section ('Digitalisation processes and policy to support digitalisation in various regional settings') illustrates and further discusses the framework by use of empirical examples of how digitalisation occurs and policy functions in each regional type. In the fourth and final section, we present a summary and our conclusions.

Asset modification for digitalisation of regional industries

In this section, we present two theoretical building blocks that are relevant in order to shed light on the question of how regions can tailor policy to support digitalisation of industries. We start by reviewing and adapting the asset modification approach to our use, and thereafter we apply the RIS concept to discuss system and firm potentials for digitalisation.

Asset modification for digitalisation

In recently published studies, authors argue that considerable changes in industries in a region require some form of asset modification (Trippl et al. 2020). The main argument is that assets need to be modified because the existing asset base in firms and RISs has been developed over time to support mainly prevailing solutions and structures (Asheim et al. 2019). In referring to the digitalisation of industries, Isaksen et al. (2020) argue that asset modification is also key for firms to apply digital technology in production processes and for the creation of new digital products and services.

MacKinnon et al. (2019) differentiate five types of assets: natural assets (resources), infrastructural and material assets (buildings, machines, infrastructure), industrial assets (technology, available capital, leadership, and organisation), human assets (knowledge and skills), and institutional assets (formal and informal rules, regulations, norms, and values). In this article, we simplify this categorisation and specify assets of relevance for digitalisation of firms and industries as being either tangible or intangible. We find support for this distinction in a report by Wolfe (2018), who argues that federal government policy in Canada has focused much on tangible assets for digitalisation, such as supporting the telecoms and mobile devices sectors. However, intangible assets are becoming increasingly more important with regard to digitalisation because 'official policy needs to take account of the shift in innovation from devices and products to systems, networks, applications, and services based on software codes' (Wolfe 2018, 5).

Furthermore, we distinguish between assets at the firm level and the RIS level (Isaksen et al. 2020; Rypestøl 2020). Firm-level assets are controlled by a firm or an organisation, whereas system-level assets are, in principle, available for all actors in a RIS. Examples of tangible and intangible assets that can support digitalisation at the two levels are provided in Table 1.

Table 1. Assets for digitalisation

Type of asset	Examples of firm-level assets	Examples of system-level assets
Tangible assets for digitalisation	In-house laboratories and digital machines, firm-specific digital technology	Publicly owned laboratories and test facilities for digital equipment, access to generic digital technology, laws and regulations that support digitalisation Education facilities and programmes for digital knowledge
Intangible assets for digitalisation	Organisational culture and networks that support digitalisation, in-house digital knowledge, and skills	Informal institutions that support digitalisation, digital knowledge, and skills available in the workforce, and access to digital R&D knowledge

We find the distinction between tangible and intangible assets and between firm-level and system-level assets useful for analytical purposes. Even so, we acknowledge that the distinct types of assets relevant for digitalisation are most often connected in different ways. Such interconnections make it hard to separate the effects of tangible and intangible assets at the firm and system level in empirical cases. For example, education facilities (tangible, system-level assets) contribute to digital knowledge and skills in firms (intangible, firm-level assets). Furthermore, firms that develop or apply digital technology (tangible, firm-level asset) can use and contribute to the development of test facilities for digital equipment (tangible, system-level asset), and these two types of assets can influence informal institutions (norms) to support digitalisation efforts in industries in a region. This mutual impact between the four asset types is further explained and exemplified in the section 'Digitalisation processes and policy to support digitalisation in various regional settings'.

Modification of assets can take three alternative forms (Trippl et al. 2020).[1] First, assets can be modified through the reuse of existing assets. Asset reuse includes recycling, redeployment, and recombination of existing assets. A second type of asset modification includes the formation of new assets from importation or through internal development. Asset importation occurs when existing assets are imported to new areas, and asset creation includes the building of new tangible or intangible assets from scratch. As a third type, asset reuse and creation can lead to the need for asset destruction (Trippl et al. 2020), which refers to processes in which hampering assets are demolished or unlearned.

The 'asset approach' implies that considerable changes in regional industries, such as digitalisation of products, services, or production processes, require modification of a broad range of various assets at both the firm level and the RIS level. Such asset modifications are challenging and complex processes within and across firms and organisations. The processes are stimulated by a level of absorptive capacity in firms and in regional environments.[2] Firms' realised absorptive capacity refers to their ability to recognise the value of

[1]Kyllingstad et al. (2021) suggest the upgrade of existing assets as a fourth type of asset modification, but in this article, we use the original version of three types of asset modification to make the argument on policy strategies more distinct.
[2]We owe thanks to an anonymous reviewer for making us aware of this point.

new, external information and knowledge (i.e. outside the firm), assimilate it, transform it, and apply it for commercial use (Cohen & Levinthal 1990; Zahra & George 2002). The absorptive capacity mainly reflects firms' level of prior related knowledge and skills.

