

Public R&D Support under Poland's Smart Growth Operational Programme and Business-Financed R&D in Polish Regions

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Abstract: This study assesses whether greater regional exposure to public R&D support under Poland's Smart Growth Operational Programme (POIR 1.1.1) is associated with higher business-financed R&D intensity and subsequent increases in that intensity. Project-level information on POIR support is combined with regional data on R&D expenditure and gross domestic product (GDP) for all Polish voivodeships over the period 2014-2024. The analysis uses panel models with fixed effects to examine associations within the same year and changes over the following one, two, and three years.

The estimates provide no statistically significant evidence that greater POIR 1.1.1 exposure is associated with higher business-financed R&D intensity in the same year or subsequent increases over one to three years. Larger new-project impulses are associated with greater active programme exposure mainly during the following two years, but their association with subsequent increases in business-financed R&D intensity is not statistically significant. The regional evidence therefore does not establish additional mobilisation of business-sector R&D financing, but cannot rule out such a response.

The study also finds evidence of regional beta-convergence: business-financed R&D intensity grew faster in regions with lower initial levels. Neither the full-period analysis nor the analysis for the post-2016 period provides statistically significant evidence linking this convergence to POIR support. Given the observational design, the findings should be interpreted as regional associations rather than causal programme effects.

Keywords: Additionality, R&D subsidies, cohesion policy, regional convergence, Poland.

1. INTRODUCTION

Business investment in innovation can contribute to productivity growth by enabling firms to develop new or improved products and production processes. Research and development constitutes one of the principal measurable inputs into technological innovation. In endogenous growth theory, purposeful investments in the creation of knowledge generate technological change and thereby support long-term economic growth (Romer, 1990). According to the Frascati Manual, R&D comprises “creative and systematic work undertaken in order to increase the stock of knowledge [...] and to devise new applications of available knowledge” (OECD, 2015). Business expenditure on R&D can therefore be understood as an investment in the knowledge base from which new technologies, products and production processes may emerge, contributing ultimately to productivity improvements and economic growth.

This raises the question of whether companies' budgets are sufficient to fund R&D investments and what role public support plays in this area. The effectiveness of R&D subsidies remains an empirical question. Public funding may stimulate additional private investment, but it may also partly substitute for expenditure that firms would have undertaken without support. A central concept in the evaluation of

public R&D support is additionality, understood as the extent to which public intervention stimulates R&D activity that would not otherwise have taken place (Buisseret et al., 1995). Subsequent literature distinguishes between input additionality related to additional R&D expenditure induced by support, output additionality which is reflected in additional innovation outcomes, and behavioral additionality that refers to changes in firms' innovation processes, strategies and organisational behavior (Clarysse et al., 2009).

Empirical evidence regarding input additionality is mixed. Dimos and Pugh (2016), in a meta-regression analysis of 52 micro-level evaluation studies, demonstrate substantial heterogeneity in the estimated effects of R&D subsidies. After controlling for publication bias and differences in research design, they reject the hypothesis of systematic crowding-out of private R&D investment, which occurs when public R&D support substitutes for expenditures that the business sector would otherwise have financed from business-sector resources, but at the same time find no evidence of strong additionality. Their results indicate that the available evidence supports neither systematic crowding-out nor substantial input additionality.

Similar ambiguity emerges from firm-level evidence. Marino et al. (2016), analysing French firms between 1993 and 2009, find either no input additionality or substitution between public and private R&D expenditure, with crowding-out effects particularly pronounced at medium-to-high subsidy levels. These findings indicate that the relationship

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between public support and private R&D investment may depend on the scale and form of assistance, as well as on the characteristics of beneficiaries and the institutional context.

At the European level, Lewandowska, Weresa and Rószkiewicz (2022), using Community Innovation Survey data for 98 809 enterprises from 14 EU countries, find that EU support generates additionality, although its dimensions differ substantially across Member States. All three types of additionality were confirmed only for Spain, while input and behavioural additionality were identified in eight countries. The results also suggest that the potential of EU support remains underexploited, particularly in Central and Eastern European countries.

Against this European background, evaluations conducted for Poland generally indicate a positive contribution of EU cohesion policy to R&D activity. Antosiewicz et al. (2017), in an ex-post evaluation of the 2007-2013 financial perspective, combined project-level evidence with macroeconomic and econometric modelling. The strongest effects were observed for R&D expenditure - during the peak of intervention in 2010-2011, EU support accounted for approximately 22 percent of total R&D expenditure in Poland. The contribution was even greater in the business enterprise sector, where in 2010 the estimated share attributable to EU-funded interventions ranged from 38.5 percent in the direct assessment to approximately 41 percent in the macroeconomic analysis.

