Solving the puzzle?
An innovation mode perspective on lagging regions

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Abstract:

The promotion of innovation-driven development in lagging regions is currently on the regional policy agenda, so a sound understanding of how learning and innovation can be successful under the conditions there is crucial. In this context, this paper demonstrates the potential of an innovation mode approach at the micro level of regional innovation systems. Based on a conceptual framework on the relationship between knowledge bases and innovation modes in the field of regional development, a systematic literature review is used to analyse whether this potential has already been exploited in previous innovation studies on lagging regions. The results show that some important steps have already been taken in this direction. However, the potential gain in terms of insights has so far only been realised to a limited extent. Against this background, the authors formulate several avenues for future research on firm-level innovation modes in lagging regions.

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1. Introduction

Promoting innovation-driven development in lagging regions is currently on the regional policy agenda – whereby 'lagging' can be defined by different, often interrelated factors, be it the peripherality of an area or structural factors such as socio-economic disadvantages or the organizational thinness of a region (European Commission, 2017; OECD, 2020). Such a policy approach should be based on a sound understanding of the corresponding knowledge and learning environments in order to take into account the fact that innovation patterns in lagging regions can be very different from those in advanced regions (Eder, 2019a; Hervás-Oliver et al., 2021; Filippopoulos & Fotopoulos, 2022). As a result, innovation policy instruments that work in strong regions do not automatically have to be equally as effective in weaker ones (Isaksen & Trippl, 2017a). From a scholarly perspective, there is thus a case for addressing the "puzzle of innovating in lagging regions" (Rodríguez-Pose & Wilkie 2019, p. 6), in order to improve the understanding of policy-makers aiming to trigger knowledge-based developments in lagging regions, in terms of how innovation can succeed under the respective learning and knowledge conditions (see, e.g., Pelkonen & Nieminen, 2016; Isaksen & Trippl, 2017b; Asheim, 2019; Faria et al., 2020).

In this paper, we argue that the Jensen et al.'s (2007) innovation mode approach has much potential in this regard – which may make it, in a sense, a missing piece of the innovation puzzle in lagging regions. In recent years, this approach to explaining heterogeneity in firms' learning activities and innovation behaviour has become quite popular in innovation research (for an overview, see Apanasovich, 2016; Parrilli et al., 2016; Santos et al., 2022). Rooted in the innovation systems approach (Lundvall, 1992; Nelson, 1993), the STI/DUI concept essentially describes two ideal modes of learning and innovation at the company level: On the one hand, there is the 'Science, Technology and Innovation' (STI) mode, which is characterized by formal research and development (R&D) processes, scientifically trained personnel and codifiable scientific and technical knowledge. This is contrasted with the 'Doing, Using and Interacting' (DUI) mode, which is based on interactive, non-R&D-driven learning processes and experience-based know-how. Both modes are ideal-typical generalizations, each emphasizing different aspects of a firm's innovative capacity. In practice, the associated learning processes are usually combined at least to some extent, with specific emphases emerging depending on the individual business context (Thomä, 2017; Alhusen & Bennat, 2021).

However, despite its generally increasing prevalence, the regional contextualization of the STI/DUI concept is still in its infancy (see, for example, Isaksen & Trippl, 2017a; Parrilli et al., 2020; Doloreux & Shearmur, 2023). Nevertheless, a growing number of studies on lagging regions refer to the STI/DUI concept, with a particular focus on the DUI mode, to explain two typical features of learning and innovation in such contexts. These are, first, a low level of private R&D – which may imply a relatively high relevance of DUI-based innovation – and, second, the widespread absence of large firms, leading to a dominance of small and medium-sized enterprises (SMEs) and their typical innovation practices, which are often closely linked to the DUI mode (e.g., Pelkonen & Nieminen, 2016; Alecke et al., 2021; Hervás-Oliver et al., 2021; Filippopoulos & Fotopoulos, 2022). This suggests that it is precisely an innovation mode perspective that is appropriate to better understand the specificities of learning and innovation in lagging regions. The above-mentioned literature on studies referring to the STI/DUI concept in the context of lagging regions has now reached a volume that justifies a first overview. Such an undertaking is relevant because, as mentioned above, the regional contextualization of the STI/DUI concept has only just begun, which makes a systematic literature review all the more important to assess the potential benefits of an innovation mode perspective on lagging regions, to evaluate the current state of research in this field and, on this basis, to outline avenues for future research.

The aim of this paper is to conduct such a systematic review of those studies on lagging regions that refer (in whatever depth) to Jensen et al.'s (2007) STI/DUI concept. The underlying research question is: What is the (potential) contribution of an innovation mode perspective to understanding learning and innovation in lagging regions? Our contribution is three-fold: First, we link the STI/DUI concept to the knowledge base approach, a well-established concept in the literature on regional innovation systems, to provide an improved theoretical framework for innovation-driven, knowledge-based development in lagging regions. Second, our systematic literature review includes several dimensions. Bibliometric information is analysed to obtain an overview of the existing studies in this emerging field of research in terms of standardisable information such as author names and keywords. Then, the innovation mode perspective adopted by the reviewed articles on lagging regions is analysed along four content categories (i.e. theoretical framework, method, topic and policy). Third, based on our findings, we point out fruitful avenues for further research on innovation modes in lagging regions. In a way, our paper thus provides a response to Eder (2019a), who argues for a more theory-driven analysis of innovation heterogeneity between different types of regions by incorporating theoretical developments such as the STI/DUI concept.

The rest of the paper is structured as follows: Section 2 describes the conceptual background, i.e., the STI/DUI concept and its potential contribution to explaining innovation-driven, knowledge-based developments in lagging regions. This is followed by a description of our methodical approach in Section 3. Section 4 presents the results of the systematic literature review. Finally, in Section 5 we formulate our conclusions and avenues for future research.

2.   Conceptual background

2.1 The knowledge base concept

In order to assess the potential added value of using the STI/DUI concept in the present context, it is useful as a first step to look at the knowledge base approach, a well-established and widely used cousin concept from the literature on regional innovation, going back to Asheim & Gertler (2005) and Asheim & Coenen (2005) (see Figure 1). According to this, regional innovation systems (Cooke et al. 1997; Braczyk et al. 1998; Asheim & Isaksen 2002) are shaped by specific knowledge base configurations at the level of sectors or industries, distinguishing between analytical (science-based), synthetic (engineering-based) and symbolic (cultural-based) types of knowledge – with a possible endogenous potential of lagging regions seen primarily in terms of synthetic knowledge (Wassmann et al., 2016; Eder, 2019a; Blažek & Kadlec, 2019; Hervás-Oliver et al., 2021). The knowledge base concept allows for an analysis of the learning environment of lagging regions by implying, for example, that triggering new or enhanced development paths there often requires both an emphasis on endogenous factors and exogenous stimuli from outside the region through the influx of external knowledge inputs (Varis et al., 2014; Nilsen, 2016; Pelkonen & Nieminen, 2016; Calignano, 2022). This suggests that a combination of different knowledge bases is highly conducive to learning and innovation and can thus be the starting point for a knowledge-based development in lagging regions. At the same time, the knowledge base concept may also imply that in certain circumstances it may make sense for a lagging region to focus on a pathway that targets a specific type of knowledge (e.g., an analytical or synthetic route), drawing on endogenous regional knowledge resources and bringing in appropriately tailored knowledge inputs from outside (Tödtling et al. 2011; Isaksen & Trippl, 2017b). The knowledge base concept thus provides a theoretical basis for smart specialization policy approaches which start from the (potentially) existing strengths of less-developed regions and want to initiate a new path development from there by addressing the prevailing learning and knowledge conditions (Martin & Trippl, 2014; Asheim, 2019; Hassink & Gong, 2019; Pinheiro et al., 2022).

Figure 1. Two cousin concepts – knowledge bases and innovation modes
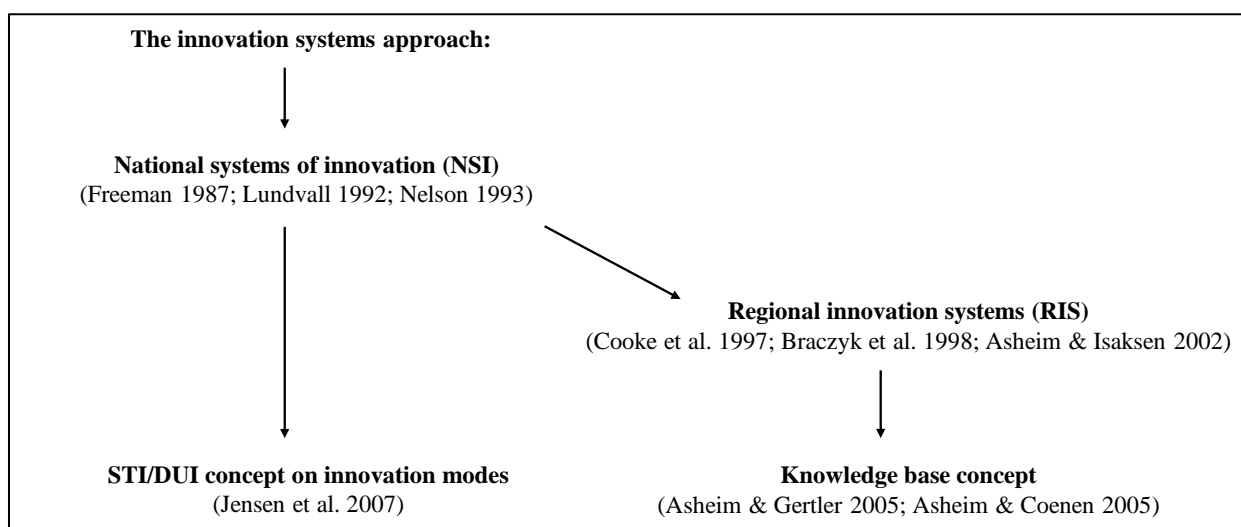
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It is important to bear in mind that the knowledge base concept refers to the aggregate level of sectors or industries to describe the general knowledge conditions for learning and innovation in a given region. In this way, it offers a differentiated view of the place-specific, context-dependent nature of regional innovation systems (Asheim & Coenen, 2005; Asheim & Gertler, 2005). However, due to this aggregated perspective, corresponding taxonomies of sectors or industries tend to be static, in a sense, focusing on either the starting point or the outcome of learning and innovation processes in a (lagging) region (Pelkonen & Nieminen, 2016; Calignano et al., 2022). This tends to neglect the fact that knowledge base settings and the corresponding adaptations provide a framework for innovation at the micro level of regions, as they have a direct impact on how the firms in these regions learn and innovate – which in turn influences the development of the surrounding knowledge base (Hervás-Oliver et al., 2021; Calignano, 2022).