However, firms' absorptive capacity also depends on the absorptive capacity of the regional environment. This in turn depends first on the capacity of firms that act as technological gatekeepers to acquire new knowledge from extra-regional sources and not least to transfer this knowledge to other regional firms (cf. Giuliani 2005, who discusses clusters' absorptive capacity). Technological gatekeepers are knowledgeable firms but could also be units of multinational corporations, and regions' absorptive capacity relies also on the structure of local firm networks and knowledge flow within them. Second, firms' absorptive capacity depends on the strength of the regional innovation system, such as knowledge generation and diffusion activities of universities, research institutes, and other knowledge organisations, and the policy support structure (Trippl et al. 2018). Inflow of extra-regional knowledge through mobility of skilled workers and through networks also affect regions' absorptive capacity (Miguélez & Moreno 2015). Thus, while some assets are historically developed properties of firms and innovation systems, absorptive capacities are the abilities of firms and organisations to modify existing assets and determine how those modified assets (as new knowledge) are spread among and applied by firms in a region.

Regional innovation systems and firms' potential for digitalisation

Based on the arguments raised in the preceding subsection, we have developed a typology that distinguishes between RISs with differing potential to support digitalisation of industries. A RIS develops over time (Asheim et al. 2019), and therefore the potential for regions to support digitalisation (and other considerable changes) of industries will vary according to the nature of the RIS development. The composition of RISs is determined mainly by the status of their three defining elements, namely actors (e.g. firms and knowledge organisations), networks (e.g. relations between firms and knowledge organisations within and beyond regional boundaries), and the institutional framework of policy tools, laws, and norms and routines (Asheim et al. 2019). In particular, the actors' preconditions and especially firms' preconditions for applying digital technology and using digital solutions in innovation activity determine the extent to which a RIS can support further digitalisation of the region's industry. Thus, we focus subsequently on the potential for digitalisation in firms and industries and in knowledge organisations (e.g. universities, research institutes, vocational schools, technology centres). We also discuss how the potential of these actors can be stimulated and hampered by the working of networks and institutional infrastructures.

The most obvious favourable precondition for digitalisation or further digitalisation is found in regions that host a number of firms with prior experience and knowledge of ICT and digitalisation, and/or that have some strength in industries that started early on with digitalisation processes such as ICT and new media. Such firms and industries hold prior related knowledge, skills, and other assets, which according to Cohen & Levinthal (1990) should lead to them having high absorptive capacity for digitalisation. Favourable conditions also include a well-developed knowledge infrastructure that diffuses digital knowledge and competence. Encouraging environments for digitalisation can also include that firms and knowledge organisations are part of global innovation networks (GINs) in which digital knowledge and expertise are developed and diffused. However, according to Chaminade & Plechero (2015, 228), 'firms engage in different forms of GIN only when they cannot find the resources they need to innovate in close proximity'. Firms outside large and industrial diversified regions often need to apply 'extra-regional asset-seeking strategies' (Chaminade & Plechero 2015, 228) for digitalisation, which requires that they have the absorptive capacity to benefit from engaging in GINs. Thus, favourable preconditions for digitalisation are found particularly in regions where firms and industries have gained experience in digitalisation and where digitalisation activities are supported by RISs and by links to relevant parts of GINs.

The opposite situation is found in regions where firms, industries, and knowledge organisations, for different reasons, have not developed experience and knowledge regarding digitalisation. In such regions, firms have low absorptive capacity to initiate digitalisation processes, they are supported to a small extent by the RIS, and they lack absorptive capacity to apply relevant competence in GINs. Unfavourable conditions for digitalisation of industries in a region may also be due to hampering factors in firms and RISs, which can be conceptualised through the lock-in concepts and the system failure approach. Lock-in includes that strong ties between regional firms, and between firms and the political support system, as well as long-standing personal ties, can lead to group-think interpretations and hinder the inflow of new ideas and knowledge (Grabher 1993; Hassink 2017). System failures identify weaknesses in the working of RISs, such as when it comes to supporting the digitalisation of industries. The failures include (1) lack of appropriate competence in firms and in knowledge and support organisations, (2) information and knowledge exchange between only a fixed set of actors (leading to lock-in) or lack of interaction and knowledge exchange between actors in the RIS, and (3) inappropriate institutions, laws, regulations, norms, and implicit 'rules of the game' that hinder innovation (Klein Woolthuis et al. 2005).

