

Mapping the twin transition in regional innovation systems: a case study approach

Keywords: Twin Transition, Agent-based modelling, Regional path development, Knowledge creation, Regional innovation systems

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ABSTRACT

The pivotal shift towards a climate-neutral European economy hinges on green innovation and clean technology. Recognising the potential of digital knowledge to propel the green transition, the concept of 'twin transition' has gained increasing importance in European policy discussions. However, to unravel potential pathways for the twin transition of European regions, it is crucial to identify its drivers, understand the diffusion of related technologies and explore the dynamics of regional path developments. Traditional evolutionary economic geography models have limitations in explaining regional structural change, focusing on firm-led processes and technological and skill relatedness and overrating local factors over non-local influences. Recent literature extended the conceptual aspects of new industrial path development to understand twin transition by combining evolutionary economic geography with the regional innovation system approach. However, to the best of our knowledge, this theoretical conceptualisation has not been sufficiently validated with real-world data to evaluate its effectiveness across different regional contexts. To fill this gap, this work-in-progress paper aims to conduct a literature review to identify regional cases and systematically categorise them within a new typology of pathways. The objective is to support a new conceptualisation of regional innovation pathways. To observe and explore these various forms of new path development, a framework that aligns these path creation types with their distinctive characteristics with the mechanisms of regional knowledge creation has been developed through a pilot case agent-based model. The potential impacts of this research are extensive, benefiting a wide range of stakeholders, including policymakers, industries, academia, and society. The generated insights can inform effective policies, guide industries through transitions, enhance environmental sustainability, and highlight societal implications.

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1. Introduction

Decarbonisation and the so-called ‘net-zero transition’ are now recognised by the international community as global security priorities. To keep the planet liveable and seize economic opportunities, the European Union is engaging in a swift and inclusive transition towards environmentally sustainable lifestyles and economies (European Commission, 2022). The European Commission’s Eco-Innovation Action Plan, the 2030 Agenda proposed by the United Nations General Assembly, the 2015 Paris Agreement, and the 2021 Glasgow Climate Agreement all indicate a consensus on integrating sustainable development into regional growth and digitalisation strategies (Xu et al., 2023). In this context, digitalisation is perceived as a key enabler for addressing energy and environmental issues, assumed to catalyse green transition through innovation by providing smarter and more efficient technological solutions (Du et al., 2023). The green and digital transitions are thus intrinsically linked, to be considered as “twins” (Montresor & Vezzani, 2022). Twin transition is a complex transition involving the interplay of innovation, societal adoption, economic restructuring, and regulatory adjustments. Successfully managing the green and digital ‘twin’ transitions is the cornerstone for delivering a sustainable, fair, and competitive future (European Commission, 2022). Given Europe’s economic landscape marked by considerable regional disparities, implementing the twin transition will depend not only on green and digital technologies but also on the distribution of innovation and technological advancement capabilities among European regions (European Commission, 2022). Indeed, the structural changes required to green and digitise Europe's economy will affect future regional income and development. Furthermore, understanding the twin transition relationship requires considering the dynamics of regional path development along the lines of regional innovation science and evolutionary economic geography (EEG) literature (Parrilli et al., 2016).

Over the years, a deep body of knowledge concerning drivers for regional growth and development to map twin transitions has emerged. Recent work has developed a more fine-grained

conceptualization of new path development, combining EEG with insights from regional and technological innovation systems, socio-technical transitions, global production, innovation networks, and sociological perspectives (Grillitsch et al., 2018; Hassink et al., 2019). This approach has helped to point out other forms of path development, such as path renewal, path creation and path importation, as explanatory patterns for the rise and transformation of regional industries.

However, to the best of our knowledge, this conceptualization has not been sufficiently validated with real-world data to assess its effectiveness in diverse regional contexts. To fill this gap, we see scope for improving the empirical underpinning of the pathway definition in EEG by conducting a literature review to identify regional cases and systematically categorise them within the new pathway typologies. To observe and explore these various forms of new path development through a pilot case using agent-based scenarios, a framework that aligns these path creation types with their distinctive characteristics with the mechanisms of regional knowledge creation has been developed. We support the more fine-grained view of different types of path development with the objective of identifying concrete regional case studies which may support the conceptualisation of new regional path development and the calibration of the pilot case simulation model.