What remains somewhat unclear in the knowledge base concept, therefore, are the dynamics of learning and innovation processes between the status quo – i.e., the input for innovation-driven, knowledge-based regional development – and the potential outcomes of such processes in a region, as the corresponding in-between learning activities take place mainly at the micro level of firms and institutions (Varis et al., 2014; Eder, 2019a; Tuitjer & Küpper, 2020;

Calignano et al., 2022). For this reason, Karlsen (2013) sees a potential deficit in the regional innovation system approach if its aggregated perspective on production and knowledge systems and their interaction leads to individual actors such as firms, knowledge institutions, networks or public policy organisations being understood as passive or static components and therefore, in the worst case, not being visible.

Hence, in other words, in the knowledge base concept the innovating firm tends to be a black box so that the dynamic path of lagging regions to a new or enhanced knowledge base is often not clear enough in such analyses: For example, the knowledge base concept can show how lagging regions are characterized by path dependencies and negative lock-in effects related to existing resource endowments (Gaddefors et al., 2020), but it cannot explain what local firms do to reduce this problem by intensifying knowledge exchange with external partners from other regions. To put another example, universities are often at the centre of policies to promote knowledge-based development in lagging regions because this promises to strengthen the analytical knowledge base that exists there. However, in order to achieve knowledge-based development in lagging regions, it is not enough to rely on universities alone, but the entire business ecosystem must also be involved (Conlé et al., 2023) – which means focusing on learning processes at the company level as well. From a theoretical point of view, therefore, there is a need to complement the knowledge base concept with an additional, more dynamic perspective on learning and innovation in lagging regions by integrating the company level in order to better understand whether and how the renewal or adaptation of knowledge bases can serve as a starting point for innovation-driven, knowledge-based development in lagging regions.

2.2 The STI/DUI concept and its regional contextualization

In contrast to the knowledge base concept, which originates from the literature on regional innovation systems, the literature on national systems of innovation – NSI – formed a direct basis for the formulation of Jensen et al.'s (2007) *STI/DUI concept* on different innovation modes at the firm level (see Figure 1). This approach takes into account the fact that firms can organize their learning and innovation processes in different ways – and that different types of knowledge may be relevant in each case. Jensen et al. (2007) distinguish two main modes: The STI (Science, Technology, Innovation) mode has a strong focus on formal processes of R&D and thus strongly resembles the traditional view of a linear innovation model. As a result, much of the innovation activity here takes place in internal R&D departments of firms, high-tech industries or in external interactions with universities and other research-oriented institutions. In this context, learning processes are largely based on the development and testing of formal, scientific models, usually carried out by scientifically trained personnel. In the STI mode, the main emphasis is on formalizing and codifying newly generated knowledge and using it for innovations that are relatively often radical in nature. Synthetic and symbolic knowledge is certainly also associated with the STI mode, but STI-based innovation activities usually require a high degree of analytical knowledge that is highly explicit in nature. Analytical, science-based knowledge can therefore be expected to be a typical input or output of STI mode learning and innovation processes (Jensen et al., 2007; Isaksen & Karlsen, 2010; Isaksen & Nilsson, 2013; Thomä, 2017).

The DUI (Doing, Using, Interacting) mode of innovation does not involve formal processes of R&D. Instead, it refers to learning and innovation processes in firms that can be expected to be strongly linked to synthetic knowledge. DUI-based innovations tend to be incremental in nature, and rely heavily on the experience-based (implicit) know-how of skilled workers, which they acquire via vocational education and training (VET) or on the job as they face new problems and solve them through trial and error. The DUI mode involves a high degree of interactive learning both within firms and between them and external partners such as customers, users, suppliers or competitors. Effective learning in the DUI mode also requires that the working environment within the firm is designed to incorporate the competences of many different types of employees, for example by promoting team working practices, internal collaboration or a general culture of open communication (Jensen et al., 2007; Isaksen & Karlsen, 2012; Matthies et al., 2023). The more informal innovation activities that characterize the majority of SMEs are a typical example of the DUI mode (Thomä & Zimmermann, 2020; Alhusen et al., 2021).

In the practice of firm-level innovation, it is unlikely that only one of these two ideal modes is present in pure form. Rather, a dynamic continuum between different STI- and DUI-based learning processes and corresponding knowledge types is to be assumed, which innovating firms combine in certain ways depending on their stage of development and their business context (Alhusen & Bennat, 2021). An empirical application of the STI/DUI concept should therefore be able to provide the required dynamic perspective on knowledge-based developments in lagging regions (see section 2.1), as it captures the underlying learning and innovation processes at the firm level, their contextual embeddedness and their dynamic interplay with intra- and extra-regional sources of innovation – and can thus better explain the transition to new or refined knowledge bases in sectors or industries of a regional innovation system (see Figure 2).

The fact that the STI/DUI concept has its roots outside the literature on regional innovation systems (Figure 1) means that its use does not per se need to include a geographical dimension, as the vast majority of studies published so far in the literature on STI and DUI confirm (for an overview see e.g. Apanasovich, 2016; Parrilli et al., 2016; Santos et al. 2022) – with the logical result that the understanding of the spatial patterns underlying innovation modes

is still underdeveloped (a rare exception is the study by Doloreux & Shearmur 2023). However, the fact that the inclusion of a geographical dimension in the STI/DUI concept is anything but artificial can already be seen in the seminal paper by Jensen et al. (2007), when the authors refer to the distinction between 'local versus global knowledge' as a criterion for differentiating between the STI mode with its focus on formal R&D processes from the DUI mode with its orientation towards practice-driven and application-oriented learning processes. According to Jensen et al. (2007), learning and innovation in the DUI mode is typically characterized by implicit knowledge and strongly localized face-to-face learning. In contrast, the ultimate goal of innovation in the STI mode is expected to be the documentation and spatially unlimited transferability of new scientific and technical knowledge, i.e., the creation and dissemination of 'global knowledge' by codifying explicit knowledge (e.g., through patenting). An underlying idea here is that the territorial stickiness of the DUI mode is closely related to the benefits of spatial proximity in innovation, making DUI particularly relevant to the functioning of innovation systems at the regional level (Fitjar & Rodríguez-Pose, 2013; Parrilli et al., 2020). Empirical studies on innovation modes have so far tended to neglect this aspect of Jensen et al.'s (2007) paper, focusing instead more or less on the difference between explicit and implicit knowledge (Apanasovich, 2016; Parrilli et al., 2016; Santos et al., 2022).

There is reason to believe that the geographical dimension of innovation modes is particularly important in explaining innovation in lagging regions. This is because these territories are mostly dominated by SMEs, which often lack their own R&D departments and the absorptive capacity to benefit from STI-oriented innovation policies (Brenner & Niebuhr, 2021; Hervás-Oliver et al., 2021). The innovation activities of such less R&D-intensive SMEs are correspondingly strongly anchored in the DUI mode (Thomä, 2017; Thomä & Zimmermann, 2020; Alhusen et al., 2021; Runst & Thomä, 2022), which is likely to shape the overarching knowledge-based dynamics in the respective regional innovation systems (Alhusen & Bennat, 2021). Indeed, as noted in Section 2.1, the dominant knowledge base in many lagging regions is rather synthetic in nature – i.e., a type of knowledge that is a typical input or outcome of DUI-based learning and innovation processes, as mentioned above. Particularly in lagging regions, the innovation activities of firms are therefore likely to be strongly influenced by the DUI mode as regionally endogenous knowledge and learning potential (Hervás-Oliver at al., 2021).

