DIPARTIMENTO DI ECONOMIA POLITICA E STATISTICA — DEPS

unisi

QUADERNI DEPS 934/2025

R&D GOVERNMENT SPENDING AND REGIONAL STRUCTURAL DYNAMICS: SECTORAL HETEROGENEITY IN EUROPE

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November 2025

UNIVERSITÀ DI SIENA 1240

Working Paper Series of the Department of Economics and Statistics of the University of Siena
Piazza San Francesco 7-8, 53100, Siena | Italy
deps.unisi.it

ISSN: 17209668

R&D Government Spending and Regional Structural Dynamics: Sectoral Heterogeneity in Europe

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JEL Codes: R11; E62; H50; O38

Keywords: Fiscal policy; Mission-Oriented Innovation Policies; R&D government spending; Sectoral heterogeneity; Regional economics; Local Projections; European regions.

Acknowledgements: This paper was developed in the context of the Project: 'Social-Ecological Effects of green public expenDitures' (SEED), financed by the Hans Böckler Foundation (Project Number: 2024-94-1).

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Abstract:

This paper evaluates the impact of Mission–Oriented Innovation Policies (MOIPs) and public R&D investment by quantifying the responses of GDP, private investment, hours worked, labour productivity, and the real hourly wage. We combine a Bartik–type identification strategy with the Local Projections method on a novel dataset with a sectoral–regional dimension, covering 333 European NUTS–2 regions over 1995–2019. Results show that R&D government spending exerts robust and persistent expansionary effects, crowding in private investment, raising employment, and boosting productivity. Sectoral heterogeneity emerges, with high multiplicative effects in construction and finance, while employment effects are concentrated in construction and market services.

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1. Introduction

The role played by the public sector and particularly by Mission–Oriented Innovation Policies (MOIPs) has recently emerged as a key instrument for fostering socio–economic transformation, particularly in addressing 'grand societal challenges' and stimulating technological progress (Mazzucato, 2013; EC, 2018). MOIPs are characterised by strategic public investments with a strong R&D component, designed to crowd in private investment, create new markets, and promote sectoral transformation (Deleidi and Mazzucato, 2021). Within the mission–oriented approach to innovation, the state is not merely a fixer of market inefficiencies but a proactive agent that creates markets, reshapes industrial structures, drives growth and innovation by generating dynamic interactions across sectors and enhancing regional cohesion (Mazzucato, 2021; Bailey et al., 2023). Recent contributions also highlight the value of missions and solution–oriented industrial policies at the regional and city–regional level (Flanagan et al., 2023), where local contexts enable coordination among actors in articulating needs, testing, and implementing solutions. Such coordination is crucial for market formation processes and for strengthening the social acceptance of proposed solutions. Within this framework, micro–missions—which complement grand challenges—provide policymakers with a more targeted and adaptive tool for addressing place–based challenges, thereby enhancing the effectiveness and inclusiveness of MOIPs (Henderson et al., 2024).

Within the European context, MOIPs are gaining prominence as pivotal tools for tackling major challenges, such as climate change and public health crises. The EU's multilevel governance system provides an especially favourable setting, combining EU–wide missions with national implementation and regional experimentation (EC, 2018). Crucial to this process is the renewal of capacity building in public organisations and institutions, together with enhanced competencies at the European, national, regional, and local levels, to ensure effective coordination in the formulation and implementation of missions. Beyond strengthening regional research and innovation capacities, EU–wide efforts are also needed to align policies with grand challenges. Yet, structural disparities across regions—linked to differences in export orientation, import dependence, and sectoral specialisation—

create heterogeneous conditions for policy effectiveness, making the regional dimension crucial (Flanagan et al., 2023). To address these disparities, the EU has promoted place–based industrial strategies (Bailey and De Propris, 2019), most notably through the Smart Specialisation Strategies (S3). These strategies leverage territorial assets while fostering interregional networks and cross–sectoral collaboration, enabling regions to build cross–border value chains. In doing so, S3 has turned territorial diversity into strength and underscored the importance of local policy experimentation and institutional networks in promoting entrepreneurship and industrial development, pointing to a strong complementarity between innovation and development policies (Lowe and Feldman, 2018).

This shift in attention to innovation policies, and MOIPs in particular, is reflected in a growing body of quantitative research on the effects of public R&D investment. However, this literature remains relatively limited, as most studies rely on country–level aggregate data, which overlook regional and sectoral heterogeneity. Regional–level studies have primarily concentrated on output effects of targeted programmes—especially Cohesion Policy (CP) (e.g. Canova and Pappa, 2021; Destefanis and Di Giacinto, 2023; Celli et al., 2024)—instead of addressing the wider impact of R&D government spending. Sectoral studies, by contrast, often extend the analysis of total public expenditure beyond output to include distributional and labour market outcomes (e.g. Ramey and Shapiro, 1998; Perotti, 2008; Cardi and Restout, 2023). Yet, the regional–sectoral dimension of R&D government spending impacts remains largely unexplored. This represents a critical gap in the literature, as little is known about how subnational and sectoral characteristics shape the effectiveness of R&D government spending. This paper contributes to filling this gap by adopting a joint regional–sectoral perspective to assess the impact of R&D government spending across European regions and sectors, and by examining its economic, technological, and distributional effects within the MOIPs framework. The main novelties of this contribution are threefold: i) evaluating the overall effects of R&D government spending in the European context by exploiting the granular regional sector–level dimension of the data; ii) exploring the heterogeneous transmission mechanisms through which R&D government spending shapes regional economic output by analysing sector–specific dynamics;

iii) extending the analysis beyond output to include distributional and technological variables, thereby providing a more comprehensive view of the channels through which R&D government spending operates.

To this end, we apply the Local Projections (LP) approach to a NUTS–2 level dataset from the Annual Regional Database of the European Commission's Directorate General for Regional and Urban Policy (ARDECO), covering 333 regions in 25 European countries over the period 1995–2019. We evaluate the impact of R&D government spending ($G\_R\&D$) on output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W). Regional R&D government spending ($G\_R\&D$) shocks are identified using a Bartik–type instrument (Bartik, 1991). As a first step, following the classification used in previous studies based on ARDECO dataset (e.g., De Groot et al., 2023; Gabriel et al., 2023), we aggregate the data into four sectors—industry (B–E), construction (F), market services (G–J), and finance (K–N)—to provide a comprehensive assessment of the overall effects on private economic activity. As a second step, we proceed with a disaggregated approach, estimating sector–specific multipliers to uncover heterogeneous effects. This two–step strategy allows us to capture both the average impact of R&D government spending ($G\_R\&D$) and its variation across sectors with different economic and production structures. Our findings yield relevant insights and can be summarised as follows: i) R&D government spending exerts robust and persistent expansionary effects on output, private investment, and labour market outcomes; ii) labour productivity increases in response to R&D government spending, challenging the view that fiscal policy lacks supply–side effects and underscoring its role as a driver of structural transformation and long–term growth; iii) the effects of R&D government spending are consistently positive but heterogeneous across sectors; iv) output and private investment respond strongly in all cases, with large multipliers in construction and finance; v) labour market effects are more uneven, with construction and market services displaying substantial job creation, whereas in finance the response is mainly driven by investment dynamics and lower labour intensity.

The remainder of the paper is organised as follows. Section 2 reviews the related literature. Section 3 presents the data, methods, and identification strategy. Section 4 discusses the empirical findings on both average and heterogeneous sectoral effects. Section 5 concludes.

2. Literature Review

In recent years, increasing attention has been devoted to the macroeconomic impact of public R&D investment and MOIPs. A growing body of literature in industrial economics has revisited the role of the state and public institutions from an entrepreneurial perspective, emphasising their capacity to act as engines of economic growth and to direct technological change (Mazzucato, 2013, 2018; Deleidi and Mazzucato, 2021). Within the mission–oriented approach to innovation, the state is understood not merely as a fixer of market inefficiencies but as a proactive agent that creates new markets, reshapes industrial structures, and mobilises innovation to tackle clearly defined societal goals. In this context, MOIPs are conceived as systemic public policies grounded in strategic investments, which operate *de facto* as industrial policies drawing on frontier knowledge to achieve transformative objectives—namely, “big science deployed to meet big problems” (Mazzucato, 2018).

In the European framework, MOIPs are increasingly recognised as an effective toolkit for addressing major societal challenges—including climate change, demographic shifts, and public health crises. Importantly, the EU’s multilevel governance structure—linking EU, national, and regional levels—offers a particularly favourable institutional setting for implementing mission–oriented strategies, enabling local experimentation within broader EU–wide missions (EC, 2018).

From an empirical perspective, a growing number of recent studies highlight that public investment in R&D—particularly within the framework of MOIPs—can generate substantial macroeconomic returns, often outperforming other types of public spending in terms of impact on output and productivity (Deleidi and Mazzucato, 2021; Ziesemer, 2021; Antolin–Diaz and Surico, 2025; Ciaffi et al., 2024; 2025). However, this emerging literature remains relatively limited, with most studies relying on country–level aggregate data and providing little insight into regional or sectoral variations in the effects of public R&D.

While current evidence highlights the macroeconomic potential of MOIPs and public R&D investment, a systematic understanding of the territorial and sectoral heterogeneity of these outcomes remains lacking. This represents a critical gap in the literature. Further research is needed to explore how subnational and industrial characteristics shape the effectiveness of public R&D spending. This paper contributes to this agenda by combining a regional and sectoral perspective to assess the impact of government R&D investment across European regions and sectors.

This section brings together two complementary strands of literature that inform the empirical approach of this paper. The first focuses on the regional effects of public expenditure, investigating how fiscal policy impacts vary across territories with different economic structures and institutional capacities. The second examines the sectoral dimension of fiscal policy, analysing the heterogeneous responses of industries to public spending and R&D investment. To facilitate clarity, the review is structured into two subsections: Section 2.1 reviews the literature on regional–level fiscal multipliers, while Section 2.2 discusses the evidence on sector–specific effects of public expenditure.

2.1 Regional estimates

The existing literature on the effects of fiscal policy at the regional level has largely focused on estimating the impact of public spending on regional output, especially in the context of the United States (see, among others, Nakamura and Steinsson, 2014; Auerbach et al., 2020; Bernardini et al., 2020). A comprehensive meta–analysis identifies an average cross–study output multiplier of approximately 1.8 (Chodorow–Reich, 2019). Several key findings emerge from this body of research. Fiscal multipliers tend to be larger in more developed regions than in lagging ones (Deleidi et al., 2021; Lucidi, 2023), and show substantial heterogeneity across sectors, regions, and countries (Destefanis et al., 2022; Gabriel et al., 2023). Public investment is generally found to produce stronger multiplier effects than government consumption, both at the national and subnational level

(Brueckner and Tuladhar, 2014; Piacentini et al., 2016; Deleidi et al., 2021). The degree of regional fiscal autonomy also plays a crucial role: multipliers tend to be close to zero in low–autonomy regions, while they approach unity in regions with greater fiscal discretion (Brueckner et al., 2023). Moreover, increases in military spending relative to regional output have been shown to raise both per capita output and employment by more than one, with effects that are particularly pronounced during economic downturns (Nakamura and Steinsson, 2014).

In the European context, an expanding literature has examined the effects of public spending at the regional level, typically focusing on Cohesion Policy (CP) and its role in promoting convergence across territories (Iammarino et al., 2019). Again, most contributions assess the impact on regional GDP, often by evaluating the effectiveness of specific EU funds such as the European Regional Development Fund (ERDF) and the European Social Fund (ESF). For example, Canova and Pappa (2021) estimate a 3–year cumulative output multiplier of 1.08 for ERDF and a much larger value of 5.09 for ESF. Other studies document positive GDP effects of CP interventions, particularly in less–developed regions (Pellegrini et al., 2013; Biedka et al., 2022; Destefanis and Di Giacinto, 2023), although some findings suggest higher returns in more advanced areas (Crescenzi and Giua, 2016).

With respect to the composition of CP, Celli et al. (2024) examine whether large–scale R&D investments contribute to growth in the least–developed EU regions. Their findings confirm that CP has a positive and statistically significant impact on regional economic performance, adding an average of 0.74 percentage points in annual GDP growth between 2006 and 2015. However, they also show that a higher share of R&D expenditure within CP allocations does not necessarily lead to faster growth, suggesting diminishing returns or contextual constraints in translating R&D investment into economic outcomes.

While the literature on output multipliers is extensive, less attention has been paid to the effects of public spending on other key economic outcomes, such as employment, productivity, and wages. Evidence on employment multipliers at the regional level is more limited and inconclusive.

While Becker et al. (2010) and Coelho (2019) find no significant employment effects from CP funding, Canova and Pappa (2021) estimate a 3–year employment multiplier of 0.88 for ERDF and 1.61 for ESF. Gabriel et al. (2023) extend the analysis of regional fiscal multipliers by showing that increases in public spending lead to significant and persistent rises in both total factor productivity and labour productivity, as well as in private investment. On impact, private investment grows by around 5%—twice the magnitude of the output response—while the estimated investment multiplier approaches 1.1 within four years. These results highlight the potential of fiscal expansions to stimulate supply–side dynamics alongside demand. More recently, Deleidi et al. (2025), using a panel structural VAR approach for Italian regions, provide compelling evidence that regional fiscal expansions—especially when combined with rising real wages—produce lasting positive effects on both employment and productivity. These results challenge traditional prescriptions favouring wage flexibility and fiscal austerity.

Overall, while the literature on regional fiscal multipliers and Cohesion Policy is substantial and expanding, it remains predominantly focused on the effects of public spending on GDP. Much less attention has been devoted to other economically relevant outcomes—such as employment, productivity, and wages—as well as to the composition of public spending, particularly with respect to R&D investment. In particular, the role of public R&D and its interaction with regional development dynamics remains relatively underexplored, especially in the context of MOIPs. This paper contributes to addressing these gaps by examining a broader set of economic outcomes and by assessing the regional impact of public R&D spending within a MOIPs framework.

2.2 Sectoral Effects

The existing literature has largely focused on the aggregate effects of fiscal policy. A growing body of research, however, examines its sectoral dimension, to uncover the transmission mechanisms through which government spending affects the broader economy. In contrast to the regional perspective discussed above, many of these studies extend the analysis beyond sectoral economic activity to examine distributional patterns and labour market dynamics.

One of the earliest works to open this line of inquiry is Ramey and Shapiro (1998), who analyse U.S. military spending between 1947 and 1996. Their theoretical model shows that sectoral fiscal multipliers vary with capital reallocation costs. Their empirical results indicate that military spending reallocates labour toward manufacturing and reduces real wages across sectors, in line with a neoclassical multisectoral framework. Barth and Ramey (2002) corroborate this view, showing that the expansion of the aerospace sector in the 1980s increased hours worked but lowered real industrial wages. In contrast, Perotti (2008), using input–output data, finds that government spending during the Vietnam War raised both hours worked and real wages in targeted sectors. These results challenge neoclassical predictions and align more closely with a New Keynesian model with nominal rigidities, in which fiscal expansions reduce markups and boost real wages. However, this interpretation is challenged by Nekarda and Ramey (2011), who find that government spending increases sectoral activity on average, but is associated with declines in real wages and labour productivity and has no significant effect on markups. Their findings support a neoclassical model with perfect competition and decreasing returns, highlighting persistent theoretical disagreement surrounding the transmission mechanisms of fiscal policy across sectors.