The remainder of the work-in-progress paper is organised as follows. To better understand the field of research, section 2 delves into the relevance of the study. Section 3 details the contribution to the field. In Section 4, we explain the methodology used in our research. Section 5 presents a comprehensive description of the results obtained from our analysis.

2. Relevance of the research

Research and innovation are key drivers of twin transition in Europe's regions, offering the advantage of bolstering European economic growth and competitiveness compared to leading countries such as the United States and China. Nevertheless, the uneven distribution of innovation and technological advancement capabilities among European regions results in varying regional capabilities to develop the technologies needed for the twin transition (Ron Boschma et al., 2023). The literature recognises regional development is influenced by a variety of factors, including local resources, institutional frameworks, and the interactions between different actors such as firms, research institutions, and policymakers (Hassink et al., 2019). Specifically, in the case of the twin transition, a strong regional agency paired with an inclusive governance approach is seen as crucial for the directionality of the regional transition (Paier & Neuberger, 2024).

Most research in EEG has a narrow understanding of regional development and considers it as an incremental, endogenous, technology-driven and firm-led path (Schamp, 2017). This framework has

limitations for several reasons. First, it very much takes the local firm as a starting point of analysis and hence neglects other actors, such as foreign companies, universities, research institutes, policy actors, etc. Second, local sources, processes and influences of new regional industrial path development are stressed at the expense of non-local ones. Third, inter-path relations are narrowly conceptualised, shedding light on the positive effects of technological and skill relatedness only and ignoring other vitally important linkages that might exist between different paths and influence their development. Recent literature in economic geography extended the conceptual aspects of new industrial path development to understand twin transition by combining EEG with the regional innovation system approach (Binz et al., 2016; Hassink et al., 2019). From rather broad categories of new path development, the literature has established a fine-grained typology, specifying path extension, upgrading, branching, importation, diversification, and creation (Martin & Sunley, 2006; Trippel et al., 2020).

Path extension results from incremental innovations within firms, representing the continuity of industrial structures and primarily relying on existing knowledge. Path branching, on the other hand, involves the emergence of new regional industrial paths based on existing industry capabilities. This can occur through the diversification of incumbent firms into related fields, the foundation of new firms using existing competencies, and spin-offs from incumbent firms. Similarly, path diversification is a micro-level process where firms enter new industries by combining their existing knowledge base with new, unrelated knowledge. Path upgrading involves significant changes to an existing regional industrial path, redirecting it in new directions. These changes can be triggered by the infusion of new technologies or significant organisational changes (renewal), improving the industry's position within global production networks, or developing niches in mature industries. Path importation refers to establishing industries new to the region and unrelated to existing ones. This process can be triggered by the arrival of non-local companies, the inflow of skilled individuals with unique competencies, or innovation partnerships with distant sources. Finally, path creation into new industries represents the most radical form of change, driven by the emergence and growth of industries based on new technological and organisational knowledge. Table 1 summarises the taxonomy of regional path creation with their distinctive characteristics.

Table 1. Types of regional path development.

Type of path development	Definition (based on Grillitsch et al. 2018, among others)
<i>Extension</i>	Continuation of an existing industrial path based on incremental innovation in existing industries along well-established technological trajectories.
<i>Related branching</i>	Diversification into a new related industry for the region building on competencies and knowledge of existing industries.
<i>Unrelated diversification</i>	Diversification into a new industry based on unrelated knowledge combinations.
<i>Upgrading</i>	Signifies major intra-path changes , including infusion of new technologies and niche development.
<i>Importation</i>	Involves establishing industries new to the region (e.g., through innovation partnerships with non-local companies).
<i>Creation</i>	Signifies radical changes ; emergence of new industries based on technological and organizational knowledge.

To observe and explore these various forms of new path development, a framework that aligns these path creation types with their distinctive characteristics with the mechanisms of regional knowledge creation has been developed. This conceptualisation is embedded in an agent-based model (ABM) currently in the testing stage. Figure 1 shows the pilot case of the project for twin transition within the thematic priority of transformation pathways and strategies.

The simulation model aims to identify drivers for digital and green transitions, comprehend the geographical distribution of related technologies, and analyse the impact of various research, technology, and innovation policy mixes.

