Spending More or Spending Smarter? A Panel Data Analysis of EU Regional Productivity

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Abstract

The European Union has pursued productivity convergence with the United States through sustained public research and development funding for two decades, most recently formalized in the 2024 Draghi report's proposed investment programme exceeding €800 billion annually. This paper examines whether public R&D investment raises regional productivity across the EU, and whether the institutional quality of the recipient region moderates that relationship. Using panel data on 215 EU NUTS-2 regions between 2016 and 2023, constructed from Eurostat regional statistics and the European Quality of Government Index, this paper finds that the conventional approach to this question — entity-only fixed-effects panel estimation — produces results that do not survive the inclusion of year fixed effects, the specification the underlying model formally requires. The entity-only specification yields a statistically significant positive R&D-productivity elasticity; this result loses significance, and reverses sign, once year effects absorb a strong common temporal trend shared by productivity and R&D expenditure across the panel period. The credible evidence instead derives from the cross-sectional dimension: a between-effects estimator, immune to the trend confound by construction, indicates a robust positive association between public R&D and productivity, accompanied by a significant negative interaction with institutional quality. This pattern is consistent with diminishing marginal returns near the productivity frontier rather than the institutional complementarity typically assumed in this literature, and suggests that EU cohesion policies conditioning R&D allocation on strong institutional governance may misallocate capital relative to where marginal returns are largest.

Points for Practitioners

Three findings from this analysis bear directly on the design and implementation of EU cohesion and innovation policy. First, claims that public R&D expenditure drives regional productivity growth, when derived from short panel datasets that do not separately control for EU-wide annual conditions, should be treated with caution; this analysis demonstrates, using Eurostat data spanning 2016 to 2023, that a statistically robust-appearing R&D-productivity relationship can be substantially attributable to a shared macroeconomic trend rather than a causal regional mechanism. Second, no evidence is found that institutional quality amplifies the productivity return to public R&D investment; the cross-sectional evidence instead indicates the opposite pattern, with regions further from the EU productivity frontier exhibiting larger marginal returns to equivalent investment than frontier-proximate, well-governed regions. Third, this finding does not imply that institutional quality is immaterial to cohesion policy outcomes absorption capacity and implementation effectiveness remain legitimate and well-

documented concerns. It does imply that using institutional quality specifically as a gatekeeping criterion for R&D fund allocation may direct capital toward regions where marginal productivity returns are comparatively smaller. Allocation frameworks that condition R&D funding on governance benchmarks should distinguish between governance as a precondition for effective fund absorption and governance as a determinant of investment productivity; the evidence presented here speaks only to the latter, and points in the opposite direction from what conditionality frameworks typically assume.

Key Words

Cohesion policy, Governance, Panel data, Productivity, Research and development

1. Introduction

The European Union's strategy for closing its productivity gap with the United States rests substantially on continued and expanded public investment in research and development. The 2024 Draghi report on European competitiveness documents the scale of the underlying shortfall — EU labour productivity growth has trailed the United States by a factor of roughly three since 2000, despite broadly comparable public R&D expenditure as a share of GDP — and proposes a coordinated investment programme exceeding €800 billion annually. This proposal rests on the assumption that scaling public R&D investment produces approximately proportional productivity gains across the Union's regional landscape.

This paper examines that assumption at the sub-national level, asking whether the productivity return to public R&D investment varies systematically with the institutional quality of the recipient region. The dominant theoretical expectation, drawn from the knowledge production function tradition (Griliches, 1979) and the institutions-as-fundamental-causes literature (Acemoglu, Johnson and Robinson, 2001, 2005), predicts positive moderation: better-governed regions should extract larger productivity gains from identical R&D investment, since institutional quality determines the efficiency of resource allocation, technology transfer, and contract enforcement. This expectation has been advanced specifically for EU cohesion policy by Farole, Rodríguez-Pose and Storper (2011) and Ketterer and Rodríguez-Pose (2018).