Another strand of the literature investigates the sectoral effects of fiscal policy in open–economy contexts, typically distinguishing between tradable sectors—mainly industry and agriculture—and non–tradable sectors, such as services and construction. Bénétrix and Lane (2010), using a VAR model on a panel of European countries, find that fiscal expansions stimulate both groups, with stronger effects observed in non–tradable sector. Similarly, Monacelli and Perotti (2008) show that government spending shocks in the U.S. raise consumption and output in both manufacturing and services, while also increasing the relative price of non–tradable goods. Galstyan and Lane (2009) further find that government consumption raises demand and prices in non–tradables, whereas public investment improves productivity, leading to a decline in their relative price. Focusing on Greece, Tagkalakis (2015) shows that spending cuts reduce aggregate output but enhance net exports by boosting tradable sector activity and improving cost competitiveness.

Several studies have also examined the sectoral effects of fiscal policy in closed–economy settings. Wesselbaum (2015), using a New Keynesian model with U.S. data, finds that public investment is more effective than public consumption in boosting output, due to sector–specific differences in hiring costs and bargaining power. Among the various subcategories of U.S. government spending, Bouakez et al. (2018) show that expenditures on durables and structures have stronger sectoral effects, although they find no clear relationship between the size of the intervention and the resulting output response.

More recently, Cardi and Restout (2023), applying the LP approach to a panel of 18 OECD countries, find that while real GDP gains are evenly distributed across sectors (with an average multiplier of 1.4), labour growth is concentrated in non–tradable industries due to labour–biased technological change. Productivity gains, a key driver of the output response, are more pronounced in sectors with high tangible asset intensity and lower reliance on skilled labour or intangible capital. Building on this, Bouakez et al. (2025) show that the aggregate fiscal multiplier varies significantly depending on the sectoral origin of government spending, with estimates ranging from 0.23 to 1.13. Using a theoretical and empirical model for the U.S. economy, they find that multipliers are higher when spending targets downstream, labour–intensive sectors such as services, and lower for upstream, capital–intensive sectors like manufacturing. These findings are particularly relevant for fiscal policy design, as defence (non–defence) spending is primarily concentrated in manufacturing (service) industries, which are associated with lower (higher) multipliers. This aligns with Boehm (2020), who finds lower multipliers for government purchases of durable and capital goods, typically concentrated in manufacturing. Finally, Gabriel et al. (2023), using regional ARDECO data, decompose the Eurozone multiplier by sector and find that industry and services drive most of the increase in private output. However, the services sector emerges as the main contributor to employment gains, reflecting its labour–intensive nature. Moreover, investment and wage responses differ markedly across sectors: investment rises most in industry and services, with a delayed increase in finance, while wage growth is most pronounced in industry and construction.

Despite the existing evidence on the effects of public spending on various economic outcomes, the regional–sectoral dimension of R&D impacts remains largely unexplored. This paper addresses this gap by assessing the regional effects of R&D government spending across sectors, and examining its role in shaping economic, technological, and distributional dynamics.

3. Data and Methodology

This section presents the data and empirical strategy used to estimate the effects of R&D government spending. Section 3.1 describes the data sources and structure of the panel dataset used in the analysis. Section 3.2 outlines the strategy adopted to identify regional spending shocks using a Bartik–type instrument. Finally, Section 3.3 presents the estimation approach based on Local Projections (LP), which we use to derive impulse response functions (IRFs) and compute cumulative effects over time.

3.1. Data

To investigate the impact of R&D government spending ($G\_R\&D$), we use annual panel data across European regions and sectors, covering output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W).[1] The main data sources are Eurostat (Science and Technology database) and the ARDECO database. Regional accounts in ARDECO are available both for the total economy and by NACE sector, allowing us to perform both aggregate and disaggregated analyses. For the sectoral dimension, we follow the classification adopted in previous studies using ARDECO (e.g., De Groot et al., 2023; Gabriel et al., 2023), and group the data into four broad sectors: i) Industry excluding construction (B–E); ii) Construction (F); iii) Wholesale, retail, transport, accommodation and food services, information and communication (G–J); and iv)

[1] We use Gross Value Added (GVA) as the output measure because GDP is not available at the sectoral level.

Financial and business services (K–N).[2] For ease of exposition, we henceforth refer to these four macro–sectors as industry, construction, market services, and finance, respectively. [3]

We build an annual unbalanced panel dataset at the NUTS–2 level, spanning the period 1995–2019, and covering 333 regions from 25 European countries. The resulting region–sector–year panel includes up to 32,904 observations. The countries included in the sample are: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom. All variables are expressed in real terms (2015 EUR).

We begin our empirical analysis by using sectoral regional data on output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W). As a first step, we aggregate data across the four sectors included in our analysis—industry (B–E), construction (F), market services (G–J), and finance (K–N)—to provide a comprehensive assessment of the effects on private economic activity. As a second step, we proceed with a disaggregated approach, estimating sector–specific multipliers to uncover heterogeneous responses. This two–step strategy allows us to capture not only the average impact of R&D government spending ($G\_R\&D$), but also the extent to which it varies across sectors with different economic roles and production structures.[4]

Given the substantial heterogeneity in economic structures across European regions, adopting a sectoral perspective is crucial for understanding the differentiated effects of R&D government

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[2] Our analysis does not include the agricultural sector, as it is subject to dedicated policy frameworks and follows production and innovation dynamics that differ markedly from those of other sectors. For the sake of analytical consistency, we approximate private economic activity through the industry, construction, and services sectors.

[3] It is important to highlight that, due to the lack of data on total public expenditure (G_TOT) at the European regional level, we follow the approach of Brueckner et al. (2023) and Gabriel et al. (2023), using the Gross Value Added (GVA) of the non–market sector as a proxy for total government spending. In our analysis, we include this measure as a control variable to account for the broader effects of government spending. For a detailed discussion on the suitability of using regional GVA of the non–market sector as a proxy for public expenditure, see Gabriel et al. (2023).

[4] Details on data sources used in the empirical analysis are provided in Table A1. Table A2 provide descriptive statistics for the following variables expressed in growth rates: output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W). For each country, the table reports the number of regions (N. Regions), the number of observations (Obs.), the mean (Mean), and the standard deviation (SD) for all variables.

spending. Our dataset includes a diverse set of countries and regions, each characterised by distinct economic profiles, resulting in marked cross–sectional variation.

To illustrate this heterogeneity and motivate a disaggregated analytical approach, we compute the average share of each broad sector in regional GDP. Figures 1 to 4 offer a visual representation of the sectoral composition across regions over the 1995–2019 period, highlighting the spatial distribution of economic specialisation. Darker shades indicate a higher sectoral share in regional GDP, while lighter shades correspond to lower shares. These maps provide an immediate sense of the diversity of economic structures in the sample and offer a first descriptive overview of the relative importance of sectors across European regions.

The sectoral composition varies significantly both across and within countries — for instance, industry accounts for more than 40% of regional GDP in the Southern region of Ireland (IE05), while representing less than 3% in the Inner London – West region of the United Kingdom (UKI3) (Figure 1). The construction sector ranges from about 2% to over 10% of GDP, with the highest share observed in the Illes Balears region of Spain (ES53) (Figure 2). Finance reaches up to 44% in the Greek region of Sterea Ellada (EL42), and market services up to 49% the Inner London – West region of the United Kingdom (UKI3) (Figures 3 and 4). Such differences reinforce the importance of moving beyond aggregate analyses, as the regional impact of R&D government spending is likely to be shaped by the underlying sectoral structure.

[FIGURES 1–4 HERE]

Figure 5 shifts the focus from sectoral composition to innovation capacity, showing the average public research intensity across regions over the 1995–2019 period. Research intensity is computed as the ratio of R&D government spending to regional GDP. Regions shaded in darker blue exhibit higher levels of public research intensity, while those in lighter blue display lower levels. This graphical representation reveals that heterogeneity is not limited to economic structure but also characterises the intensity of R&D government spending. The highest value is found in the Dutch region of Flevoland (NL23), where public research intensity reaches 2.027%, while the lowest is recorded is in the Spanish region of Ciudad Autónoma de Melilla (ES63), at just 0.001% (Figure 5).

[FIGURE 5 HERE]

3.2. Shock identification

To evaluate the impact of R&D government spending ($G\_R\&D$) shocks on key economic outcomes, namely output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W), we employ the Local Projection (LP) approach. A crucial component of the LP methodology is the use of a credible identification strategy to isolate exogenous fiscal shocks. In this context, we identify regional government spending shocks using a Bartik–type instrument (Bartik, 1991), following the approach of Nekarda and Ramey (2011) and Gabriel et al. (2023). The instrument is computed as:

$$Bartik_{r,j,t} = s_r \frac{G\_R\&D_{R,t} - G\_R\&D_{R,t-1}}{Y_{r,j,t-1}} \quad (1)$$

Where subscripts r, j, t refer to region, sector, and time, respectively. The term $s_r = \frac{\overline{G\_R\&D_r}}{\overline{G\_R\&D_R}}$ represents the average share of R&D government spending ($G\_R\&D$) in region r and country R. Regional shares are constructed using absolute values, so that they serve as scaling factors and sum to one at the country level. To account for potential structural changes over time, we compute regional shares using the full Eurozone sample period.[5] Our results are robust to alternative definitions of s_r, such as using the average over the first 5 or 10 years of the sample.

The logic behind the Bartik instrument is to scale national government spending changes in a way that generates more variation in regions with a larger predetermined share of national spending.

[5] In Appendix A, Figure A1, we show the evolution of the regional–to–national ratio of government R&D spending ($s_r = \frac{G\_R\&D_r}{G\_R\&D_R}$) for a set of selected regions, which display a certain degree of variability over time.

In Appendix A, Figure A2 presents a map depicting the regional R&D government spending shares s_r for the considered NUTS–2 regions, while Table A3 reports summary statistics for s_r by country. There is considerable cross–sectional variation in this measure, with values ranging from 0.00005 to 1 (Figure A2). We calculate the lowest shares for Bourgogne (FRI2, France), East Yorkshire and Northern Lincolnshire (UKE1, United Kingdom), and Tees Valley and Durham (UKC1, United Kingdom), and the highest shares for Zahodna Slovenija (SI04, Slovenia), Yugozapaden (BG41, Bulgaria), and București–Ilfov (RO32, Romania). While some countries consist of a single NUTS–2 region (e.g., EE, LU, CY), where the regional share is mechanically equal to one, others display significant within–country dispersion. For instance, in Germany, shares range from 0.001 to 0.12 (mean = 0.026), and in Spain from 0.006 to 0.40 (mean = 0.059), reflecting marked heterogeneity in the allocation of government R&D spending across regions (Table A3).

This regional heterogeneity in R&D government spending is crucial for identification, as it provides exogenous variation in the intensity of national policy shocks across regions. The Bartik shock ($shock_{r,j,t}$) is used as the instrumented fiscal variable in the Local Projection (LP) approach discussed in the next section.

3.3. Methodology

Once the Bartik instrument ($shock_{r,j,t}$) is constructed, we include it in the Local Projections (LP) equation (equation 2) to obtain the impulse response functions (IRFs) and compute the cumulative effects. This approach entails the estimation of a single equation for each variable of interest ($y_{r,t+h}$) at various horizons following the realisation of the shock.

We adopt a two–step estimation strategy. In the first step, we pool all sectors j—industry, construction, market services, and finance—to estimate the average effect of R&D spending shocks on private economic activity. In the second step, we re–estimate the model separately for each sector j to explore heterogeneity in the dynamic responses.

We consider five outcome variables: output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W). For each outcome, we estimate the LP equation over four-time horizons $h = 0,1,\ldots,4$. The general form of the equation is as follows:

$$y_{r,j,t+h} = \alpha_{r,j} + \delta_\tau + \beta^h shock_{r,j,t} + \vartheta_1^h x_{r,j,t-1} + \varepsilon_{r,j,t+h} \quad (2)$$

where $\alpha_{r,j}$ and δ_τ are region–sector and time–fixed effects, respectively; y is the outcome variable of interest (Y, Inv, $Hours$, $Prod$, and W) in region r, sector j considered at each horizon $h = 0, 1, \ldots H$; $shock_{r,j,t}$ is the instrumented R&D government spending shock described in section 3.2 ; $x_{r,j,t-1}$ is composed by a set of control variables and includes the lag of all variables considered in the model.[6] In this case, β^h directly captures the response of the variable of interest to a 1% increase in R&D government spending ($G\_R\&D$) relative to GDP, instrumented using the Bartik measure.

For Y, Inv, and $Hours$ we compute multipliers, which indicate the change in the outcome variable following a unit increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$ (Auerbach and Gorodnichenko, 2012). For $Prod$ and W, we estimate elasticities.

In the case of multiplier estimation, it is important to provide a clarification. In all estimated models, variables are expressed in growth rates, and we apply the procedures of Owyang et al. (2013) and Ramey and Zubairy (2018) to calculate IRFs and multipliers. Specifically, fiscal policy shocks ($shock_{r,j,t}$) are rescaled by the ratio of the selected fiscal variable ($G\_R\&D$) to the dependent variable

[6] The vector of control variables $x_{r,j,t-1}$ includes, for each specification, the lag of the dependent variable, namely, output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W), alongside a set of additional macroeconomic–related controls, in line with the empirical specification adopted by De Groot et al. (2023). Specifically, we include the lagged growth rate of real regional GDP (Y_r), total government spending at the regional level (G_TOT_r), private R&D expenditure at the regional level ($R\&D_r$), and R&D government spending ($G\_R\&D$) at the regional level. To account for broader national dynamics, we also control for lagged real GDP growth at the country level (Y_R), as well as for R&D and total government spending at the national level ($G\_R\&D_R$ and G_TOT_R). In all specifications, given the annual frequency of the data, a lag equal to 1 ($j = 1$) is considered. In all our regression analysis, we use robust Driscoll and Kraay (1998) standard errors to correct for potential heteroskedasticity, autocorrelation in the lags, and error correlation across panels.

(Y, Inv, and $Hours$) at each point in time, so that changes in these variables are measured as a percentage of the dependent variable. This avoids biases that may arise from using a constant sample average.[7] In this way, the β^hcoefficients in equations 2 directly represent the multiplier.

We also calculate the cumulative multipliers that allow us to study the response of our variable of interest per unit increase in $G\_R\&D$. Cumulative coefficients are obtained by dividing the cumulative response of the variable of interest y by the cumulative change in government expenditure that occurred from t to $t+h$ (Ramey and Zubairy, 2018). IRFs and cumulative multipliers are calculated over four years (from t to $t+4$).

4. Results

In this section, we present the empirical results of our analysis. We begin in Section 4.1, where we report the average sectoral effects of R&D government spending on output, private investment, hours worked, labour productivity, and the real hourly wage. This provides an overall picture of how public R&D affects regional economic activity across sectors when aggregated. In Section 4.2, we turn to the heterogeneous sectoral effects, documenting how the responses differ across industry, construction, market services, and finance. This two–step structure allows us to assess not only the aggregate sectoral impact of R&D government spending, but also the differentiated dynamics that emerge when sectoral heterogeneity is considered.

4.1 Average Sectoral Effect

In this section, we analyse the estimated IRFs and cumulative effects, which depict the average sectoral responses of output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W), to a regional R&D government spending shock ($G\_R\&D$). We estimate equation 2 in Section 3.3 for a horizon of four years (h=4). Figure 6 and Table

[7] For a more in–depth discussion of this aspect, see Owyang et al. (2013) and Ramey and Zubairy (2018). Note that our dataset spans 40 years and covers 243 heterogeneous European regions.