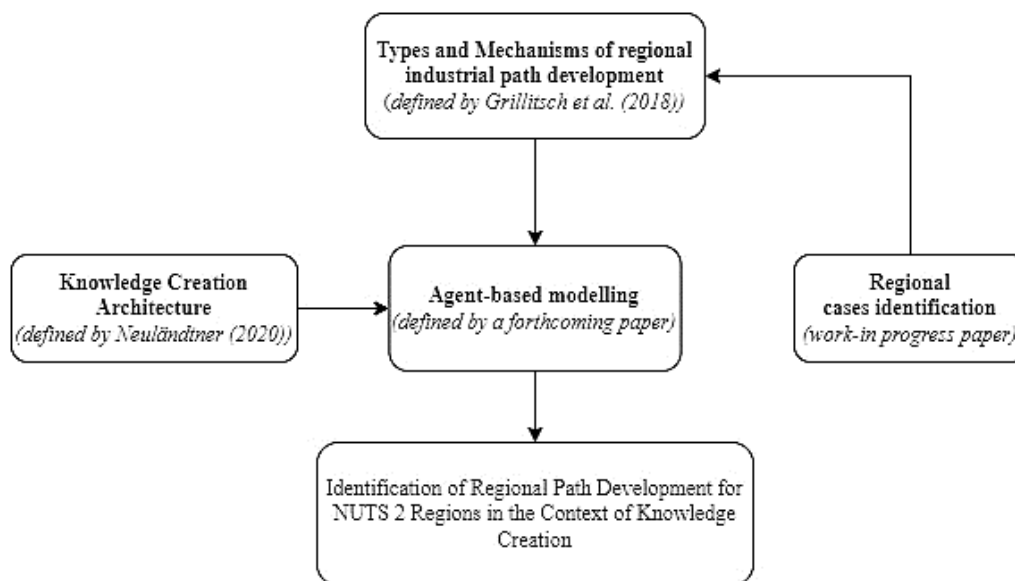


Figure 1. Pilot case for twin transition within the thematic priority of transformation pathways and strategies

The framework simulating regional knowledge creation is extensively detailed in Neuländtner (2020), which is then translated into the regional twin transition context of the pilot case. The model comprises three key characteristics: (i) a set of interacting agents, their attributes and behaviours, (ii) a set of relationships and methods of interaction situated within (iii) a model environment. The agents in the model will be innovating research actors characterised by organisation-level empirically based attributes (detailed geographical and technological positioning). The agents' relationships and interactions are defined within the knowledge-creation process. This process is driven by different strategies (explorative or exploitative) and modes of knowledge creation (internal research or collaboration). Rules for interaction (e.g. spatially close actors collaborate more intensively) will be empirically calibrated and enriched in this pilot case. Successful research efforts by agents result in knowledge gains, which can result in innovation like patents. Figure 2 shows the basic model architecture.

