Driving Regional Development:

A Case-Based Perspective

Maione V.[1], Ponsiglione C.[1], Primario S.[1], Paier M.[2], Burscher T.[2]

(1) Dept. of Industrial Engineering – University of Naples Federico II – Italy

(2) AIT Austrian Institute of Technology GmbH

Abstract

Recent geopolitical tensions, energy shocks, and regulatory developments have intensified pressure for Europe's twin transition, exposing structural vulnerabilities and deepening regional disparities in adaptive capacity. Understanding how regions respond to these pressures requires a framework capable of capturing region-specific pathways of transformation. The regional path development framework offers a valuable lens to analyse how regions evolve through mechanisms such as extension, upgrading, diversification, importation, branching, or creation. Yet its application to the twin transition remains limited. Existing studies are often fragmented and case-specific, offering little comparative insight into how structural and institutional conditions shape regional engagement in green, digital, and twin transitions. To address this gap, this paper develops a configurational framework linking development paths to twin transitions, based on a review of regional case studies and operationalising the derived conditions through fuzzy-set Qualitative Comparative Analysis for Italian NUTS-2 regions. The resulting configurations are interpreted through the lens of path development, revealing how distinct combinations of structural and institutional factors correspond to different regional transition trajectories. The study contributes to bridging evolutionary economic geography and transition-oriented policy, offering a comparative diagnostic tool to support place-sensitive strategies across structurally diverse regional contexts.

Keywords – Twin Transition, Regional path development, Knowledge creation, Regional innovation systems, Complex systems

1. Introduction

The geopolitical and energy crises triggered by the war in Ukraine have intensified the urgency of Europe's green and digital transitions (European Commission, 2023b). These shocks have exposed structural vulnerabilities in global value chains and accelerated the decarbonisation agenda, while revealing stark interregional disparities in resilience, technological capacity, and innovation governance (European Commission, 2024). In parallel, the introduction of the EU's Artificial Intelligence Act has highlighted uneven regional readiness to engage with complex digital transformations (European Commission, 2021).

Understanding how regions respond to these pressures requires analytical tools capable of capturing territorially embedded and historically conditioned transformation pathways. Among existing approaches, the regional path development framework offers a promising lens to trace how regions evolve through mechanisms such as extension, upgrading, diversification, importation, branching, or creation. Reflecting this view, the European Commission has increasingly recognised that the twin transition must be understood as a territorially embedded challenge, shaped by uneven regional capacities to engage with green and digital transformation (European Commission, 2024), making it essential to analyse how region-specific development paths influence these responses.

Despite its conceptual relevance, the path development framework still lacks a shared operational architecture. Many empirical studies remain fragmented and case-specific, which limits comparability and hinders cumulative insight. Crucially, the relationship between path mechanisms and regional engagement in green, digital, and twin transitions remains largely underexplored.

This paper addresses these gaps by reviewing empirical cases through the lens of path development and proposing a configurational model linking path types to twin transition outcomes. Using fuzzy-set Qualitative Comparative Analysis (fsQCA) on Italian NUTS-2 regions (2007–2017), it identifies combinations of structural and institutional conditions that enable regional engagement in green, digital, and twin transitions.

The remainder of the paper is structured as follows. Section 2 outlines the theoretical background, reviewing key contributions from EEG. Section 3 presents the methodological approach, including case selection, operationalisation of variables, and the logic of fsQCA. Section 4 presents the model, while section 5 discusses the main results, highlighting the configurations of conditions conducive to twin transition outcomes. Finally, Section 6 concludes by summarising the theoretical and practical contributions of the study, outlining its limitations, and proposing directions for further research.

2. Literature Background

Understanding how regions transform their industrial base in response to transformative pressures—such as decarbonisation and digitalisation- has become a central concern in EEG and regional studies (Boschma, 2017). In this context, the concept of regional path development has gained analytical traction as a lens for capturing differentiated trajectories of structural change (Grillitsch et al., 2018; Hassink et al., 2019). Grounded in the distinction between path dependence and path creation (Martin & Sunley, 2006), the framework has evolved into a typology encompassing mechanisms such as extension, upgrading, branching, diversification, importation, and creation (Grillitsch et al., 2018; Hassink et al., 2019; Trippl et al., 2020). These categories offer a nuanced understanding of how regions evolve by combining established assets with emergent opportunities, under varying degrees

of disruption and directionality. Table 1 summarises the taxonomy of regional path development with its distinctive characteristics.