Analytical framework

Based on the arguments presented in the preceding subsection, Table 2 shows the potential for digitalisation in regions ranked according to their stock of relevant assets (i.e. related, firm- and system-level assets) and indicates possible broad policy strategies to promote further digitalisation of industries. With regard to policy strategies, and as mentioned in the Introduction, we distinguish between actor-based and system-based strategies. Actor-based policy approaches support entrepreneurship and innovation activity in incumbent firms and by other RIS actors. By contrast, 'system-based strategies aim to improve the RIS functioning by targeting system failures, promoting local and non-local knowledge flows and adapting the organisational and institutional set-up of the RIS' (Isaksen et al. 2018, 6).

Following Isaksen et al. (2018), we argue that changes, such as digitalisation, in industries in a region can benefit from a combination of actor-based and system-based policy initiatives. Such combinations are particularly important in regions with few assets of relevance for digitalisation at both the firm level and RIS level. In regions with few relevant assets in either firms and/or industries or the RIS, we argue that strategies should focus on the 'underdeveloped' level. Finally, in regions with well-developed digital assets in both firms and RISs, we argue that policy often needs to align assets and asset modifications in better ways at the two levels.

In Table 2, we distinguish between four types of regions with various preconditions for digitalisation. Cell C in Table 2 includes regions that possess a small stock of assets relevant for digitalisation at both the firm level and the system level. Such regions are often found in peripheral areas with relatively few firms, and where the knowledge infrastructure is weakly developed, with either very few or no universities and research institutes. The framework in Table 2 suggests that digitalisation in regions represented in cell C needs support from both actor-based and system-based policy strategies. Such policies should focus on asset creation, as the actual regions have low potential for asset reuse.

Table 2. Relevant policy approaches to promote digitalisation of industries in various regional settings

		Stock of tangible and intangible assets relevant for digitalisation in *RIS actors* beyond firms	
		Small	Large
Stock of tangible and intangible assets relevant for digitalisation in *firms*	Large	**A** System-based policy strategies	**B** Policy strategies to increase alignment between firm-level and system-level assets
	Small	**C** Both actor-based and system-based policy strategies	**D** Actor-based policy strategies

Regions represented in cell A in Table 2 have a high level of relevant assets for digitalisation at the firm level and a low stock of assets at the RIS level (which means, for example, low flow of 'digital knowledge' between knowledge organisations and firms). Such environments can be found in dynamic industrial regions, where the industrial community is early in developing or adopting new technology and business models. Firms' digitalisation may be supported by their participation in global production and innovation networks, but the RIS will lag somewhat behind in digital development. Such regions have firm-driven potential for digitalisation, and we argue that further digitalisation in such regions can benefit most from system-based policy strategies.

Regions represented in cell D in Table 2 are in an opposite situation to those in cell C, as they have a system-driven potential to support further digitalisation of industries. Such regions have a high stock of relevant assets at the RIS level, whereas regional firms are in general poorly equipped with relevant assets. This group includes regions with universities and research institutes that carry out research on digitalisation in global research networks, but where this knowledge to a very small extent flows to, and is used by, each region's industry. Table 2 suggests that actor-based policy is particularly relevant in these cases, for example to support capacity building and digitalisation in existing firms, and links between firms and the regions' knowledge organisations.

Lastly, the regions represented in cell B in Table 2 have developed a large stock of relevant assets for digitalisation at both the firm and the RIS level, where both firms and RISs may be inserted into global networks. Such regions are typically large industrially diversified regions.

In such regions, policy strategies can focus on aligning relevant assets at the firm and the system level. Also, regions in cell B are best equipped to foster the creation of new digital assets from scratch, as they possess a diverse portfolio of assets at both levels.

Digitalisation processes and policy to support digitalisation in various regional settings

In this section we specify and present examples of opportunities for digitalisation and barriers to it, and we discuss types of policy that can stimulate digitalisation of industries in the four types of regions represented in Table 2. The discussions are complemented by relevant empirical examples from the existing literature.