1 show, respectively, the IRFs and cumulative coefficients of all models estimated in our baseline analysis. It is worth noting that the tables also report the average effects over the four–year horizon, as well as the peak responses for each variable of interest.[8]

Moreover, we re–estimate the various models to rule out the possibility that our results are driven by specific groups of countries, particularly those with a larger or smaller number of regions. These results are shown in Appendix B, Figures B1 and B2, and in Tables B1 and B2, respectively. As an additional robustness check, we also re–examine the effects of R&D government spending shock ($G\_R\&D$) on the labour market, testing the response of total employment (Emp) and expressing both labour productivity ($Prod\_2$) and real wage (W_2) in per–employee terms. Due to space constraints, we report the responses of these labour market variables in Table B3.[9]

Starting from our baseline analysis, the estimated IRFs indicate that $G\_R\&D$ responds positively and persistently to initial shock throughout the entire horizon considered. Furthermore, the IRFs indicate a lasting positive effect of R&D government spending ($G\_R\&D$) on economic activity levels (Y). Considering the cumulative output multipliers, we estimate an average value of 2.31, ranging from an impact value of 1.39 to 2.86 four years after the shock (Table 1). These results are consistent with previous findings on the effects of government spending at the regional level, as summarized by Chodorow–Reich (2019), who reports an average cross–study output multiplier of 1.8. More specifically, using a Bartik instrument for the U.S., Nakamura and Steinsson (2014) estimate a two–year output multiplier of 2.5, while Bernardini et al. (2020) find an impact multiplier of 2.0. In line with these findings, Gabriel et al. (2023), combining a Bartik–type instrument with a LP approach, estimate an output multiplier for regional government spending in Europe of 2.14 on impact, which remains at a similar level even four years after the fiscal shock. These positive effects on aggregate demand are also associated with a crowding–in of private investment (Inv). Indeed, a

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[8] Following Spillimbergo et al. (2009), we define the peak multiplier as $\underset{H}{max} \frac{\Delta Y(t+H)}{\Delta G\_IN(t)}$ over all horizons H.

[9] The IRFs of Emp, $Prod\_2$ and W_2 to a government R&D government spending shock ($G\_R\&D$) are available upon request.

positive shock to R&D government spending ($G\_R\&D$) appears to generate additional productive capacity already on impact, as indicated by a significant investment multiplier of 0.13. Four years after the fiscal shock, the multiplier on private investment increases to 0.17, with an average value over the horizon considered of 0.16. These estimates confirm the potential of fiscal expansions to stimulate private business investment not only at the national level—as emphasised by D'Alessandro et al. (2019) for the U.S.—but also at regional and sectoral levels. This is consistent with previous findings by Gabriel et al. (2023), who estimate an impact increase in private investment of 5% in response to a regional fiscal shock in Europe, twice the magnitude of the corresponding output response.

The positive effects of a R&D government spending expansion are not limited to overall economic activity but also extend to the labour market. As shown in Figure 6, a positive shock to this type of public spending leads to a significant and persistent increase in total hours worked ($Hours$). Specifically, we quantify the hours worked multiplier, which captures the change in hours worked following a €100,000 increase in $G\_R\&D$. According to the values reported in Table 1, such a fiscal expansion results in an additional 1,683 hours worked already in the year of the shock. This trend continues over time, with the multiplier reaching over 6,000 additional hours after four years, essentially quadrupling its initial effect. These findings are consistent with Gabriel et al. (2023), who show that a regional fiscal expansion in Europe increases total hours worked by 2.5% within two years. Our results suggest that such an increase in hours worked can also be achieved through targeted regional public spending in R&D. The positive response of both output and hours worked to a $G\_R\&D$ shock naturally raises the question of its effect on their ratio—namely, labour productivity ($Prod$). Again, referring to Figure 6, we find that a 1% increase in R&D government spending leads to a positive response in labour productivity, with an average increase of 0.6% over the four–year horizon (see Table 1). These findings align with a growing literature documenting the persistent productivity effects of fiscal expansions, both at the aggregate level (e.g., Deleidi and Mazzucato, 2021; Ziesemer, 2021; Antolin–Diaz and Surico, 2025; Ciaffi, 2025) and at the regional level (e.g., Deleidi et al., 2021; Lucidi, 2023; Gabriel et al., 2023). Taken together, this evidence challenges the notion that public spending cannot generate supply–side effects in the economy. Furthermore, it is also interesting to explore the distributional impact of a R&D government spending expansion on the real hourly wage (W). However, as seen in both Figure 6 and Table 1, while a 1% increase in $G\_R\&D$ raises the real hourly wage by up to 0.2%, this effect is not statistically significant at any point within the four–year window. Therefore, while our estimates do not support the negative relationship between public spending and real wages identified by Nekarda and Ramey (2011), they also do not provide strong evidence in favour of a positive wage response at the regional level, as suggested by Deleidi et al. (2025).

To further test the robustness of our findings, we perform a set of additional exercises. First, we verify that our results are not driven by specific groups of countries. To this end, we re–estimate equation 2 while alternatively excluding countries with the highest number of regions—such as Germany and the UK, which together account for 79 regions in our dataset—and those with only one or two regions (i.e., CY, EE, LT, LU, LV, MT, SI). As shown in Figures B1 and B2 and Tables B1 and B2, the main results remain substantially unchanged, confirming the robustness of our findings across different country compositions. Finally, we reassess the labour market effects of the R&D government spending shock by focusing on employment rather than hours worked and examining the response of total employment (Emp), labour productivity per employee ($Prod\_2$), and real wage per employee (W_2). As shown in Table B3 in Appendix B, a €100,000 increase in R&D government spending leads to 0.78 additional jobs in the year of the shock, rising to 2.24 jobs after four years. These results confirm the positive impact of the fiscal shock on total employment, as well as a statistically significant increase in labour productivity ($Prod\_2$) and a positive but not statistically significant effect on real wages (W_2).

In summary, our findings indicate that regional R&D government spending exerts robust and persistent expansionary effects on the average sectoral responses of output, private investment, and labour market outcomes. This evidence confirms, at the regional level, what a growing body of macroeconomic literature has documented at the national level (Deleidi and Mazzucato, 2021; Ziesemer, 2021; Antolin–Diaz and Surico, 2025; Ciaffi et al., 2024). The crowding–in of private investment, alongside sustained increases in both hours worked and total employment, underscores the potential of R&D–oriented fiscal policy to stimulate both demand and supply. When combined with the positive impact on labour productivity, this evidence challenges the view that fiscal policy lacks supply–side effects at the regional level and supports the notion that public R&D spending can serve as an effective tool for fostering structural change and long–term growth.

This prompts further investigation into whether these average sectoral effects mask substantial heterogeneity across sectors, potentially driven by sector–specific characteristics—an issue we address in the next section.

[FIGURE 6 HERE]

[TABLE 1 HERE]

4.2 Heterogeneous sectoral effect

Our previous evidence shows that expansions in regional R&D government spending generate positive effects on both the demand and supply sides at the sectoral level, affecting economic activity and labour market outcomes. These results, however, capture average effects that may obscure substantial heterogeneity across sectors. In this section, we enrich our analysis by identifying the sectors that primarily drive these dynamics. Exploiting the granularity of our dataset, we examine the transmission mechanisms through which R&D government spending influences the regional economy. To do so, we re–estimate equation 2, focusing in turn on the four sectors included in our analysis: industry, construction, market services, and finance.

Figures 7 to 10 and Tables 2 to 5 report the estimated IRFs and cumulative effects over a four–year horizon, showing for each sector the responses of output (Y), private investment (Inv), hours worked ($Hours$), labour productivity ($Prod$), and real hourly wage (W), to a R&D government spending shock ($G\_R\&D$). Consistent with the previous section, we verify that our findings are not driven by specific countries with either a large or small number of regions. The corresponding robustness checks are reported in Appendix C, from Figure C1 to Figure C8, and in Tables C1 and C2. In addition, Table C3 presents the responses to a $G\_R\&D$ shock of other labour market indicators, such as employment (Emp) and both labour productivity ($Prod\_2$) and real wage (W_2) in per–employee terms.[10]

The IRFs reported in Figures 7 to 10 indicate that a $G\_R\&D$ shock at time t exerts a persistently positive effect across all sectors over four years. Regarding sectoral output (Y), we find sizable multipliers in most cases (see Tables 2–5). The adjustment unfolds gradually, but in the industry sector the cumulative four–year multiplier is 1.30. Remaining outside the services economy, the construction sector shows an even stronger response, with an impact multiplier of 1.68 and a cumulative four–year multiplier of 3.50. Within services, heterogeneity emerges. As shown in Table 4, although the impact multiplier exceeds unity, the response of market services is never statistically significant. By contrast, in the finance sector the multiplier becomes significant almost immediately and rises above 4 after four years (Table 5). Overall, this positive effect of government R&D spending on the output of finance is associated with an average multiplier of 2.7, broadly comparable to that observed in construction.

These findings are partly consistent with existing evidence on sectoral fiscal multipliers, which generally highlight stronger effects in services. For instance, Benetrix and Lane (2010) show, for a panel of European countries, that fiscal stimuli have larger impacts on non–tradables, proxied mainly by services. More recently, Boehm (2020) and Bouakez et al. (2025) document stronger multipliers in the United States in downstream and labour–intensive sectors, such as services. For European regions, Gabriel et al. (2023) find that fiscal policy primarily transmits to output through

[10] Here as well, the IRFs of Emp, $Prod\_2$, and W_2 to a government R&D spending shock ($G\_R\&D$) for each sector are available upon request.

industry and services. Our results, however, qualify this evidence in two respects. First, although we find significantly positive effects for industry, the sizeable multipliers observed in the construction sector should not be overlooked. Second, within services, the stimulus from R&D government spending ($G\_R\&D$) is far from homogeneous, being concentrated in the finance sector —likely due to components more directly related to R&D expenditure—rather than in market services.

The generally positive effects of R&D government spending on sectoral output also extend to private investment (Inv) across sectors, suggesting the presence of crowding–in effects. In industry, we observe a strong and significant response of productive capacity, with a two–year cumulative investment multiplier of 0.70 (Table 2). In construction (Table 3), the effect is also positive but considerably smaller than in industry. Turning to services, market services record a four–year cumulative investment multiplier of 0.75 (Table 4). By contrast, finance displays sustained crowding–in, with a cumulative investment multiplier exceeding unity in every period and averaging 1.15 (Table 5). Taken together, our results provide consistent evidence that R&D government spending stimulates private investment growth across sectors. This evidence is in line with Gabriel et al. (2023), who show that total public spending stimulates investment growth in both industry and services across European regions. Our findings complement this evidence by focusing specifically on R&D–related expenditures and highlighting their particularly positive effects on the capitalization of traditionally labour–intensive sectors such as services.

The analysis of private investment responses highlights the importance of considering the structural and technological characteristics of each sector, particularly their degree of labour intensity. Examining hours worked ($Hours$) is therefore informative not only about how the labour market responds to $G\_R\&D$ shock but also about how such shock reshape sectoral technological dynamics. Following the approach of the previous section, we compute the hours worked multiplier, which measures the change in hours worked following a €100,000 increase in R&D government spending ($G\_R\&D$). The results reveal heterogeneity across sectors. In industry, the average hours worked multiplier is slightly above 2,000 (Figure 7 and Table 2). The effect is much stronger in construction, where an additional €100,000 in $G\_R\&D$ already translates into more than 2,000 additional hours worked on impact, rising above 9,000 by the end of the horizon (Figure 8 and Table 3). The service economy, however, is heterogeneous: market services show a substantial increase in hours worked, with the multiplier close to 2,000 on impact and rising to almost 8,000 after four years, while the response in finance is never statistically significant and not consistently positive (Figures 9 and 10, Tables 4 and 5). These findings align with the literature documenting large labour market effects of fiscal expansions in services due to their labour–intensive nature (Cardi and Restout, 2023; Gabriel et al., 2023). Yet, our results qualify this evidence by showing that when focusing on R&D government spending, the traditional employment response of services is concentrated in market services. In contrast, the strong output multiplier in finance appears to operate primary through investment dynamics and a likely reduction in labour intensity. Finally, the sizeable multiplier in construction translates directly into substantial job creation, underscoring the high labour intensity of the sector.

In the previous section we showed that, on average, R&D government expenditure raises sectoral labour productivity ($Prod$). This result is broadly confirmed when examining the four sectors separately. As illustrated in Figure 7 and Table 2, a 1% increase in $G\_R\&D$ stimulates labour productivity growth in industry, with a significant response only in the first year after the fiscal shock (0.8%). The effect is stronger in construction (Figure 8 and Table 2), where labour productivity rises by 111 basis points after four years, with an average increase of 77 basis points over the horizon. Market services also exhibit a significant and persistent response, with labour productivity rising by 0.35% on impact and remaining positive on average over the four years. Finally, finance displays a sizeable increase, with a 123-basis point rise in productivity three years after the shock (Figure 10 and Table 5), consistent with the strong output response to R&D government spending documented previously. Overall, although significance varies across years, our estimates consistently point to a positive effect of R&D government spending on labour productivity across all four sectors. Thus, our findings diverge from Nekarda and Ramey (2011), who report negative productivity effects of government spending in the United States, but align more closely with the sectoral evidence of Cardi and Restout (2023) for a panel of 18 OECD countries.

In the previous section, we show that $G\_R\&D$ shocks have a significantly positive effect on labour productivity. By contrast, this effect does not carry over to real hourly wages. Even after decomposing the analysis at the sectoral level, in most cases we do not detect statistically significant positive responses of real hourly wage (W) to increases in $G\_R\&D$. As shown in Figure 10 and Table 5, the only exception is the finance sector, where a 100–basis point increase in $G\_R\&D$ leads, after three years, to a 0.27% rise in real hourly wage. Once again, our estimates do not support the existence of negative wage effects of public spending, as suggested by Nekarda and Ramey (2011). At the same time, however, we do not find significantly positive effects for industry or construction, contrary to Gabriel et al. (2023), who report such evidence for a panel of European regions. If any significant wage effects emerge, they appear to be concentrated in finance—a sector that also displays a high output multiplier, robust productivity gains, and greater capital intensity in response to government R&D expansions.

We conduct a set of robustness checks. First, we verify that the results are not driven by specific groups of countries by re–estimating equation 2 while sequentially excluding those with the largest number of regions and those with only one or two regions. The results are reported in Appendix C (Figures C1–C8 and Tables C1–C2) and broadly confirm the plausibility of our findings under alternative sample compositions. Second, we extend the analysis of labour market outcomes by examining the response of total employment (Emp), labour productivity per employee ($Prod\_2$), and real wages per employee (W_2) to a $G\_R\&D$ shock. Table C3 summarises these results, showing once again that—except for finance— R&D government spending has a positive effect on total employment across all other sectors. The positive response of labour productivity to increases in $G\_R\&D$ is also confirmed in all sectors considered. Finally, real wages per employee do not react significantly, except for finance and industry, where effects are positive but limited to the first years.

In summary, our findings show that R&D government spending generates consistently positive but heterogeneous effects across sectors. Output and private investment respond strongly in all cases, with especially large multipliers in construction and finance. Labour market effects are more uneven: construction and market services display substantial job creation, whereas in finance the response is mainly driven by investment dynamics and lower labour intensity. Labour productivity generally increases across sectors, while real wage effects are modest and statistically significant only in finance. Overall, these results indicate that R&D government spending stimulates structural transformation in regional economies, operating not only at the aggregate level but also within individual sectors through multiple channels—by boosting output growth, stimulating private investment, raising productivity, and reshaping labour intensity.