Table 1. Types and mechanisms of regional industrial path development

Type of path development	Definition
Path extension	Continuation of an existing industrial path based on incremental innovation in existing industries along well-established technological trajectories.
Path upgrading	
I – Climbing GPN	Major change of a regional industrial path related to enhancement of position within global production networks; moving up the value chain based on upgrading of skills and production capabilities.
II – Renewal	Major change of an industrial path into a new direction based on new technologies or organisational innovations, or new business models.
III–Niche development	Development of niches through the integration of symbolic knowledge.
Path importation	Setting up of an established industry that is new to the region (for example, through non-local firms) and unrelated with existing industries in the region.
Path branching	Diversification into a new related industry for the region building on competencies and knowledge of existing industries.
Path diversification	Diversification into a new industry based on unrelated knowledge combinations.
Path creation	Emergence and growth of entirely new industries based on radically new technologies and scientific discoveries or as an outcome of search processes for new business models, user-driven innovation and social innovation.

Despite its theoretical consolidation, empirical applications remain fragmented, often descriptive, and lacking shared operational criteria. While several illustrative case studies exist—ranging from path renewal and upgrading in Italian and Romanian regions to path creation through unrelated diversification in France—the link between path development and the twin transition remains underexplored. Most studies are qualitative and do not offer systematic or comparative insight into how specific trajectories enable engagement with green and digital transformations. To address this gap, we conducted a structured literature review and identified about thirty empirical case studies that could be consistently classified using the path development typology. This corpus forms the empirical foundation for our analysis.

Beyond these empirical limitations, a further constraint lies in the conceptual assumptions of the framework. While the typology captures a broad spectrum of regional transformation processes, it typically treats development paths as discrete and distinct. In reality, regional change often results from hybrid, overlapping, or even conflicting paths shaped by the interaction of multiple actors and institutional logics (Binz et al., 2016a; Grillitsch et al., 2018). This complexity becomes particularly salient in the context of the twin transition, which requires the simultaneous pursuit of decarbonisation and digitalisation. These processes often involve concurrent mechanisms of the typology yet demanding a more integrated analytical lens.

To the best of our knowledge, no study has systematically examined whether—and how—specific combinations of path development underpin regional engagement in the twin transition. Nor has the typology been empirically validated through comparative, cross-regional evidence. To fill this gap, we propose a configurational framework that links types of path development with twin transitions

based on a structured literature review of empirical cases. Because regional transformation results from complex causal structures, fsQCA is particularly well suited to identifying the combinations associated with twin transition outcomes (Ragin, 2014). Our empirical focus is on Italian regions, selected for their structural diversity and relevance within EU transition policy.

3. Methodology

Based on the conceptual framework outlined above, we conducted a structured literature review aimed at identifying empirical studies that explicitly apply the path development typology across regional contexts. The review followed a multi-stage protocol.

We queried Scopus using a combination of relevant keywords—including "regional innovation", "pathway", "path development", "smart specialisation", "industrial district", "extension", "branching", "diversification", "upgrading", "importation", and "creation". The search was limited to peer-reviewed articles written in English. No restriction was placed on geography or time. Exclusion criteria were applied to filter out studies from unrelated disciplines (e.g., psychology, medicine, arts and humanities). Each abstract was screened for references to European countries and NUTS-2 regions to focus the selection on case studies. This yielded a set of 228 publications. Thirteen items were subsequently excluded due to the unavailability of full-text access, resulting in a final corpus of 215 articles subjected to full-text analysis. Additional papers were included based on the research team's expert judgement. In total, 33 cases were systematically classified according to their dominant path development trajectory. Figure 1 summarises the literature review protocol.