These results are consistent with the review by Krupnik, Szczucka and Lisek (2022), which concludes that EU-funded interventions contributed positively to business R&D expenditure and innovation performance in Poland. Evaluations of the Smart Growth Operational Programme (Borowczak et al., 2020) also point to an incentive effect - supported firms increased their R&D expenditure more strongly than unsupported firms, while beneficiaries reported that, without public assistance, R&D activities would have been undertaken on a smaller scale, later, or not at all.

Nevertheless, evidence that public intervention increases total R&D expenditure or R&D activity among beneficiaries does not necessarily imply a corresponding increase in expenditure financed from the business sector's financing at the regional level. This distinction is particularly relevant when assessing input additionality. An increase in R&D expenditure performed by enterprises may partly reflect the direct contribution of public funding rather than additional mobilisation of business-sector financing. Accordingly, the present analysis focuses primarily on R&D expenditure financed by the business enterprise sector, rather than on total business enterprise expenditure on R&D (BERD).

1.1. The Smart Growth Operational Programme and Enterprise R&D Support

The Smart Growth Operational Programme 2014-2020 (Program Operacyjny Inteligentny Rozwój, POIR) was one of the main instruments for supporting research, development and innovation in Poland through EU cohesion policy funds. At the time of signing the Partnership Agreement, it was the largest operational programme in the European Union specifically dedicated to financing research, development and in-

novation. Projects implemented under the programme, involving both enterprises and research organisations, were designed according to the "from idea to market" principle, with the aim of increasing the practical application and commercial use of R&D results in the economy.

The programme was organised into priority axes, measures and sub-measures. Priority Axis I focused specifically on supporting R&D activities undertaken by enterprises. Within this axis, Measure 1.1 covered business R&D projects, while Sub-measure 1.1.1 supported industrial research and experimental development carried out by enterprises.

The scale of this instrument was substantial. Between 2016 and 2022, more than 11 000 funding applications were submitted to the National Centre for Research and Development (NCBR), of which more than three quarters concerned Sub-measure POIR 1.1.1 through successive editions of NCBR's flagship "Fast Track" competition. This confirms that Sub-measure 1.1.1 constituted one of the principal instruments for supporting enterprise-led R&D within the NCBR-managed part of the programme (Czarnecka et al., 2025).

The project database analysed in this study contains 2454 projects under POIR 1.1.1, representing approximately PLN 14.56 billion in EU co-financing. Of these, 2338 projects could be assigned unambiguously to one voivodeship and were retained, while 116 multi-voivodeship projects were excluded from regional allocation. The substantial scale of the intervention, together with its uneven regional distribution, provides a relevant setting for examining whether greater regional exposure to public R&D support was accompanied by stronger mobilisation of business-sector resources for research and development.

1.2. The Temporal Dimension of R&D Support

The effects of public R&D support may not materialise immediately. R&D projects typically require time for implementation, recruitment, acquisition of equipment, experimentation and subsequent adaptation of firms' own investment decisions. Consequently, the relationship between public intervention and business-financed R&D may extend beyond the period in which supported activities begin.

Previous research provides evidence of such delayed effects. Guellec and van Pottelsberghe de la Potterie (2000), using data for 17 OECD countries, find that direct government funding of R&D performed by firms is positively associated with business-financed R&D. They also show that stable support is more effective, as uncertainty about its durability discourages firms from committing additional R&D resources. Dimos, Fai and Tomlinson (2024) find that input additionality among UK firms occurs in the year following receipt of R&D grants, whereas behavioural additionality may take approximately three years to materialise.

These findings provide a rationale for examining not only contemporaneous relationships between the regional intensity of POIR support and business-financed R&D expenditure, but also subsequent changes over one-, two- and three-year horizons. The one-year horizon can capture early co-financing commitments and adjustments in staffing or

equipment, the two-year horizon allows these inputs to become operational and sustained R&D activity to develop. The three-year horizon allows learning, changes in innovation routines and business-financed follow-on R&D to emerge. These stages may overlap and vary across firms, so the horizons test possible adjustment sequences rather than impose a uniform project timetable.

1.3. Regional Variation and Convergence

The spatial distribution of both R&D activity and public support is highly uneven. In this study, Polish regions are operationalised as the country's 16 voivodeships, corresponding to the NUTS 2 level of the European Union's territorial classification. Regions differ substantially in their economic structure, innovation capacity, availability of skilled labour, research infrastructure and concentration of innovative firms. These differences may influence both their ability to attract public R&D funding and the subsequent evolution of business R&D activity.

The convergence literature distinguishes between beta-convergence, whereby regions with lower initial levels of an economic indicator subsequently grow faster, and sigma-convergence, which occurs when the overall dispersion of that indicator across regions declines over time (Barro and Sala-i-Martin, 1992). In the context of the present study, beta-convergence would imply that voivodeships with lower initial business-financed R&D intensity subsequently record larger increases, whereas sigma-convergence would require the dispersion of that intensity across voivodeships to decline.