Figure 2. A conceptual framework on innovation-driven, knowledge-based developments in (lagging) regions
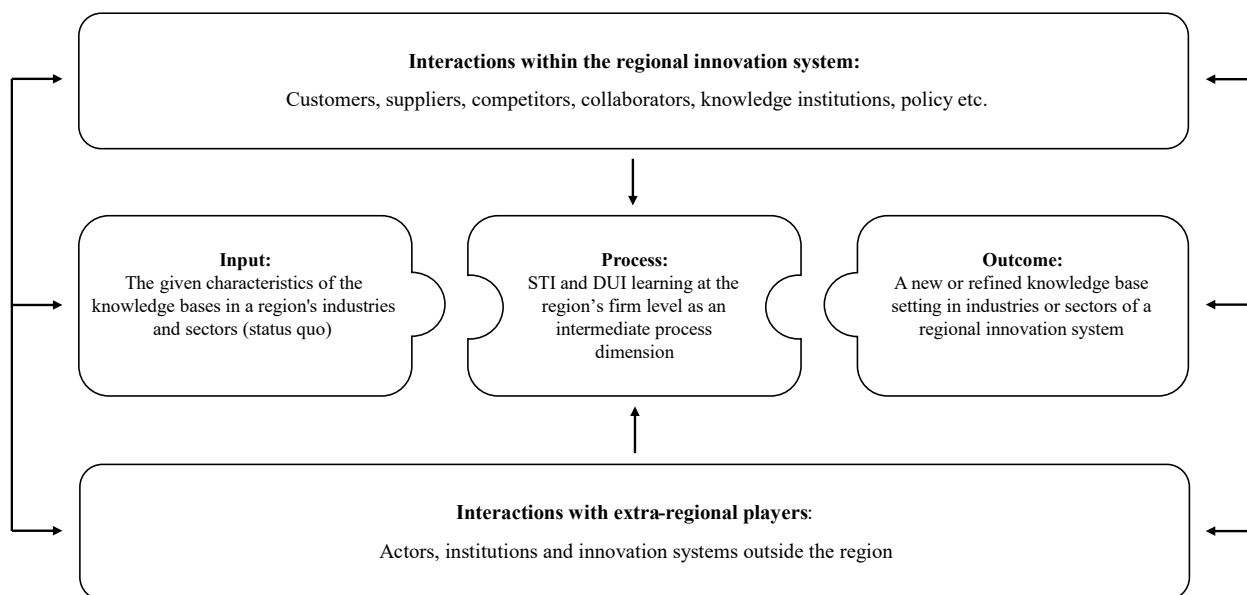
Source: own figure

At the same time, interactive learning beyond one's own region to improve absorptive capacity at the company level is likely to be particularly important for this type of region and the firms located there, also with regard to the DUI mode. After all, typical forms of STI-oriented technology transfer to improve a region's knowledge base is just one way in which firms from lagging regions may compensate for their lack of R&D-based absorptive capacities (Eder, 2019a; Filippopoulos & Fotopoulos, 2022). The studies of Fitjar & Rodríguez-Pose (2013) and Parrilli & Alcalde Heras (2016) have shown that external DUI interactions are particularly conducive to innovation at the firm level when they come from outside the region and thus strengthen the synthetic knowledge base of a regional innovation system.

Taken together, the results of Sections 2.1 and 2.2 thus suggest that the dynamics of knowledge-based developments in lagging regions are determined not least by firm-level innovation modes as outlined in Jensen et al.'s (2007) STI/DUI concept. Figure 2 shows the components of a regional innovation system, with the knowledge bases of industries and sectors as an essential component. As mentioned above, the knowledge base approach has its strengths in analysing the learning environment of lagging regions, thus reflecting the input and output dimensions of innovation-driven, knowledge-based developments. What it is less able to do is to analyse the dynamic interplay of learning and innovation processes in between. For this, one has to look at the micro level of firms and institutions (Karlsen 2013). An innovation mode perspective on lagging regions should therefore have the potential to provide a better understanding of learning and innovation in lagging regions, both from an academic and policy perspective, as it brings firm-level perspectives into the analysis when it comes to finding or stimulating pathways to new or enhanced knowledge bases in respective innovation systems. If this is indeed the case, it can be a piece of the "innovation puzzle of lagging regions" that complements the well-established knowledge base concept (see Figure 2).
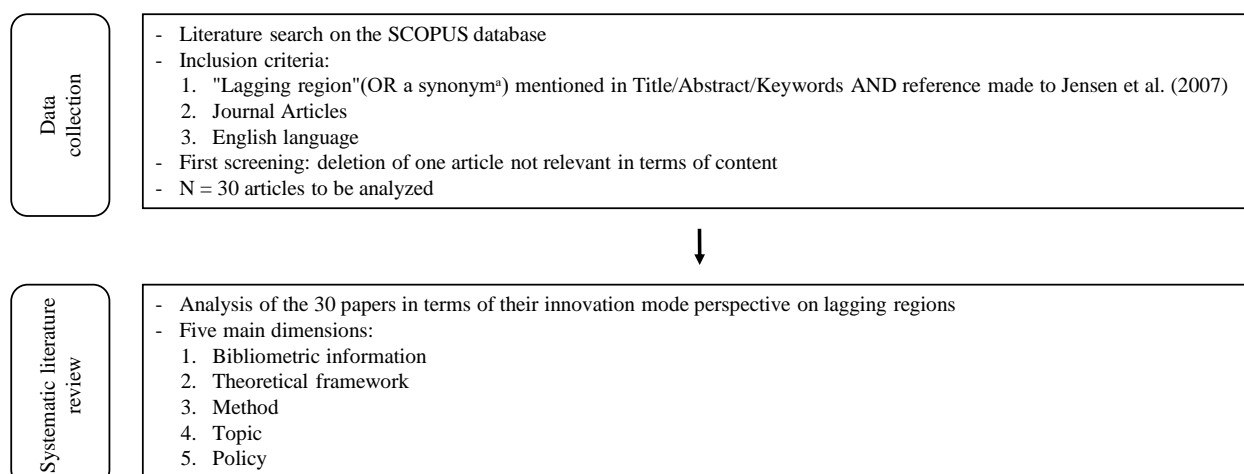
3. Method

Systematic literature reviews are a research method that has become increasingly popular in innovation research in recent years (see, e.g., Biggi & Giuliani, 2021; Calabrò et al., 2019; Eder, 2019a; Hurmelinna-Laukkanen & Yang, 2022). In this paper, in order to provide a synthesis of the relevant research, we carry out a systematic review of the literature on studies relating to lagging regions that deal with the STI/DUI concept. As a first step in this regard, we conduct a search query using Scopus (Figure 3).[1] Compared to other bibliographic databases (such as Web of Science), this database has the advantage that we can include the cited references in the search algorithm: In other words, we filter out all published journal articles from Scopus that use the term 'lagging region' (or related synonyms, all of which refer to a lower functional development of a region in terms of economic or institutional factors and thus cover typical characteristics of lagging regions, see Figure 3)[2] in their title, keywords or abstracts and at the same time list the seminal paper by Jensen et al. (2007) on the STI/DUI concept in their references. This provides a useful basis for a concept-centred synthesis – one of the typical aims of a systematic literature review (Kraus et al., 2020). The search query returned a set of 31 papers, of which one was deleted after an initial screening for lack of thematic relevance. This results in a final sample of 30 articles that are used in the further analysis. The rather limited number of publications identified confirms that this is a relatively young, emerging literature – probably not least due to the fact that the regional contextualization of the STI/DUI concept is still in its infancy (see above).

In the second step (Figure 3), a systematic literature review is conducted to analyse the 30 articles from an innovation mode perspective. This is guided by the research question presented above: What is the (potential) contribution of an innovation mode perspective to understanding learning and innovation in lagging regions? As a starting point, bibliometric information is employed to obtain an overview of the sampled papers. This is done using data such as titles, author names, abstracts and keywords. On this basis, for example, it is possible to determine in which journals the articles have been published and which authors have published the most. In a next step, the 30 articles are analysed according to the four content dimensions 'Theoretical framework', 'Method', 'Topic' and 'Policy'. Therefore, we first examine the extent to which the STI/DUI concept of Jensen et al. (2007) actually forms an integral part of the theoretical frameworks of the papers under review (*theoretical framework*). The methodical approaches of the papers are then of interest, e.g. whether and to what extent the innovation mode approach is actually made empirically tangible (*method*). In addition, we are interested in the different topics and related research questions that are dealt with in the papers under review (*topic*). Finally, we want to find out what implications the results of the analysed papers have for the design of innovation policies towards lagging regions, which – as called for by Hervás-Oliver et al. (2021) – are not only oriented towards the R&D investment target, but also take into account the breadth and diversity of innovation modes at the company level (*policy*).

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[1] The date of the last search query was 28 August 2023.

[2] Table A1 in the appendix shows the distribution of regional operators used to identify the studies.

Figure 3. Methodical approach

Data collection	- Literature search on the SCOPUS database
	- Inclusion criteria:
	  1. "Lagging region"(OR a synonym[a]) mentioned in Title/Abstract/Keywords AND reference made to Jensen et al. (2007)
	  2. Journal Articles
	  3. English language
	- First screening: deletion of one article not relevant in terms of content
	- N = 30 articles to be analyzed

$\downarrow$

Systematic literature review	- Analysis of the 30 papers in terms of their innovation mode perspective on lagging regions
	- Five main dimensions:
	  1. Bibliometric information
	  2. Theoretical framework
	  3. Method
	  4. Topic
	  5. Policy

[a] Apart from the term "lagging region", synonyms such as "weak region", "laggard region", "catch-up region", "thin region", "less developed region","less innovative region", "region with less developed", "under-developed region", "peripheral region", "rural region", "less-favoured region" or "low-technology region" were used. For a detailed overview, see Table A1 in the Appendix.