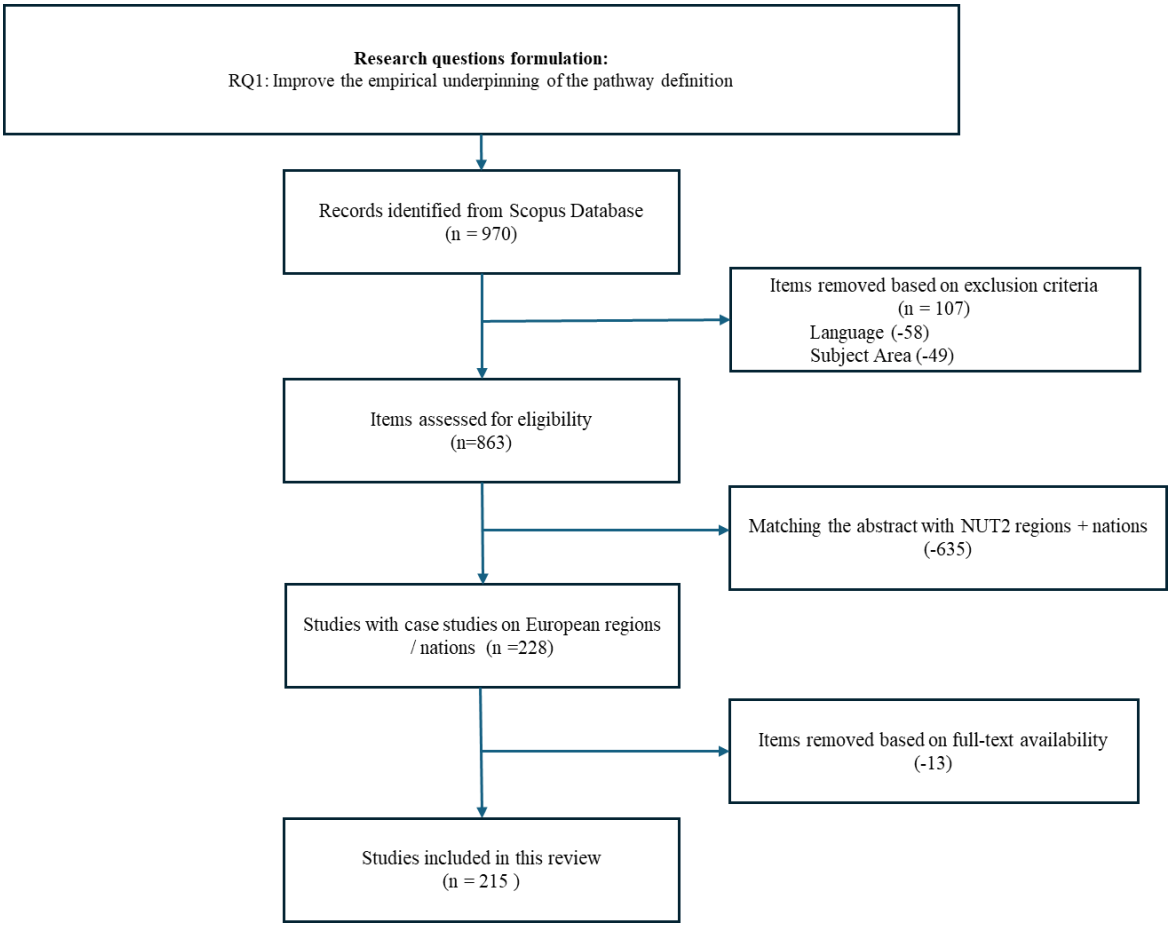

Figure 1. Literature review protocol

The outcome of the systematic review is summarised in Table 2, which reports the reference for each empirical case, the regional context investigated, and the corresponding types of regional development paths (RDPs) identified. This review was conducted by applying the taxonomy drawn from the literature (Grillitsch et al., 2018) to each case, based on the mechanisms explicitly described by the original authors. This systematic review provided the empirical foundation for the selection of causal conditions used in the fsQCA analysis.

Table 2. Regional Cases Classified by Path Development Mechanisms

Reference	Region	RDP
(Morisson & Mayer, 2021)	Vierzon	Path creation, Unrelated diversification
(Bellandi et al., 2021)	Macerata, Fermo, Sassuolo	Path Extension, Path Renewal
(Isaksen & Trippl, 2017)	Arendal-Grimstad, Mühlviertel	Path creation
(Trippl & Otto, 2009)	Styria, Saarland	Path creation, Path extension, unelated diversification
(Asheim, 2019)	Mazovia, Emilia Romagna	Path creation, Unrelated diversification, Path importation, Path upgrading
(Chaminade et al., 2019)	Prato, Boras	Path creation, Path extension, Path renewal
(Ostapenko et al., 2024)	Douro	Related branching, Path renewal
(Nieth & Radinger-Peer, 2023)	Aalborg, Kaiserslautern, Twente	Path creation, Path extension, Path upgrading, Path importation
(Nilsen & Njøs, 2022)	Norway	Path importation
(Corodescu-Roșca et al., 2023)	Timisoara, Cluj Napoca	Path extension, Path upgrading
(Binz & Gong, 2022)	California, Hamburg	Path creation, Path importation
(Wang et al., 2012)	Zhongguancun, Bangalore, Silicon Valley	Path creation
(Cassia et al., 2008)	Cambridge, Goteborg, Baden-Württemberg, Singapore, Pittsburgh, Milwaukee	Path renewal
(Simmie, 2012)	Denmark	Path creation
(Isaksen, 2015)	Lister	Path creation, Path extension
(Binz et al., 2016b)	Beijing	Path creation