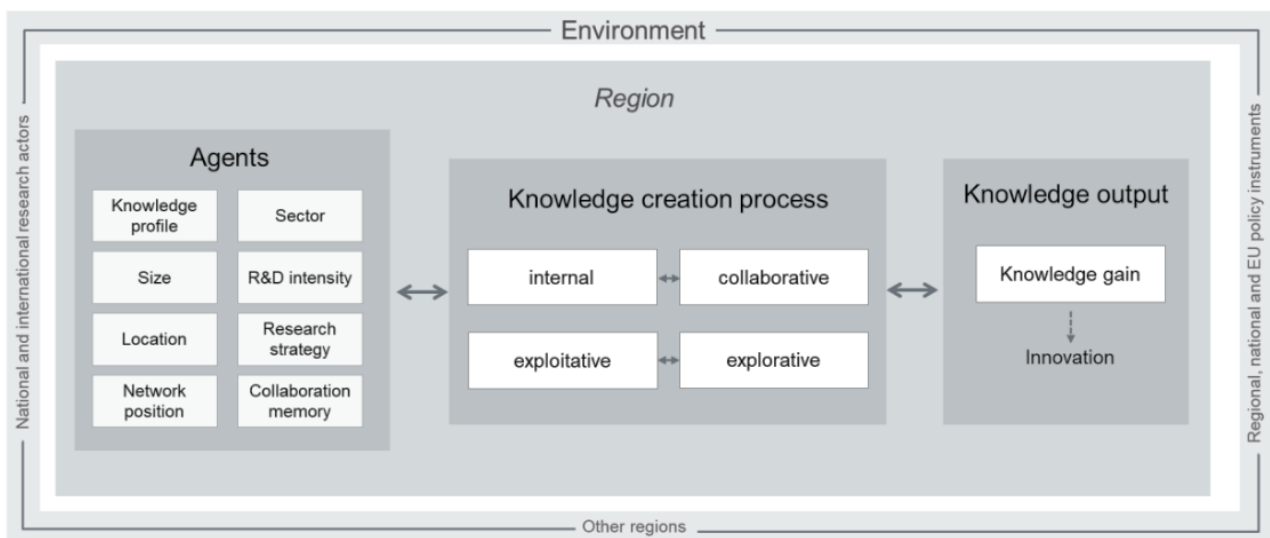


Figure 2. Basic model architecture

Building on this basic model architecture, the pilot case ABM explores the potential pathways for the twin transition of European regions by developing a new conceptualisation of regional path development. This new conceptualisation closely follows the literature on new regional path development reported above, which distinguishes different trajectories regions might follow in their industrial and technological development (Binz et al., 2016; Hassink et al., 2019; Isaksen et al., 2018; Martin & Sunley, 2006; Veldhuizen, 2020). Table 2 shows the potential operationalisation of the different types of path development.

Table 2. Potential operationalisation of the different types of path development.

Type of path development	Definition (based on Grillitsch et al. 2018, among others)	Potential operationalisation in the simulation model (to be refined in the project)
<i>Extension</i>	Continuation of an existing industrial path based on incremental innovation in existing industries along well-established technological trajectories	> represented by an additional (already existing) highly related technology class(es) in the region's knowledge portfolio
<i>Branching</i>	Diversification into a new related industry for the region building on competencies and knowledge of existing industries	> represented by an additional (already existing) moderately related technology class(es) in the region's knowledge portfolio
<i>Diversification</i>	Diversification into a new industry based on unrelated knowledge combinations	> represented by an additional (already existing) unrelated technology class(es) in the region's knowledge portfolio
<i>Upgrading</i>	Signifies major intra-path changes , including infusion of new technologies and niche development	> represented by an additional (already existing) complex technology class(es) in the region's knowledge portfolio
<i>Importation</i>	Involves establishing industries new to the region (e.g., through innovation partnerships with non-local companies)	> represented by new unrelated technology class(es) – that are new to the region – in the region's knowledge portfolio
<i>Creation</i>	Signifies radical changes ; emergence of new industries based on technological and organizational knowledge	> represented by new complex and unrelated technology class(es) – that are new to the region – in the region's knowledge portfolio

To connect 'path development' to 'transition pathways', it is essential to evaluate the shift from merely adopting a new technology to an evolution and transformation of a region's technological landscape, qualifying as a technological transition. Consequently, a specific set of criteria is established to measure the extent and quality of the technological changes the regions have experienced. Note that these are preliminary considerations that will be developed and finalised during the project. Finally, given the dominant type of path development, we can then observe a region's green/digital transition. Figure 3 illustrates the process of identifying and evaluating regional development paths.