The effects of R&D policy may themselves have an important spatial dimension. Fitjar (2025), analysing 200 regions in 22 European countries between 2009 and 2018, shows that public R&D funding is not spatially neutral. More developed regions tend to attract greater public R&D expenditure, partly because they already possess stronger business R&D activity and more human capital. Such concentration creates a risk that public R&D policy may reinforce existing regional advantages rather than reduce spatial disparities.

At the same time, Fitjar (2025) identifies unconditional beta-convergence in public R&D expenditure across European regions, but no evidence of sigma-convergence. Business R&D expenditure displays both beta- and sigma-convergence in the overall European sample. Within Poland, the study reports beta-convergence in both public and business R&D funding, while its descriptive analysis indicates declining regional inequality in both categories, however, the formal country-level variance-ratio tests do not identify Poland among the cases with statistically significant sigma-convergence.

1.4. Research Gap and Contribution

Taken together, the existing literature points to three issues that remain particularly relevant in the Polish context. First, positive changes in total BERD or in the R&D activity of supported firms do not necessarily demonstrate that public assistance is accompanied by greater mobilisation of

resources financed by the business sector itself. Second, the relationship between support and business R&D activity may become visible only in subsequent periods. Third, national-level developments may conceal substantial differences in R&D trajectories across regions.

Existing evaluations provide considerable evidence on the effects of EU-funded R&D support on programme beneficiaries and on aggregate R&D activity in Poland. Less is known about whether differences in the regional intensity of such support are reflected in the mobilisation of business-financed R&D resources across Polish regions, whether this relationship extends to subsequent changes in R&D intensity, and whether any regional catching-up process is systematically associated with POIR support.

This article contributes to the literature by linking project-level information on POIR 1.1.1 support with regional R&D and GDP statistics for all 16 Polish voivodeships. The study focuses specifically on R&D expenditure financed by the business enterprise sector rather than relying exclusively on BERD and examines the issue from three complementary perspectives: the contemporaneous association between POIR support intensity and business-financed R&D intensity, subsequent changes over one-, two- and three-year horizons, and regional beta-convergence together with the role of cumulative POIR exposure in the catching-up process.

The analysis is regional and observational. It therefore does not identify causal input additionality in the same sense as firm-level counterfactual evaluations. Instead, it assesses whether regional patterns are consistent with the mobilisation of additional business-sector resources following greater exposure to public R&D support.

The main research question is therefore:

To what extent is the regional intensity of POIR 1.1.1 support associated with business-financed R&D expenditure across Polish voivodeships, does greater support intensity correspond to subsequent increases in R&D intensity, and is any observed regional beta-convergence systematically associated with POIR support?

The empirical analysis tests four clearly separated propositions:

H1. Higher active POIR 1.1.1 support relative to regional GDP is positively associated with higher business-financed R&D expenditure relative to GDP in the same year.

H2a. Higher active POIR 1.1.1 support relative to regional GDP in year t is positively associated with an increase in business-financed R&D intensity related to GDP over horizons $t+1$ to $t+3$.

H2b. A larger value of grants assigned to projects starting in region i in year t , relative to regional GDP, is positively associated with growth in business-financed R&D intensity over horizons $t+1$ to $t+3$.

H3. Regional beta-convergence in business-financed R&D intensity over 2014–2024 is associated with POIR 1.1.1 support: regions with greater cumulative support intensity exhibit faster R&D growth, with a stronger association among voivodeships starting from lower R&D intensity.

2. MATERIALS AND METHODOLOGY

2.1. Data and Analytical Sample

The unit of observation is a voivodeship-year. Poland is divided into 16 voivodeships, which constitute the regional units used in this study and correspond to the NUTS 2 level. The main dataset is a balanced panel of 16 Polish voivodeships observed annually from 2014 through 2024, yielding 176 observations. The analytical file combines the accepted POIR 1.1.1 project panel with Statistics Poland data on internal R&D expenditure and regional GDP at current prices. All data preparation and statistical analyses were conducted in Python. The panel-data models used to test H1, H2a and H2b were estimated using the *PanelOLS* estimator from the *linearmodels* package. The specifications included voivodeship and year fixed effects, with standard errors clustered by voivodeship. The cross-sectional regressions used to test beta-convergence under H3 were estimated by ordinary least squares using the *OLS* estimator from the *statsmodels* package, with heteroskedasticity-robust HC3 standard errors. Data processing was performed primarily using the *pandas* and *NumPy* packages.