Building on the review of regional development paths, we adopt a configurational approach to investigate whether specific combinations of path types are conducive to digital, green, and twin transitions. This methodological choice is grounded in a growing body of literature that conceptualises regional innovation systems as Complex Adaptive Systems —dynamic structures characterised by non-linearity, feedback loops, and emergent properties arising from interactions among heterogeneous agents (Ponsiglione et al., 2018). Such systems require analytical approaches that emphasise interdependence and contextual specificity (Cooke, 2013), particularly in relation to geographically mediated knowledge transfer influenced by institutional, scientific, financial, and policy environments (Asheim et al., 2011).

FsQCA is well suited to capture this complexity, as it accounts for causal asymmetry and equifinality (Rihoux & Ragin, 2012). Unlike regression-based methods, it does not assume additive or independent effects, but identifies condition sets that are jointly sufficient for a given outcome (Schneider & Wagemann, 2009). This aligns with the configurational paradigm in innovation studies, which emphasises that socio-economic outcomes emerge from interdependent condition combinations rather than isolated effects (Misangyi et al., 2017).

In this study, fsQCA is applied to Italian NUTS-2 regions, where the outcome corresponds to revealed technological advantage (RTA) scores in the green, digital and twin transition domains. Both the outcome and causal condition variables were calibrated into fuzzy sets using the direct method. Each condition is first tested for necessity, adopting a consistency threshold of 0.90. Subsequently, sufficiency is assessed by constructing and logically minimising the truth table, following standard procedures to derive complex, intermediate, and parsimonious solutions. Cases with an outcome score above 0.65 were included as positive instances for the analysis, and a minimum consistency threshold of 0.75 was applied to identify configurations considered empirically sufficient. The analysis was performed using fsQCA 3.1 software.

4. The model

This section describes the model used to investigate how combinations of regional development paths influence technological specialisation in twin transition domains.

The selection of causal conditions builds on both theoretical insights from EEG and empirical patterns emerging from the literature review. In particular, the conditions reflect two overarching categories: structural assets, which shape the baseline capacity of regions to innovate and diversify, and enabling mechanisms, which activate or sustain transformative processes. All causal conditions were calibrated as fuzzy sets using the direct method, based on three anchor points corresponding to the 25th percentile (full non-membership), the median (crossover point), and the 75th percentile (full membership) of their empirical distributions.

Table 3 presents the set of causal conditions included in the analysis, along with their operational definitions, sources, the association with different types of path development, and relevant references.

Table 3. Causal Conditions

Label	Dimension	Index	Source	References
UV	Unrelated Variety	Unrelated Variety	Eurostat	(Frenken et al., 2007)
EKIA	Structural complexity	Employment in Knowledge-intensive activities	Regional Innovation scoreboard	(European Commission, 2023a)
FDI	FDI Intensity	FDI inward stock % GDP	OECD	(Fu, 2007)
ICOLL	Collaborative R&D activity	Innovative SMEs collaborating with others	Regional innovation Scoreboard	(European Commission, 2023a)
PP	Policy Pressure	Historic EU payments annual timeseries - modelled	Cohesion Data	(Mohl & Hagen, 2010)
RII	Innovation Performance	Regional Innovation Index	Regional Innovation Scoreboard	(European Commission, 2023a)
NEWB	Entrepreneurial Activity	Business entries	OECD Data Explorer	(Fritsch, 2011)

The outcome is constructed using the indicator of revealed technological advantage (RTA), a widely used proxy for regional technological specialisation derived from patent data (Balland et al., 2019). RTAs were calculated separately for green and digital technologies using regionalised patent application data from the OECD REGPAT database. Green technologies correspond to the

"environment-related technologies" domain, while digital technologies include patents classified under "ICT", following the OECD taxonomy. RTA is calculated as follows:

$$RTA_{r,d} = \frac{\frac{P_{r,d}}{P_r}}{\frac{P_d}{P_T}}$$

where:

- $P_{r,d}$ is the number of patent applications in domain d filed in region r,
- P_r is the total number of patent applications filed in region r,
- P_d is the total number of patent applications in domain d across all regions,
- P_T is the total number of patent applications in all domains and regions.