The empirical analysis is based on a panel of 215 EU NUTS-2 regions observed from 2016 to 2023, constructed from Eurostat regional statistics and the European Quality of Government Index (EQI). The analysis identifies a specification problem with direct implications for how this literature should be interpreted. Entity-only fixed-effects estimation — region effects without year effects, the specification conventionally applied in EU regional panel research — produces a statistically significant, positive R&D-productivity elasticity. This result does not survive the inclusion of year fixed effects, the specification the underlying production-function model formally requires. The reversal is attributable to a common temporal trend: EU-wide productivity and public R&D expenditure both increase nearly monotonically across the panel period, with a correlation between their annual trajectories of 0.92. An estimator without year-specific controls cannot distinguish a causal R&D effect from two series exhibiting coincident upward drift for unrelated reasons.

The cross-sectional dimension of the panel is unaffected by this confound. A between-effects estimator, which uses only the time-averaged values of each region, indicates a robust positive association between public R&D investment and productivity, accompanied by a significant negative interaction with institutional quality: better-

governed regions exhibit smaller, not larger, marginal returns to R&D investment. This pattern is consistent with convergence dynamics — diminishing marginal returns near the productivity frontier — rather than with the institutional complementarity mechanism conventionally assumed in this literature.

This paper makes three contributions. First, it documents a specific and replicable sensitivity of short-panel R&D-productivity estimates to year-fixed-effects specification, with implications extending beyond the present dataset. Second, it provides between-effects evidence of a negative R&D×governance interaction at NUTS-2 level that diverges from the positive-complementarity assumption embedded in several EU cohesion policy frameworks. Third, it establishes the empirical basis for an instrumental variable strategy as a necessary extension for credible causal identification.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature. Section 3 describes the data, including the strategy applied to address attrition arising from missing R&D expenditure observations. Section 4 presents the econometric methodology and the rationale for comparing three estimators. Section 5 reports results. Section 6 discusses their interpretation. Section 7 concludes. Section 8 addresses limitations.

2. Literature Review

2.1 Public R&D and Regional Productivity

The proposition that R&D expenditure generates productivity gains beyond the investing unit originates with Griliches (1979), whose knowledge production function established the standard framework for treating R&D as an input generating measurable output externalities. Hall, Mairesse and Mohnen (2010), surveying several decades of subsequent empirical work, report social returns to R&D in the range of 30 to 80 percent, substantially exceeding private returns — the conventional rationale for public R&D investment on allocative efficiency grounds.

Regional-level evidence indicates substantial heterogeneity in these returns. Bronzini and Piselli (2009), examining Italian regions, find significant but geographically uneven productivity returns to public R&D, human capital, and infrastructure investment. Moreno, Paci and Usai (2005) demonstrate that R&D spillovers at NUTS-2 level are spatially bounded, indicating that regional context shapes both the generation and diffusion of knowledge.

Two recent contributions bear directly on the present analysis. Gianelle et al. (2023), employing a spatial general equilibrium model calibrated on Italian NUTS-2 data, find that the quality of regional innovation policy governance materially determines the magnitude of total factor productivity gains realised from cohesion-funded R&D investment, with poorly governed regions failing to realise a substantial share of potential GDP impact. Borsekova et al. (2025), applying decision-tree classification across 233 EU NUTS-2 regions, find that institutional quality functions as a necessary condition for innovation-led regional growth, with regions exhibiting high innovation capacity but weak governance failing to convert that capacity into sustained productivity gains. Both studies indicate institutional quality as a positive moderator of R&D effectiveness, a finding the present analysis does not replicate for the productivity-elasticity relationship specifically.

This literature has not, to the author's knowledge, systematically examined the sensitivity of short-panel R&D-productivity estimates to year-fixed-effects specification, a gap the present analysis addresses directly.

2.2 Institutions, Governance, and the Complementarity Hypothesis

North (1990) distinguishes formal rules from informal constraints as determinants of economic performance. Acemoglu, Johnson and Robinson (2001) extend this through an instrumental variable strategy demonstrating that institutions explain a substantial share of cross-country income variation independent of geography. The standard extension to a conditional production function predicts positive moderation: institutional quality should improve the efficiency with which any given input converts to output.

Applied to EU regional policy, Farole, Rodríguez-Pose and Storper (2011) argue that the limited relationship between cohesion expenditure and regional convergence reflects the mediating role of institutional quality in determining investment efficiency. Ketterer and Rodríguez-Pose (2018) provide cross-sectional evidence that structural fund effectiveness increases with regional institutional quality. The between-effects results reported in Section 5 diverge from this pattern: the estimated cross-sectional interaction between R&D and governance quality is negative rather than positive.