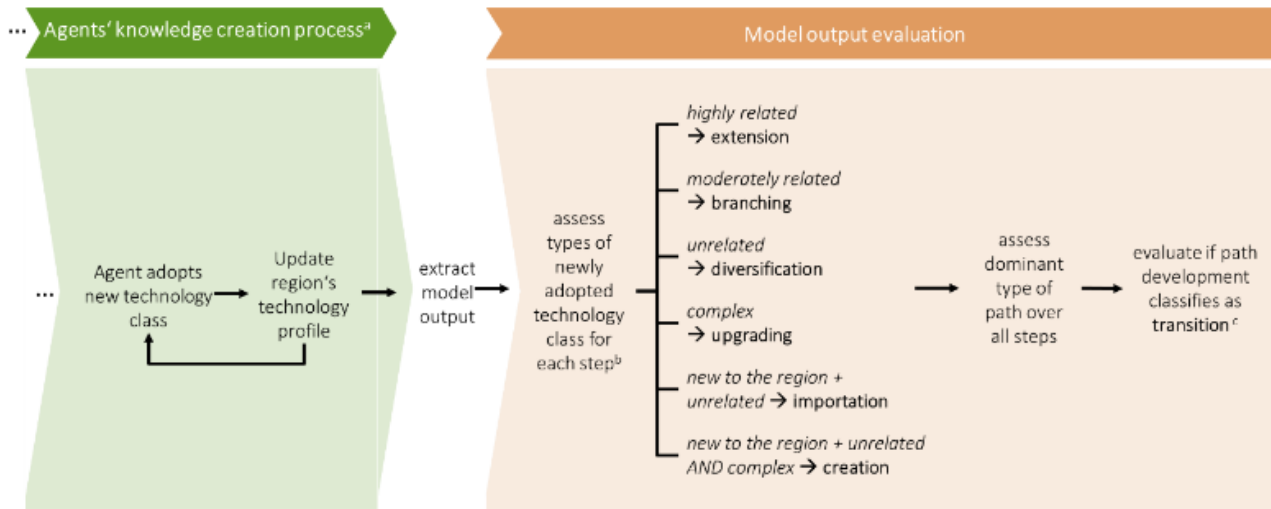


Figure 3. Process of identifying regional development path

However, to the best of our knowledge, the theoretical conceptualisation has not been sufficiently validated with real-world data to evaluate its effectiveness across different regional contexts. To fill this gap, the aim of this work-in-progress paper is to conduct a literature review aimed at identifying regional cases and systematically categorising them within the new typology of pathways. The objective of the literature review is to identify concrete regional case studies that may support our conceptualisation of the regional innovation pathways and be considered for the characterisation of the model at the setup.

To identify such regional cases of trajectories, the idea is to analyse both the literature that explicitly uses the new regional path development framework and the broader literature analysing regional innovation and industrial development, including policy approaches. The focus of the empirical analysis is laid on European regions.

3. Contribution

The contribution of this work-in-progress is to support the elicitation of potential pathways for the twin transition of European regions from an empirically grounded modelling perspective and the development of an in-depth understanding of the drivers of twin transition and their implications. An in-depth analysis of case studies may help to assign concrete empirical examples of regional development paths to the new taxonomy of pathways. Specifically, our contribution is two-fold:

- (i) Improve the empirical underpinning of the pathway definition. This first sub-objective aims to enhance the theoretical conceptualisation of new regional path development. Integrating empirical data into the pilot case ABM assists in enhancing and confirming theoretical paradigms defined in the literature. This procedure facilitates the recognition and

classification of different types of new path development, specifying path extension, upgrading, branching, importation, diversification, and creation (Martin & Sunley, 2006; Trippel et al., 2020). This guarantees that these classifications are not solely theoretically robust but also applicable and detectable in practical instances.

- (ii) Empirical calibration of the pilot case ABM. The second sub-objective focuses on calibrating the simulation of different pathways for regional twin transition. This approach allows for a detailed examination of the underlying mechanisms driving path development and potentially identifies ways to quantify the criteria for analysing the model outputs. This, in turn, contributes to the understanding of both green and digital transitions.

4. Method

Based on this conceptual framework, a literature review to calibrate the conceptualisation of the regional innovation pathways may be structured in multiple ways. First, the procedure for selecting articles should be described and how it was obtained, including the keywords and databases used. Second, a mix of recently published and older literature should be systematically searched. Additionally, the inclusion of niche-quality publications will further enhance the outcome.

Using a combination of appropriate keywords (i.e. “regional innovation”, “pathway”, “smart specialisation”, “industrial district”, "extension", "branching", "diversification", "upgrading", "importation", "creation"), relevant articles were selected for review from online journal databases. Scopus was thoroughly explored for gathering relevant publications; these records were then subjected to a rigorous screening process based on predefined exclusion criteria. We excluded subject areas such as psychology, medicine, arts and humanities and limited the language to English. We selected papers from countries that are either members of the European Union or are in Europe. There was no filter on the year; we considered the entire available time horizon. We selected 53 papers by reviewing abstracts for mentions of NUTS 2 European regions, focusing on those that include case studies. Of these, 47 were particularly relevant to the theme. Additionally, we included other papers based on the expertise of our research group. Figure 4 shows our review protocol.