An RTA value greater than 1 indicates that a region is more specialised than the national average in that domain. We construct three outcome variables: green RTA, digital RTA, and twin transition RTA. A region is considered engaged in the green or digital transition in a given year if its RTA exceeds 1 in the respective domain. Engagement in the twin transition is defined as meeting both conditions (green RTA > 1 and digital RTA > 1) in the same year. For each region, we compute the number of years (2018–2021) in which this twin condition is satisfied. The outcome is calibrated into fuzzy scores as follows: 0 years = 0.00 (full non-membership), 1 year = 0.33 (weak membership), 2 years = 0.67 (crossover), and 3–4 years = 1.00 (full membership). This dynamic operationalisation captures the persistence of twin specialisation over time.

5. Results

The necessity analysis confirms that no condition reaches the 0.90 consistency threshold for any of the three transition outcomes. This indicates that no single condition is independently necessary to produce the outcomes. For the digital transition, the highest consistencies are observed in EKIA (0.66), FDI (0.66), and ICOLL (0.65). In the green transition, FDI (0.87) approaches the threshold, followed by PP (0.78) and UV (0.70). For the twin transition, the most consistent conditions are again FDI (0.83) and PP (0.74), pointing to the recurrent role of external investments and institutional support across outcomes. In terms of coverage, all conditions fall below the 0.50 threshold. This is consistent with the logic of path development: the conditions included in the model were selected for their distinctive role in enabling specific types of trajectories. These findings support the configurational logic of the study, where regional engagement emerges from context-specific combinations of enablers. Summary results are provided in Table 4.

Table 4. Necessity analysis for the twin transition outcome.

Causal Condition	Consistency			Coverage		
	OUT D	OUT G	OUT TT	OUT D	OUT G	OUT TT
EKIA	0.66	0.60	0.68	0.35	0.23	0.19
ICOLL	0.65	0.59	0.48	0.33	0.22	0.13
NEWB	0.47	0.50	0.49	0.24	0.19	0.14
FDI	0.66	0.87	0.83	0.31	0.30	0.21
UV	0.56	0.70	0.59	0.27	0.25	0.15
PP	0.59	0.78	0.74	0.30	0.30	0.20
RII	0.23	0.22	0.05	0.11	0.08	0.013

The sufficiency analysis identifies distinct configurations of structural and institutional conditions associated with regional engagement in green, digital, and twin transitions. Interpreted through the lens of path development and grounded in empirical case knowledge, these configurations are reported in Tables 5, 6, and 7, which display core (large circles) and peripheral (small circles) conditions alongside corresponding regional cases and path types. The green transition configuration for Lazio, although slightly below the consistency threshold, is discussed because of its proximity to the cut-off.

Table 5. Sufficiency analysis for the digital transition outcome

	1	**2**
EKIA	⊗	●
ICOLL	●	●
NEWB	●	●
FDI	●	●
UV	⊗	⊗
PP	⊗	●
RII	⊗	⊗
Consistency	0.854831	0.892997
Raw coverage	0.129369	0.137941
Unique coverage	0.0981504	0.106722
Cases with greater than 0.5 membership in term	Lazio (0.52,1)	Lombardia (0.54,0.67)
Solution coverage	0.236091	
Solution consistency	0.895664	
Consistency cutoff	0.854831	
RDP	Path Importation	Path branching

Table 6. Sufficiency analysis for the green transition outcome

	1	**2**	**3**
EKIA	⊗	⊗	●
ICOLL	●	●	●
NEWB	●	⊗	●
FDI	●	●	●
UV	⊗	●	⊗
PP	⊗	●	●
RII	⊗	⊗	⊗
Consistency	0.744722	0.758054	0.791654
Raw coverage	0.153857	0.236881	0.166936
Unique coverage	0.13261	0.215297	0.144952
Cases with greater than 0.5 membership in term	Lazio (0.52,0.67)	Friuli-VeneziaGiulia (0.57,0.67)	Lombardia (0.54,0.67)
Solution coverage	0.514842		
Solution consistency	0.837737		
Consistency cutoff	0.744722		
RDP	Path Importation	Path Importation (Path branching)	Path branching