2.3 Convergence and Diminishing Returns as an Alternative Explanation

Standard neoclassical convergence theory (Solow, 1956; Barro and Sala-i-Martin, 1992) predicts that regions further from their productivity frontier exhibit larger marginal returns to capital and technology investment, since diminishing returns have not yet exhausted available efficiency gains. Where institutional quality correlates with proximity to the frontier — better-governed regions typically exhibiting higher existing productivity levels — this generates a prediction observationally distinct from, though superficially similar to, the complementarity hypothesis: higher-governance regions should exhibit smaller marginal R&D returns as a mechanical consequence of diminishing returns, independent of any causal institutional channel.

Distinguishing between these two explanations requires the three-estimator comparison developed in Section 4: entity-only fixed effects, two-way fixed effects, and between-effects estimation, each exploiting a distinct dimension of variation in the panel.

2.4 Measuring Institutional Quality: The European Quality of Government Index

The institutional quality measure applied throughout this analysis is the European Quality of Government Index (EQI), constructed by Charron, Dijkstra and Lapuente (2014) at the University of Gothenburg's Quality of Government Institute. It is the only governance measure available at NUTS-2 resolution across the European Union, and is consequently the only viable option for regional-level analysis of this kind; national-level governance indices exist in greater number but would eliminate the within-country regional variation central to this analysis. Charron, Dijkstra and Lapuente document substantial governance variation within individual member states. Their analysis is primarily descriptive and does not embed institutional quality within a conditional production function using panel data, a gap the present analysis addresses.

3. Data and Variables

The dataset combines regional productivity, R&D expenditure, education, and training data from Eurostat's regional statistics with institutional quality data from the European Quality of Government Index. Eurostat's NUTS-2 classification was substantially revised in 2016, with several member states — France most significantly

— altering regional boundaries and codes. A region-code correspondence table was constructed to reconcile pre- and post-2016 regional identifiers across source tables, cross-validated against Eurostat's official NUTS 2021 correspondence documentation, ensuring consistent region-year matching across the productivity, R&D, education, and training datasets.

3.1 Dependent Variable: Regional Labour Productivity

Productivity is measured as GDP at purchasing power standards per hour worked, drawn from Eurostat's regional accounts (nama_10r_2lp10) and expressed in natural logarithms. The logarithmic transformation is standard practice for this variable, both due to the substantial cross-regional range in productivity levels observed in the sample (approximately tenfold between the least and most productive regions) and because it permits coefficients to be interpreted on an approximate elasticity scale.

3.2 Public R&D Expenditure: Construction, Data Attrition, and Interpolation Strategy

Public R&D expenditure (X1) is measured as government and higher-education sector R&D spending in purchasing power standards, drawn from Eurostat's regional R&D database (rd_e_gerdreg) and expressed in natural logarithms. All explanatory variables enter the model at a two-year lag ($t-2$), consistent with standard treatment of R&D absorption periods in the regional innovation literature (Griliches, 1979; Bronzini and Piselli, 2009), reflecting the expectation that R&D investment requires a multi-year period before generating measurable productivity effects.

Eurostat's regional R&D database exhibits substantial missingness: approximately one-third of required region-year observations were initially unavailable, concentrated in regions where data is published biennially rather than annually, and in three member states (the Netherlands, Belgium, and France) where sub-national R&D figures are not consistently disaggregated below NUTS-1 level. Listwise deletion of these observations was rejected on two grounds. First, it would discard a substantial share of usable panel variation. Second, and more significantly, preliminary analysis indicated that regions with missing R&D data differ systematically from regions with complete data: excluded observations exhibit significantly higher productivity (mean log productivity 3.890 versus 3.620, $t=-10.63$, $p<0.001$) and significantly higher institutional quality (mean EQI 0.714 versus 0.055, $t=-9.70$, $p<0.001$) than retained observations. Listwise deletion under these conditions would systematically exclude high-productivity, high-governance regions from the analytic sample, biasing subsequent estimates of the relationship between governance and R&D returns.