4. Results

4.1 Bibliometric information

Basic information on our literature sample can be found in Table A2 in the Appendix. It shows that the identified papers were all published between 2011 and 2023, most of them relatively recent (the average age of the papers is 5.1 years). In total, 58 authors and 24 journals are represented. In addition, there is information on 132 author's and 112 indexed keywords. Table 1 provides an overview of the 30 papers. Not surprisingly, journals with a regional focus predominate. However, there are also journals with a focus on innovation and policy. The sample varies considerably in terms of the impact of the journals in which the sampled papers were published and, consequently, the frequency with which these papers are cited. Key articles have been published in the Journal of Economic Geography, Regional Studies and in Research Policy. The most globally cited papers are from Isaksen (2015), Eder (2019a), Trippl et al. (2020), Isaksen & Trippl (2017a), Hervás-Oliver et al. (2021) and Karlsen et al. (2011). Some journals in the list appear two or three times (e.g., European Planning Studies or Entrepreneurship and Regional Development), which may indicate an emerging debate within these journals. The authors with the most publications in the sample are Arne Isaksen and James Karlsen. Overall, however, the wide dispersion across journals and authors is striking. This could be another indication that the topic of 'innovation modes in lagging regions' is not yet an established field of research, but one that is still emerging.

Further analysis of the available bibliometric information suggests that the sample is a good match in terms of content. Table 2 shows the most frequently used words in the 30 articles, either in the keywords chosen by the authors to best describe the subject of their work, in the indexed keywords compiled by Scopus using the vocabulary from the thesauri of the datasets from which the references were taken, or in the text of the titles and the abstracts. Terms such as innovation, learning or knowledge appear frequently, indicating a content fit. Furthermore, the results in Table 2 also suggest that a number of papers do indeed have a firm-level perspective – the word 'firms' appears comparatively frequently in both titles and abstracts. In addition, terms such as 'constructing regional advantage', 'regional development' and 'smart specialisation' also suggest that at least some of the papers in the sample are indeed concerned with innovation-driven, knowledge-based developments in lagging regions. It should be noted that we did not perform any such content-related tailoring as part of the search algorithm used; instead, the literature search in Scopus was limited exclusively to whether there was a link to lagging regions and whether Jensen et al. (2007) was cited at the same time (see Section 3). Logically, therefore, the paper by Jensen et al. (2007) is the most cited one in the sample. However, a number of other papers frequently cited by the articles in the sample also relate to learning and knowledge dynamics, particularly in relation to regional innovation (see Table A3 in the Appendix). For example, Asheim & Gertler (2005) and Asheim & Coenen (2005) are frequently cited, showing that several of the sampled papers also seem to refer to the knowledge base approach as a related concept to the STI/DUI concept (see above).

Table 1. Overview of identified papers (N=30, descending by global citations)

Article	Authors	Journal	Global citations[a]
Isaksen (2015)	Isaksen, A.	Journal of Economic Geography	370
Eder (2019a)	Eder, J.	International Regional Science Review	219
Trippl et al. (2020)	Trippl, M.; Zukauskaite, E.; Healy, A.	Regional Studies	157
Hervás-Oliver et al. (2021)	Hervás-Oliver, J.-L.; Parrilli, M. D.; Rodríguez-Pose, A.; Sempere-Ripoll, F.	Research Policy	127
Isaksen/Trippl (2017a)	Isaksen, A.; Trippl, M.	Oxford Review of Economic Policy	125
Karlsen et al. (2011)	Karlsen, J.; Isaksen, A.; Spilling, O- R.	Entrepreneurship and Regional Development	106
Coenen/Morgan (2020)	Coenen, L.; Morgan, K.	Norwegian Journal of Geography	101
Fernández-Esquinas et al. (2016)	Fernández-Esquinas, M.; Pinto, H.; Yruela, M. P.; Pereira, T. S.	Technological Forecasting and Social Change	101
Isaksen/Karlsen (2013)	Isaksen, A.; Karlsen, J.	European Urban and Regional Studies	99
Bonaccorsi (2017)	Bonaccorsi, A.	Journal of Economic Policy Reform	89
Nordberg (2015)	Nordberg, K.	Journal of the Knowledge Economy	72
Eder (2019b)	Eder, J.	European Planning Studies	42
Blažek/Kadlec (2019)	Blažek, J.; Kadlec, V.	Innovation: The European Journal of Social Science Research	40
Flåten et al. (2015)	Flåten, B.-T.; Isaksen, A.; Karlsen, J.	Norwegian Journal of Geography	38
Vlados/Chatzinikolaou (2019)	Vlados, C.; Chatzinikolaou, D.	Journal of Entrepreneurship, Management and Innovation	35
Rypestøl/Aarstad (2018)	Rypestøl, J. O.; Aarstad, J.	Entrepreneurship and Regional Development	34
Karlsen (2013)	Karlsen, J.	Systemic Practice and Action Research	30
Čábelková et al. (2017)	Čábelková, I.; Normann, R.; Pinheiro, R.	Higher Education Policy	19
Glückler et al. (2020)	Glückler, J.; Punstein, A. M.; Wuttke, C.; Kirchner, P.	European Planning Studies	18
Wassmann et al. (2016)	Wassmann, P.; Schiller, D.; Thomsen, S. L.	European Planning Studies	16
Arendt & Grabowski, (2019)	Arendt, L.; Grabowski, W.	Journal of Entrepreneurship, Management and Innovation	16
Suitner et al. (2023)	Suitner, J.; Haider, W.; Philipp, S.	Regional Studies	11
Pasciaroni et al. (2018)	Pasciaroni, C.; Gorenstein, S.; Barbero, A.	International Journal of Technological Learning, Innovation and Development	10
Amir et al. (2013)	Amir, A. F.; Thiruchelvam, K.; Ng, B.-K.	International Development Planning Review	9
Nilsson (2017)	Nilsson, P.	Review of Regional Studies	5
Srholec et al. (2021)	Srholec, M.; Žížalová, P.; Horák, P.	Economics of Innovation and New Technology	3
Gyurkovics/Vas (2018)	Gyurkovics, J.; Vas, Z.	International Journal of Innovation and Learning	3
Doloreux et al. (2023)	Doloreux, D.; Shearmur, R.; Kristensen, I.	Journal of Rural Studies	2
Pinto (2023)	Pinto, H.	Regional Science Policy and Practice	1
Friedrich/Feser (2023)	Friedrich, C.; Feser, D.	Review of Regional Research	-

[a] According to Google Scholar on 05 December 2023.

This picture is completed by a co-occurrence network analysis based on the indexed keywords of the 30 articles (see Figure 4): A number of interrelated aspects are grouped around the theme of innovation as a focal point, ranging from theoretical considerations, geographical issues and demarcations, to thematic matters related to learning and knowledge, as well as questions of policy in this context. This again suggests that, despite the broad distribution of the sample articles across different journals, we can speak of a distinct, emerging field of innovation research. Finally, it is interesting to note that only two of the sampled papers refer to innovation modes in the authors' keywords (Isaksen & Karlsen 2013: 'modes of innovation'; Isaksen & Trippl 2017a: 'STI innovation mode', 'DUI innovation mode'). This is a first indication that the innovation mode perspective is not strong, or at least not made explicit, in several of the papers in the sample.

Table 2. Top 10 most frequently used words in descending order (occurrences in parentheses)

Author's keywords	Indexed keywords	Titles	Abstracts
Innovation (8)	Innovation (16)	Regions (17)	Innovation (87)
Peripheral regions (7)	Norway (5)	Innovation (16)	Knowledge (61)
Regional development (4)	Peripheral region (5)	Regional (12)	Regional (57)
Smart specialization (4)	Regional development (5)	Peripheral (8)	Regions (55)
Knowledge bases (3)	Learning (4)	Knowledge (7)	Firms (46)
Related variety (3)	Research and development (4)	Role (5)	Research (29)
Constructing regional advantage (2)	Conceptual framework (3)	Firms (4)	Paper (21)
Innovation activity (2)	Europe (3)	Rural (4)	Article (20)
Knowledge transfer (2)	Knowledge based system (3)	Systems (4)	Development (20)
Less-developed regions (2)	Regional policy (3)	Thin (4)	Region (20)

Source: Bibliometrix

Figure 4. Co-occurrence network in the sample, by indexed keywords
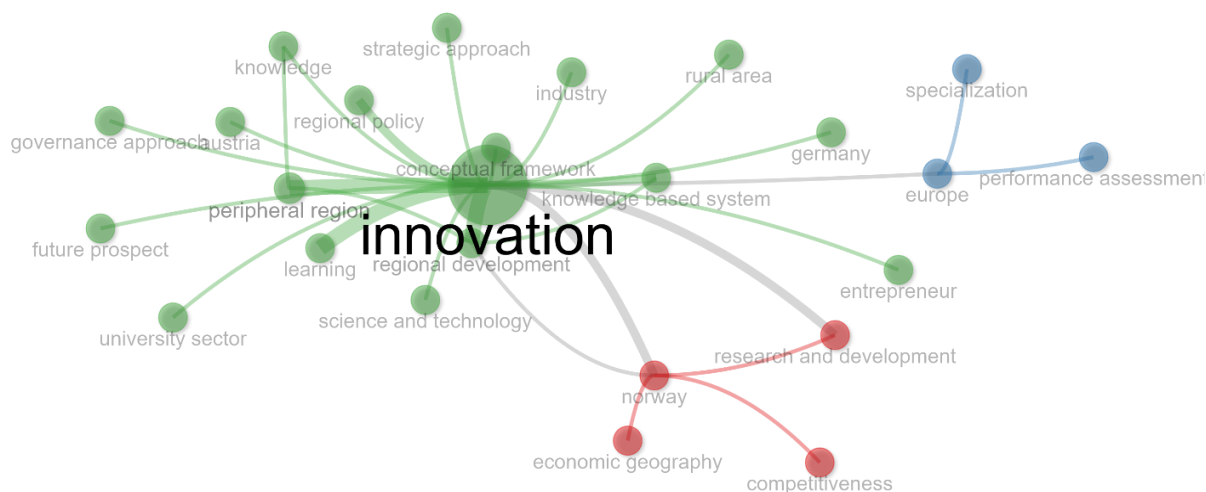
Source: Bibliometrix