Regions with low digital potential

Regions with low potential for digitalisation (Table 2, cell C) have firms and organisations with few assets that are relevant for digitalisation, and an institutional framework that offers weak support for the digitalisation of industries. In many cases, the low digital potential will also include important barriers, such as system failures with few knowledge links, and cell c in Table 2 suggests that low-potential regions can benefit from both actor-based and system-based policy strategies.

Isaksen et al. (2020) argue that firms that mainly rely on experience-based knowledge for innovation most often modify assets for innovation through the reuse mechanism facilitated by cumulative learning in stable organisations. However, as highlighted in the theory section, regions with low potential for digitalisation lack tangible and intangible assets relevant for digitalisation, since over time and for various reasons firms and the RISs have not focused on applying or developing digital technology. In general, local firms can strengthen their absorptive capacity from formal education and R&D activity, as well as from experience building and learning in daily work. However, since there are few relevant regional actors with experience-based digital knowledge, strengthening of formal education in digitalisation becomes vital to enhance firm-level absorptive capacity.

At the system level, the literature suggests that RISs can be strengthened through adaptation of existing tangible assets such as education programmes and incubators (Miörner & Trippl 2017). In addition, regions with low potential for digitalisation of industries can seek to strengthen firms' intangible assets by supporting formal and informal competence building in order to strengthen their capacity to absorb digital knowledge in firms and RISs.

Regions with low digital potential can also stimulate asset creation through importation. Regions can facilitate asset importation through joint projects between regional and non-regional actors, through skilled labour mobility from extra-regional sources or through acquisition of non-local firms' organisations. Bathelt et al. (2004) highlight the importance of global knowledge pipelines for regional firms to provide access to distant knowledge sources and refill firms' asset base. Bürgin & Mayer (2020) find both support for this argument and that connecting to non-regional actors is key to regions with low digitalisation potential. When researching digitalisation in Switzerland's mountain regions, Bürgin & Mayer (2020) found that regional actors established co-working spaces and invited 'digital nomads', knowledgeable entrepreneurs, and representatives of digitally forward-leaning companies to come to work in the Alpine landscape and collaborate with local entrepreneurs and business owners. In this case, co-working spaces became digital hubs that facilitated asset-creation processes among regional entrepreneurs and firms. Even in Switzerland, which has one of the highest national coverages of broadband in the world, spatial peripheries[3] such as the mountain regions are concerned about lagging digitally behind due to lack of digital connectivity and issues related to speed and reliability of the Internet (Bürgin & Mayer 2020). Thus, to anchor incoming actors, the mountain regions need to upgrade their broad band connections (tangible asset creation) still further. Incoming actors are important, as they can increase awareness and spread knowledge and competence about the use of digital technologies (intangible assets).

In regions with low potential for digitalisation, actors may need to destroy existing hampering assets. While some tangible assets such as machines and education programmes are easily destroyed or replaced, the change of intangible assets such as culture and routines can cause more friction, take more time, and require more complex, time-consuming processes that involve processes of unlearning, as described by Tsang & Zahra (2008). At the firm level, Chauhan et al. (2021) found that firm-internal institutional arrangements such as digitalisation vision, digitalisation strategy, and other stakeholders' resistance were significant for digitalisation. At the system level, they found that lack of standard architecture, lack of issues related to contractual, privacy, and security issues, and regulatory underdevelopment hampered digitalisation.

[3]Our classification of the Swiss mountain regions as spatially peripheral is in line with the categorisation argued for by Bürgin & Mayer (2020, 68).

Also, Meyn (2020) points to the importance of assets destruction for fostering digitalisation in low-potential regions. Based on studies of digitalisation in Swiss mountain regions, Meyn (2020) found that a lack of recognition and political will could significantly hinder digital empowerment in firms and innovation systems with low potential for digitalisation. To summarise, we suggest that regions with low potential for digitalisation have low absorptive capacity for digitalisation in firms and RISs, and to some extent they have institutional barriers that hinder digitalisation. We suggest that policy should focus on lowering barriers to digitalisation and on strengthening regional absorptive capacity for digitalisation by supporting processes of digital assets importation and implementation.