Within-region linear interpolation was applied to address this attrition. For regions with at least two years of observed X1 data, missing values were recovered through linear interpolation between known observations (interior gaps) or extrapolation from the nearest known value (boundary years, including regions with a single observed year). This procedure recovered 353 of the 611 initially missing observations, expanding the analytic sample from 1,326 to 1,679 region-year observations across 215 regions. A residual 224 observations remain unrecoverable due to the complete absence of regional GERD data at any point in the panel for the affected regions, concentrated in the Netherlands (96), Belgium (80), France (32), and Spain (16). Each interpolated observation retains a source flag, permitting direct sensitivity testing reported in Section 5.4; results are materially unchanged whether interpolated observations are included or excluded.

Given the directional attrition bias documented above, the negative governance-moderation effect reported in Section 5 should be interpreted as a conservative estimate of the underlying population-level relationship, since the regions most likely to be under-represented in the analytic sample are precisely those exhibiting the highest institutional quality.

3.3 Education, Training, and Institutional Quality

Two further explanatory variables are drawn from Eurostat's labour force survey data: the share of the working-age population holding a university-level qualification (edat_lfse_04), and the share of adults aged 25 to 64 participating in formal or non-formal learning in the four weeks preceding survey (trng_lfse_04). Both variables serve as standard human-capital controls and permit a test of whether the institutional-moderation pattern identified for R&D generalises to other policy-relevant inputs, addressed in Section 5.

Institutional quality (W) is the EQI described in Section 2.4, standardised and linearly interpolated to an annual series between the index's five survey waves (2010, 2013, 2017, 2021, 2024), then lagged two years consistent with the remaining regressors. EQI is not published at NUTS-2 resolution for all member states; where regional-level data is unavailable, a country or NUTS-1 average is substituted, affecting approximately one quarter of the sample, predominantly in Germany, Belgium, and several smaller member states with limited sub-national governance data availability.

3.4 Sample Overview

The final analytic sample comprises 1,679 region-year observations across 215 of the European Union's 243 NUTS-2 regions, spanning 2016 to 2023. Table 1 reports descriptive statistics for the core variables.

Table 1: Descriptive Statistics (N=1,679 region-years, 215 NUTS-2 regions, 2016–2023)

Variable	Mean	Std. Dev.	Min	Max
Productivity (log, PPS/hour)	3.620	0.374	2.522	4.801
Public R&D (log, PPS)	5.099	1.503	0.331	8.571
Tertiary education (%)	29.25	9.34	11.40	60.60
Adult training (%)	10.05	7.25	0.50	36.50
Institutional quality (EQI, standardised)	0.055	0.984	-2.412	2.713

Source: author's calculations from Eurostat regional accounts (nama_10r_2lp10), Eurostat regional R&D statistics (rd_e_gerdreg), Eurostat regional labour force survey data (edat_lfse_04, trng_lfse_04), and the European Quality of Government Index, Quality of Government Institute, University of Gothenburg.

Mean regional productivity corresponds to approximately €37 per hour, consistent with published EU regional productivity benchmarks for the period under analysis.

4. Research Methodology

The primary specification is given by:

$$Y_{it} = \beta_1 X_{1,i,t-2} + \beta_2 X_{2,i,t-2} + \beta_3 X_{3,i,t-2} + \beta_4 W_{i,t-2} + \beta_5 (X_1 \times W)_{i,t-2} + \alpha_i + \delta_t + \varepsilon_{it}$$

where Y denotes log productivity, X1 log public R&D expenditure, X2 tertiary education attainment, X3 adult training participation, and W institutional quality (EQI); α_i denotes region fixed effects and δ_t denotes year fixed effects. The interaction term X1×W tests whether the R&D-productivity relationship varies with institutional quality, the central question addressed by this analysis. Two further specifications replace X1×W with X2×W and X3×W respectively, testing whether the interaction pattern generalises to education and training inputs.

4.1 Estimator Comparison: Identification Strategy

Three estimators of the model specified above were compared, each exploiting a distinct dimension of variation in the panel.