4.2 Theoretical framework

A closer look at the papers reveals that only in a few papers is the STI/DUI concept really used as such, as an independent approach to explaining innovation in lagging regions (Table 3).[3] Here, the STI/DUI concept is treated as a stand-alone conceptual approach to adopting an innovation mode perspective on lagging regions. In some of these studies, the question of which mode of learning and innovation is dominant in a region is seen as crucial for the way innovation systems function at the regional level (Karlsen et al., 2011; Isaksen & Karlsen, 2013; Isaksen, 2015; Isaksen & Trippl, 2017a). For example, according to Isaksen (2015), the dominance of DUI-oriented SMEs in organizationally thin regions and the general deficits of corresponding regional innovation systems often lead to difficulties for these regions in terms of negative lock-in effects and problems in creating new development paths. With regard to these papers, however, it should be noted that although there is a clear link to the STI/DUI concept, the enterprise, industry and regional levels tend to merge, so that a clear distinction between the characteristics of the knowledge base setting at the regional level and the learning and innovation modes at the micro level of firms is not always possible. In contrast, Nordberg (2015) provides an example of such a conceptual separation of knowledge bases and innovation modes. He examines the opportunities for peripheral, non-university regions to engage in innovation, for example by focusing on the interaction between DUI-oriented firms and supra-regional STI actors.

Similarly, but looking at different types of regions, Hervás-Oliver et al. (2021) use the STI/DUI concept to explain

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[3] Of these, only four studies use the innovation mode approach as their main concepts (Hervás-Oliver et al., 2021; Isaksen & Trippl, 2017a; Wassmann et al., 2016; Doloreux et al., 2023).

the variety of internal and external sources used by SMEs as impulses for innovation depending on the regional context. One of their findings is that SMEs in lagging regions are dependent on external sources of innovation and, in particular, on DUI-based interaction with other firms. In contrast, Doloreux et al. (2023) use the STI/DUI concept to examine the interaction between rural firms and knowledge-intensive business services (KIBS), with the results suggesting that KIBS are an important intermediary for rural innovation systems in terms of innovation-related knowledge sourcing. Finally, while not applying the STI/DUI concept himself, Eder (2019a) argues for a more theory-driven analysis of innovation in peripheral regions in future research, using the STI/DUI concept as an independent approach alongside the knowledge base concept to better identify the strengths and weaknesses of different types of regions in relation to innovation.

Table 3. Conceptual orientation of the papers analysed

Article	STI/DUI as a stand-alone concept for analysing innovation in lagging regions?	Link to the knowledge base concept?
Amir et al. (2013)		x
Arendt & Grabowski, (2019)		x
Blažek & Kadlec (2019)		x
Bonaccorsi (2017)		x
Čábelková et al. (2017)		
Coenen & Morgan (2020)		x
Doloreux et al. (2023)	x	x
Eder (2019a)	x	x
Eder (2019b)		x
Fernández-Esquinas et al. (2016)		x
Flåten et al. (2015)		
Friedrich & Feser (2023)		x
Glückler et al. (2020)		
Gyurkovics & Vas (2018)		x
Hervás-Oliver et al. (2021)	x	x
Isaksen (2015)	x	
Isaksen & Karlsen (2013)	x	
Isaksen & Trippl (2017a)	x	x
Karlsen (2013)		x
Karlsen et al. (2011)	x	x
Nilsson (2017)		x
Nordberg (2015)	x	x
Pasciaroni et al. (2018)		x
Pinto (2023)		
Rypestøl & Aarstad (2018)		x
Srholec et al. (2021)		x
Suitner et al. (2023)		
Trippl et al. (2020)		x
Vlados & Chatzinikolaou (2019)		
Wassmann et al. (2016)	x	x

At first sight, it may seem surprising that the vast majority of papers in our sample also refer to the knowledge base concept (Table 3). This is worth mentioning because, apart from the reference to lagging regions, the only necessary condition for inclusion in the literature sample was that the paper of Jensen et al. (2007) on firm-level innovation modes was cited (see Section 3). On the other hand, this is in line with our theoretical framework outlined in Section 2, where the STI/DUI concept is described as an important component for a better understanding of innovation-driven, knowledge-based developments in lagging regions. Nevertheless, the use of the innovation mode approach in many of these papers that refer to the knowledge base approach remains rather unclear, as the reference to Jensen et al. (2007) is often only used to characterise certain knowledge types or to illustrate specific features of innovation in lagging regions, with the knowledge base concept and the STI/DUI concept often used synonymously (e.g. Fernández-Esquinas et al. 2016; Bonaccorsi, 2017; Čábelková et al., 2017; Blažek/Kadlec, 2019; Glückler et al., 2020; Suitner et al., 2023).

4.3 Method

Our sample of papers is characterized by a wide range of methodical approaches (Table 4). Most of the papers are case studies (12), most of which are purely qualitative data analyses or based on a mixed methods approach. Seven

studies use regression analysis and a further four use basic quantitative methods such as descriptive statistic or statistic correlations. In addition, four studies are purely conceptual in nature. Similar to our study, Eder (2019a) conducts a systematic literature review on innovation in the periphery. Our contribution complements this in that we follow one of his proposed avenues for future research of a more theory-based analysis of regional innovation heterogeneity, focusing in particular on the role of different innovation modes and their respective relevance in knowledge-based development of lagging regions.

Table 4. Methodical approach of the analysed papers

Method used	Papers
Case study (n=12)	Amir et al. (2013); Čábelková et al. (2017); Flåten et al. (2015); Friedrich & Feser (2023); Glückler et al. (2020); Isaksen (2015); Isaksen & Karlsen (2013); Karlsen et al. (2011); Nordberg (2015); Pasciaroni et al. (2018); Suitner et al. (2022); Vlados & Chatzinikolaou (2019)
Qualitative (n=6)	Amir et al. (2013); Čábelková et al. (2017); Flåten et al. (2015); Friedrich & Feser (2023); Isaksen (2015); Nordberg (2015)
Mixed-methods (n=7)	Glückler et al. (2020); Isaksen & Karlsen (2013); Karlsen et al. (2011); Karlsen (2013); Pasciaroni et al. (2018); Suitner et al. (2022); Trippl et al. (2020); Pinto (2023)
Basic quantitative methods (n=4)	Blažek & Kadlec (2019); Eder (2019b); Gyurkovics & Vas (2018); Srholec et al. (2021); Vlados & Chatzinikolaou (2019)
Regression analysis (n=7)	Arendt & Grabowski (2019); Doloreux et al. (2023); Fernández-Esquinas et al. (2016); Hervás-Oliver et al. (2021); Nilsson (2017); Rypestøl & Aarstad (2018); Wassmann et al. (2016)
Systematic literature review (n=1)	Eder (2019a)
Conceptual (n=4)	Bonaccorsi (2017); Coenen & Morgan (2020); Eder (2019a); Isaksen & Trippl (2017a)

The studies analyzed either compare lagging regions with non-lagging regions (e.g., on the basis of a RIS ranking, see Trippl et al., 2020 or Hervás-Oliver et al., 2021), while others, especially case studies, often focus only on the former (e.g., Amir et al., 2013 or Karlsen, 2013). With regard to the underlying understanding of lagging regions on which the 30 papers are based, it is important that a functional definition in terms of economic or institutional factors is also present in those studies that were only included in the sample via a purely geographical oriented search operator (i.e., 'peripheral region' or 'rural region', see Section 3). This confirms that the focus of all the different studies in our sample is indeed on lagging regions; allowing also the papers on seemingly just peripheral or rural regions to analyse the corresponding specificities of innovation. For example, studies with the operator 'peripheral region' (see Table A1) consistently refer to typical characteristic of peripheral regions such as the organizational thinness of the regional innovation system, weak industrial agglomeration due to the absence of large companies, a dominance of less R&D-oriented SMEs characterized by limited absorptive capacity, weak human capital resources in the region or low market connectivity (see Bonaccorsi, 2017; Čábelková et al., 2017, Eder, 2019a; Fernández-Esquinas et al., 2016; Friedrich & Feser, 2023; Gyurkovics & Vas, 2018; Isaksen & Trippl, 2017a; Karlsen et al., 2011; Nordberg, 2015; Pinto, 2023). Similarly, studies that were only included in the sample via the term 'rural region' (Table A1) list potential disadvantages of rural regions in terms of agglomeration economies, endogenous development potentials, availability of qualified workers or organizational support structures (see Doloreux et al., 2023; Glückler et al., 2020; Srholec et al., 2021).