2.1.1. POIR 1.1.1 Projects Data

Project information comes from the official list of projects co-financed under the 2014-2020 financial perspective, in the snapshot dated 30 November 2025. The source contains 2454 projects classified strictly as POIR 1.1.1, with total EU co-financing of PLN 14.564 billion. Projects were assigned by reported implementation location. A total of 2338 projects were assigned unambiguously to one voivodeship and retained; 116 projects covering more than one voivodeship were excluded because the source does not split their value across locations. The excluded projects account for 4.73 percent of projects and 6.51 percent of EU co-financing (PLN 0.948 billion). Exclusion avoids assigning the full grant to one region or imposing an arbitrary split across locations, either of which could distort regional exposure. It may nevertheless introduce regional selection bias if multi-voivodeship projects differ systematically in size, collaboration structure or location. Their larger share of co-financing than of project counts indicates higher average grant values. The retained sample covers most recorded funding but represents projects located in a single voivodeship, not the full regional footprint of POIR 1.1.1. Unevenly distributed excluded funding could alter regional exposure rankings and estimated associations- its direction and magnitude cannot be established without location-specific allocations.

For active exposure, each retained project's EU co-financing was allocated across calendar years in proportion to the number of project implementation days falling in each year. The regional-year total therefore measures the value of grants attached to projects under active implementation, not actual annual payments or disbursements. The sum of day-weighted active allocations falling within 2014-2024 equals PLN 13.527 billion; it is lower than the retained-project grant total because portions of implementation may fall outside the panel window.

$$ActiveGrant_{it} = \sum_{p \in i} Grant_p \frac{Days_{pt}}{Days_p} \quad (1)$$

The new-project impulse is defined separately. It assigns the full EU co-financing value of a retained project to the year in which implementation began. It therefore identifies the timing and scale of newly initiated projects rather than annual programme exposure.

2.1.2. R&D Outcomes and the Frascati Methodological Transition

The main outcome is intramural R&D expenditure financed by the business enterprise sector, drawn from the Statistics Poland cross-section "Poland, voivodeships; funding sectors". Mentioned funding-source measure is aligned with the research question because it captures resources financed by enterprises, irrespective of the sector in which R&D is performed. It is not interchangeable with BERD.

BERD measures R&D expenditure performed in the business enterprise sector, irrespective of the source of funding. The distinction between sector of funding and sector of performance follows the Frascati framework (OECD, 2015). It is drawn from the cross-section "Poland, voivodeships; sectors of performance" and is used as a secondary robustness outcome. Fourteen region-year BERD observations are missing, whereas the principal business-financed R&D series is complete. We therefore estimate BERD models on the available observations without imputation and report them as complete-case robustness checks rather than as an alternative main specification. To distinguish differences in outcome definition from changes in sample composition, the main business-financed R&D model is also re-estimated on the same restricted sample.

Statistics Poland's Local Data Bank metadata state that, from 2016, data by institutional sector were compiled according to the Frascati Manual 2015 methodology. Consequently, the 2014-2015 observations and the 2016-2024 observations span a methodological transition in the institutional-sector classification used to produce the R&D statistics. (OECD, 2015; Statistics Poland, 2026).

2.1.3. Regional GDP and Variable Definitions

Regional GDP at current prices comes from the Statistics Poland Local Data Bank. It is used to normalise both R&D expenditure and POIR support and, in augmented specifications, its natural logarithm is included as a control for regional economic scale.

$$BR_GDP_{it} = 100 \times \frac{BRfunded_{it}}{GDP_{it}} \quad (2)$$

$$POIR_GDP_{it} = 100 \times \frac{ActiveGrant_{it}}{GDP_{it}} \quad (3)$$

$$NEW_POIR_GDP_{it} = 100 \times \frac{NewGrant_{it}}{GDP_{it}} \quad (4)$$

All three ratios are expressed in percentage points of regional GDP. A one-basis-point change in a ratio equals 0.01 percentage points. Because GDP appears in the denominator of both the outcome and the support variables, the regressions are interpreted as within-region associations and the specification including $\ln(GDP)$ is reported as a sensitivity check.

2.2. Empirical Strategy

2.2.1. H1: Contemporaneous Panel Relationship

$$BR_GDP_{it} = \alpha_i + \lambda_t + \beta POIR_GDP_{it} + \gamma \cdot \ln(GDP_{it}) + \varepsilon_{it} \quad (5)$$

The model includes voivodeship fixed effects and year fixed effects. The augmented specification includes $\ln(GDP)$. H1 predicts $\beta > 0$. The fixed effects control for time-invariant regional characteristics and common annual shocks, but do not resolve endogenous project location.