[FIGURES 7-10 HERE]

[TABLES 2-5 HERE]

5. Conclusion

The role of R&D government spending is gaining renewed centrality, with both academics and international institutions increasingly emphasising its strategic importance in addressing today's grand societal challenges (European Commission, 2018; IMF, 2024; Antolin–Diaz and Surico, 2025). Recent international initiatives—including the US CHIPS and Inflation Reduction Acts, the EU Green Deal Industrial Plan, Japan's New Direction on Economy and Industrial Policy, Korea's K–Chips Act, and China's long–standing strategies—share a common emphasis on expanding public investment in R&D to foster innovation in strategic sectors such as Artificial Intelligence (AI), semiconductors, and green technologies. In this context, MOIPs have emerged as emblematic programs, characterised by a strong reliance on public investment in R&D. By explicitly targeting transformative objectives MOIPs place R&D government spending at the core of broader strategies for structural change and long–term competitiveness (Mazzucato, 2018; Deleidi and Mazzucato, 2021). Moreover, Europe's multilevel governance system provides a particularly fertile ground for this approach, as it allows both member states and regions to experiment and adapt policies within the overarching framework of EU–wide missions (EC, 2018). Despite this growing attention, the empirical literature still lacks systematic evidence on how R&D government spending operates across regions and sectors, and on the extent to which its effects vary depending on the productive structure. Based on these premises, this paper aims to contribute to this literature by quantifying the regional and sectoral effects of government R&D spending in Europe. To this end, we employ a Bartik–type identification strategy combined with the Local Projections (LP) approach on a dataset covering 333 NUTS–2 European regions over the period 1995–2019. This approach allows us to assess the impact of R&D government spending on output, private investment, hours worked, labour productivity, and real hourly wage.

Our findings reveal several key insights. First, R&D government spending exerts robust and persistent expansionary effects on GDP, private investment, and labour market outcomes, confirming its role in stimulating regional economic activity. In addition, labour productivity increases significantly in response to public R&D, thereby challenging the view that fiscal policy lacks supply–side effects and underscoring its potential as a driver of structural transformation and long–term growth. These results are consistent with a growing body of evidence that highlights the capacity of fiscal expansions to crowd in private investment and foster productivity, both at the aggregate level (Deleidi and Mazzucato, 2021; Ziesemer, 2021; Antolin–Diaz and Surico, 2025; Ciaffi et al., 2024) and at the regional level (Deleidi et al., 2021; Lucidi, 2023; Gabriel et al., 2023). Taken together, this evidence supports the view that public R&D spending can serve as an effective tool for fostering both short–term demand expansion and long–term structural change. Second, the heterogeneity of the effects of R&D government spending at sectoral level emerges as a particularly relevant dimension. While output, private investment, and labour productivity respond positively across sectors, the largest multipliers are observed in construction and finance, suggesting that these sectors are especially responsive to public R&D support. These results add to the literature documenting stronger fiscal effects in service sectors (Benetrix and Lane, 2010; Boehm, 2020; Bouakez et al., 2025). Third, labour market effects are more mixed. Construction displays substantial job creation, and within services the response is concentrated in market services, whereas in finance the adjustment is mainly driven by investment dynamics and lower labour intensity. These findings add to the literature highlighting stronger employment effects of fiscal expansions in labour–intensive services (Cardi and Restout, 2023; Gabriel et al., 2023), and qualify this evidence by showing that, in the case of R&D government spending, the employment response of services is not uniform but concentrated in market services. Overall, our results underline that sectoral heterogeneity is a key factor to consider when evaluating the effectiveness of public R&D spending. By explicitly documenting these differentiated responses, our analysis demonstrates the importance of assessing the effects at the sectoral level rather than relying solely on aggregate outcomes.

In terms of policy implications, our study complements the growing macroeconomic literature evaluating the effects of public R&D spending (e.g., Deleidi and Mazzucato, 2021; Ciaffi et al., 2024; Antolin–Diaz and Surico, 2025) by showing that the heterogeneous impact across countries may largely stem from the composition of their productive structures. Indeed, our findings suggest that the effectiveness of R&D government spending is not uniform but varies across sectors, with some sectors generating stronger multiplier effects and larger contributions to productivity and employment than others. This dimension is even more relevant in a multilevel governance system such as the European Union, and it should be carefully considered by policymakers when designing spending programmes, as the sectoral allocation of R&D investment may condition both its short–term effectiveness and its contribution to long–term structural change.

References

Acemoglu, D., García–Jimeno, C., & Robinson, J. A. (2015). State capacity and economic development: A network approach. *American Economic Review*, *105*(8), 2364–2409.

Antolin–Diaz, J., & Surico, P. (2025). The long–run effects of government spending. *American Economic Review*, *115*(7), 2376–2413.

Auerbach, A. J., & Gorodnichenko, Y. (2012). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy, 4(2),* 1–27.

Auerbach, Alan J., Yuriy Gorodnichenko, and Daniel Murphy (2020). Local Fiscal Multipliers and Fiscal Spillovers in the United States. *IMF Economic Review, 68,* 195–229.

Bailey, D., & De Propris, L. (2019). Industry 4.0, regional disparities and transformative industrial policy. In *M. Barzotto, C. Corradini, F. M. Fai, S. Labory, & P. R. Tomlinson (Eds.), Revitalising lagging regions: Smart specialisation and Industry 4.0* (pp. 67–78). Routledge.

Bailey, D., Pitelis, C. N., & Tomlinson, P. R. (2023). Place–Based Industrial and Regional Strategy – Levelling the Playing Field. *Regional Studies*, *57*(6), 977–983.

Barth III, M. J., & Ramey, V. A. (2001). The cost channel of monetary transmission. *NBER macroeconomics annual*, *16*, 199–240.

Bartik, T. J. (1991). *Who benefits from state and local economic development policies?* W.E. Upjohn Institute for Employment Research.

Becker, S. O., Egger, P. H., & von Ehrlich, M. (2010). Going NUTS: The effect of EU structural funds on regional performance. *Journal of Public Economics, 94*(9–10), 578–590.

Bénétrix, A. S., & Lane, P. R. (2010). Fiscal shocks and the sectoral composition of output. *Open Economies Review*, *21*(3), 335–350.

Bernardini, M., De Schryder, S., & Peersman, G. (2020). Heterogeneous government spending multipliers in the era surrounding the great recession. *Review of Economics and Statistics*, *102*(2), 304–322.

Biedka, W., Herbst, M., Rok, J., & Wojcik, P. (2022). The local-level impact of human capital investment within the EU cohesion policy in Poland. *Papers in Regional Science*, *101*(2), 303–326.

Boehm, C. E. (2020). Government consumption and investment: Does the composition of purchases affect the multiplier?. *Journal of Monetary Economics*, 115, 80–93.

Bouakez, H., Larocque, D., & Normandin, M. (2018). Separating the wheat from the chaff: A disaggregate analysis of the effects of public spending in the US. *Canadian Journal of Economics/Revue canadienne d'économique,* 51(2), 361–390.

Bouakez, H., Rachedi, O., & Santoro, E. (2025). The sectoral origins of heterogeneous spending multipliers. *Journal of Public Economics*, *248*, 105404.

Brueckner, M., & Tuladhar, A. (2014). Local government spending multipliers and financial distress: Evidence from Japanese prefectures. *The Economic Journal*, *124*(581), 1279–1316.

Brueckner, M., Pappa, E., & Valentinyi, A. (2023). Geographic cross-sectional fiscal spending multipliers and the role of local autonomy: Evidence from European Regions. *Journal of Money, Credit and Banking*, 55(6), 1357–1396.

Canova, F., & Pappa, E. (2021). What are the likely macroeconomic effects of the EU Recovery plan?. *CEPR Discussion Paper*.

Cardi, O., & Restout, R. (2023). Sectoral fiscal multipliers and technology in open economy. *Journal of International Economics*, 144, 103789.

Celli, V., Cerqua, A., & Pellegrini, G. (2024). Does R&D expenditure boost economic growth in lagging regions?. *Social Indicators Research*, 173(1), 249–268.
Chodorow–Reich, G. (2019). Geographic cross–sectional fiscal spending multipliers: What have we learned?. *American Economic Journal: Economic Policy*, *11*(2), 1–34.
Ciaffi, G. (2025). Innovation and demand as drivers of labour productivity: An integrated analysis for OECD countries. *Review of Political Economy*, *37*(2), 369–391.
Ciaffi, G., Deleidi, M., & Mazzucato, M. (2024). Measuring the macroeconomic responses to public investment in innovation: evidence from OECD countries. *Industrial and Corporate Change*, 33(2), 363–382.
Coelho, M. (2019). Fiscal stimulus in a monetary union: Evidence from eurozone regions. *IMF Economic Review*, *67*, 573–617.
Crescenzi, R., & Giua, M. (2016). The EU Cohesion Policy in context: Does a bottom–up approach work in all regions?. *Environment and Planning A: Economy and Space*, *48*(11), 2340–2357.
D'Alessandro, A., Fella, G., & Melosi, L. (2019). Fiscal stimulus with learning by doing. *International Economic Review, 60*(4), 1413–1432.
De Groot, O., Hauptmeier, S., Holm–Hadulla, F., & Nikalexi, K. (2023. Monetary policy and regional inequality. *Working Paper Series No. 2385/March 2020, Revised 2023, December*. European Central Bank.
Deleidi, M., & Mazzucato, M. (2021). Directed innovation policies and the supermultiplier: An empirical assessment of mission–oriented policies in the US economy. *Research Policy*, 50(2), 104151.
Deleidi, M., Romaniello, D., & Tosi, F. (2021). Quantifying fiscal multipliers in Italy: A Panel SVAR analysis using regional data. *Papers in Regional Science*, 100(5), 1158–1178.
Deleidi, M., Romaniello, D., Salvati, L., & Tosi, F. (2025). Wage and fiscal policy re–examined. An assessment of employment and productivity using Italian regional data. *International Journal of Manpower*, *46*(2), 218–238.
Destefanis, S., & Di Giacinto, V. (2023). EU structural funds and GDP per capita: spatial var evidence for the European regions. *Bank of Italy Temi di Discussione (Working Paper) No*, *1409*.
Destefanis, S., Di Serio, M., & Fragetta, M. (2022). Regional multipliers across the Italian regions. *Journal of Regional Science*, *62*(4), 1179–1205.
Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, *80*(4), 549–560.
European Commission (EC) (2018). *Mission–Oriented Research and Innovation in the European Union: A Problem–solving Approach to Fuel Innovation–led Growth*. European Commission, Directorate–General for Research and Innovation, ISBN 978–92–79–85794–2.
Flanagan, K., Uyarra, E., & Wanzenböck, I. (2023). Towards a problem–oriented regional industrial policy: possibilities for public intervention in framing, valuation and market formation. *Regional Studies*, *57*(6), 998–1010.
Gabriel, R. D., Klein, M., & Pessoa, A. S. (2023). The effects of government spending in the Eurozone. *Journal of the European Economic Association*, 21(4), 1397–1427.
Galstyan, V., & Lane, P. R. (2009). The composition of government spending and the real exchange rate. *Journal of Money, Credit and Banking*, *41*(6), 1233–1249.

Henderson, D., Morgan, K., & Delbridge, R. (2024). Putting missions in their place: micro–missions and the role of universities in delivering challenge–led innovation. *Regional Studies*, *58*(1), 208–219.

Iammarino, S., Rodriguez–Pose, A., & Storper, M. (2019). Regional inequality in Europe: evidence, theory and policy implications. *Journal of economic geography*, *19*(2), 273–298.

International Monetary Fund (IMF) (2024). Chapter 2: Expanding frontiers—Fiscal policies for innovation and technology diffusion. In *Fiscal Monitor*, April 2024 (pp. 27–54). International Monetary Fund.

Lowe, N., & Feldman, M. P. (2018). Breaking the waves: Innovating at the intersections of economic development. *Economic Development Quarterly*, 32(3), 183–194.

Lucidi, F. S. (2023). The misalignment of fiscal multipliers in Italian regions. *Regional Studies*, 57(10), 2073–2086.

Mazzucato, M. (2013) *The Entrepreneurial State: Debunking the Public vs. Private Myth in Risk and Innovation*. Anthem Press, London.

Mazzucato, M. (2018). *Mission–oriented research & innovation in the European Union*. European Commission, 36.

Monacelli, T., & Perotti, R. (2008). Openness and the sectoral effects of fiscal policy. *Journal of the European Economic Association*, 6(2–3), 395–403.

Nakamura, E., & Steinsson, J. (2014). Fiscal stimulus in a monetary union: Evidence from US regions. *American Economic Review*, 104(3), 753–792. https://doi.org/10.1257/aer.104.3.753.

Nekarda, C. J., & Ramey, V. A. (2011). Industry evidence on the effects of government spending. *American Economic Journal: Macroeconomics*, *3*(1), 36–59.

Owyang, M. T., Ramey, V. A., & Zubairy, S. (2013). Are government spending multipliers greater during periods of slack? Evidence from twentieth–century historical data. *American Economic Review*, *103*(3), 129–34.

Pellegrini, G., Terribile, F., Tarola, O., Muccigrosso, T., & Busillo, F. (2013). Measuring the effects of European regional policy on economic growth: A regression discontinuity approach. *Papers in Regional Science, 92*(1), 217–233.

Perotti, R. (2008). In search of the transmission mechanism of fiscal policy. In D. Acemoglu, K. Rogoff, & M. Woodford (Eds.), *NBER macroeconomics annual 2007* (Vol. 22, pp. 169–226). University of Chicago Press. https://doi.org/10.1086/ma.22.3585148

Piacentini, P., Prezioso, S., & Testa, G. (2016). Effects of fiscal policy in the Northern and Southern regions of Italy. *International Review of Applied Economics*, *30*(6), 747–770.

Ramey, V. A., & Shapiro, M. D. (1998). Costly capital reallocation and the effects of government spending. *Carnegie–Rochester Conference Series on Public Policy, 48*, 145–194.

Ramey, V., & Zubairy, S. (2018). Government Spending Multipliers in Good Times and in Bad: Evidence from U.S. Historical Data. *Journal of Political Economy, 126*, 850–901.

Spilimbergo, A., Schindler, M., & Symansky, S. A. (2009). *Fiscal multipliers* (No. 2009–2011). Washington, DC: International Monetary Fund.

Tagkalakis, A. O. (2015). Fiscal policy, net exports, and the sectoral composition of output in Greece. *International economics and economic policy,* 12(4), 521–539.

Wesselbaum, D. (2015). Sectoral labor market effects of fiscal spending. *Structural Change and Economic Dynamics*, 34, 19–35.

Ziesemer, T. H. (2021). Mission–oriented R&D and growth. *Journal of Applied Economics, 24(1)*, 460–477.

TABLES

Government R&D Investment – $G\_R\&D$

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	**1.39**	**2.24**	**2.44**	**2.62**	**2.86**	2.31	2.35
Inv	**0.13**	**0.16**	**0.19**	**0.18**	0.17	0.16	0.15
$Hours$	**1682.50**	**3482.18**	**4333.21**	**4910.47**	**6050.07**	4091.69	6544.80
$Prod$	**0.30**	**0.51**	**0.73**	**0.72**	0.64	0.58	0.77
W	0.02	0.11	0.11	0.16	0.05	0.09	0.21

Table 1. Cumulative effects. Significant estimates are in bold (68%). Full Sample. All Sectors.
For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t + h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots . 4$.

