Institutions and the Complexity-Relatedness Nexus: A New Analytical Lens for Smart Specialization Strategy

Introduction and Objectives

Since its emergence in the 2010s, the Smart Specialization Strategy (S3) has become a cornerstone of Europe's innovation-led regional development agenda. S3 represents a bottom-up framework that rejects earlier one-size-fits-all policies, instead tasking regions with identifying niche domains for investment based on their existing local capabilities. The theoretical foundation of this strategy has increasingly relied on the principles of economic complexity and technological relatedness. As articulated by Hidalgo et al. (2018) and operationalized by Balland et al. (2019), this framework suggests that regions diversify most effectively by branching into technologies that are related to their current knowledge base (relatedness) and that offer higher value-added potential (complexity). However, a critical gap remains in this analytical framework. While the literature frequently emphasizes that institutional quality and governance capacity are vital for reducing lock-in risks and ensuring the success of diversification strategies, these factors are often treated merely as external context rather than integral components of the S3 analytical model. Scholars such as Rodríguez-Pose (2013) and Hassink and Gong (2019) argue that regions with low institutional capacity fail to reap the benefits of S3, suggesting that governance determines the feasibility of technological transformation. Despite this, key foundational studies, such as those by Balland et al. (2019) and Rigby et al. (2022), do not explicitly incorporate institutional capacity into the quantitative metrics used to prioritize regional strategies.

The primary objective of this study is to address this limitation by integrating institutional capacity directly into the analytical core of the complexity-relatedness framework. We hypothesize that institutional quality is not merely a background condition but a decisive factor that enables or inhibits the translation of technological potential into actual economic diversification. By constructing a new composite index that synthesizes technological complexity, relatedness density, and governance quality, this paper aims to provide a more robust, feasibility-aware tool for policy prioritization.

Data and Methodology

Data

To test our hypothesis, we utilized a dataset covering 235 NUTS-2 regions across 22 European Union member states. The analysis draws on three primary data sources. First, we derived measures of technological complexity and relatedness density from the OECD REGPAT database, utilizing patent applications under the Patent Cooperation Treaty (PCT) for the period 1996-2022. The analysis focuses on 4-digit IPC codes. Second, institutional quality is measured using the European Quality of Government Index (EQI) provided by the Quality of Government Institute at the University of Gothenburg. We utilized data for the available benchmark years: 2010, 2013, 2017, and 2021. And finally, regional economic performance indicators, including Gross Domestic Product (GDP), Gross Value Added (GVA), and employment rates, were sourced from the European Commission's ARDECO database and Eurostat.

Construction of the Composite Index

We first compute five year rolling averages of fractional patent counts by NUTS-2 regions and IPC 4-digit class to smooth annual volatility and capture medium term innovation trends. Although the raw data cover 1996-2022, the rolling series begins in 2000 because the first complete window is

1996-2000. Using these smoothed counts, we build a binary presence (specialization) matrix based on a patent adapted Balassa index (RTA), where a region is coded as present in a technology if it meets the standard RTA≥1 criterion. Because patenting can be highly concentrated in some IPCs, we follow Hausmann et al. (2024) and augment this rule using concentration information (HHI), ranking regions within each technology-year and coding additional effective contributors as present even if they fall below RTA≥1. This augmented presence matrix is then used to compute technological complexity via the fitness-complexity algorithm, employing the robust formulation of Servedio et al. (2018) (building on Tacchella et al., 2012) to ensure stable convergence in concentrated matrices through regularized iterative updates. In parallel, we estimate pairwise technological proximity between IPC classes using the conditional co-occurrence probability approach (Hidalgo et al., 2007), and we derive each region's relatedness density as the share of a missing technology's links that connect to technologies already present in the region's portfolio, averaged across technologies not yet present. These metrics, regional technological complexity and relatedness density, form the technological capability component that we later combine with institutional quality (EQI) to construct the *CDQGeo* composite index.