Entity-only fixed effects (region effects, no year effects) constitutes the specification conventionally applied in the EU regional panel literature. This estimator identifies from within-region variation over time but does not absorb shocks common to all regions in a given year, leaving common temporal trends undifferentiated from genuine within-region signal.

Two-way fixed effects (region and year effects) corresponds to the specification the model above formally requires. Year effects absorb shocks and trends common across all regions in a given year, isolating the idiosyncratic within-region variation remaining once both region-specific levels and EU-wide annual effects are removed.

Between-effects estimation uses only the cross-sectional dimension, collapsing each region to its time-averaged value. This estimator is immune to common-trend confounds by construction, since it contains no temporal dimension to confound. It is, however, vulnerable to omitted variable bias arising from unobserved, time-invariant regional characteristics correlated with both the explanatory variables and the outcome. Unlike the fixed-effects estimators, between-effects estimation cannot net out time-invariant regional heterogeneity — geography, historical industrial structure, accession timing, or other persistent regional characteristics — that may be correlated with both institutional quality and the R&D-productivity relationship. Results derived from this estimator should accordingly be interpreted as documenting a robust cross-sectional association rather than an isolated causal effect; this limitation is addressed explicitly in Sections 5.3 and 6.4.

If the R&D-productivity relationship reflects a genuine within-region mechanism, entity-only and two-way fixed-effects estimates should be comparable, net of efficiency loss. If the relationship instead reflects a common temporal trend, the two specifications diverge systematically: entity-only estimates are inflated by the unmodelled trend, while two-way estimates are attenuated once the trend is absorbed. Between-effects estimation provides an independent cross-check using variation unaffected by either consideration.

The interaction term X1×W was constructed using mean-centred values of X1 and W prior to multiplication.[1] Centring does not alter point estimates or inferential conclusions for any coefficient but substantially reduces multicollinearity introduced by the interaction term.

[1]Centring follows the standard transformation $X1^* = X1 - \bar{X}_1$ and $W^* = W - \bar{W}$, with the interaction term constructed as $X1^* \times W^* = (X1 - \bar{X}_1)(W - \bar{W})$. This transformation reduces the variance inflation factor on W from 12.30 to 1.84 and on the interaction term from 10.97 to 1.03, eliminating multicollinearity introduced by the uncentred interaction without altering any coefficient estimate, standard error, or p-value relative to the uncentred specification.

Standard errors are clustered at the NUTS-2 region level throughout. The Hausman test rejects random effects in favour of fixed effects (χ^2=2065.8, p<0.001). Heteroskedasticity is present (Breusch-Pagan BP=105.85, p<0.001), as is serial correlation (Wooldridge χ^2=236.64, p<0.001); both are addressed through clustering.

5. Findings

5.1 Sensitivity of the Entity-Only R&D Effect to Year-Fixed-Effects Specification

Table 2 reports the R&D-productivity relationship under entity-only and two-way fixed-effects specifications.

Table 2: The R&D-Productivity Coefficient, Entity-Only vs. Two-Way Fixed Effects

	Entity FE only	**Two-way FE**
Public R&D (X1)	0.0368** (0.0129)	-0.0010 (0.0041)
Within R^2	0.533	-0.094
N / Regions	1,679 / 215	1,679 / 215

*Source: author's estimates from the model specified in Section 4. Clustered standard errors (region level) in parentheses. †p<0.10, *p<0.05, **p<0.01, ***p<0.001.*

The entity-only specification yields a positive, statistically significant R&D elasticity of 0.037 (p=0.004). This estimate loses statistical significance, and reverses sign, once year fixed effects are included: the coefficient falls to −0.001 (p=0.81).

This divergence is attributable to a common temporal trend shared between productivity and public R&D expenditure across the panel period. EU-wide mean log productivity increases from 3.512 in 2016 to 3.770 in 2023; EU-wide mean log public R&D expenditure increases from 5.023 to 5.237 over the same interval. The correlation between these annual trajectories is 0.92. The entity-only estimator, lacking year-specific controls, cannot distinguish a causal R&D effect from the coincident upward movement of two trending series. Once year fixed effects absorb this common trend, minimal within-region variation remains for the regressors to explain, as indicated by the negative within R^2 in the two-way specification.