2.2.2. H2a: Active Exposure and Subsequent R&D Growth

$$\Delta_h BR_GDP_{it} = \alpha_i + \lambda_t + \beta_h POIR_GDP_{it} + \rho_h BR_GDP_{it} + \gamma_h \ln(GDP_{it}) + \varepsilon_{i,t+h} \quad (6)$$

Here,

$\Delta_h BR_GDP_{it} = BR_GDP_{i,t+h} - BR_GDP_{it}$, $h \in \{1,2,3\}$. A common baseline sample $t=2015-2021$ is used for all horizons, producing 112 observations in each model. H2a predicts $\beta_h > 0$. Including the initial outcome controls for starting conditions, although its presence in both the regressor set and the constructed change implies that a negative coefficient on initial R&D may partly reflect regression to the mean or mechanical coupling.

2.2.3. H2b: New-Project Impulse

The new-project impulse is first subjected to an implementation-stage validation and is then used in the substantive outcome model. The validation checks whether grants assigned to project start years translate into active programme exposure in subsequent years. Because both measures are constructed from the same underlying grant values, this pipeline relationship is treated as a measurement and timing diagnostic rather than as part of H2b itself.

$$POIR_GDP_{i,t+h} = \alpha_i + \lambda_t + \delta_h NEW_POIR_GDP_{it} + u_{i,t+h}, h \in \{0,1,2,3\} \quad (7)$$

$$\Delta_h BR_GDP_{it} = \alpha_i + \lambda_t + \beta_h NEW_POIR_GDP_{it} + \rho_h BR_GDP_{it} + \gamma_h \ln(GDP_{it}) + \varepsilon_{i,t+h} \quad (8)$$

The pipeline equation is estimated for $h=0,1,2,3$; the outcome equation for $h=1,2,3$. The common impulse years are 2015-2021, while subsequent outcomes may extend through 2024. The δ coefficients validate the intended timing of the constructed programme measure and are not interpreted causally. H2b is tested by the β coefficients in the outcome equation, which assess whether the start-year grant impulse predicts later growth in business-financed R&D intensity.

2.2.4. H3: Beta-Convergence and the Role of POIR Support

$$g_i = \frac{\ln(BR_GDP_{i,2024}) - \ln(BR_GDP_{i,2014})}{10} = a + b \cdot \ln(BR_GDP_{i,2014}) + e_i \quad (9)$$

H3 is evaluated in two steps. First, the standard unconditional beta-convergence framework of Barro and Sala-i-Martin (1992) is estimated across the 16 voivodeships. Evidence of convergence requires $b < 0$. The implied annual convergence speed is calculated as $\lambda = -\ln(1+10b)/10$, and the half-life as $\ln(2)/\lambda$. This first model establishes whether convergence occurred, but does not by itself attribute the catching-up process to POIR.

Second, cumulative POIR intensity is added to the convergence model. It is defined as the sum of active POIR grants over 2015-2021 divided by the sum of regional GDP over the same period, expressed as a percentage. Three compact cross-sectional models are estimated for the 16 voivodeships using HC3 heteroskedasticity-robust standard errors. In the interaction specification, initial R&D intensity and cumulative POIR intensity are mean-centred. H3 predicts a positive coefficient on cumulative POIR intensity and a negative interaction between initial R&D intensity and POIR, indicating a stronger support-growth association among initially weaker regions.

$$POIR^{cum} = 100 \frac{\sum POIR_{i,t}}{\sum GDP_{i,t}}; t = 2015, \dots, 2021$$

$$M0: g_i = a + b \cdot \ln(BR_GDP_{i,2014}) + e_i \quad (10)$$

$$M1: g_i = a + b \cdot \ln(BR_GDP_{i,2014}) + \theta \cdot POIR^{cum}_i + e_i \quad (11)$$

$$M2: g_i = a + b \cdot \text{Initial}BR_i + \theta \cdot POIR_i + \delta \cdot (\text{Initial}BR_i \cdot POIR_i) + e_i \quad (12)$$

2.3. Statistical Inference

For H1, H2a and H2b, standard errors are clustered by voivodeship because observations from the same region over time may be correlated. As the analysis includes only 16 voivodeships, a small-sample correction is applied and statistical inference uses Student's t distribution with 15 degrees of freedom (one fewer than the number of clusters). Basing the reference distribution on the cluster count recognises that repeated observations within a region do not provide independent replications. Relative to normal critical values, the heavier-tailed t distribution gives wider confidence intervals and reduces over-rejection. This is a pragmatic finite-sample adjustment, consistent with Cameron and Miller (2015). All tests are two-sided and 95 percent confidence intervals are reported.

With only 16 clusters this correction does not ensure accurate test size or confidence-interval coverage. Cluster-robust variance estimates may still be biased downward, and the results may remain sensitive to regions. Clustering also assumes independence across voivodeships after conditioning on the model. Year fixed effects remove common annual shocks but may leave spatially correlated disturbances. The reported p -values and confidence intervals are therefore approximate, and statistically insignificant estimates do not exclude economically meaningful associations. Wild cluster bootstrap inference would provide a useful further sensitivity check (Cameron and Miller, 2015).