Firm-driven potential

Regions with firm-driven potential for digitalisation of industries (Table 2, cell A) have firms in digital sectors, such as ICT consulting, and/or firms in other sectors that have been early adopters of digital tools. Wolfe (2018) argues that a digital revolution is accelerating. The revolution is being propelled by 'the rapid spread of mobile devices, cloud computing and data analytics, which has shifted the focus of innovation from hardware to software and data' (Wolfe 2018, 3). Based on his argument, regions that have some strength within the ICT consulting and software development industries should have good preconditions for stimulating the digitalisation of regional industries in general. Firms in other industries can use digital tools either to make production processes more efficient or as a basis for product and service innovations, such as to make use of the Internet-of-Things (IoT). Geographical proximity to firms that have much digital knowledge and competence can stimulate the use of such knowledge and competence by other firms. This view builds on research results demonstrating that scientific, codified (analytical) types of knowledge can travel easily over distance, which may have been made even easier through increasing digitalisation (Martin & Moodysson 2013). However, experience-based competence with tacit elements (synthetic knowledge) is transferred when, for example, new ways of doing things are shown and discussed face-to-face, through observations of neighbouring firms, in communities of practice (Wenger et al. 2002), and through labour mobility, all which are facilitated by short geographical distances (Leamer & Storper 2001; Wenger et al. 2002).

Thus, digitalisation can be promoted in regions with firm-driven potential through different types of knowledge spillover between firms. However, digitalisation can be hampered in such regions if the knowledge is retained within specific firm networks. Thus, a key question for regions with firm-driven potential for digitalisation is how actors in the RIS can reuse and/or create assets that support digitalisation of industries in the regions in general. The digital firms and industries are part of the RIS and can support the digitalisation of other industries in different ways, such as by providing input factors as suppliers of digital tools and as consultants in different aspects of digitalisation. However, other parts of the RIS should also modify relevant assets to support further digitalisation through system-based policies. This can take place through the establishment of tangible assets such as education facilities and programmes for digital knowledge creation and diffusion or test facilities for digital equipment. Lund & Karlsen (2020) emphasise the importance of vocational education and training tailored to build competence in workers regarding digitalisation in firms. Skilled workers have a key role in implementing and adapting new digital technologies on the shop floor in manufacturing firms in particular (Lund & Karlsen 2020). Upgrading of RISs can also occur through changes in laws and regulations, and in informal norms that support digitalisation.

Firm-driven potential for digitalisation and the role of system-based policy can be illustrated by the growth of the artificial intelligence (AI) industry in Montreal, Canada. Montreal is, relatively speaking, one of the world's most AI-intensive regions (Doloreux & Turkina 2021). AI can be interpreted 'as an incipient general-purpose technology derived from academic breakthroughs in computer science' (Gherhes et al. 2021, 2). In the case of Montreal, the AI industry developed as part of a strong ICT cluster in the city, illustrating the importance of related technological knowledge, but subsequently it grew into an independent local industry (Doloreux & Turkina 2021), which today constitutes a scientific and industrial centre within AI. Some key local and successive global entrepreneurs and multinational companies were key in the preformation phase of the AI industry in Montreal, a phase that was characterised by distributed and uncoordinated agency (Gherhes et al. 2021). A few leading AI scientists and a group of tech entrepreneurs co-funded an important start-up. The firm both expanded globally and became 'a platform for financing and training new local start-ups' (Doloreux & Turkina 2021, 7). Non-firms actors such as research institutes in AI, organisations aiming to help start-ups, and growing firms with developing business networks also emerged in Montreal (Doloreux & Turkina 2021, 7).

Non-firm actors became important in the more strategic formative phase of intense development (Gherhes et al. 2021). The strategic approach consists particularly of system-building. Access to venture capital enables more entrepreneurial experimentation and is key to the formation of an entrepreneurial ecosystem. Universities and private research laboratories serve as anchors for a large number of local students and scientists, as well as for incoming scientists and firms, and they form a core of the development of the Montreal AI industry (Gherhes et al. 2021). Additionally, government support and new policies, mainly shaped by local entrepreneurs, have been important for the growth of the Montreal AI industry (Doloreux & Turkina 2021). The Montreal example illustrates how digitalisation, in this case the emergence of a new digital industry, in regions with firm-driven potential is initiated by entrepreneurs who can utilise knowledge and skills in related industries, and from research activity. This creates start-ups, and a platform for learning and spin-offs. The example also illustrates the importance of system-building for anchoring and further growth of a new digital industry, which takes place through coordinated efforts by firm and non-firm actors. The system-building has moved the Montreal region from cell A to B (Table 2) in terms of the potential for further digitalisation. Thus, Montreal ends up in the same cell as Trondheim, which is described in the next section. It is the point of departure with firm-driven potential and the direction of change that distinguishes the Montreal case from the Trondheim case.