Government R&D Investment – $G\_R\&D - Industry$

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	-0.13	**0.78**	0.72	0.91	**1.30**	0.72	1.61
Inv	**0.46**	**0.54**	**0.70**	0.56	0.47	0.55	0.63
$Hours$	1048.00	**2562.00**	2210.48	2321.45	2295.65	2087.52	3220.30
$Prod$	0.27	**0.80**	0.66	**0.19**	0.12	0.41	1.06
W	0.22	0.28	0.31	0.34	0.18	0.27	-0.37

Table 2. Cumulative effects. Significant estimates are in bold (68%). Full Sample. Industry.
For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t + h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots . 4$.

Government R&D Investment – $G\_R\&D - Construction$

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	**1.68**	**2.46**	**2.81**	**3.14**	**3.47**	2.71	2.82
Inv	**0.07**	0.08	**0.10**	0.10	0.08	0.09	0.08
$Hours$	**2271.40**	**4253.87**	**5774.54**	**6829.66**	**9163.46**	5658.59	11641.10
$Prod$	0.30	0.56	**0.93**	**0.95**	**1.11**	0.77	1.16
W	0.08	0.13	0.14	0.16	0.12	0.13	0.14

Table 3. Cumulative effects. Significant estimates are in bold (68%). Full Sample. Construction.
For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t + h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots .4$.

Government R&D Investment – $G\_R\&D - Market\ services$

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	0.97	1.75	2.17	1.19	1.15	1.45	2.10
Inv	**0.55**	**0.56**	**0.74**	**0.72**	**0.75**	0.67	0.77
$Hours$	**1977.70**	**4814.65**	**6227.66**	**7506.85**	7909.47	5687.27	8022.10
$Prod$	**0.35**	0.18	**0.45**	0.42	0.28	0.34	0.73
W	-0.06	-0.07	-0.05	**0.05**	-0.02	-0.03	0.26

Table 4. Cumulative effects. Significant estimates are in bold (68%). Full Sample. Market services.
For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t + h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots .4$.

Government R&D Investment – $G\_R\&D - Finance$

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	0.05	**1.82**	**3.10**	**4.00**	**4.22**	2.64	4.64
Inv	**1.20**	**1.37**	1.07	**1.05**	**1.04**	1.15	1.20
$Hours$	-2180.70	-232.44	421.23	522.28	-445.00	-382.93	-3065.3
$Prod$	0.24	**0.47**	**0.84**	**1.23**	1.03	0.76	1.68
W	-0.09	**0.21**	0.21	**0.27**	0.15	0.15	0.45

Table 5. Cumulative effects. Significant estimates are in bold (68%). Full Sample. Finance.
For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t + h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots. 4$.

FIGURES

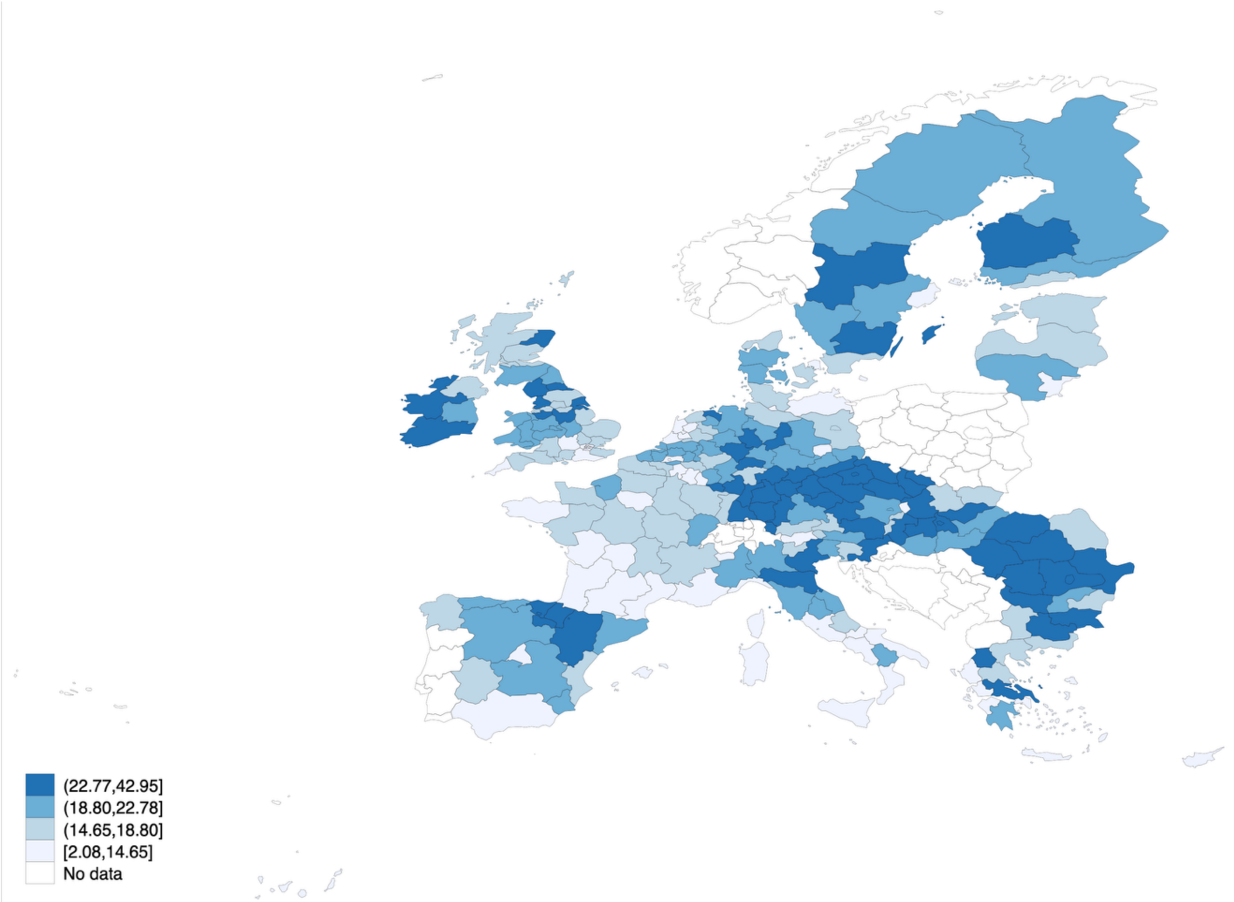

Figure 1. Average share of Industry in regional GDP (1995-2019). Darker blue regions represent a higher sectoral share in regional GDP, while lighter blue regions indicate a lower share.

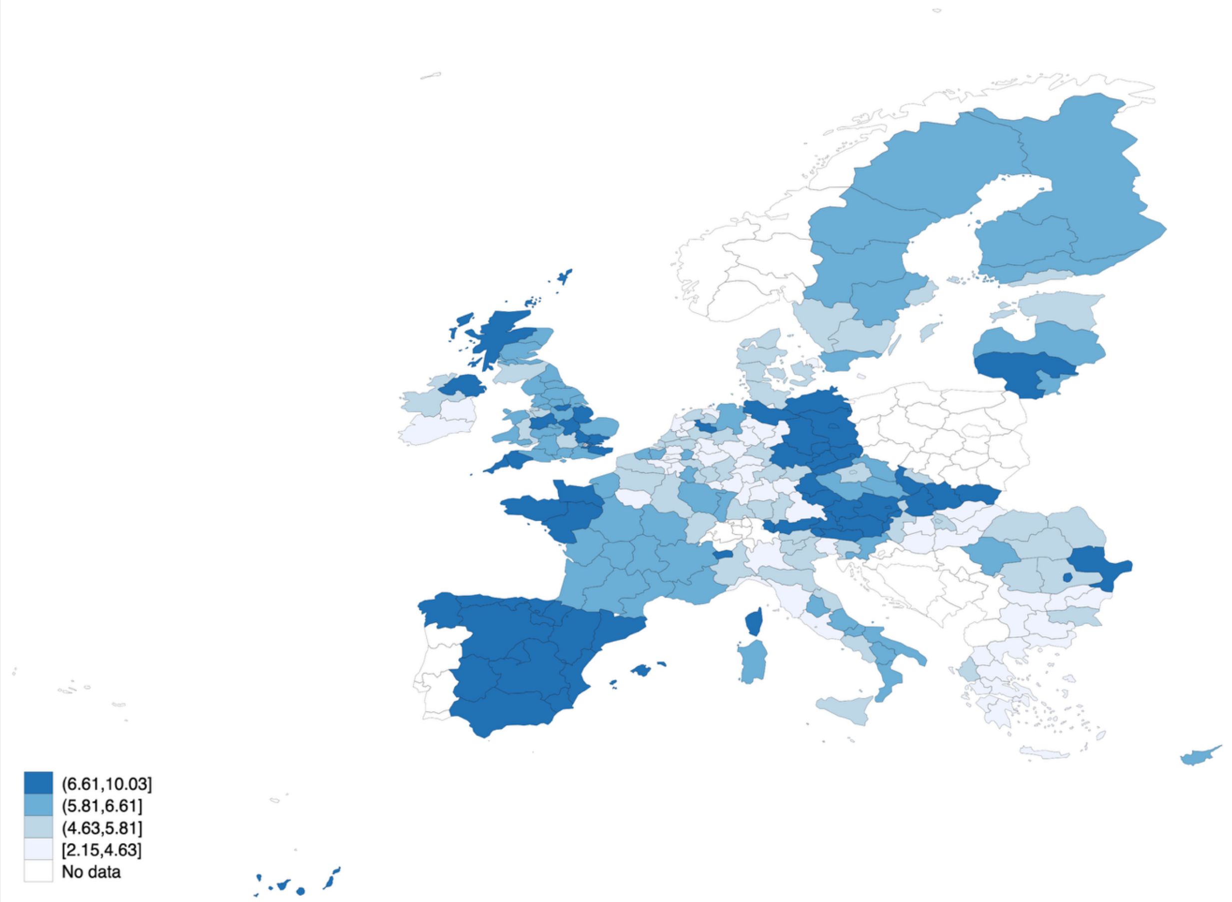

Figure 2. Average share of Construction in regional GDP (1995-2019). Darker blue regions represent a higher sectoral share in regional GDP, while lighter blue regions indicate a lower share.

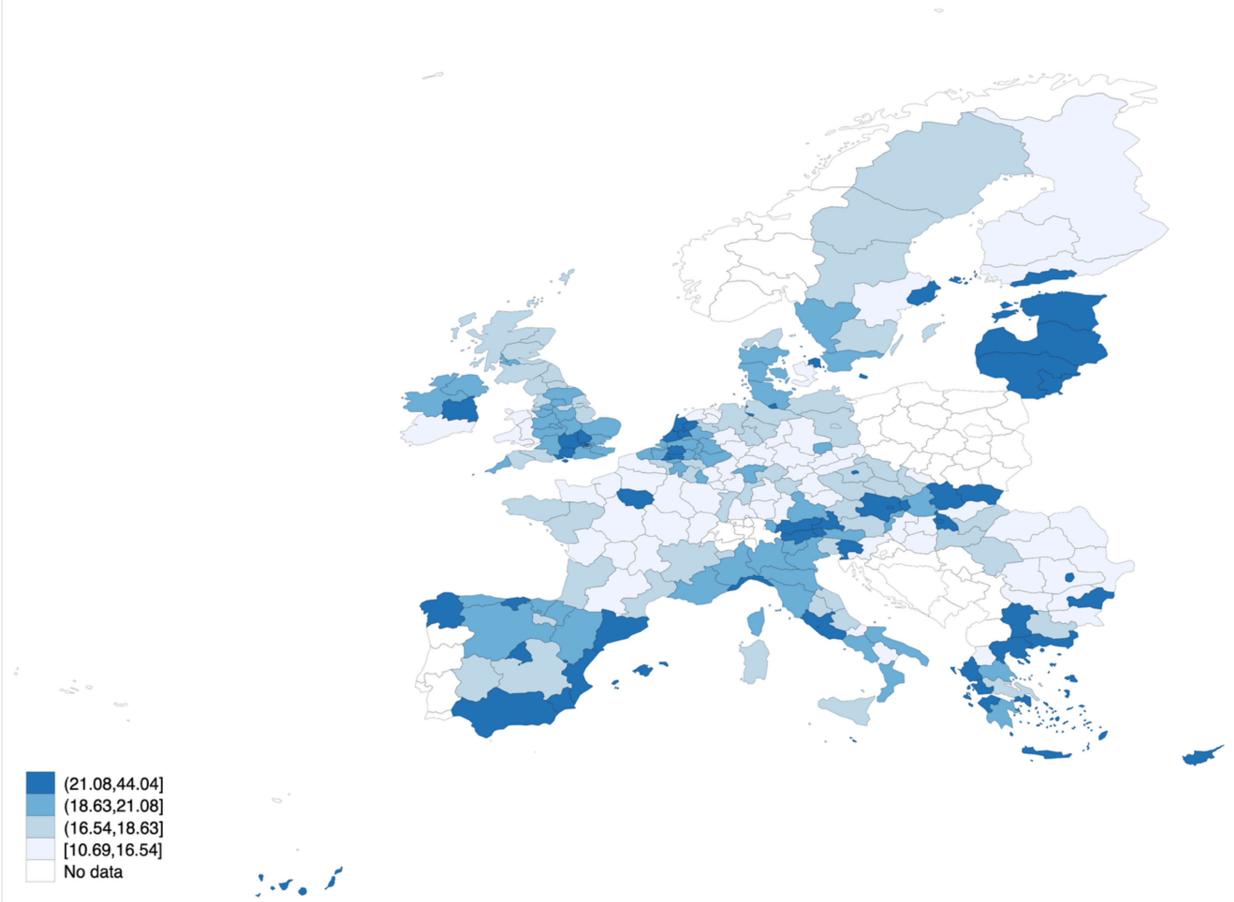

Figure 3. Average share of Market services in regional GDP (1995-2019). Darker blue regions represent a higher sectoral share in regional GDP, while lighter blue regions indicate a lower share.