The convergence models use HC3 robust standard errors with finite-sample t inference. Two additional robustness exercises are reported: (i) the H1 and H2a models are re-

estimated for BERD on complete cases and the principal business-financed outcome is re-estimated on exactly the same restricted samples; and (ii) H3 is repeated for 2016-2024 to avoid using observations before the Frascati Manual 2015 methodological transition. Sigma-convergence is assessed separately from H3 using the annual coefficient of variation and a linear trend in $\ln(CV)$. Given the limited number of regions and the observational nature of the study, all results are interpreted as associations rather than causal effects.

3. RESULTS

3.1. Descriptive Evidence

Table 1. Descriptive statistics for the balanced regional panel, 2014-2024.

Variable	N	Mean	SD	Min	Max
Business-financed R&D / GDP (%)	176	0.474	0.382	0.047	1.596
Active POIR 1.1.1 / GDP (%)	176	0.0485	0.0450	0.000	0.163
Regional GDP (PLN million)	176	153,625	139,095	36,178	872,530

Across the 176 region-year observations, business-financed R&D intensity averaged 0.474 percent of regional GDP, while active POIR exposure averaged 0.0485 percent. Both measures varied substantially across regions and over time. The wide dispersion in regional GDP also supports expressing programme support and R&D expenditure relative to regional economic size rather than in nominal terms.

3.2. H1: Contemporaneous Association

Table 2. Two-way fixed-effects estimates for H1.

Specification	β	Clustered SE	p	95% CI	N
Region and year FE	0.757	1.089	0.498	[-1.565; 3.078]	176
+ $\ln(GDP)$	0.721	0.738	0.344	[-0.851; 2.293]	176

The estimated contemporaneous association is positive in both specifications, but it is not statistically distinguishable from zero. In the augmented model, one additional basis point of active POIR support relative to GDP is associated with 0.0072 percentage points higher business-financed R&D intensity. The confidence interval remains wide and

includes zero, so these estimates do not provide empirical support for H1.

3.3. H2a: Active Support and Subsequent Change

Table 3. Active POIR exposure and cumulative change in business-financed R&D intensity

Horizon	β	Clustered SE	p	95% CI	N
t+1	0.352	0.813	0.671	[-1.380; 2.085]	112
t+2	0.379	0.643	0.564	[-0.991; 1.749]	112
t+3	-0.122	0.733	0.870	[-1.686; 1.441]	112

At the one- and two-year horizons, the estimated coefficients are positive, whereas the three-year coefficient is negative. None of the three estimates is statistically significant. Their confidence intervals are sufficiently wide to accommodate both economically meaningful positive and negative associations, and H2a is therefore not supported by these results.

3.4. H2b: New-Project Impulse

Table 4. Timing and scale of new POIR 1.1.1 projects.

Start Year	New Projects	New Grants (PLN m)	Mean active POIR/GDP (%)
2015	104	508.3	0.0017
2016	158	747.5	0.0131
2017	301	1,462.7	0.0262
2018	308	2,107.0	0.0480
2019	247	1,730.8	0.0566
2020	466	3,154.2	0.0837
2021	640	3,412.6	0.1111
2022	79	320.4	0.1021
2023	35	173.1	0.0832
2024	0	0.0	0.0077

Project starts expanded markedly over the programme period, although the increase was not monotonic. Both the number and value of newly initiated projects reached their highest level in 2021 and fell sharply thereafter. Using 2015-2021 as the common impulse period therefore captures the main wave of project entry while still allowing subsequent outcomes to be observed through 2024.

Table 5. Pipeline test: new-project impulse and active POIR exposure.

Active Exposure	δ	Clustered SE	p	95% CI
t	0.138	0.047	0.011	[0.037; 0.238]
t+1	0.236	0.045	<0.001	[0.140; 0.332]
t+2	0.218	0.044	<0.001	[0.125; 0.312]
t+3	0.056	0.019	0.010	[0.016; 0.097]

The timing diagnostic indicates that the new-project impulse translates into active programme exposure at each examined horizon, with the strongest associations one and two years after project start. One additional basis point of new-project grants relative to GDP is associated with 0.236 basis points more active exposure at t+1 and 0.218 basis points at t+2. This pattern is consistent with the expected implementation cycle of supported projects.

Table 6. Outcome test: new-project impulse and cumulative R&D growth.

Horizon	β_h	Clustered SE	p	95% CI	Effect of 1 bp (pp)
t+1	0.134	0.218	0.548	[-0.330; 0.598]	0.0013
t+2	0.314	0.312	0.329	[-0.350; 0.979]	0.0031
t+3	-0.165	0.247	0.513	[-0.691; 0.360]	-0.0017

The outcome regressions do not show a comparable response in business-financed R&D intensity. The largest positive coefficient appears at t+2, but it is not statistically significant; the estimates for t+1 and t+3 are likewise insignificant. Thus, although the start-year impulse is a useful predictor of subsequent active programme exposure, that relationship validates the timing measure rather than H2b. Larger new-project impulses are not associated with statistically detectable increases in subsequent regional R&D intensity.