System-driven potential

In regions with system-driven potential (Table 2, cell D), knowledge and competence in digitalisation are mainly developed by other RIS actors than by firms. They are knowledge and diffusion organisations, such as universities, vocational colleges, research institutes, and technology centres. While knowledge development in such organisations provides a good starting point for digitalisation of a region's industry, a key question in regions with system-driven potential is how to diffuse knowledge and other assets related to digitalisation from system-level actors to firms, and how to increase firms' absorptive capacity for digital solutions. In essence, the rationale is to avoid a 'cathedrals in the desert' type of development, which occurs if regions have fairly well-developed universities and R&D institutes, often publicly financed, but at the same time have a regional industry that is less capable of utilising analytical knowledge (i.e. research-based knowledge). Such situations can be interpreted with reference to Table 1 as the building of system-level assets (research-based knowledge, laboratories, policy tools), but a lack of complementary asset modification at the firm level. Hence, actor-based strategies are important in regions of this type.

The county of Agder in Norway and the building of a support system focused on the University of Agder's campus in Grimstad illustrate activities and policy strategies for digitalisation in regions with system-driven potential. Firms' innovation activities were strengthened from 2004 to 2012 in Agder, and in contrast to other parts of Norway 'more of this activity was conducted in collaboration with local research system institutions' (Herstad & Sandven 2017, 10). Further strengthening of the Agder innovation system has occurred since 2012, particularly through three new organisations (i.e. tangible assets) located on the university campus in Grimstad: SFI Offshore Mechatronics, MIL, and I4Helse. In addition, a new vocational college, which includes a study programme in automatisation, is due to open close to the Grimstad campus in August 2022. The college, Fagskolen i Agder, will bring together study programmes in former vocational schools in Grimstad and Kristiansand.

SFI Offshore Mechatronics, a Centre for Research-based Innovation, was established in 2015 (Kyllingstad 2021). Centres for Research-based Innovation (CRI; SFI in Norwegian) are a policy instrument funded by the Research Council of Norway for up to eight years. The centres are intended to stimulate long-term research collaboration between research-intensive firms and R&D institutes. SFI Offshore Mechatronics started during the peak of the oil and gas industry in Norway and aimed to support innovation activity in this important industry in the region.

The partly state-funded Mechatronics Innovation Lab (MIL) was opened in 2017 (Rypestøl 2022). MIL offers piloting and technology qualification in mechatronics and related areas for firms.

I4Helse builds on a similar idea as MIL. The I4Helse education centre opened in 2019 and aims to stimulate innovation and service development within health and care services (Universitetet i Agder n.d.). The centre has different laboratory facilities, such as rooms with welfare technology solutions, with opportunities for simulation, testing, and development of new technology.

The above-mentioned three organisations stimulate digitalisation and development in industries in Agder to different degrees. The SFI Offshore Mechatronics mainly includes PhD students and conducts basic research that has limited effects on the innovation activity and digitalisation in firms in the short term, and it mainly targets the oil supplier industry. I4Helse started recently but is the result of long-term research activity within e-health at the University of Agder. The e-health solution has been introduced in the municipalities' organised health care services throughout Agder County, which is a pioneer county in that sense. However, hardly any regional firms develop and produce e-health solutions, and therefore the research results are limited.

By contrast, MIL seems to have had a larger effect than the other two organisations with regard to the digitalisation of production processes in parts of the manufacturing industry in Agder. This might be due to the fact that MIL staff are very proactive in visiting firms, analysing the potential for digitalisation (such as the use of robots) in firms, offering testing facilities, and arranging workshops (Rypestøl 2022). In this way, MIL contributes to building intangible assets for digitalisation in firms, such as acquaintance with the use of robots and digitalisation, and MIL performs analyses and provides advice on how digital equipment can fit into firms' production processes. While SFI Offshore Mechatronics may to some extent seem like a 'cathedral in the desert', MIL is more active in spreading practical knowledge about digitalisation to industries both within and outside the Agder region. This experience points to a general conclusion that system-level actors and policy strategies in regions with system-driven potential should actively contribute to awareness and absorptive capacity in firms with regard to digitalisation.