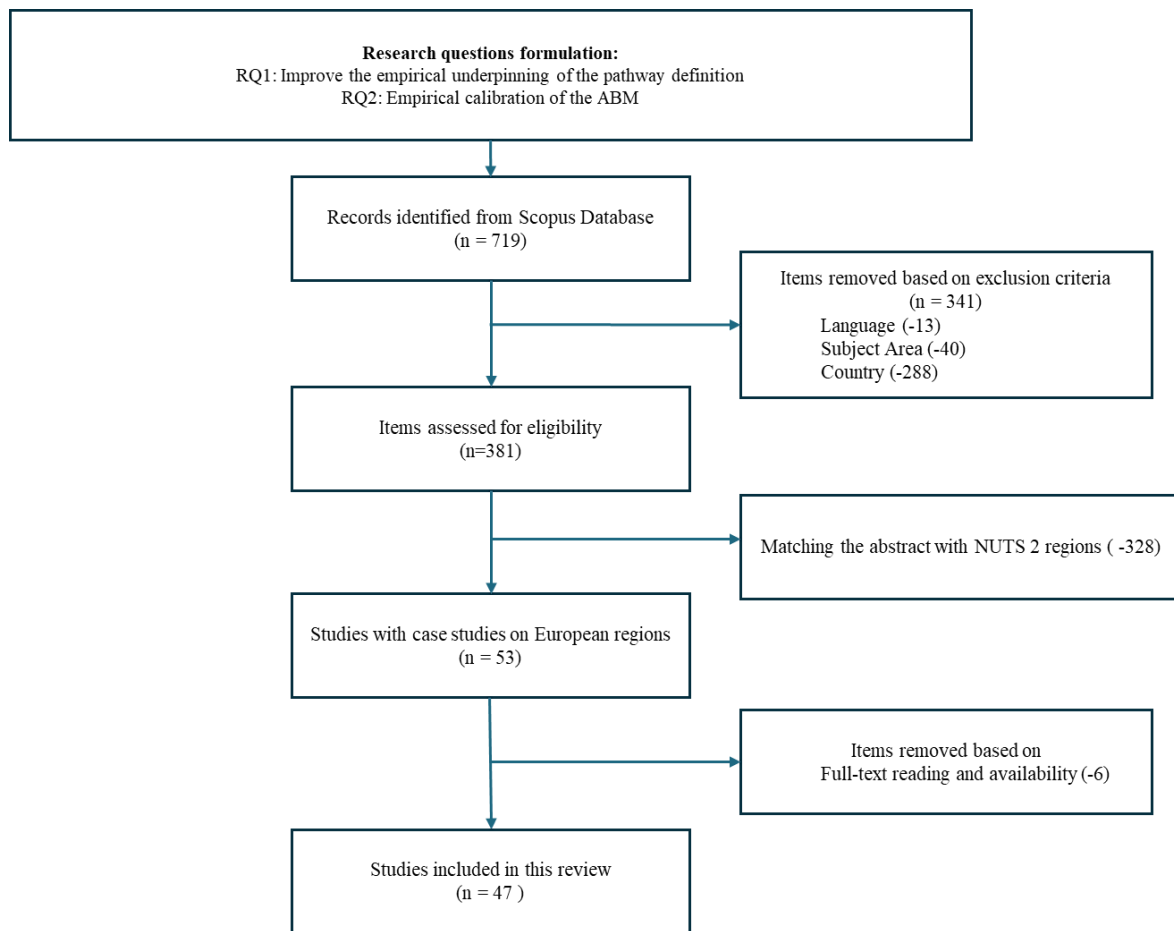


Figure 4. Review protocol

Below, we provide some examples of classification according to the new path development framework.

Sassuolo. Since the 1990s, the Sassuolo ceramic tiles industrial district has implemented an internationalisation strategy based on foreign direct investment. This strategy has reduced the number of local producers while simultaneously contributing to expanding complementary activities such as design, innovation, distribution management, and product variety. As a result, the Sassuolo industrial district has positioned itself on a path extension, maintaining its leadership in the high-end ceramic tiles market.

Fermo and Macerata districts. The Fermo footwear district has faced various challenges from globalisation and technological changes since the 1990s. The primary strategy implemented was extending the production path through "unlearning" processes focused on the core production area. This approach led to a reduction in specific traditional footwear production skills while placing greater emphasis on new organisational and process management competencies. As a result, the Fermo district has positioned itself on a path of extension, maintaining its relevance in the industry by continually evolving skills within its core production area. In contrast, the Macerata footwear

district began specialising in producing footwear components, particularly heels and soles, around the turn of the century. The primary strategy was to expand expertise in rubber moulding, transitioning from leather to rubber soles in line with fashion trends. Pre-existing skills in other local non-core industries, such as musical instrument manufacturing and plastic products, supported this approach. Consequently, the Macerata district embarked on multiple paths, including path extension and related branching, evolving core production competencies and expanding interactions between core and non-core sectors. This diversification has enabled the district to explore new development opportunities and maintain its competitive edge.