Tertiary education exhibits an analogous pattern (entity-only: 0.030, p<0.001; two-way: −0.003, p=0.09), indicating that this sensitivity is not specific to R&D expenditure but reflects a general characteristic of short EU regional panels in which multiple policy-relevant variables exhibit correlated temporal trends. Adult training participation, conversely, gains statistical significance under two-way fixed effects (0.005, p<0.001), suggesting within-region variation independent of the common trend identified for the other two regressors.

5.2 Entity-Only Interaction Results

Table 3 reports interaction results under the entity-only specification, presented for comparability with the existing literature and subject to the trend-sensitivity established in Section 5.1.

Table 3: Interaction Models, Entity-Only Fixed Effects (interpret with reference to Section 5.2)

	M1: R&D×Gov.	**M2: Educ.×Gov.**	**M3: Train.×Gov.**
X1 (public R&D)	0.0368** (0.0129)	0.0334** (0.0126)	0.0342** (0.0127)
X2 (tertiary educ.)	0.0301*** (0.0016)	0.0308*** (0.0016)	0.0298*** (0.0015)

X3 (adult training)	0.0027† (0.0014)	0.0022 (0.0014)	0.0048** (0.0018)
W (governance)	-0.0029 (0.0883)	0.1097† (0.0588)	0.0663 (0.0448)
Interaction term	0.0068 (0.0134)	-0.0027* (0.0012)	-0.0042* (0.0021)
N / Regions	1,679 / 215	1,679 / 215	1,679 / 215

*Source: author's estimates. Clustered standard errors (region level) in parentheses. †p<0.10, *p<0.05, **p<0.01, ***p<0.001. None of the interaction terms reported in this table remains statistically significant under the two-way fixed-effects specification (Section 5.1).*

The R&D×governance interaction is not statistically significant under entity-only fixed effects. Education×governance and training×governance interactions are both statistically significant and negative. None of the three interaction terms remains significant under two-way fixed effects (R&D×governance: p=0.19; education×governance: p=0.10; training×governance: p=0.20), consistent with the trend-sensitivity established in Section 5.1. The education×governance result reported in this table is accordingly attributable, with reasonable confidence, to the same common-trend confound rather than to a genuine cross-regional relationship.

5.3 Between-Effects Estimation: Cross-Sectional Evidence

The between-effects estimator, described in Section 4.1, is immune to the common temporal trend confounding the fixed-effects specifications reported above; however, it collapses the panel into a cross-section and is consequently vulnerable to unobserved time-invariant regional heterogeneity — omitted variable bias arising from regional characteristics, such as historical industrial structure, geography, or accession timing, that are correlated with both governance quality and productivity but are not captured by the regressors in the model. The estimates reported in this section document a robust cross-sectional association and should not be interpreted as a fully identified causal effect; Section 6.4 returns to this point directly.

Table 4: Between-Effects Estimates

	M1: R&D×Gov.	**M3: Train.×Gov.**
X1 / X3 (R&D or training level)	0.1035*** (0.0115)	0.0771*** (0.0118)
W (governance)	0.3170*** (0.0531)	0.2763*** (0.0255)
Interaction term	-0.0249* (0.0097)	-0.0142*** (0.0026)
R^2	0.657	0.689
N (regions)	215	215

*Source: author's estimates, between-effects specification. Standard errors in parentheses. *p<0.05, ***p<0.001. Result is materially unchanged whether interpolated R&D observations are included (Section 5.4) and after controlling for private R&D expenditure (Section 5.4).*

Across regions, public R&D investment is significantly and positively associated with productivity (0.104, p<0.001), exceeding the entity-only within-region estimate by an order of magnitude and unaffected by the trend confound documented in Section 5.1. Institutional quality enters positively in levels (0.317, p<0.001), consistent with the established governance-development correlation in the broader literature. The R&D×governance interaction is statistically significant and negative (−0.025, p=0.011): regions with persistently higher institutional quality exhibit smaller marginal productivity returns to R&D investment, holding constant the level of R&D, education, and training.

The training×governance interaction is also significantly negative (−0.014, p<0.001), replicating the direction of the entity-only fixed-effects result identified in Section 5.2 within a specification immune to common-trend confounds. The education×governance interaction, by contrast, is not statistically significant in the cross-section (p=0.68), reinforcing the conclusion drawn in Section 5.2 that the entity-only education result is attributable to the common-trend confound rather than a genuine cross-regional pattern.