The fact that the STI/DUI concept is only actually used as a stand-alone theoretical approach in roughly a third proportion of the sampled papers (see Section 4.1) goes hand in hand with the fact that innovation modes are often not really made empirically tangible by many studies in the sample – i.e., in such papers there is a purely theoretical link to the STI/DUI concept or, if there is an empirical measurement approach, it is only implicit in nature. There are only two papers that explicitly aim to measure DUI and STI innovation modes empirically. Hervás-Oliver et al. (2021) use aggregated data at the regional level to measure STI (indicators: public and private R&D expenditure, collaboration with SMEs, public-private co-publications) and DUI (indicators: non-R&D innovation, collaboration with SMEs). In contrast, Doloreux et al. (2023) rely on indicators for external STI interactions (e.g., collaboration with universities), internal STI (e.g., internal R&D activities or knowledge of R&D employees) and DUI (e.g., links with suppliers and customers or knowledge of the production staff). However, the measurement approaches of these two studies can only be understood as rough indications, especially with regard to the DUI mode, which is difficult to capture (on this issue, see Alhusen et al. 2021). In several other cases, empirical measures of innovation activity are used that are actually related to STI and DUI but are not labelled as such. Thus, these are papers that implicitly address both DUI and STI in terms of empirical measurement – and again, it is primarily the possibility of measuring the DUI mode that is challenging – (e.g., Flåten et al., 2015; Glückler et al., 2020; Gyurkovics & Vas, 2018; Isaksen, 2015;

Srholec et al., 2021; Wassmann et al., 2016), while others implicitly deal only with STI (e.g., Arendt & Grabowski, 2019; Fernández-Esquinas, et al. 2016; Rypestøl & Aarstad, 2018).

Finally, it is interesting that some of the analysed studies also try to empirically capture the specific character of lagging regions by using innovation indicators through the use of data on RIS rankings (Blažek & Kadlec, 2019; Hervás-Oliver et al., 2021; Trippl et al., 2020). The motivation behind this is probably that the inclusion of innovation indicators in the classification of regions is potentially very useful for measuring functional characteristics of lagging regions in terms of innovation, e.g. with regard to the distinction between thin vs. thick regional innovation systems (Isaksen & Trippl, 2017a; Karlsen, 2013; Rypestøl & Aarstad, 2018), and thus provide policy makers with a better information base for designing innovation policies in lagging regions (see e.g. Arendt & Grabowski, 2019; Hertrich & Brenner, 2023; Koschatzky & Kroll, 2019). In this context, however, it is particularly striking that the RIS indicators used in the above-mentioned papers are able to cover the STI mode quite well (e.g., by providing aggregated R&D expenditure in a region), but so far there are still clear weaknesses in the consideration of DUI innovation activities, which can probably be explained by the corresponding measurement difficulties mentioned above.

4.4 Topic

In order to identify the overarching themes explored in the sample, the 30 articles are grouped according to their content orientation (Table 5). The papers in the first thematic group, *'Regional innovation pattern variability'*, are concerned with differences in innovation between different types of regions, for example, comparing lagging and non-lagging regions. Knowledge bases and modes of innovation are seen here as important drivers of such spatial patterns of learning and innovation. For example, Isaksen & Trippl (2017a) distinguish between three cases of DUI depending on the type of regional innovation system: Thick and diversified RISs – DUI in cultural industries in core region; Thick and specialised RISs – DUI in traditional manufacturing industries in old industrial regions; and Thin RIS – DUI in resource-based industries in peripheral regions. As another example, Hervás-Oliver et al. (2021) show that the main drivers of SME innovation vary significantly between different types of regions, with one result implying that "SMEs in less innovative regions are fundamentally dependent on external sources, and in particular on collaboration with other firms" (p. 1).

The second theme, *'Path development'*, refers to studies that examine the difficulties and challenges faced by lagging regions in revitalizing established pathways, creating new paths or building a regional advantage (Table 5). The reasons for such obstacles are described as linked to typical characteristics of lagging regions, such as limited R&D-based absorptive capacities, low knowledge flows and the dominance of the DUI mode, which means that in addition to improving intra-regional knowledge exchange to stimulate DUI-mode firms, innovation impulses from outside the region (often in the form of STI-based knowledge inputs) are considered necessary to actually initiate knowledge-based development in lagging regions (e.g. Isaksen, 2015; Isaksen & Karlsen, 2013; Karlsen et al., 2011).

Another part of the studies reviewed takes a more positive view of lagging regions by addressing the question of whether lagging regions have endogenous development potential that could be unleashed through smart specialization (*'Possibilities for smart specialization'*, Table 5). Here, the view of DUI is less critical than in the aforementioned literature, because a basic idea of corresponding policy approaches is that smart regional growth can also work in lagging regions if place-based policies are implemented that acknowledge that regions with different knowledge bases also innovate differently at the firm level. As such, according to Nordberg (2015), a focus on the DUI mode, for example, can help to refine and maintain region-specific specializations and orientations, thus creating new market niches. He therefore sees the innovation-promoting combination of DUI and STI as an opportunity to achieve the necessary adaptation of analytical knowledge bases in lagging regions. Such a combination of DUI and STI, which is evident in the interaction of different regional actors, is often a major challenge when different innovation cultures collide. Trippl et al. (2020) point out that smart specialization can therefore have a positive impact on RIS development even in regions lagging behind, but that a mutual understanding of the benefits of collaboration, a reduction in mutual mistrust and a strengthening of policy-making capacities in these regions must first take place.

A fourth theme deals specifically with the contribution of universities – as a typical representative of the STI mode – to the knowledge-based development of lagging regions (*'Role of universities'*; Table 5). On the one hand, universities are seen as enablers to unleash possible endogenous innovation potentials that have not yet developed due to a lack of university-industry links within the region (e.g., interactions with DUI firms). On the other hand, universities are also seen as knowledge brokers or gatekeepers to the external level in order to bring important innovation impulses from outside into the region. Universities are therefore sometimes expected to upgrade lagging regions and their firms and industries in terms of analytical knowledge and new technologies (Čábelková et al., 2017; Pasciaroni et al., 2018; Pinto, 2023). However, there is also a critical discussion about what contributions can realistically be expected. For example, with regard to the knowledge base and the dominant innovation modes in lagging regions (often highly synthetic knowledge bases, innovation at the firm level often based on the DUI mode), it is discussed whether the presumed role of universities for innovation in lagging regions might be overestimated because the gap with the less R&D-oriented

SMEs in these regions is simply too large. Accordingly, it can be argued that, in addition to universities, non-university educational institutions such as technical colleges and vocational training centres should be given greater consideration in this context to move "beyond the one-size (of university)-fits-all approach" (Bonaccorsi, 2017, p. 11).

Table 5. Overarching themes explored in the articles

Overarching theme	Papers
Regional innovation pattern variability	Blažek & Kadlec (2019), Eder (2019a), Eder (2019b); Hervás-Oliver et al. (2021); Isaksen & Trippl (2017a); Trippl et al. (2020)
Path development	Isaksen (2015); Isaksen & Karlsen (2013); Isaksen & Trippl (2017a); Karlsen et al. (2011)
Possibilities for smart specialization	Coenen & Morgan (2020); Friedrich & Feser (2023); Nilsson (2017); Nordberg (2015); Pinto (2023); Suitner et al. (2023); Trippl et al. (2020)
Role of universities	Bonaccorsi (2017); Čábelková et al. (2017); Fernández-Esquinas et al. (2016); Pasciaroni et al. (2018); Pinto (2023)
Firm-level perspectives	Arendt & Grabowski, (2019); Doloreux et al. (2023); Fernández-Esquinas et al. (2016); Flåten et al. (2015); Glückler et al. (2020); Gyurkovics & Vas (2018); Hervás-Oliver et al. (2021); Karlsen (2013); Nilsson (2017); Rypestøl & Aarstad (2018); Srholec et al. (2021); Vlados & Chatzinikolaou (2019); Wassmann et al. (2016)

Finally, the sample includes a number of studies on innovation at the level of the firm ('*Firm-level perspectives'*; Table 5), which is not surprising as the STI/DUI concept describes different ways in which firms learn and innovate (see Section 2). These studies can be broadly categorized into those that, with regard to the case of lagging regions, either identify different drivers of SME innovation (Arendt & Grabowski, 2019; Hervás-Oliver et al., 2021; Vlados & Chatzinikolaou, 2019), focus on the knowledge sourcing and collaboration activities of firms in regional innovation systems (Doloreux et al., 2023; Fernández-Esquinas et al., 2016; Glückler et al., 2020; Gyurkovics & Vas, 2018; Wassmann et al., 2016), examine the impact on firm performance (Flåten et al., 2015; Nilsson, 2017; Rypestøl & Aarstad, 2018) or focus on the role of certain anchor or lead firms in the functioning of less developed regional innovation systems (Karlsen 2013; Srholec et al., 2021). More or less explicitly, these studies often address the question of why firms from lagging regions are often surprisingly successful, despite the limitations of lagging regions in terms of innovation. For example, the findings of Flåten et al. (2015) suggest that internationally competitive firms from thin regional innovation systems can ensure absorptive capacity without intensive in-house R&D thanks to specific organizational characteristics in the context of workplace learning – an implicit reference to the DUI mode and the fact that its core lies in the innovation potential of a learning work organization within firms (see Section 2).