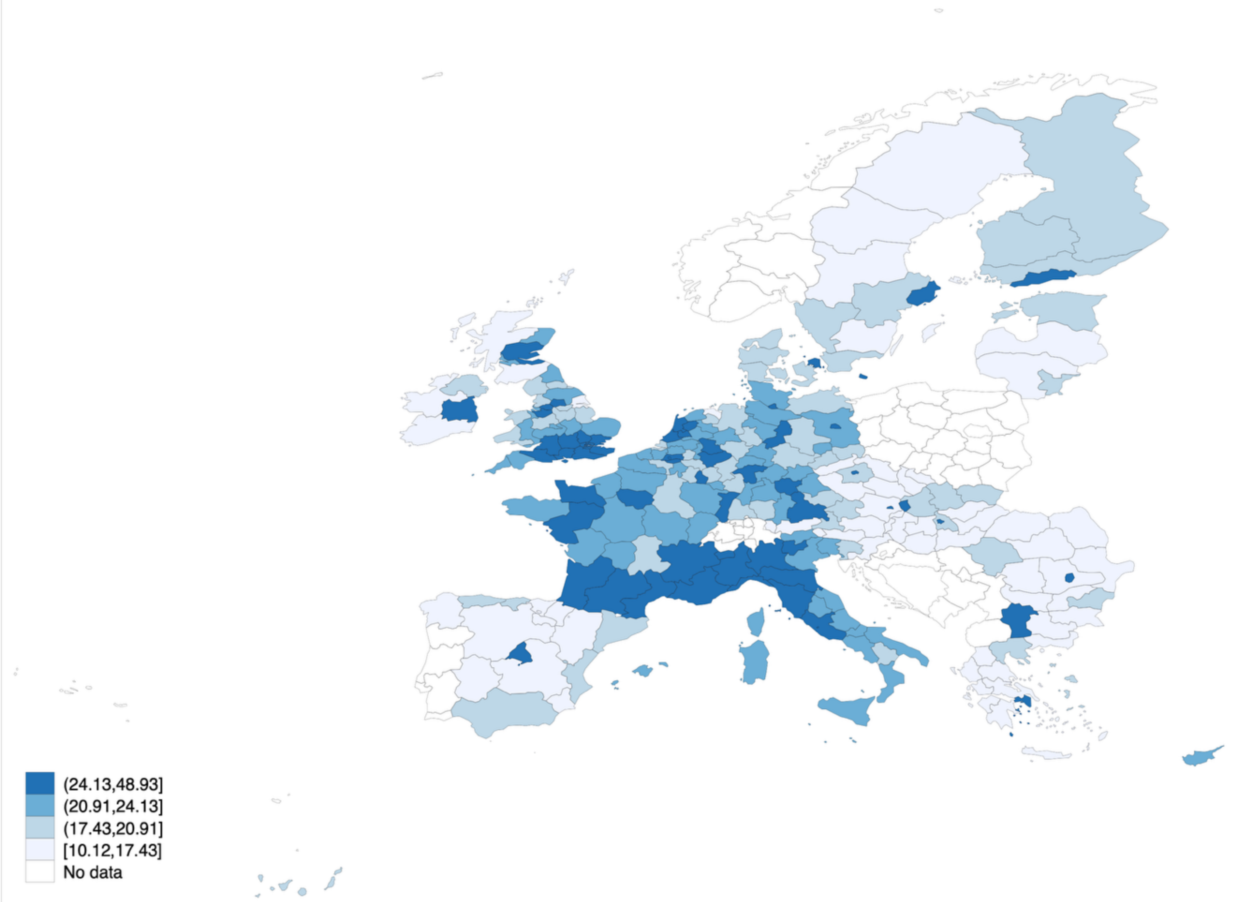

Figure 4. Average share of Finance in regional GDP (1995-2019). Darker blue regions represent a higher sectoral share in regional GDP, while lighter blue regions indicate a lower share.

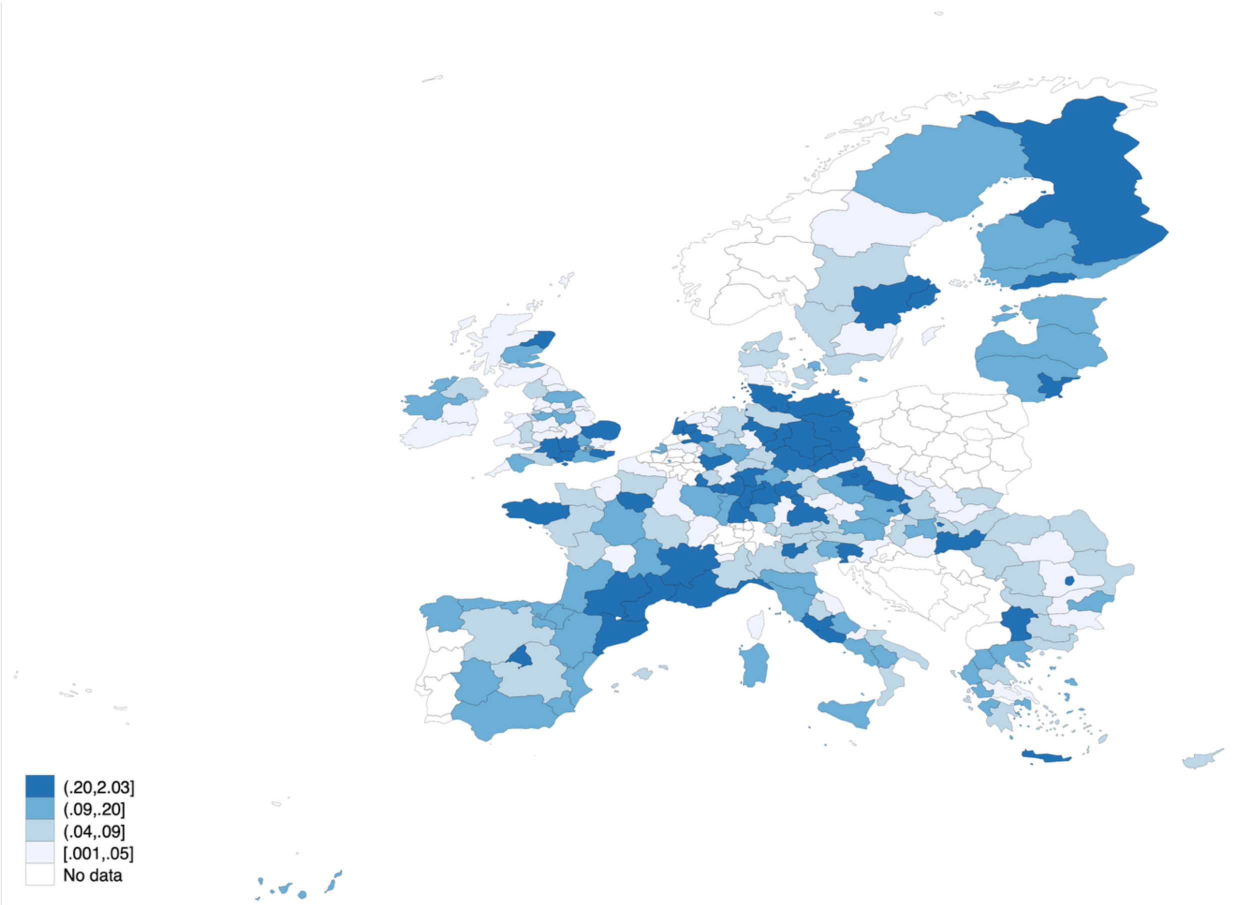

Figure 5. Average public research intensity across regions (1995-2019). Research intensity is computed as R&D government spending divided by GDP. Darker blue regions represent a higher share of research intensity, while lighter blue regions indicate a lower share.

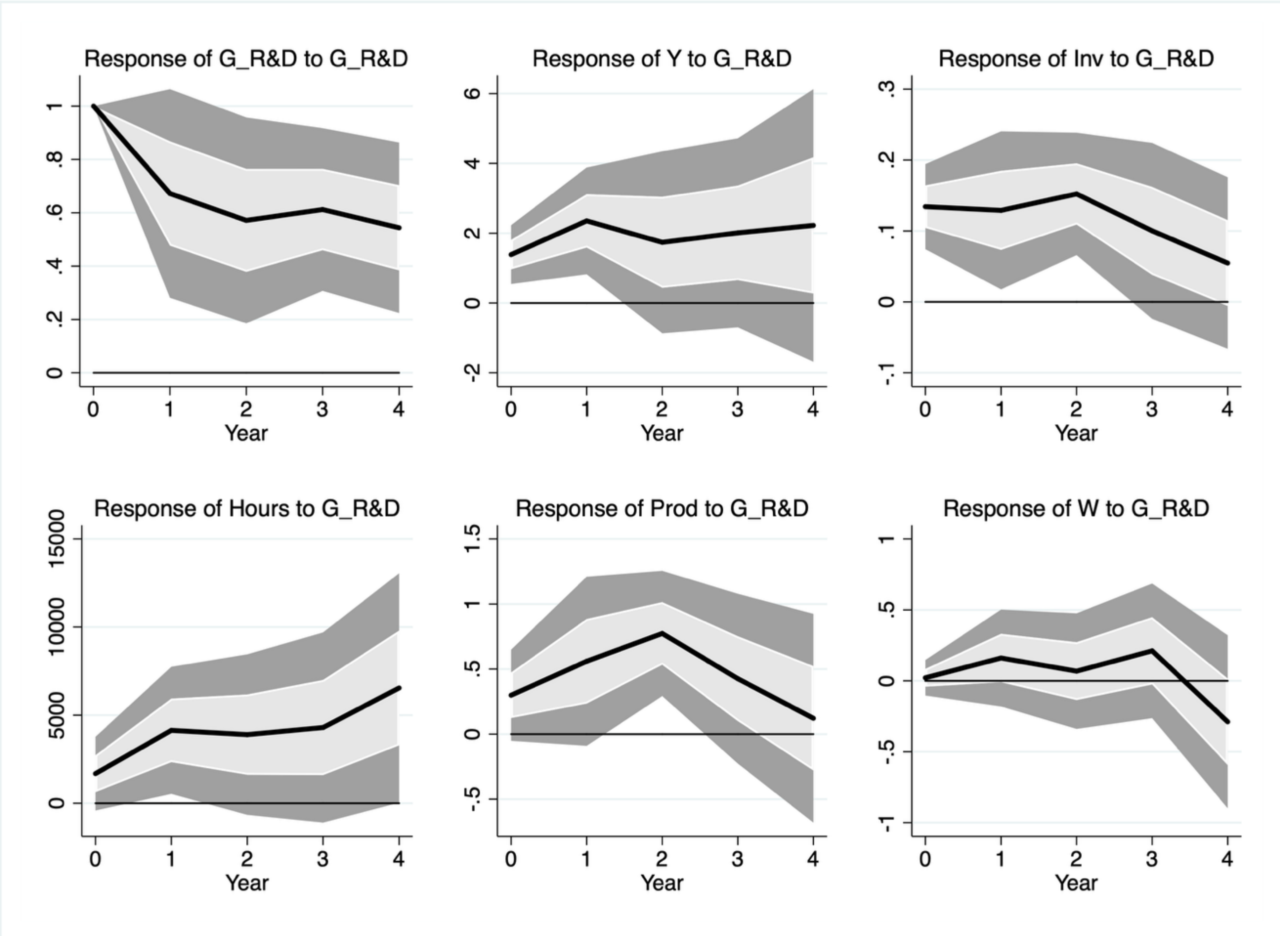

Figure 6. Impulse Response Functions. Full Sample. Shaded areas depict 68% and 95% confidence intervals. All Sectors.

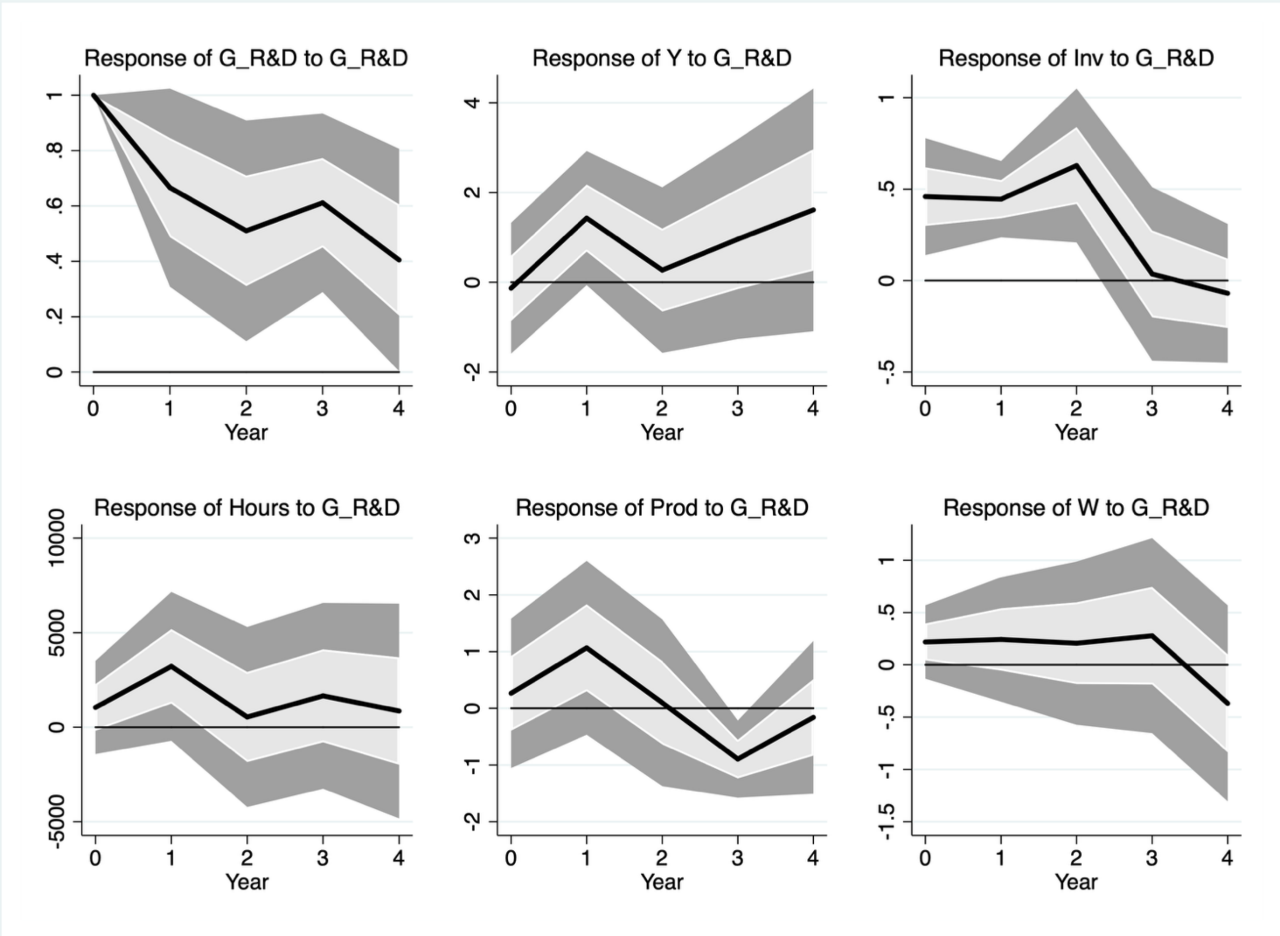

Figure 7. Impulse Response Functions. Full Sample. Shaded areas depict 68% and 95% confidence intervals. Industry.