The economic magnitude of the R&D×governance interaction is substantial. At the 10th percentile of the EQI distribution, the marginal productivity return to public R&D investment is approximately twice the marginal return estimated at the 90th percentile.

5.4 Robustness

Three robustness procedures were conducted. First, a private R&D control (BERD) was added to the between-effects specification using a reduced subsample (N=1,180) where data coverage permits. The negative governance interaction remains significant and increases marginally in magnitude (−0.027, p=0.006) once private R&D is held constant; private R&D itself is significantly positively associated with productivity (0.072, p<0.001), consistent with public and private R&D functioning as complements rather than substitutes.

Second, five regions identified as systematically influential via Cook's Distance — the two Irish NUTS-2 regions, whose productivity figures are affected by multinational profit relocation, together with Bucureşti-Ilfov, Valle d'Aosta, and Åland — were excluded from the sample. Coefficient estimates under both the entity-only and two-way specifications were materially unchanged, indicating the reported results are not driven by a small number of atypical observations.

Third, the analysis was re-estimated using only the original 1,326 non-interpolated observations, to assess whether the interpolation procedure described in Section 3.2 affects the results. Entity-only and between-effects estimates derived from the non-interpolated sample are statistically indistinguishable from estimates derived from the full 1,679-observation sample (entity-only X1: 0.035, p=0.003, versus 0.037, p=0.004; between-effects X1×governance: −0.026, p=0.011, versus −0.025, p=0.011), indicating the interpolation procedure does not drive the reported results.

A development-cluster stratification (less-developed, transition, more-developed regions, classified by average productivity relative to the EU mean) was additionally conducted; no statistically significant interaction was identified in any stratum under either estimator. Given subsample sizes of 50, 40, and 125 regions respectively, this result is attributed to limited statistical power and is reported as an inconclusive check rather than evidence against the pooled-sample finding.

6. Discussion

6.1 Common Temporal Trends in Short-Panel Specifications

The central methodological finding of this analysis is that entity-only fixed effects, applied to a short panel in which the dependent variable and the principal regressor exhibit a strong common trend, produce an estimate substantially inflated relative to the trend-controlled specification. This sensitivity is not specific to the present dataset: any short panel in which two variables trend together for reasons unrelated to the hypothesised causal

mechanism is vulnerable to this confound. The 2016–2023 panel window — spanning post-crisis recovery, pre-pandemic expansion, pandemic contraction, and post-pandemic recovery — represents a macroeconomic environment in which a common-trend confound is particularly pronounced.

Entity-only fixed effects without year controls remain in use across the EU regional panel literature, including in influential studies of structural fund effectiveness and R&D returns. The present findings indicate that positive R&D-productivity elasticities derived from comparable short panels without year-effects controls warrant re-examination.

6.2 The Between-Effects Interaction: Convergence Rather Than Complementarity

The between-effects estimate of the R&D×governance interaction is significant and negative, opposite in sign to the complementarity prediction reviewed in Section 2.2. This pattern persists across a private R&D control, an outlier-trimmed sample, and replication on non-interpolated data, with the coefficient remaining stable in the range of −0.025 to −0.027 throughout.

This pattern is consistent with a distance-to-frontier convergence mechanism. Regions with persistently strong governance tend to operate closer to the EU productivity frontier, leaving mechanically less scope for additional R&D investment to generate further productivity gains, independent of any causal effect of governance on investment efficiency. Regions further from the frontier, which are frequently though not exclusively associated with weaker governance, exhibit greater capacity for productivity growth, such that the same investment yields proportionally larger returns.

This interpretation does not preclude a complementary role for institutions as fundamental causes of long-run development levels, consistent with the between-region productivity differences absorbed by the region fixed effects in the primary specification. The between-effects estimator cannot fully disentangle a convergence channel from a complementarity channel given its vulnerability to omitted variable bias, as established in Section 5.3. It does, however, establish a robust empirical regularity that any complementarity-based account of institutional moderation must address.

