

Extended abstract

Title: Exploring regional disparities in R&D efficiency: A stochastic frontier approach

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One legacy of neoclassical economics is the premise that technological change is fundamental for promoting long-term economic development (Solow, 1956; Romer, 1990). Hence, in 2000, the European Union (EU), in its first economic growth strategy (known as the Lisbon Strategy), positioned technological development and innovation as primary variables for promoting the productivity, cohesion, and international competitiveness of EU regions. Between 2000 and 2010, the concern for innovation shown by European growth and innovation policy translated into a concern for investing in research and development (R&D). In the Lisbon Strategy, the EU set a target of achieving 3% of gross domestic expenditure on R&D (GERD), arguing that this would contribute to the economic development of the EU. As discussed by Rubiera and Fernández (2023), achieving this target would generate more than 400,000 jobs per year in the EU and increase the GDP growth rate by 0.5% per year. The EU has increased GERD in recent decades, starting from levels close to 1.8% at the beginning of the century and currently (2025) reaching levels close to 2.3%. On the other hand, several regions in Central and Northern Europe have moved beyond this goal, exceeding 3%.

In recent decades, the EU has allocated substantial funding for R&D through its framework programs. However, income gaps persist and even widen at the top of the income distribution (Diemer et al., 2022). The EU suspected that the reason for this contradictory scenario lies in the inefficient use of resources and, as a consequence, has mandated the design of a Regional Smart Specialization Strategy (RIS3) according to which each European region can access funds under the EU cohesion policy for the period 2014–2020. The development of an RIS3 involves a thorough diagnosis of the regional economy, identifying its strengths and weaknesses, understanding the productivity or specialization of its economic sectors, and seeking out opportunities for economic growth that is tailored to the specific circumstances of each region (European Commission, 2015; Capello and Kroll, 2018). As a result of the need to develop RIS3, a body of literature has emerged that explores in detail the sectoral characteristics of regions in relation to their

innovative potential (e.g., Boschma and Ginelle (2014); Lo Conte et al. (2025); Capello and Kroll (2018)).

One perspective that has not yet been explored is the understanding of regional risks. Risks have been identified in the failure to effectively leverage regional assets for the fostering of development through technological and knowledge-based advancement. These shortcomings may undermine the RIS3 objectives, in particular through phenomena such as regional lock-ins and the perpetuation of existing industrial structures without sufficient diversification. Regions having very weak foundations lack an economic system and a business and innovation network to pursue significant specializations. Therefore, knowing whether the regional strategy is at risk means understanding whether resources are efficiently employed. Recent EU strategies, such as Europe 2020 and Horizon Europe, not only continue to promote R&D funding but also emphasize the need for territories to be efficient (European Commission, 2010; Silander, 2019; European Commission, 2020). This R&D efficiency refers to the region's ability to optimize expenditures for maximizing innovation outputs. In other words, the measurement of regional R&D efficiency could help evaluate whether each RIS3 is properly designed: low levels of regional R&D efficiency could indicate an incorrect design in growth and innovation policies, which suggests room for improvement.

In light of this evidence, in this study, we measure and analyze the R&D efficiency of EU regions in terms of their capacity to maximize innovation outputs. For this purpose, we make use of a parametric stochastic frontier (SF) model to estimate R&D efficiency, using patents as the innovation output. The main advantages of this method over other nonparametric alternatives are that it allows for more flexible use of panel data, distinguishes random noise from inefficiency, and is less sensitive to outliers, thereby permitting more efficient inference (Asmare and Begashaw, 2018). Most importantly, it allows for the simultaneous estimation of efficiency values, combining the production function and the effects of external inefficiency determinants in a one-stage approach, thereby avoiding potential estimation bias arising in two-stage strategies (Simar and Wilson, 2007). To this end, we construct a database containing socioeconomic and demographic data on European regions gathered from the OECD and Eurostat databases for the period 2008–2021. The choice of NUTS-2 level data is justified by two main considerations. First, this is the aggregation level at which European innovation policies are applied, and RIS3 is established; thus, we consider this spatial scale the most appropriate since our results can contribute to evaluating the appropriateness of these strategies and thus provide valuable information for regional policy-making. Second, the NUTS-2 reference unit is the most disaggregated for which information on crucial variables for our analysis, such as R&D investment, is available. On the other hand, we

select our analysis period on the basis of data availability for the considered set of variables and spatial units.

This paper makes a threefold contribution. First, to the best of our knowledge, it represents the first measurement of regional R&D efficiency in Europe. Consequently, it provides a first snapshot of the efficiency of European regions in allocating resources to the promotion of innovation. As mentioned, this new knowledge opens the door for policy-makers to analyze the spatial patterns and characteristics of regions performing better or worse and, importantly, identifying less efficient regions where RIS3 consequently has room for improvement.

Second, the results have major implications for the possible explanation of regional European growth and convergence dynamics. While the literature has focused predominantly on the direct relationship between R&D and economic growth, it has overlooked an important intermediate step, namely, the efficiency with which R&D resources are used. This step is crucial, as it may shape regions' innovation performance and, in turn, their long-term growth dynamics.

This study provides empirical evidence on how regional differences influence the use of R&D resources and thus the generation of innovation outputs; consequently, they may contribute to divergent economic growth trajectories derived from heterogeneous R&D efficiency performance.

Third, from a policy-related perspective, R&D EU goals should be established. This paper raises a question about the effectiveness of the current EU GERD target. Our results suggest that while the high-investing regions are, in fact, the best performers (on average), there is marked heterogeneity. This means that some regions are increasing their investment, but this does not translate into higher innovation output. On the other hand, there is still a deep and constant center-periphery efficiency gap among European regions, which has widened over time. Thus, well-targeted and tailored innovation policies—focused not only on increasing investment but also on enhancing the efficient use of regional resources—are emphasized to foster balanced economic growth and mitigate the risk of regional income traps.