3.5. H3: Regional Convergence and POIR Support

Table 7. Unconditional beta-convergence in business-financed R&D intensity, 2014-2024.

Coefficient	Estimate	HC3 SE	p	95% CI	N	R ²
ln(BR/GDP), 2014	-0.0390	0.0135	0.012	[-0.0680; -0.0100]	16	0.476

Initial business-financed R&D intensity enters the convergence regression with a negative and statistically significant coefficient. Regions starting from lower levels therefore recorded faster proportional growth over 2014-2024. The estimate corresponds to an annual convergence speed of approximately 4.94 percent and a half-life of about 14 years. This result establishes beta-convergence, but on its own says nothing about whether POIR support contributed to that process.

Table 8. Beta-convergence conditional on cumulative POIR support.

Model	Variable	Estimate	HC3 SE	p
M0	ln(BR/GDP), 2014	-0.0390	0.0135	0.012
M1	ln(BR/GDP), 2014	-0.0410	0.0158	0.022
M1	Cumulative POIR, 2015-2021	0.403	0.793	0.620
M2	Cumulative POIR (centred)	0.330	1.062	0.761
M2	Initial R&D $\times$ cumulative POIR	0.294	1.304	0.825

Adding cumulative POIR intensity leaves the convergence result essentially unchanged. The coefficient on initial R&D intensity shifts only from -0.0390 to -0.0410, while the POIR coefficient is positive but imprecisely estimated ($\theta=0.403$, $p=0.620$). Regions with greater cumulative programme intensity therefore do not exhibit statistically distinguishable faster long-run growth in business-financed R&D intensity.

The interaction specification leads to the same conclusion. The interaction between initial R&D intensity and cumulative POIR is positive rather than negative and is far from statistical significance ($\delta=0.294$, $p=0.825$). The observed beta-convergence cannot therefore be linked statistically to stronger POIR-related growth among initially weaker regions, and the evidence does not support H3.

Cross-regional dispersion declined in descriptive terms: the coefficient of variation in business-financed R&D intensity fell from 0.975 in 2014 to 0.788 in 2024, although the path between those years was non-monotonic. The estimated trend in ln(CV) is negative (-0.023 per year; HC3 SE=0.0136), but it does not reach statistical significance ($p=0.126$). Formal evidence of sigma-convergence over the full period is therefore absent.

3.6. Robustness Checks

Two robustness exercises address the main measurement concerns: the Frascati methodological transition and incomplete BERD coverage.

Table 9. H3 robustness to the post-Frascati window, 2016-2024.

Model	Variable	Estimate	HC3 SE	p
M0	ln(BR/GDP), 2016	-0.0326	0.0142	0.037
M1	ln(BR/GDP), 2016	-0.0331	0.0189	0.104
M1	Cumulative POIR, 2016-2021	0.068	0.800	0.933
M2	Cumulative POIR (centred)	0.178	0.876	0.843
M2	Initial R&D × cumulative POIR	-0.468	0.651	0.487

The post-2016 estimates support the robustness of unconditional beta-convergence. Unconditional beta-convergence remains statistically significant ($b = -0.0326$, $p = 0.037$), corresponding to an annual convergence speed of approximately 3.78 percent and a half-life of about 18.4 years. After cumulative POIR intensity is introduced, neither the POIR term ($p = 0.933$) nor its interaction with initial R&D intensity ($p = 0.487$) is significant. The shorter window retains all 16 regions- it changes the measurement period rather than the number of regional observations. However, the initial-intensity term is no longer significant when cumulative POIR intensity is included ($p = 0.104$), so the convergence evidence is more stable in the unconditional model.

Table 10. BERD complete-case and common-sample robustness checks.

Test	Outcome / Sample	Horizon	β	Clustered SE	p	N
H1	Business-financed R&D, BERD-complete sample	t	0.508	0.801	0.536	162
H1	BERD, complete-case	t	0.421	0.918	0.653	162
H2a	Business-financed R&D, common sample	t+1	-0.191	0.690	0.786	100
H2a	BERD, complete-case	t+1	-0.197	0.780	0.804	100
H2a	Business-financed R&D, common sample	t+2	0.344	0.683	0.622	98
H2a	BERD, complete-case	t+2	0.622	0.776	0.436	98
H2a	Business-financed R&D, common sample	t+3	0.186	0.781	0.815	96

Test	Outcome / Sample	Horizon	β	Clustered SE	p	N
H2a	BERD, complete-case	t+3	0.557	0.911	0.550	96

The complete-case exercise yields a similar pattern. BERD coefficients are statistically insignificant in both the contemporaneous and delayed-effect specifications, and the principal business-financed R&D outcome remains insignificant when re-estimated on exactly the same BERD-available samples. This provides limited evidence that the absence of a statistically detectable association is not specific to the outcome definition on the available common samples.