High potential

Regions with high potential for digitalisation (Table 2, cell B) have already developed a significant stock of tangible and intangible assets that are relevant for digitalisation at the firm level and/or industry level, and at the knowledge infrastructure level. Thus, high-potential regions have knowledge organisations that offer education within ICT at multiple levels, R&D organisations that use advanced digital technologies, and milieus that develop scientific knowledge needed to create new digital technology. Also, regions that offer high potential for digitalisation have firms with high absorptive capacity for digital knowledge and skills, and a portfolio of local firms that are highly interactive and knowledge sourcing, both locally and beyond. These favourable conditions for digitalisation are most often found within large urban areas, since such regions host many firms in diversified industries and a well-developed knowledge creation and diffusion sector.

Table 2 (cell B) suggests that policy to support digitalisation in high-potential regions could include the coordination of asset modification in firms and in other RIS actors, in order to align actor-based and system-based strategies. Such alignment is vital in order to extract the full potential for digitalisation, as regions that host uncoupled digitally competent firms and other RIS actors may suffer from untapped digital potential. Furthermore, regions that have high potential for digitalisation also have favourable preconditions for the creation of digitally relevant assets from scratch. The creation of assets can include the formation of novel scientific principles that potentially can lead to radically new tangible assets such as technologies and machines, and new intangible assets such as new skills and ways of organising activities. Therefore, policy could support advanced R&D projects within the field of digitalisation, as well as high-level education in this field, and the diffusion of advanced digital knowledge. An example of a high-potential region for digitalisation in Norway is the Trondheim region. Trondheim is the third largest city in Norway, with 207,595 inhabitants and a diverse industry sector (Statistics Norway 2021). The region is a centre for technology and digitalisation in Norway; it hosts a high number of technology firms and is a dominating R&D milieu for research and education in technology around the Norwegian University of Science and Technology (NTNU). At the firm level, the technology sector in the Trondheim region consisted of 759 firms with 13,000 employees, and it had an annual revenue of NOK 25.6 billion in 2018 (USD 3.1 billion) (Skjelstad et al. 2020). At the innovation system level, the region hosts NTNU, which has a large number of students in technology-related education programmes at bachelor, master's, and doctoral degree level. NTNU hosts 42,000 students and 9000 employees (NTNU n.d.), and focuses highly on international collaboration. Also, Trondheim is host to SINTEF, which is the largest independent research institute in Norway, with c.2000 employees and in 2020 had a revenue of NOK 3.4 billion (USD 360 million in 2020) (SINTEF n.d.,a). According to SINTEF's annual report for 2020 (SINTEF n.d.,a), the institute conducted more than 6800 research projects for c.3400 clients, at regional, national, and international levels, in 2020. SINTEF claims that this high degree of activity places it among the four largest contract research institutions in Europe. SINTEF Digital (SINTEF n.d.,b) is a significant division within SINTEF that delivers research-based systems and services within the field of digitalisation. The division has several laboratories for the testing and development of digital technology. Fitjar & Rodríguez-Pose (2015) refer to the high level of technical knowledge and competence in the Trondheim region and highlight that local firms in Trondheim can benefit more from local technological knowledge spillover and active local knowledge sourcing than firms located in other parts of Norway. Skjelstad et al. (2020) provide statistical data concerning the number of academic spin-offs in Trondheim. They found that the number of academic spin-offs from NTNU and SINTEF averaged 14.1 per year between 2009 and 2019, and that in 2018 a total 164 technology firms originated from the same local research community. In 2021, Trondheim was recognised as an innovative city by the EU and was awarded third place in the 2021 Rising Innovative City award (European Innovation Council n.d.).

The Trondheim case illustrates that, in contrast to system-driven regions, regions with high potential for digitalisation have stimulated the development of companies with high absorptive capacity for digitalisation, such as through labour mobility and spin-offs from university and R&D organisations, and in contrast to regions with firm-driven potential they have developed a functioning RIS. The Trondheim region is probably an example of a former system-driven region (through the establishment of NTNU) that has developed a technology-based business community with a high absorptive capacity, while the Montreal case discussed above moved in the opposite direction, starting as a firm-driven region. Because of the high absorptive capacity in high-potential regions, policy can support digitalisation by supporting digital asset reuse and creation processes, and by stimulating alignment between firm and system-level assets relevant for digitalisation.

Conclusions

This article contributes to the literature on regional policy designed to stimulate digitalisation of industries by combining a classification of four types of regions (shown in Table 2) with relevant asset modification for digitalisation in each regional type (summarised in Table 3). Essentially, we argue that strengthened digitalisation of regions' industries requires relevant assets in firms and in the RISs. This interpretation leads to the argument that policy to increase industries' digitalisation can include modification, namely the reuse, creation, and possible destruction of firm-level and innovation system level assets. However, regions differ in their potential for digitalisation of industries, due to different historically developed stocks of relevant assets at the RIS level and the firm level, including firms' capability to utilise assets from the regional, national, and global levels. Therefore, policy to stimulate digitalisation processes in industries must also vary between regions.