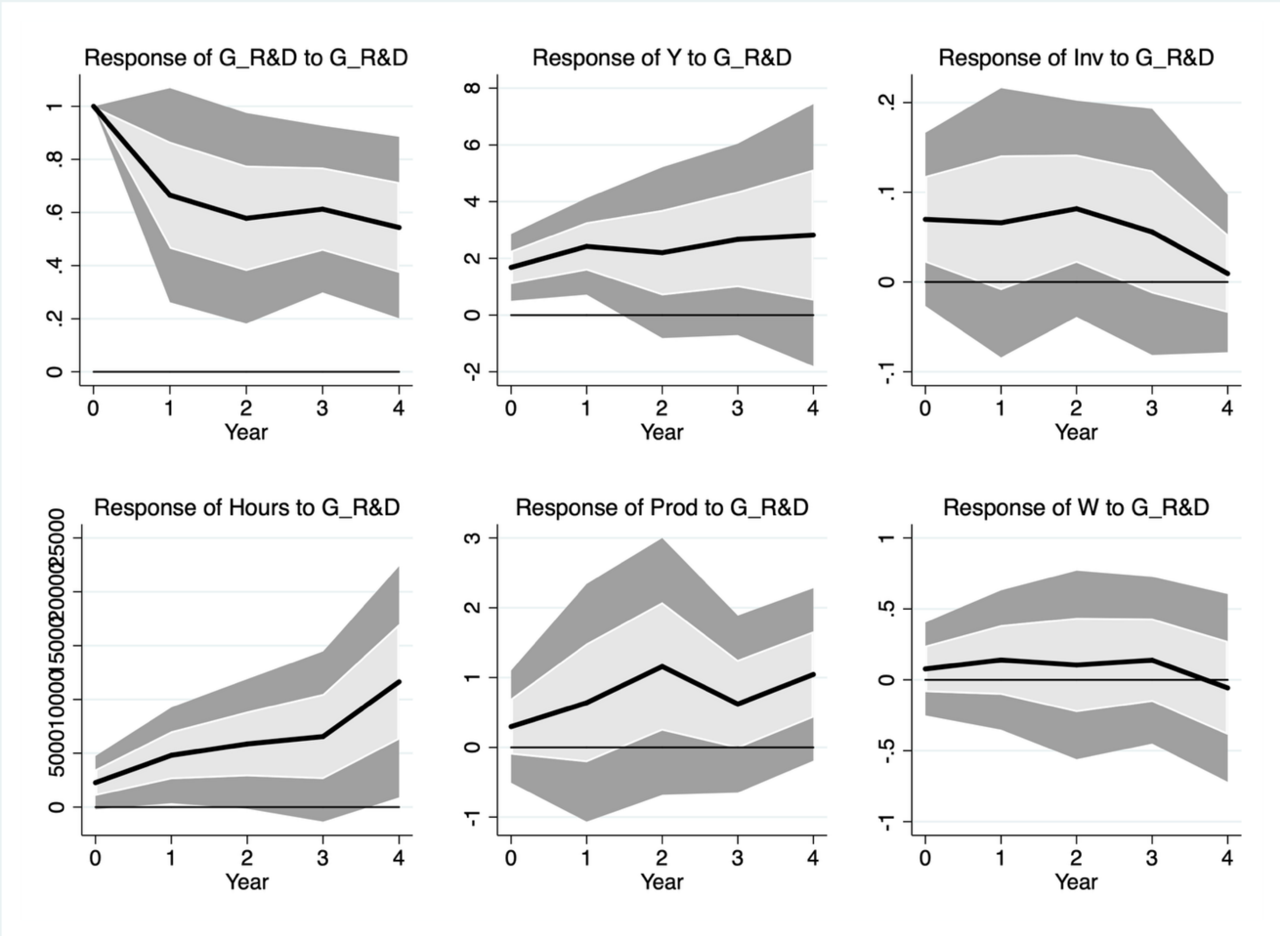

Figure 8. Impulse Response Functions. Full Sample. Shaded areas depict 68% and 95% confidence intervals. Construction.

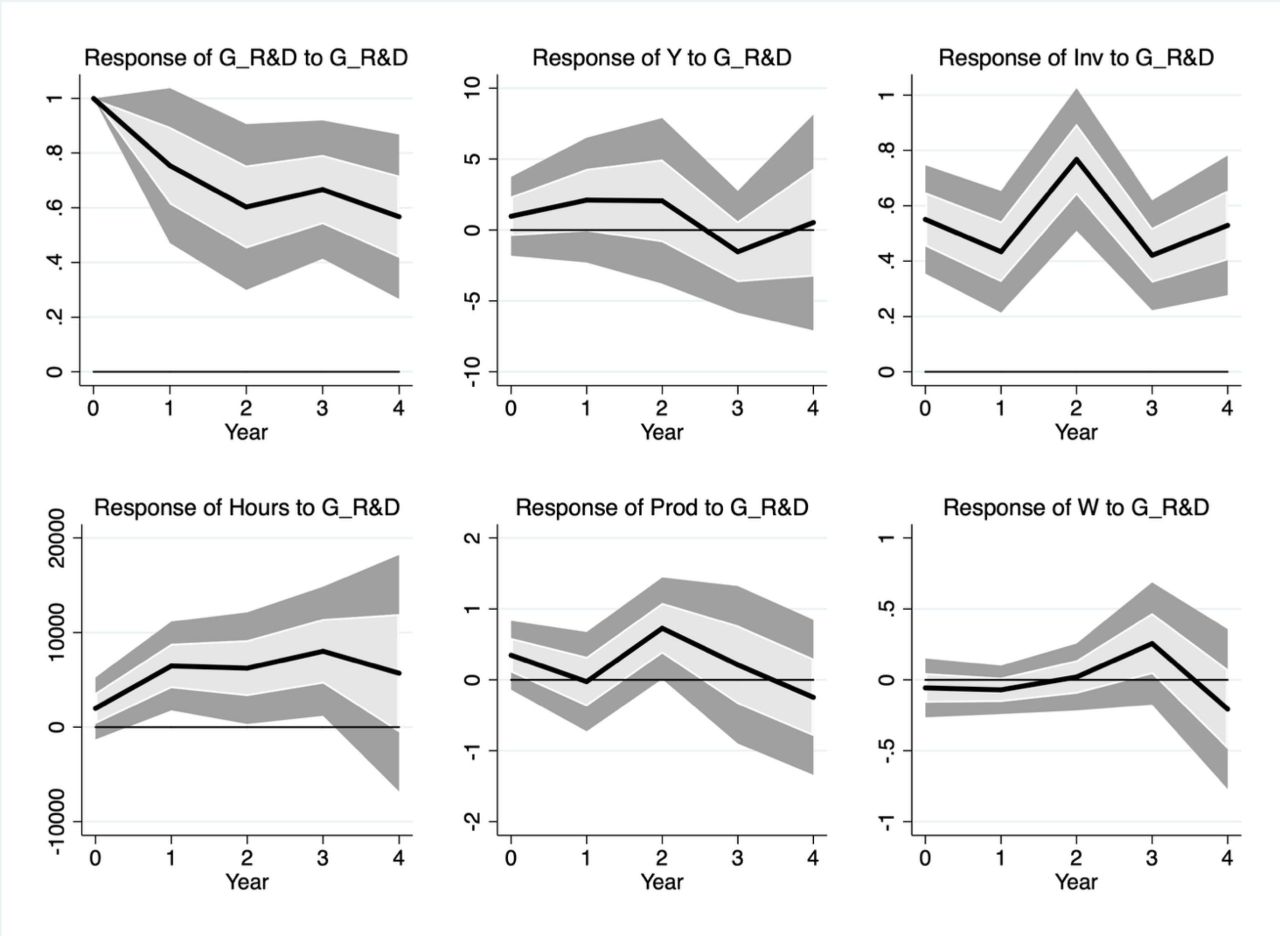

Figure 9. Impulse Response Functions. Full Sample. Shaded areas depict 68% and 95% confidence intervals. Market services.

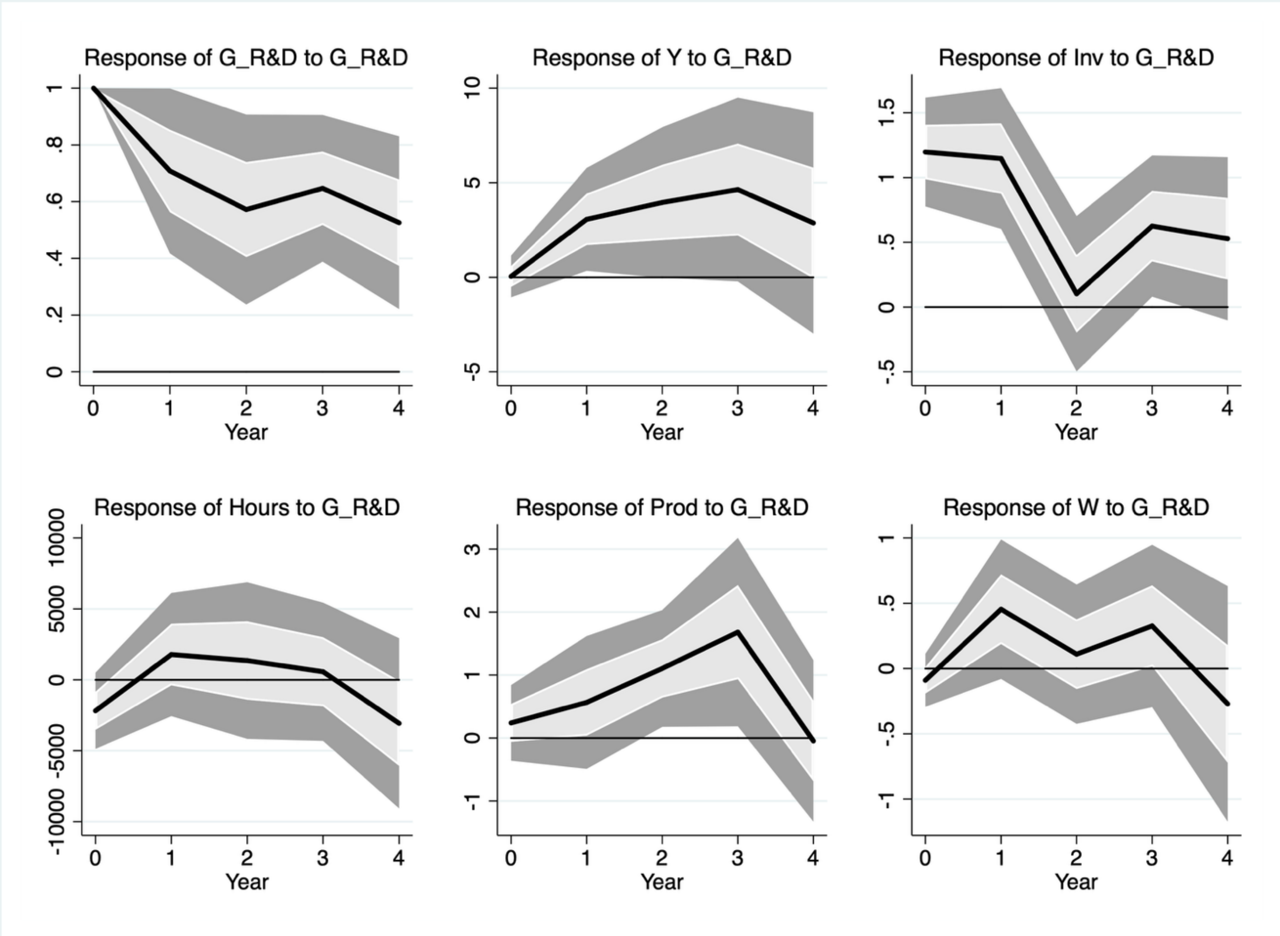

Figure 10. Impulse Response Functions. Full Sample. Shaded areas depict 68% and 95% confidence intervals. Finance.

Appendix A

Name	Description	Source
Output (Y)	Gross value added (GVA) at sectoral level. Volume at constant EUR 2015.	ARDECO database
Private investment (Inv)	Net fixed capital formation at sectoral level. Calculated as the difference between Gross fixed capital formation and Consumption of fixed capital. Volume at constant EUR 2015.	ARDECO database
Hours worked ($Hours$)	Hours Worked (Thousands of Hours) at sectoral level.	ARDECO database
Labour productivity ($Prod$)	Real labour productivity per hour worked at sectoral level. Volume at constant EUR 2015.	ARDECO database
Real hourly wage (W)	Real compensation per hour worked at sectoral level. Volume at constant EUR 2015.	ARDECO database
Total Employment (Emp)	Total Employment (Thousands of Persons) at sectoral level.	ARDECO database
Labour productivity per-employee ($Prod\_2$)	Real labour productivity per person employed at sectoral level. Volume at constant EUR 2015.	ARDECO database
Real wage per-employee (W_2)	Real compensation per employee at sectoral level. Volume at constant EUR 2015.	ARDECO database
R&D government spending ($G\_R\&D$)	Gross domestic expenditure on R&D by government sector. Aggregated at regional level. Volume at constant EUR 2015.	Eurostat and OECD
Regional Private R&D ($R\&D$)	Gross domestic expenditure on R&D by business enterprise sector. Aggregated at regional level. Volume at constant EUR 2015.	Eurostat and OECD
Regional Total Public Expenditure (G_TOT)	Gross value added of non-market sector (O-U). Aggregated at regional level. Volume at constant EUR 2015.	ARDECO database
Regional Gross Domestic Product (Y_r)	Gross domestic product. Aggregated at regional level. Volume at constant EUR 2015.	ARDECO database
National R&D government spending ($G\_R\&D_R$)	Gross domestic expenditure on R&D by government sector. Aggregated at country level. Volume at constant EUR 2015.	Eurostat and OECD
National Total Public Expenditure (G_TOT_R)	Gross value added of non-market sector (O-U). Aggregated at country level. Volume at constant EUR 2015.	ARDECO database
National Gross Domestic Product (Y_R)	Gross domestic product. Aggregated at country level. Volume at constant EUR 2015.	ARDECO database

Table A1. Variables and description.

Country (N. Regions)	Obs.	Statistics	GDP	Inv	Hours	Prod	W
AT (9)	864	Mean	1.66%	0.91%	0.84%	0.82%	0.95%
		SD	0.04	0.62	0.03	0.03	0.03
BE (11)	1056	Mean	1.75%	-0.69%	0.92%	0.83%	0.85%
		SD	0.04	0.75	0.03	0.04	0.03
BG (6)	576	Mean	2.48%	8.36%	0.32%	2.15%	2.37%
		SD	0.13	0.98	0.08	0.14	0.14
CY (1)	96	Mean	2.57%	4.47%	1.44%	1.14%	2.36%
		SD	0.07	1.09	0.07	0.04	0.06
CZ (8)	768	Mean	1.75%	1.62%	-0.06%	1.81%	2.26%
		SD	0.07	0.86	0.05	0.08	0.07
DE (38)	3648	Mean	0.97%	0.10%	0.05%	0.92%	0.68%
		SD	0.05	0.84	0.03	0.04	0.03
DK (5)	480	Mean	1.48%	0.17%	0.50%	0.98%	0.94%
		SD	0.05	0.98	0.04	0.05	0.03
EE (1)	96	Mean	4.81%	6.28%	0.41%	4.39%	4.34%
		SD	0.09	0.62	0.10	0.08	0.08
EL (13)	1248	Mean	0.10%	10.37%	0.43%	-0.33%	1.43%
		SD	0.12	0.96	0.08	0.11	0.10
ES (19)	1824	Mean	1.71%	0.62%	1.59%	0.11%	0.20%
		SD	0.05	0.71	0.07	0.04	0.04
FI (5)	480	Mean	2.23%	6.85%	0.91%	1.32%	1.43%
		SD	0.06	0.84	0.04	0.06	0.05
FR (22)	2112	Mean	1.21%	4.78%	0.41%	0.80%	0.85%
		SD	0.03	0.62	0.03	0.04	0.04
HU (8)	768	Mean	2.58%	11.75%	1.44%	1.14%	0.74%
		SD	0.07	0.93	0.06	0.08	0.07
IE (3)	288	Mean	3.97%	11.71%	1.34%	2.63%	1.62%
		SD	0.13	0.95	0.09	0.12	0.13
IT (21)	2016	Mean	0.21%	-4.66%	0.46%	-0.25%	0.34%
		SD	0.05	0.82	0.04	0.05	0.04
LT (2)	192	Mean	4.82%	18.13%	1.03%	3.80%	4.46%
		SD	0.10	0.63	0.09	0.09	0.09
LU (1)	96	Mean	2.77%	3.60%	2.34%	0.44%	0.50%
		SD	0.06	0.78	0.03	0.05	0.05
LV (1)	96	Mean	4.26%	15.88%	-0.17%	4.43%	5.40%
		SD	0.10	0.80	0.09	0.07	0.08
MT (1)	76	Mean	3.87%	12.80%	2.19%	1.68%	1.67%
		SD	0.08	0.96	0.06	0.08	0.05
NL (12)	1152	Mean	1.99%	3.98%	0.69%	1.31%	0.71%
		SD	0.05	1.01	0.04	0.05	0.04
RO (8)	768	Mean	3.46%	0.75%	0.21%	3.25%	3.46%
		SD	0.12	0.95	0.07	0.12	0.17
SE (8)	768	Mean	2.43%	4.81%	1.02%	1.42%	1.70%
		SD	0.06	0.70	0.03	0.06	0.04
SI (2)	192	Mean	2.60%	4.90%	0.90%	1.70%	1.40%
		SD	0.06	0.76	0.05	0.06	0.05
SK (4)	384	Mean	3.64%	8.35%	1.10%	2.53%	2.38%
		SD	0.09	0.86	0.05	0.09	0.07
UK (41)	3936	Mean	1.73%	4.00%	0.48%	1.24%	1.62%
		SD	0.05	0.77	0.08	0.08	0.09

Table A2. Descriptive statistics on regional variables (GDP, Inv, Hours, Prod, W) by country.