4. DISCUSSION

The results separate programme implementation, regional R&D responses and convergence. First, regions with higher active POIR intensity do not display a statistically distinguishable contemporaneous increase in R&D financed by enterprises. Second, neither active exposure nor the value of newly initiated projects significantly predicts subsequent growth in the principal R&D outcome over one to three years. Third, the project accounting pipeline behaves as expected: a strong start-year impulse becomes active exposure primarily in the next two years. This validates the timing construction but is not evidence of input additionality. Finally, regional beta-convergence is present, but the POIR terms do not provide statistically significant evidence linking support to the catching-up process. The robustness checks retain evidence of unconditional beta-convergence and do not reveal a statistically detectable POIR association, although the smaller common samples limit the strength of the latter finding.

The absence of statistically significant regional coefficients should not be read as proof of no programme effect. With only 16 regional clusters, the estimates are imprecise. Aggregation can hide effects among beneficiaries, regional placement of supported projects is endogenous, and the dependent variable captures the source of financing for R&D rather than total R&D performed by enterprises. Public support could raise BERD without producing an immediately observable increase in enterprise-financed expenditure if it temporarily substitutes for firms' own resources or if responses occur at a more granular level.

The convergence finding should be interpreted separately from the programme-effect analysis. Significant beta-convergence indicates that regions with lower initial R&D intensity grew faster in proportional terms between 2014 and 2024. However, neither the cumulative POIR coefficient nor its interaction with initial R&D intensity is statistically significant, so the analysis provides no evidence that POIR support disproportionately contributed to this catching-up process.

The Frascati transition requires explicit caution. The move to Frascati Manual 2015 institutional-sector methodology from 2016 improves alignment with the current international standard but means that the panel crosses a change in statistical compilation. Year fixed effects absorb a common

shift in 2016, but they cannot correct region-specific changes in measurement. Re-estimating the convergence analysis for 2016–2024 therefore provides an important robustness check.

4.1. Limitations and Further Research

The analysis is observational and cannot establish causal additionality. The allocation measure is based on implementation days rather than payments, multi-voivodeship projects are excluded, GDP is a common denominator of key ratios, and the small number of regions limits statistical power and the reliability of complex interaction models. The new-project impulse uses the full grant value at project start and should be understood as an initiation shock, not a cash-flow measure. BERD robustness models rely on complete cases because 14 region-year observations are unavailable. Finally, the Frascati methodological transition may affect comparability around 2016, although the post-2016 convergence check yields the same substantive conclusion regarding the role of POIR.

The most useful extension is a beneficiary-level design comparing supported firms with observationally similar unsupported firms and exploiting application scores, timing or other defensible sources of quasi-experimental variation. At the regional level, a heterogeneity check could compare initially low- and high-R&D voivodeships, but such results should be labelled exploratory. Better payment data and a precise allocation of multi-regional projects would also improve exposure measurement.

5. CONCLUSION

Using a strict POIR 1.1.1 regional panel for 2014–2024, this study finds no statistically significant evidence that higher programme intensity is associated with higher contemporaneous business-financed R&D intensity or with its subsequent growth over one to three years. A new-project impulse translates clearly into active programme exposure in the next one to two years, but no corresponding regional R&D response is detected. Polish voivodeships display significant unconditional beta-convergence in business-financed R&D intensity. The coefficient of variation declines descriptively over the full period, but the trend is not statistically significant. Moreover, the estimates do not provide statistically significant evidence linking the catching-up process to cumulative POIR intensity or its interaction with initial R&D intensity in either the full or post-2016 window. Complete-case BERD checks also yield no statistically detectable POIR association, but their smaller samples do not establish that any underlying association is negligible. Therefore the available regional panel identifies a measurable programme implementation cycle and regional convergence, but does not provide statistically significant evidence of additional mobilisation of enterprise-financed R&D associated with differential regional POIR exposure.

LIST OF ABBREVIATIONS

BERD	=	Business Enterprise Expenditure on Research and Development
CV	=	Coefficient of Variation
EU	=	European Union

FE	=	fixed Effects
GDP	=	Gross Domestic Product
HC3	=	Heteroskedasticity-consistent Standard Error Estimator
NCBR	=	National Centre for Research and Development
NUTS	=	Nomenclature of Territorial Units for Statistics
OLS	=	Ordinary Least Squares
POIR	=	Smart Growth Operational Programme (Program Operacyjny Inteligentny Rozwój)
R&D	=	Research and Development

CONFLICT OF INTEREST

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