Geographical Core-Periphery and Network Convergence: Which European Regions Converge Most in European Knowledge Networks?

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European integration and the rapid expansion of cross-border R&D programs have raised an empirical question that can be phrased in explicitly network-theoretic terms: are European regions converging in their positions within the interregional knowledge network, or does the hierarchy remain persistent? The presentation addresses that question by modelling beta-convergence in regional network embeddedness. The main objective is to answer whether initially peripheral regions can catch up in network position relative to initially central ones. In order to do so, I'm using a multiplex representation of interregional knowledge connections rather than any single observable channel.

Prior work in network-based regional studies suggests that knowledge networks tend to exhibit strong core-periphery structure, where a small set of regions repeatedly occupy central positions and most others remain weakly connected. This phenomenon implies that convergence, if present, is likely to be weak, selective, and path-dependent rather than automatic. The preferential attachment nature of new link formation further limits the convergence possibilities of given regions. Empirical debates around the European Research Area similarly revolve around whether intensified cross-border collaboration reduces fragmentation or instead reproduces existing hierarchies through cumulative advantage of central regions by them attracting more partners, resources, and visibility. In this framing, convergence is not judged by aggregate participation growth, but by changes in relative position. To measure convergence from this aspect, I analyze whether the distribution of centrality and coreness becomes less concentrated over time. Accordingly, convergence is assessed separately for connectedness (centrality-based access to partners) and for hierarchical position (core-periphery coreness), because these dimensions can evolve differently even when overall collaboration intensity rises.

A second strand of the literature highlights that the knowledge network is not a single object: interregional connectivity is observed through multiple relational layers (co-patenting, project collaboration, co-authorship), each capturing different mechanisms and actor populations and each subject to distinct biases. This creates a direct implication for convergence analysis: conclusions drawn from one layer may reflect that layer's institutional logic rather than a general shift in Europe's knowledge-network topology. A multiplex approach, by contrast, treats convergence (or divergence) as a property of the joint structure of knowledge ties, enabling tests of whether catch-up appears consistently across indicators and whether observed trends survive once core-periphery geographies are introduced into the regression framework by placing the research into the framework of dual core-periphery setup.

The analysis operationalizes European knowledge-network convergence as beta-convergence in regional network position within a multiplex interregional collaboration network. The multiplex is built by combining three complementary relational layers, which are collaborative

patenting, EU Framework Programme project collaboration, and scientific co-authorship. The analyses were conducted using and aggregated multiplex network of European Union's NUTS3 regions. To avoid drawing conclusions from a single, institution-specific collaboration channel, the multiplex construction applies a uniform weighting logic across layers so that subsequent indicators capture changes in relative embeddedness rather than artefacts of one data source's scale or density.

Convergence is tested with cross-sectional beta-convergence regressions that relate the change in network position, to the initial network position. Network position is measured with two complementary outcomes: a connectedness indicator (degree-based centrality) and a structural hierarchy indicator (alpha-coreness, a continuous core-periphery indicator). Regions with no observed participation in a given layer/year are treated as having zero network position (substantively: no ties and hence minimal access/brokerage advantages), avoiding the misinterpretation of non-participation as missing data. The baseline beta-convergence specification is then extended by introducing geographical core-periphery topologies directly into the regression framework: (i) an urban-rural settlement-hierarchy dimension and (ii) a pre-/post-2000 EU-accession divide (capturing the old vs new member state division). This staged modelling strategy is designed to show whether any estimated catch-up in network position is (a) present in the aggregate and (b) systematically conditioned by Europe's enduring spatial hierarchies.

Across the baseline OLS specifications, the estimates provide consistent evidence of (weak) beta-convergence in regional network positions over the period (change between the 2001-2003 and 2017-2019 averages). In both dependent variables (degree centrality and alpha-coreness) the coefficient on the initial network value is negative and the relationship is statistically significant, implying that regions starting from a more peripheral network position tended, on average, to improve slightly more than initially central regions. These are signs in the direction of some level of convergence within the multiplex network. At the same time, the overall magnitude of convergence remains limited, aligning with the broader interpretation that only a relatively small subset of regions achieved meaningful upward movement in the European knowledge-network hierarchy. The macro controls behave stably across models: R&D intensity is consistently negative and significant, while GDP is particularly strongly and negatively related to alpha-coreness change (suggesting that already more developed regions did not systematically move further toward the core in core-periphery terms during the period, or in other words, the relative position within the network changed better for the less developed, typically peripheral regions of the sample.

When geographical core-periphery topologies are introduced, two patterns stand out. First, the urban-rural dimension is strongly associated with network upgrading: relative to rural regions, urban (and, for degree centrality, intermediate regions as well) exhibit significantly larger improvements in network position. Second, the pre- vs post-2000 EU-accession divide matters in a way that depends on the network indicator. For degree centrality, the "East-West"

(EU13 vs EU15) dummy is not statistically significant, implying that the main structural difference is captured better by the urban-rural split. By contrast, a continuous core-periphery proxy (distance from Brussels) is positive and significant, indicating stronger degree centrality improvements further from the socio-economical center of Europe. For alpha-coreness, however, the "East" (post-2000 accession) effect becomes positive and significant, indicating that regions in later-accession member states improved their relative position in the core-periphery structure; similarly, greater distance from Brussels is associated with larger alpha-coreness gains during the examined time period. In combined models that consider both geographical dimensions jointly, model fit improves, and the positive convergence signal is traced mainly to eastern urban and to a lesser extent eastern intermediate regions, while western rural regions display the weakest catch-up dynamics in pairwise coefficient comparisons.

Taken together, the regression evidence points to statistically significant, but substantively modest beta-convergence in European interregional knowledge-network positions: regions that were initially more peripheral tended to improve slightly more over 2001-2003 to 2017-2019, yet the overall hierarchy remains sticky. Importantly, convergence is not spatially neutral. Once geographical core-periphery topologies are accounted for, the estimated catch-up is largely structured by urban-rural divides and (especially for core-periphery-type alpha-coreness) by the pre-/post-2000 accession cleavage. In other words, the results are more consistent with selective, position-dependent upgrading than with broad-based equalization: improvements are concentrated among particular regional types (notably more urbanized and, in some specifications, later-accession regions), rather than reflecting a generalized flattening of Europe's knowledge-network core-periphery structure.

The findings imply that policies aiming at network convergence should be designed around structural constraints implied by geography and settlement hierarchy, not merely around raising R&D spending or participation counts. Since urban regions show systematically stronger upgrading, peripheral/rural regions may require connectivity-oriented interventions (e.g., brokerage support, incentives for cross-regional consortia roles beyond junior partnership, and instruments that help local actors access non-redundant external ties) rather than place-blind innovation funding. Likewise, the positive association of later-accession status (and/or distance from Brussels) with improvements in alpha-coreness suggests that cohesion-style instruments can foster some catch-up in the structural core-periphery network-yet the modest overall convergence warns against assuming that integration alone dissolves hierarchy. For evaluation, this argues for monitoring network-position outcomes (centrality and coreness trajectories) alongside traditional outputs, because the regressions show that who connects to whom, and from where is a key mediator of longer-run regional innovation potential.