Table 7. Sufficiency analysis for the twin transition outcome

	1	**2**
EKIA	⊗	●
ICOLL	●	●
NEWB	●	●
FDI	●	●
UV	⊗	⊗
PP	⊗	●
RII	⊗	⊗
Consistency	0.715666	0.763186
Raw coverage	0.20323	0.221207
Unique coverage	0.182276	0.200253
Cases with greater than 0.5 membership in term	Lazio (0.52,0.67)	Lombardia (0.54,0.67)
Solution coverage	0.403483	
Solution consistency	0.815764	
Consistency cutoff	0.715666	
RDP	Path Importation	Path branching

In Lazio, path importation could support the digital and green transition and is enabled by ICOLL, NEWB, and FDI, suggesting a collaborative and entrepreneurial dynamic driven by external investment in a context of limited structural variety. These findings are consistent with recent evidence highlighting the role of open innovation and institutional brokerage in peripheral regions (Grillitsch & Sotarauta, 2020; Trippl et al., 2018), and align with policy insights emphasising that entrepreneurial ecosystems can compensate for structural weaknesses when adequately supported by investment and coordination mechanisms (Accenture, 2021). In Friuli-Venezia Giulia, the green transition is primarily linked to path importation, enabled by FDI, UV, PP, and ICOLL. This reflects a process of externally anchored transformation, supported by institutional pressure, sectoral variety, and knowledge inflows. The presence of ICOLL suggests that local actors are engaged in collaborative R&D activities, indicating the emergence of knowledge innovation. While RII is absent—limiting evidence of system-wide innovation output—the configuration could signal the activation of path branching, plausibly evolving from importation but not yet consolidated into a mature innovation path. This ambiguity reflects a broader limitation of typological approaches to path development: while conceptual distinctions help classify trajectories, regional processes are often more complex and may unfold through overlapping or hybrid path dynamics. In this case, Friuli-Venezia Giulia might represent a hybrid configuration where importation and branching co-evolve over time. In Lombardia, path branching is enabled by EKIA, ICOLL, NEWB, FDI, and PP, reflecting a structurally grounded diversification process sustained by collaborative innovation, entrepreneurial dynamism, and institutional pressure. This is consistent with both the evolutionary literature on path diversification (Boschma, 2017) and recent policy narratives identifying "twin transformation leaders" as territories capable of simultaneously leveraging digital and green trajectories (Accenture, 2021; European Commission, 2023b).

The recurrence of identical configurations across domains suggests that in both Lazio and Lombardia consistent enabling structures can underpin multiple transformation processes.

6. Conclusion

This paper has investigated whether different combinations of regional path development mechanisms are conducive to the twin transition. Drawing on a structured literature review and an fsQCA applied to Italian NUTS-2 regions, we proposed a configurational approach linking path development trajectories to empirical patterns of structural and institutional conditions. The findings support the assumptions of causal complexity and equifinality: no single condition is necessary, and multiple sufficient configurations are associated with twin transition outcomes. Importantly, the emerging configurations reveal combinations of path mechanisms underscoring the interdependence of trajectories rather than their mutual exclusivity.

These results illustrate that the twin transitions can be supported by different path development, depending on region-specific combinations of structural and institutional conditions. At the same time, the presence of overlapping causal patterns suggests that regional transformations often follow hybrid and context-dependent trajectories, rather than neatly bounded path types.

The contribution of this study is intended to be twofold. Conceptually, the study advances the empirical operationalisation of the path development framework. Methodologically, it introduces a configurational approach to regional transition analysis grounded in empirical evidence.

Nonetheless, this study has limitations. Calibration thresholds may influence sensitivity; fsQCA’s cross-sectional design limits temporal inference; and the classification of regions into discrete path

types is a simplification that does not fully capture the hybrid and overlapping nature of real-world trajectories.

Future work should extend this framework to cross-country comparisons and adopt dynamic QCA to capture the temporal sequencing of regional transformations. Integration with policy evaluation tools could further enhance its relevance for place-based transition strategies.

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