Vierzon. Vierzon has experienced both path creation and path diversification due to several factors. The emergence of the company Ledger, a frontier blockchain start-up, significantly influenced path creation in Vierzon. This start-up chose to locate its production facilities in Vierzon, a decision driven by multiple factors such as cost, product specificities, institutional support, and recruitment opportunities. The local government and economic development offices supported Ledger through subsidies, providing office spaces, and facilitating connections with regional and national funding opportunities. Path diversification in Vierzon was made possible through the broader economic and institutional context. The town's strategic location, national urban regeneration programs, and establishment of the Sologne Technology Park attracted various industries, enhancing its economic landscape. The collaboration between local stakeholders and Ledger fostered a conducive environment for new industrial paths, thereby diversifying the economic activities in Vierzon beyond traditional industries. These efforts collectively contributed to creating new paths and diversifying existing ones, positioning Vierzon as a hub for innovative and high-tech industries despite its historical industrial decline

5. Description of results

As this work-in-progress outlines the ongoing research on regional twin transition pathways, the empirical results are being gathered and analysed. The following points summarise the expected outcomes and the planned approach to present the results:

1. **Data collection and classification:** data on new regional path development across European regions are being collected and classified. This includes identifying case studies that illustrate various types of new path development, such as path extension, upgrading, branching, importation, diversification, and creation.
2. **Calibration of the simulation model:** the pilot case ABM is being developed and calibrated using the collected data. This model will simulate different policy scenarios and their impacts

on regional development pathways, aiming to provide realistic and meaningful insights into the twin transition.

The detailed results, including comprehensive data analysis and simulation outcomes, will be included in this paper's final presentation.

Potential impact

The results of this research could significantly advance the ongoing scholarly field regarding regional path development. Previous studies, such as those by Martin and Sunley (2006), Trippel et al. (2020), and Hassink et al. (2019), have predominantly concentrated on the theoretical definition of new path development, including path extension, upgrading, branching, importation, diversification, and creation. While these frameworks have provided valuable theoretical insights, to the best of our knowledge, their empirical validation across diverse regional contexts remains limited. This manuscript addresses this gap by identifying and analysing regional case studies across regional contexts, offering empirical substantiation that enhances and refines this theoretical conceptualisation. The literature review conducted in this study plays a pivotal role in complementing the pilot case ABM by supporting the empirical foundation of the conceptual framework proposed by Hassink et al. (2019). It provides a more comprehensive understanding of the diversity of regional pathways, enabling further refinement and calibration of both the model itself and the criteria used for evaluating its outputs. In particular, the pilot case ABM, which is still in the testing stage, provides valuable insights into the pathways of regional knowledge creation. The model focuses on simulating knowledge creation as a specific aspect of new path development, offering a structured approach to understanding the emergence of regional pathways. By identifying and analysing regional case studies, our review enhances the pilot case ABM's adaptation to simulate regional development dynamics in diverse contexts and enriches the model's capacity to account for variations across different regional environments.

These findings validate the theoretical constructs posited within the realm of EEG and augment them by furnishing practical insights into the strategies that regions may employ to confront the challenges posed by the twin transition. The paper presents novel suggestions for scholars and policymakers examining path development in regional economies. The proposed research can influence diverse stakeholders, including policymakers, industries, academics, and society. The project's impacts are wide-ranging and multifaceted (see Figure 5 for an overview).



Figure 5. Expected impacts of the project

First, the research can provide valuable insights for policymakers by fostering a deeper understanding of the dynamics of technological transitions. Second, findings from the study may guide industries undergoing technological transitions, helping them navigate challenges, adopt new technologies, and identify opportunities for growth and diversification. Third, insights into the digital-green nexus, particularly within green transitions, can contribute to environmental sustainability efforts. Shedding light on the environmental implications of technological choices and the digital transition can guide decisions towards more sustainable practices. Fourth, the research can shed light on the societal impact of technological transitions, including effects on employment, inequality, and access to resources. This knowledge can inform discussions about technological change's ethical and social dimensions. Fifth, enhancing the theoretical framework of new regional path development can stimulate further research in economic geography. Sixth, the developed simulation model may be a valuable tool for decision-makers, allowing them to simulate various scenarios, test policies, and anticipate the potential outcomes of different technological trajectories. Seventh, the project can contribute to understanding how technological transitions impact regional development. Insights into the factors influencing regional paths and interactions can guide efforts to promote balanced and sustainable growth across different regions. Finally, businesses, research institutions, and regional decision-makers can benefit from insights into new path development and innovation strategies in the context of the twin transition. Understanding how different paths evolve can inform strategic decision-making and foster a culture of innovation.