4.5 Policy

Given that the papers included in the sample address several issues relevant to the current regional policy agenda, in which innovation-driven, knowledge-based development has become one of the main priorities, it is not surprising that several policy implications regarding innovation modes in lagging regions are either explicitly or implicitly formulated in the papers under review. For example, a number of articles stress the importance of place-based policies (*'Place-based policies are needed'*, Table 6) that take into account the diversity of regional innovation patterns and thus can better address the specificities of lagging regions. With regard to the latter, it is emphasised that a regional policy that aims at one-size-fits-all solutions and neglects specific regional contexts in terms of knowledge bases and innovation modes is not sufficiently targeted. For example, a one-sided focus on promoting private R&D (e.g., Hervás-Oliver et al., 2021), an overemphasis on the role that universities can play in the functioning of regional innovation systems (e.g., Bonaccorsi, 2017), or an over-reliance on cluster policies to exploit agglomeration and network advantages (e.g., Isaksen, 2015) – all of which relate to the STI mode– are discussed as examples of policy approaches that can be effective in non-lagging metropolitan regions, but often have little or no impact in lagging regions.

Accordingly, stimulating the potential of DUI-mode firms through a broad-based approach of knowledge generation and capability development is emphasised in order to avoid a mismatch between policy and regional context in the case of lagging regions (*'Supporting DUI-mode firms'*, Table 6). In this regard, it is considered important that policy makers have a broad understanding of innovation that goes beyond R&D, while recognising that, particularly at the regional level, the interplay of different complementary elements and policy areas is central to the generation of innovation, i.e. in addition to research, for example, labour, finance and education. Moreover, a focus on the actual innovation needs of local firms and industries is considered crucial for the effectiveness of DUI innovation policies in lagging regions. For example, it is important for policy makers to understand the synthetic knowledge bases of more

traditional industries in order to identify innovation strategies that actually fit the regional context in lagging regions and to exploit existing opportunities (e.g., in the context of smart specialisation). Starting points for supporting local firms in this way include expanding opportunities for DUI-based collaboration (e.g., with other firms, customers or other actors in the supply chain), generally strengthening local ecosystems in terms of connectivity and human capital resources, promoting non-R&D innovation activities, considering non-university higher education institutions such as vocational colleges, or the encouragement of on-the-job training activities by companies.

Table 6. Policy lessons in the articles

Implication	Papers
Place-based policies are needed	Blažek & Kadlec (2019); Eder (2019a); Eder (2019b); Glückler et al. (2020); Hervás-Oliver et al. (2021); Isaksen & Trippl (2017a); Karlsen (2013); Nilsson (2017); Srholec et al. (2021); Trippl et al. (2020)
Supporting DUI-mode firms	Amir et al. (2013); Blažek & Kadlec (2019); Nordberg (2015); Bonaccorsi (2017); Gyurkovics & Vas (2018); Flåten et al. (2015); Hervás-Oliver et al. (2021); Isaksen & Karlsen (2013); Srholec et al. (2021); Trippl et al. (2020)
Strengthening the STI mode	Karlsen et al. (2011); Rypestøl & Aarstad (2018); Isaksen & Karlsen (2013); Isaksen (2015); Vlados & Chatzinikolaou (2019)
Finding complementarities	Bonaccorsi (2017); Čábelková et al. (2017); Doloreux et al. (2023); Eder (2019a); Eder (2020b); Fernández-Esquinas et al. (2016); Friedrich & Feser (2023); Hervás-Oliver et al. (2021); Isaksen & Karlsen (2013); Isaksen & Trippl (2017a); Karlsen et al. (2011); Karlsen (2013); Nordberg (2015); Pasciaroni et al. (2018); Pinto (2023); Trippl et al. (2020); Wassmann et al. (2016)
Improving regional governance	Amir et al. (2013); Blažek & Kadlec (2019); Bonaccorsi (2017); Coenen & Morgan (2020); Pasciaroni et al. (2018); Pinto (2023); Suitner et al. (2022); Trippl et al. (2020)

In addition, a few studies also discuss how the STI mode can be directly strengthened in lagging regions (*'Strengthening the STI mode'*, Table 6). This topic is probably relatively little discussed because the potential to build up the STI mode in lagging regions is limited for obvious reasons. Related approaches mentioned in the papers include attracting STI firms, industries with an analytical knowledge base and research institutions from outside the region ('inward transplantation'; Isaksen 2015). The foundation of new STI firms in lagging regions through measures such as incubation or entrepreneurship programmes is also mentioned in this context. Such an expansion of the STI mode may be crucial in lagging regions with low endogenous dynamism in order to embark on new or different development paths. However, the success of such strategies should not be overestimated, as docking to an existing synthetic knowledge base and its 'regional industrial atmosphere' often determines whether strengthening the STI mode in lagging regions is actually successful in the long run (Karlsen et al. 2011).

It is therefore not surprising that a number of studies in the sample focus in their policy implications on finding complementarities between DUI- and STI-related forms of learning and knowledge as a way to advance lagging regions from an innovation mode perspective (*'Finding complementarities'*, Table 6). It is assumed that such combinations of different types of learning and knowledge in a lagging region can further stimulate and strengthen the innovation potential of the DUI firms located there – Isaksen & Karlsen (2013) refer to this as 'upgrading'. In concrete terms, this may involve co-specialisation between local research institutions, existing technological capabilities and region-specific industrial needs. Such combinations of DUI and STI require a special culture of communication and interaction within the region, which poses several challenges. Local DUI firms, for example, often find it difficult to engage in such collaboration, so building trust-based, long-term relationships is often a prerequisite for them to open up to those interactions. At the same time, however, universities or other STI-actors must also adapt and ensure that the desired interplay is successful, for example, by taking care that the knowledge and learning inputs they provide are genuinely tailored to the actual needs and demands of local firms. Bonaccorsi (2017), in this context, speaks of a common interest between a local university and the local industry as a prerequisite for the desired DUI-STI complementarities to be effective. Particularly in lagging regions, where the endogenous STI potential is often weakly developed, it is also important to focus on extra-regional linkages so that the innovation-promoting interplay of STI and DUI is actually set in motion. This fact is repeatedly emphasised in the studies examined, as it is often the only way to stimulate new or adapted knowledge-based development paths based on the endogenous DUI potential of a lagging region. For this strengthening of a lagging region's STI capacity through extra-regional linkages, the use of intermediaries such as technology centres (Nordberg, 2015) or knowledge-intensive business services (Doloreux et al., 2023) is seen as useful, as they can play an important role in translating between regional expertise and STI actors outside the region, thus increasing the likelihood that the new external knowledge will actually be absorbed.

The micro-level perspective of the STI/DUI approach may also explain why several studies also draw implications

for the design of regional governance (*'Improving regional governance'*, Table 6). The ability of policy makers to learn interactively with other stakeholders in the region (firms, knowledge institutions, networks, etc.) is described as an important implication in this context. The process of regional policy-making should therefore be understood as a dynamic, collective and, above all, long-term process, which is necessary to achieve an effective innovation policy for lagging regions. It should also be accompanied by a certain willingness on the part of the actors involved to engage in experimental learning, as the specific circumstances of lagging regions require the search for non-standard solutions that are tailored to the needs of the local firms and industries. In this regard, multi-level governance is described as important (Blažek & Kadlec 2019; Coenen & Morgan 2020), involving the national level while at the same time allowing for a certain degree of institutional autonomy and decision-making freedom at the regional level, so that existing local expertise can actually be incorporated into regional development processes. Developing such governance structures is certainly a major challenge, especially for lagging regions with a high degree of institutional thinness, but taking first steps in this direction may initiate a gradual process of policy learning and catching up for these regions. A coordinating institution at the regional level that drives the regional innovation agenda, clarifies coordination issues, promotes conflict resolution and thus improves interaction and knowledge flow between the various stakeholders in the region and the region's external environment can be helpful in this respect.

5.   Conclusion and outline of future research avenue

5.1 Concluding remarks

Promoting innovation in lagging regions requires a good understanding of the learning and knowledge environments in these areas. The regional innovation systems approach, with its well-established knowledge base concept, provides a useful theoretical framework for policy makers in this respect. However, a potential weakness of this framework is that the micro configuration of firms, institutions and other actors is viewed rather passively, so that the dynamic, knowledge-based development process towards new or adapted pathways in lagging regions remains too unclear. For this reason, it is worth looking at the firm level of lagging regions in order to better understand the underlying dynamics of learning and innovation (Karlsen 2013). To this end, the present paper links the STI/DUI concept of Jensen et al. (2007) on the different learning and innovation modes of firms to the knowledge base concept and presents a correspondingly extended conceptual framework for explaining innovation-driven, knowledge-based development in lagging regions.

To date, this potential of the STI/DUI concept has been used only to a limited extent. This is shown by the results of a systematic literature review on studies that refer to Jensen et al.'s (2007) innovation modes approach in the context of lagging regions. An evaluation of various bibliometric information has provided a first overview of these studies. At the same time, it has given several indications that examining innovation modes in lagging regions is a relatively young, emerging field of literature – probably also due to the fact that the regional contextualisation of the STI/DUI concept is still in its infancy. Regarding the theoretical foundation of the papers under review, it is striking that most of the studies in our sample are indeed concerned with the knowledge-based development of lagging regions. However, with a few exceptions, the STI/DUI concept is used in a vague theoretical way in many of the studies reviewed and is sometimes confused with the knowledge base concept. The latter can be problematic if, for example, DUI is more or less automatically equated with a synthetic knowledge base and STI with an analytical knowledge base, without taking into account that STI learning can also take place at the firm level in industries and regions with a strong synthetic knowledge base, and that DUI learning also occurs in firms in industries with a strong analytical knowledge base (Asheim & Parrilli, 2012). However, as the results of our systematic literature review imply, there are already examples of studies that systematically look at lagging regions from an innovation mode perspective, which points to the potential of such an approach from a theoretical point of view. A further indication of this is the fact that the use of the STI/DUI concept in our sample of papers is linked to a wide range of different theoretical or empirical approaches and topics (such as SME innovation, business ecosystems, non-R&D innovation, smart specialisation, social innovation, regional advantage, etc.), which also points to the conceptual potential of an innovation mode perspective on lagging regions.