6.3 Policy Implications

These findings bear on two aspects of EU cohesion policy and the broader competitiveness agenda associated with the Draghi report. First, R&D-productivity elasticities used to justify large-scale investment commitments should be assessed for sensitivity to common-trend confounds; where positive within-region estimates prove attributable to coincident temporal trends, the productivity returns to scaling R&D investment may be materially overstated relative to current projections. Second, these findings suggest that cohesion policies conditioning R&D allocation on strong institutional governance may misallocate capital relative to the distribution of marginal returns: if marginal R&D returns are larger in weaker-governance regions rather than smaller, allocation rules premised on the opposite assumption direct investment away from regions where it would generate the largest marginal productivity gains.

6.4 Limits to Causal Interpretation

The between-effects estimator documents an association robust to several specification checks, not a fully identified causal effect. As established in Section 5.3, this estimator does not control for unobserved, time-

invariant regional characteristics correlated with both institutional quality and distance from the productivity frontier — geography, historical industrial composition, or timing of EU accession, among other candidates. An instrumental variable strategy capable of isolating exogenous variation in institutional quality, identified in Section 8 as the principal extension for future research, is required before the convergence interpretation developed here can be treated as more than the most plausible explanation currently available for the observed pattern.

7. Conclusion

This paper examines whether institutional quality moderates the productivity return to public R&D investment across EU NUTS-2 regions, using 1,679 region-year observations across 215 regions from 2016 to 2023. The analytic sample reflects a 27 percent expansion over the listwise-deletion baseline, achieved through systematic within-region interpolation addressing directional attrition bias in Eurostat's regional R&D data.

Under the entity-only fixed-effects specification conventional in this literature, public R&D exhibits a significant positive productivity elasticity (0.037, $p<0.01$). This result does not survive the inclusion of year fixed effects, the specification the underlying model formally requires: productivity and R&D both trend upward across the panel period with a correlation of 0.92, and the entity-only estimator cannot separate a causal relationship from this coincident trend. The credible evidence resides in the cross-sectional dimension: the between-effects estimator indicates a robust R&D-productivity association (0.104, $p<0.001$) accompanied by a significant negative governance interaction (-0.025, $p=0.011$), stable across multiple specification checks and consistent with diminishing marginal returns near the productivity frontier.

These findings caution against uncritical reliance on entity-only fixed-effects estimates in short EU regional panels, and against institutional-conditionality allocation rules in EU cohesion policy premised on the assumption that better-governed regions generate larger returns to R&D investment.

8. Limitations and Future Research

The two-way fixed-effects null result may reflect either the absence of a genuine within-region R&D effect over this time horizon, or insufficient statistical power once year effects absorb the majority of available variation; distinguishing between these explanations requires either a longer panel or an alternative identification strategy.

As discussed in Sections 5.3 and 6.4, the between-effects estimator does not control for unobserved, time-invariant confounders. An instrumental variable approach — exploiting, for example, the timing of EQI survey waves or institutional inheritance predating the panel period — constitutes the priority methodological extension for this research programme.

The model specified in Section 4 does not incorporate a spatial weighting structure. Public R&D investment, as established by Moreno, Paci and Usai (2005), generates spillovers that are not confined within NUTS-2 administrative boundaries; the absence of a spatial lag or spatial error structure (for example, SLM or SDM specifications) in the present analysis means that estimated coefficients may be affected by unmodelled spatial spillovers or spatial autocorrelation in the error structure. Incorporating a spatial weighting matrix is identified as a priority extension for subsequent work.

A total of 224 observations remain excluded due to the complete absence of regional GERD data in Eurostat's public database for the Netherlands, Belgium, France, and Spain. As established in Section 3.2, these excluded regions are systematically more productive and better-governed than included regions, implying the negative-moderation finding reported in this paper likely understates the true population-level effect.

Labour productivity, the outcome variable applied throughout, conflates capital deepening with genuine total factor productivity growth. Regional capital stock data of sufficient quality for a true TFP specification is not available at NUTS-2 resolution in Eurostat's regional accounts.

The development-cluster analysis reported in Section 5.4 identified no significant interaction in any development tier; given subsample sizes of 40 to 125 regions, this result should be attributed to limited statistical power rather than interpreted as evidence against the pooled-sample finding.

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