The core methodological contribution of this study is the construction of an institution-conditioned composite index. Standard approaches typically view regional potential as a function of technological relatedness and complexity (Balland et al, 2019; Rigby et al., 2022; Pinheiro et al., 2025; Balland and Boschma, 2025). We advanced this by calculating a composite score (*CDQGeo*) in two steps. First, we combined technological complexity ($C_{r,t}$) and relatedness density ($D_{r,t}$) using an arithmetic mean to represent a region's technological capability ($CD_{r,t}$). Second, we aggregated this technological score with the region's institutional quality ($Q_{r,t}$) using a geometric mean.

$$CDQ_{r,t}Geo = \sqrt{(CD_{r,t})^2 \times} (Q_{r,t})^2$$

The use of the geometric mean is deliberate and theoretically significant. Unlike the arithmetic mean, which allows strong performance in one dimension to fully offset weak performance in another, the geometric mean penalizes such imbalances, reflecting the theoretical reality that a region with high technological potential but weak institutions (or vice versa) has a lower overall capacity to implement complex diversification strategies effectively.

In addition, two alternative formulations of the composite indicator are tested to evaluate the robustness of the results. *CDQ*, a fully multiplicative version integrating all three dimensions (*C*, *D*, *Q*), and *CD-Mean*, an arithmetic average of technological complexity and relatedness density excluding institutional quality.

Econometric Strategy:

1. Entry Models: We used logit models to estimate the probability of a region developing a new Revealed Technological Advantage ($RTA > 1$) in a specific technology class over five-year windows (2010-2014 and 2017-2021). The model tests whether the composite index (*CDQGeo*) predicts technological entry better than metrics excluding institutions.

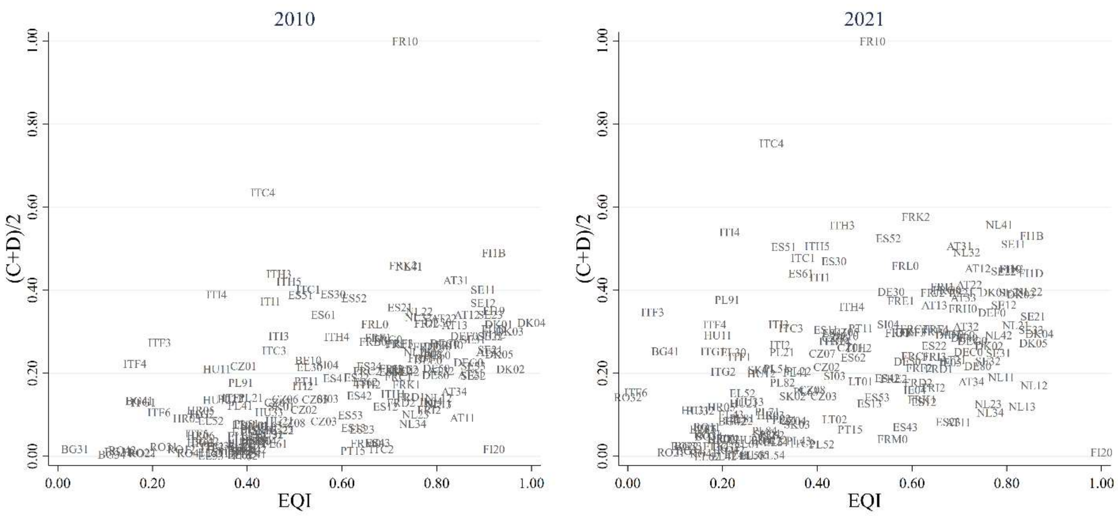
2. Economic Performance Models: We utilized twoway fixed effects panel regressions to assess the impact of regional capabilities on medium-term economic growth (GDP, GVA, and employment rate). The models control for labor, capital intensity, population density, and unobserved regional and temporal heterogeneity.

Additionally, the study examined spatial spillovers by including spatially weighted variables representing the average capabilities of neighboring regions within the same NUTS-1 administrative unit ($W^{(1)}$) and within the same country ($W^{(0)}$) to capture administrative and national ecosystem effects.