From a methodical point of view, most of the studies included in the literature sample are based on qualitative data or are purely conceptual in nature. All studies have an understanding of lagging regions based on certain functional factors that form the basis for examining innovation in this specific type of region, e.g., in terms of organizational thickness or other characteristics of less-developed regional innovation systems. Only a few of the studies under review are based on firm-level data in lagging regions, while many others are limited to an aggregated regional perspective. This means that the STI/DUI concept has so far only been analysed empirically in a few exceptional cases. In addition, there have been only initial attempts to empirically classify lagging regions on the basis of innovation indicators and to include DUI in this respect according to its importance for innovation in lagging regions. There are

probably two reasons for this: First, the fact that the STI/DUI concept is actually a stand-alone or even their main theoretical approach in only a few studies in the sample is likely to play a role. Secondly, the availability of innovation indicators is also likely to be an issue, which is often still difficult, especially in case of measuring the DUI mode (e.g., Alhusen et al., 2021; Haus-Reve et al., 2023). However, such a measurement would be important as it can be assumed that DUI mode learning is of formative importance for innovation in lagging regions.

Moreover, the results of the systematic literature review also imply that the studies reviewed address a number of relevant topics in the context of innovation-driven, knowledge-based development of lagging regions. Our findings suggest that using the STI/DUI concept in the present context leads to new insights, which in turn confirms the potential of an innovation mode perspective on lagging regions. For example, the studies analysed often raise the question of the extent to which the DUI mode represents an independently effective endogenous innovation resource for lagging regions, or whether it still requires STI impulses, for example via universities or other forms of technology transfer, in order to really unfold. The findings of the studies under review also confirm previous evidence that lagging regions do indeed have special characteristics in terms of the way in which learning, innovation and knowledge generation take place. However, due to the vague use of the STI/DUI concept, the innovation mode perspective on lagging regions is only really explicit in a very few studies. Often there are only indirect references. This leaves the impression that the potential of the STI/DUI concept for a better understanding of innovation in lagging regions has so far been exploited only to a limited extent.

The results of the systematic literature review then make it clear that various policy implications can be found in the studies analysed, which once again illustrates the existing potential of an innovation mode perspective on lagging regions. The papers emphasise the fundamental importance of place-based policies in order to take into account the specific contextual conditions of lagging regions when formulating innovation policies and thus achieve greater effectiveness compared to one-size-fits-all solutions. In addition, different elements of a policy oriented towards an innovation mode perspective on lagging regions are highlighted (i.e., 1. Supporting DUI mode firms, 2. Strengthening the STI mode, 3. Finding complementarities, 4. Improving regional governance). At the same time, the detailed formulation and delimitation of what exactly could be meant by STI and DUI innovation policies in lagging regions, and which approaches and measures are associated with each, remains very vague. More in-depth issues, such as the economic justification for such policies or the effectiveness and impact of such measures, have not been empirically explored at all. This is in line with the overall impression from the systematic literature reviews that there is still a lot of untapped potential in terms of an innovation mode perspective on the lagging region, which needs to be realised in future research efforts.

5.2 Future research

We see four main avenues for future research: The first is *conceptual clarification*, in relation to STI/DUI itself, but especially in relation to the knowledge base concept. By clarifying what is actually meant by STI and DUI in theoretical terms, the necessary basis is created for an empirical analysis of innovation modes in lagging regions. It also seems promising to combine the STI/DUI concept with other approaches that repeatedly play a role in the innovation literature on lagging regions (e.g., SME innovation, business ecosystems, non-R&D innovation, smart specialization, etc.) and systematically explore the existing conceptual cross-references. Second, *more micro-level studies* of learning and innovation are crucial to gain a better understanding of the dynamic processes of innovation-driven, knowledge-based development in lagging regions. Both quantitative and qualitative methods can contribute to this if they help to make the modes of innovation in the regions under study tangible or are able to capture the specificities of the regional context. An important prerequisite for this to succeed is, in particular, a *better empirical measurement of the DUI mode*. For example, Alhusen et al. (2021) have provided a possible starting point for this by developing a set of indicators to comprehensively measure DUI innovation activity for the first time. In particular, learning and innovation in lagging regions, with its strong anchoring in the DUI mode, would provide a vivid testing ground for validating these new indicators in practice. Moreover, if this is successful, the next step could perhaps be to use the DUI indicators for the empirical classification of lagging regions themselves – which would be an important contribution to clarifying what exactly is meant by lagging regions in terms of innovation. Finally, future research efforts could also focus on *developing an integrated approach to innovation policy* in relation to lagging regions, distinguishing between STI and DUI and addressing the links between them. In this context, it would also be important to develop a convincing rationale for promoting STI or DUI innovation activities in lagging regions, e.g., by compiling relevant arguments or by conducting comprehensive evaluations of relevant innovation policies, including economic impact analyses of concrete regional policy measures.

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Appendix

Table A1. Regional search operators used to identify the studies in the sample (multiple assignments possible)

Search operator	Paper
weak region	-
lagging region*	Blažek & Kadlec (2019); Coenen & Morgan (2020); Eder (2019b)
laggard region*	-
catch-up region*	-
thin region*	Flåten et al. (2015); Isaksen, (2015); Karlsen (2013); Rypestøl & Aarstad (2018)
less developed region*	Amir et al. (2013); Arendt & Grabowski (2019); Isaksen & Karlsen (2013); Trippl et al. (2020); Vlados & Chatzinikolaou (2019)
less innovative region*	Hervás-Oliver et al. (2021); Pasciaroni et al. (2018)
region* with less developed	Isaksen & Karlsen (2013)
underdeveloped region*	-
peripheral region*	Bonaccorsi (2017); Čábelková et al. (2017); Eder (2019b), (2019a); Fernández-Esquinas et al. (2016); Friedrich & Feser (2023); Gyurkovics & Vas (2018); Isaksen (2015); Isaksen & Trippl (2017a); Karlsen et al. (2011); Nordberg (2015); Pinto (2023)
rural region*	Doloreux et al. (2023); Glückler et al. (2020); Nilsson (2017); Srholec et al. (2021); Wassmann et al. (2016)
less favoured region*	-
non-core region*	Suitner et al. (2022)
low-technology region*	Wassmann et al. (2016)
low-tech region*	-
old industrial area*	Isaksen & Trippl (2017a)

Table A2. Basic information about the sample (N = 30)

Publication period	2011 to 2023
No. of journals	24
No. of authors	58
Co-authors per paper	2.27
Paper's average age in years	5.07
Annual Growth Rate	12.25%
Average citations per paper	30.73
No. of author's Keywords	132
No. of indexed keywords	112
References	2062

Source: Bibliometrix

Table A3. Top 10 most cited publications in the sample (N=30, in descending order of local citations)

Publication	Local citations	Global citations[a]
Jensen, M. B., Johnson, B., Lorenz, E., & Lundvall, B. Å. (2007). *Forms of knowledge and modes of innovation*. Research Policy, 36(5), 680–693.	30	2.790
Tödtling, F., & Trippl, M. (2005). *One size fits all?: Towards a differentiated regional innovation policy approach*. Research Policy, 34(8), 1203–1219.	19	3.178
Asheim, B. T., & Gertler, M. S. (2005). *The geography of innovation: regional innovation systems*. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), The Oxford handbook of innovation (pp. 291–317). Oxford: Oxford Univ. Press.	14	3.260
Boschma, R. (2005). *Proximity and Innovation: A Critical Assessment*. Regional Studies, 39(1), 61–74.	14	8.849
Asheim, B. T., Boschma, R., & Cooke, P. (2011). *Constructing Regional Advantage: Platform Policies Based on Related Variety and Differentiated Knowledge Bases*. Regional Studies, 45(7), 893–904.	12	1.575
Bathelt, H., Malmberg, A., & Maskell, P. (2004). *Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation*. Progress in Human Geography, 28(1), 31–56.	9	6.842
Asheim, B. T., & Coenen, L. (2005). *Knowledge bases and regional innovation systems: Comparing Nordic clusters*. Research Policy, 34(8), 1173–1190.	9	2.353
Martin, R., & Moodysson, J. (2013). *Comparing knowledge bases: on the geography and organization of knowledge sourcing in the regional innovation system of Scania, Sweden*. European Urban and Regional Studies, 20(2), 170–187.	7	300
Grillitsch, M., & Nilsson, M. (2015). *Innovation in peripheral regions: Do collaborations compensate for a lack of local knowledge spillovers?* The Annals of Regional Science, 54(1), 299–321.	7	316
Isaksen A., & Trippl, M. (2016), *Path Development in Different Regional Innovation Systems: A Conceptual Analysis*. In M. D. Parrilli, R. D. Fitjar, & A. Rodriguez-Pose (Eds.), Innovation Drivers and Regional Innovation Strategies (pp. 66–84), London, Routledge.	7	318

[a] According to Google Scholar on 05 December 2023.