Some regions, often those in peripheral areas, have basically low potential for considerable digitalisation of their industries. We argue that such regions have few opportunities to reuse existing tangible and intangible assets, and to build new assets from scratch that can support digitalisation processes. Hence, importation of relevant assets is the closest option, but there may also be a need to destroy hampering assets, such as regulations, policy tools, and norms that support outdated solutions in core firms and industries in a low-potential region (Table 3).

Two types of regions have already well-developed assets for digitalisation in some regional industries or in the RIS, respectively. Regions in which some firms and industries have been early to apply digital solutions may need to support the emerging digital industries by strengthening parts of the RIS through modification of system-level assets. Emerging digital industries without a supportive RIS can lead to what could be termed 'isolated innovator failure'. This includes the presence of one or a few industries that develop or apply digital solutions, but that do not have wider effects on the digitalisation of the regional economy. Thus, policy strategies for further digitalisation in regions characterised by firm-driven potential could include supporting the reuse or creation of tangible assets in the innovation system, such as new or changed education programmes from secondary education, through tertiary education, to university level, as well as test facilities, laws, and regulations. This, in turn, could lead to the development of intangible system-level assets, such as increased knowledge of digitalisation.

Regions that have already developed relevant system-level assets for digitalisation may need policy strategies that could help firms and industries to apply digital technology. This would mean avoiding knowledge actors operating as 'cathedrals in the desert' and instead becoming 'oases in the desert', to follow this terminology. The strategy may include stimulating the reuse and creation of tangible and intangible assets for digitalisation in firms, while some firms may also need to destroy intangible assets (i.e. norms and routines) that hamper digitalisation. Providing firms with absorptive capacity for digitalisation can be supplemented with strategies for increased collaboration and knowledge flow between knowledge organisations with digital knowledge and expertise, and firms in need of digital upgrading. The MIL example points to the fact that knowledge organisations can work proactively to create awareness, positive attitudes, and skills in firms to employ digital equipment and solutions.

Finally, in regions that have high potential for digitalisation, firms and other RIS actors have high absorptive capacity for digitalisation from their significant stock of relevant assets in firms and/or industries and knowledge organisations. However, digitalisation also require agency at the firm and system levels that exploits the potential for

Table 3. Policy strategies for digitalisation in various types of regions

	Strategies for asset modification to support digitalisation			
		Asset creation		
Regional potential for digitalisation	Asset reuse	Importation	From scratch	Asset destruction
Low potential	–	X	–	X
Firm-driven potential	X	–	X	–
System-driven potential	–	–	X	X
High potential	X	–	X	–

digitalisation through modification of the existing assets base. Thus, in high-potential regions, policy could stimulate further asset reuse and asset creation for digitalisation and not least seek to release untapped potential by promoting alignment between assets relevant for digitalisation at the firm level and RIS level, among other ways though knowledge spillover and knowledge flow between the two subsystems of RISs. A summarised version of the suggested strategies for digitalisation in the four regional settings presented in this article is provided in Table 3.

We acknowledge significant heterogeneity within each of the four types of regions outlined in this article. For this reason, the strategies to support digitalisation through asset modification (Table 3) should be considered more as broad guidelines than as specifically tailored instruments. The guidelines fulfil two primary purposes. First, the theoretical considerations and the analytical framework (Table 2) can assist regions in categorising their potential for digitalisation by offering theory-founded descriptions of each of the four regional types. Second, Table 3 suggests broadly defined strategies that are relevant for stimulating asset modification to support digitalisation within each of the four regional types.

In this article we have introduced an analytical framework for categorising regions' potential for digitalisation or continued digitalisation of their industries, and we have discussed relevant asset modification strategies for increased digitalisation in each regional type. We have illustrated the theoretical framework and potential policies with examples from current literature. Future research could test the relevance of the framework through more dedicated research. That might, for example, include identification of relevant assets for digitalisation in firms and knowledge organisations in different regions, examination of to what extent and how such assets are created through dedicated policy tools, and how the assets affect the digitalisation of regions' industries. Also, future studies could investigate whether and how regions change their potential for digitalisation, for example from firm-driven or system-driven regions to high-potential regions, as we have suggested is the case in Trondheim.

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