Empirical Results

The descriptive analysis of European regions between 2010 and 2021 reveals a persistent, positive association between institutional quality and technological capabilities. Regions such as Île-de-France, Lombardia, and Stockholm consistently cluster in the high performance quadrant (high complexity-relatedness, high institutional quality). Over the decade observed, the relationship between these variables has steepened. Regions with strong institutions have further advanced technologically, while those with weak governance have largely remained stagnant in less complex domains, indicating rising regional heterogeneity.

Figure 1: Institutional Quality (EQI) and Technological Capabilities ((C+D)/2) across European NUTS-2 Regions.



FI20 (Åland), an autonomous region of Finland, is a notable outlier because it has ranked first among EU regions in the European Quality of Government Index across all survey rounds from 2010 to 2024, indicating exceptionally high institutional quality (Charron et al., 2024). Yet the European Commission's Regional Innovation Scoreboard 2025 shows Åland has a markedly weaker research and innovation base than other Finnish regions. It ranks very low EU-wide in public and business R&D expenditure and in international and public-private co-publications, signalling thin research capacity and weak knowledge linkages (European Commission, 2025). This is largely explained by Åland's small, peripheral island economic structure, dominated by transport, shipping, tourism, and accommodation, with only a modest manufacturing sector.

The results from the logit models provide strong evidence that institutional quality is a critical determinant of diversification. The coefficient for the institution conditioned composite index (*CDQGeo*) is positive and statistically significant at the 1% level across all specifications. Specifically, a one unit increase in the composite index raises the odds of a region entering a new technological domain by nearly fivefold.

When comparing alternative index specifications, the importance of institutions becomes even clearer. The *CD-Mean* index (which averages only complexity and relatedness, excluding institutions) has a significantly lower explanatory power compared to the geometric composite indices (*CDQ* and *CDQGeo*) confirming that institutional capacity acts as a magnifying force. Regions with high complexity and relatedness are substantially more likely to realize their diversification potential if they also possess strong governance structures.

The fixed effects regressions demonstrate that the proposed composite index is a robust predictor of medium-term economic performance. The composite indices (*CDQGeo* and the fully multiplicative *CDQ*) are positively and significantly associated with growth in both GDP and GVA. In contrast, the *CD-Mean* index (technological factors only) fails to achieve statistical significance in many specifications. Finding for economic performance implies that high technological potential alone does not guarantee economic growth. It must be embedded within a supportive institutional context to translate into value added production. The analysis of labor market dynamics also mirrors the results for GDP and GVA growth. Regions with higher scores on the tripartite capability index (*CDQGeo*) experience significantly faster growth in employment rates.

However, the inclusion of spatial interaction terms revealed nuanced spillover effects. We observed positive externalities at the country level. Regions benefit from being located in countries with high average institutional and technological capabilities, suggesting that strong national innovation systems lift local performance. Conversely, spillovers within immediate administrative units (NUTS-1) exhibited negative interaction effects. The interaction term between a region's capability and that of its NUTS-1 neighbors was consistently negative implying diminishing marginal returns to local capability when neighbors are also highly capable, likely pointing to crowding out effects or competition for shared resources and skilled labor within the same administrative vicinity.

Discussion and Contribution

This study makes a contribution to the field of Evolutionary Economic Geography and regional policy design by empirically validating the concept of institutional embeddedness within the S3 framework. While previous literature acknowledged institutions as a background condition, our results show that they are part of the endogenous capability set that defines a region's growth trajectory.

The performance of the geometric composite index over the arithmetic technological mean (*CD-Mean*) confirms that structural capabilities (technology) and governance are multiplicative, not additive. A region cannot simply offset poor governance with slightly higher technological potential. Furthermore, the results clarify the dual role of institutions. They not only increase the probability of entering new domains (technological diversification) but also ensure that such diversification translates into tangible economic outcomes (GDP and employment growth).

The study also acknowledges limitations regarding its reliance on patent data, which may underrepresent innovation in service oriented or less developed regions. Additionally, the analysis focuses on medium term growth (3 year windows), which may not fully capture long term structural changes. Future research should aim to incorporate nontechnological capabilities, such as occupational or industrial skills, and test the framework over longer time horizons to further refine the understanding of how institutions condition regional development trajectories.

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