6. Bibliography

XXXV Annual Scientific Meeting - RSA AiIG 2024
" How AI is Changing Economic Systems, Organisations, and Society"
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- Binz, C., Truffer, B., & Coenen, L. (2016). Path creation as a process of resource alignment and anchoring: Industry formation for on-site water recycling in Beijing. *Economic Geography*, 92(2), 172–200. <https://doi.org/10.1080/00130095.2015.1103177>
- Du, J., Shen, Z., Song, M., & Zhang, L. (2023). Nexus between digital transformation and energy technology innovation: An empirical test of A-share listed enterprises. *Energy Economics*, 120. <https://doi.org/10.1016/j.eneco.2023.106572>
- European Commission. (2022). *Towards a green & digital future*. <https://doi.org/10.2760/977331>
- European commission. (2022). *Twinning the green and digital transitions in the new geopolitical context*. <https://publications.jrc.ec.europa.eu/repository/handle/JRC129319>.
- Grillitsch, M., Asheim, B., & Trippl, M. (2018). Unrelated knowledge combinations: The unexplored potential for regional industrial path development. *Cambridge Journal of Regions, Economy and Society*, 11(2), 257–274. <https://doi.org/10.1093/cjres/rsy012>
- Hassink, R., Isaksen, A., & Trippl, M. (2019). Towards a comprehensive understanding of new regional industrial path development. *Regional Studies*, 53(11), 1636–1645. <https://doi.org/10.1080/00343404.2019.1566704>
- Isaksen, A., Martin, R., & Trippl, M. (2018). New avenues for regional innovation systems - theoretical advances, empirical cases and policy lessons. In *New Avenues for Regional Innovation Systems - Theoretical Advances, Empirical Cases and Policy Lessons*. Springer International Publishing. <https://doi.org/10.1007/978-3-319-71661-9>
- Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, 6(4), 395–437. <https://doi.org/10.1093/jeg/lbl012>
- Montresor, S., & Vezzani, A. (2022). *Digital technologies and eco-innovation. Evidence of the twin transition from Italian firms*.
- Neuländtner, M. (2020). An empirical agent-based model for regional knowledge creation in Europe. *ISPRS International Journal of Geo-Information*, 9(8). <https://doi.org/10.3390/ijgi9080477>
- Parrilli, M. D., Fitjar, R. D., & Rodriguez-Pose, A. (2016). *Innovation Drivers and Regional Innovation Strategies*. www.routledge.com
- Ron Boschma, Pierre-Alexandre Balland, Julia Bachtroglér-unger, & Thomas Schwab. (2023). Technological capabilities and the twin transition in Europe Opportunities for regional collaboration and economic cohesion. *BERTELSMANN STIFTUNG (HRSG.)*. <https://doi.org/10.11586/2023017>
- Schamp, E. W. (2017). Evolutionary Economic Geography. In *International Encyclopedia of Geography*. <https://doi.org/10.1002/9781118786352.wbieg0997>
- Trippl, M., Baumgartinger-Seiringer, S., Frangenheim, A., Isaksen, A., & Rypestøl, J. O. (2020). Unravelling green regional industrial path development: Regional preconditions, asset modification and agency. *Geoforum*, 111, 189–197. <https://doi.org/10.1016/j.geoforum.2020.02.016>
- Veldhuizen, C. (2020). Smart Specialisation as a transition management framework: Driving sustainability-focused regional innovation policy? *Research Policy*, 49(6). <https://doi.org/10.1016/j.respol.2020.103982>

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" How AI is Changing Economic Systems, Organisations, and Society"
Palermo, October 10-11, 2024

Xu, J., Yu, Y., Zhang, M., & Zhang, J. Z. (2023). Impacts of digital transformation on eco-innovation and sustainable performance: Evidence from Chinese manufacturing companies. *Journal of Cleaner Production*, 393. <https://doi.org/10.1016/j.jclepro.2023.136278>