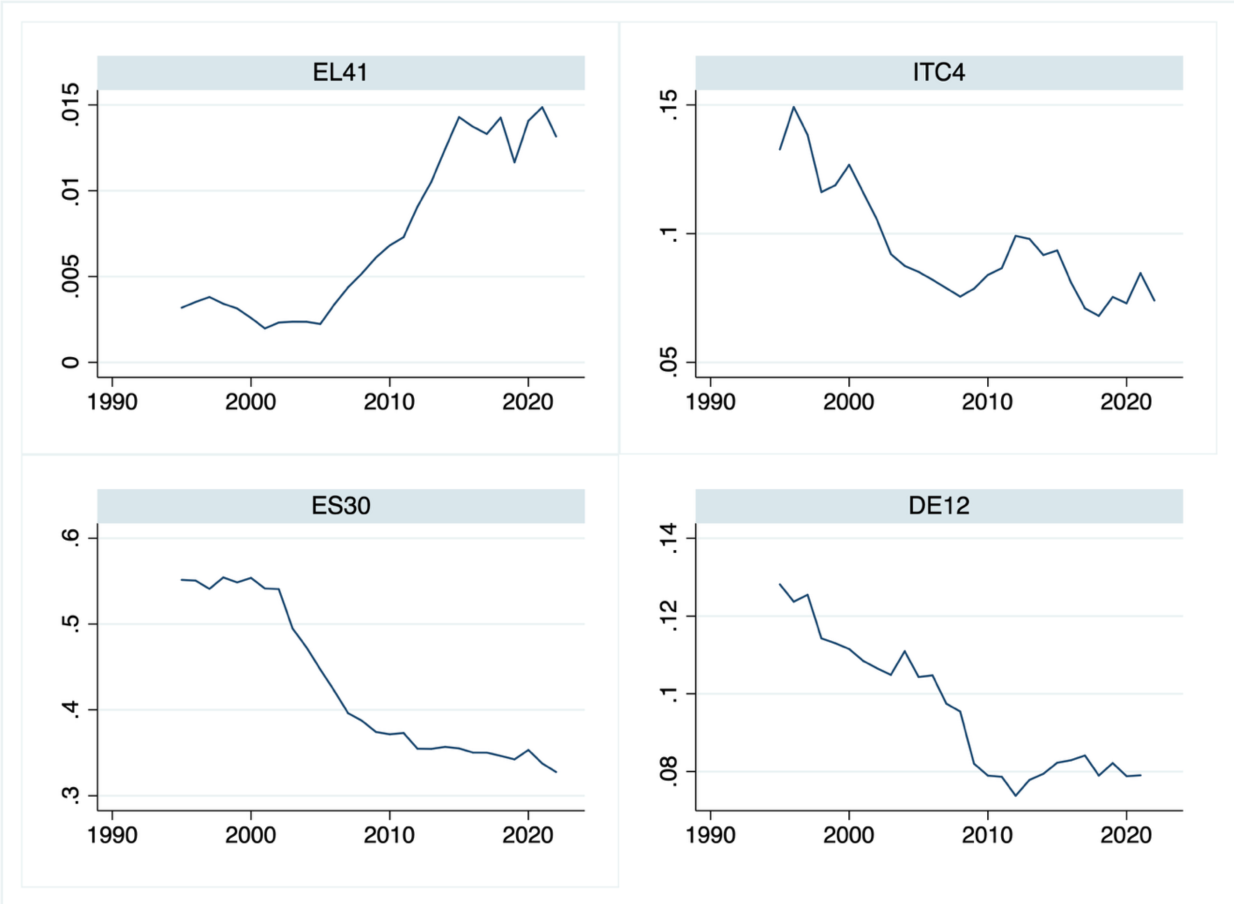

Figure A1. Ratio between Regional and National R&D Government Spending (G_R&D).
This figure plots the ratio between regional and national per capita government R&D spending over time for four selected regions: Voreia Ellada (EL41, Greece), Lombardia (ITC4, Italy), Madrid (ES30, Spain), and Karlsruhe (DE12, Germany).

Country (N. Regions)	Obs.	Mean	SD	Min	Max
AT (9)	189	0.111	0.176	0.007	0.567
BE (11)	24	1.000	1.000	1.000	1.000
BG (6)	105	0.167	0.333	0.005	0.845
CY (1)	21	1.000	1.000	1.000	1.000
CZ (8)	144	0.125	0.237	0.002	0.700
DE (38)	843	0.026	0.033	0.001	0.121
DK (5)	60	0.200	0.240	0.060	0.626
EE (1)	24	1.000	1.000	1.000	1.000
EL (13)	312	0.077	0.149	0.006	0.548
ES (19)	416	0.059	0.101	0.006	0.400
FI (5)	72	0.200	0.230	0.001	0.591
FR (22)	553	0.046	0.130	0.000	0.613
HU (8)	124	0.167	0.146	0.017	0.420
IE (3)	32	0.333	0.082	0.240	0.397
IT (21)	488	0.048	0.094	0.001	0.446
LT (2)	23	0.500	0.045	0.468	0.532
LU (1)	19	1.000	1.000	1.000	1.000
LV (1)	24	1.000	1.000	1.000	1.000
MT (1)	17	1.000	1.000	1.000	1.000
NL (12)	162	0.100	0.145	0.004	0.376
RO (8)	144	0.125	0.266	0.009	0.782
SE (8)	160	0.125	0.146	0.009	0.439
SI (2)	32	0.500	0.683	0.017	0.983
SK (4)	76	0.250	0.333	0.045	0.748
UK (41)	509	0.024	0.035	0.000	0.148

Table A3. Summary statistics of regional shares in government R&D spending by country.
This table reports descriptive statistics for regional shares in government R&D spending (s_r) used in the construction of the Bartik instrument. These shares are calculated as the ratio of regional to national R&D government spending. For each country, we report the number of NUTS-2 regions included in the sample (in parentheses), the number of observations, the mean, the standard deviation, the minimum, and the maximum of the regional shares over the period 1995-2019.

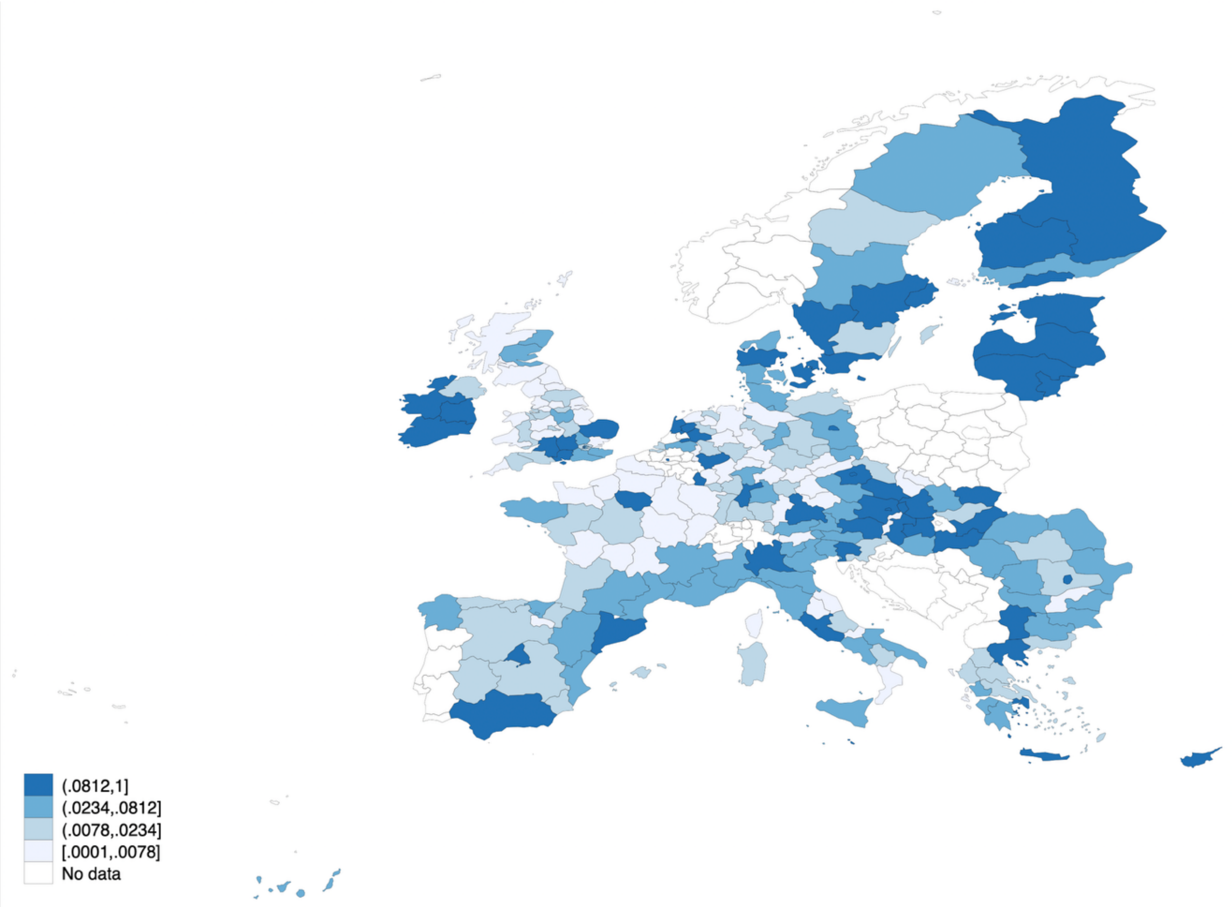

Figure A2. Regional shares in government R&D spending (s_r) across regions.
s_r represents the average share of R&D government spending ($G\_R\&D$) allocated to region r relative to its national total R, over the period 1995–2019. Darker shades indicate higher values of s_r reflecting a stronger relative exposure to national R&D spending.

Appendix B

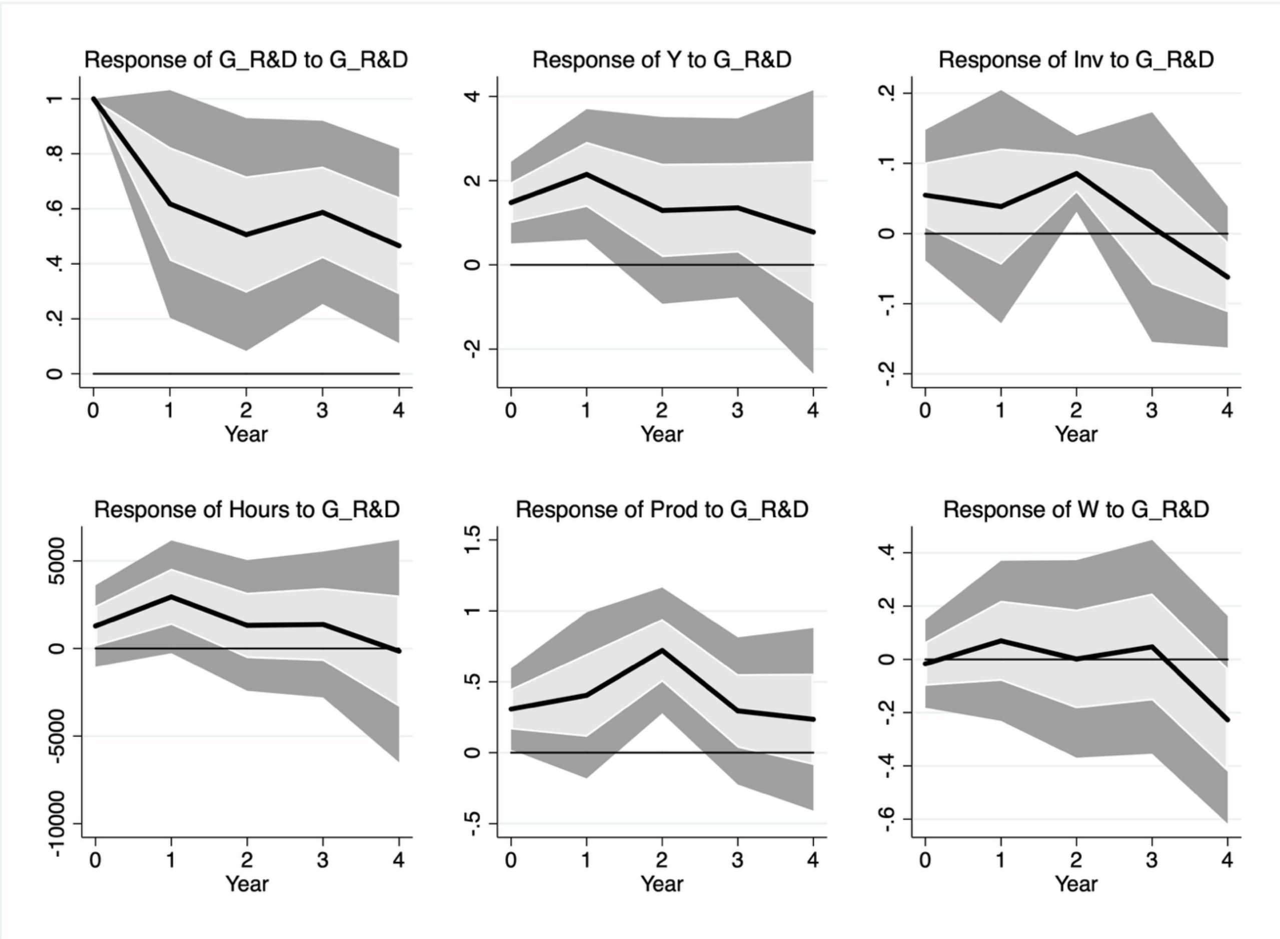

Figure B1. Robustness checks. Impulse Response Functions. Excluding countries with the larger number of regions (DE and UK). Shaded areas depict 68% and 95% confidence intervals. All Sectors.

Government R&D Investment – $G\_R\&D$

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	**1.48**	**2.24**	**2.31**	**2.31**	2.22	2.11	2.15
Inv	**0.05**	0.06	**0.08**	0.07	0.04	0.06	0.09
$Hours$	**1282.90**	**2614.71**	2611.44	2552.05	2130.19	2238.26	2947.70
$Prod$	**0.31**	**0.44**	**0.68**	**0.64**	0.62	0.54	0.72
W	-0.02	0.03	0.03	0.04	**-0.04**	0.01	-0.20

Table B1. Robustness checks. Excluding countries with the larger number of regions (DE and UK). Cumulative effects. Significant estimates are in bold (68%). All Sectors.

For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t + h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots . 4$.

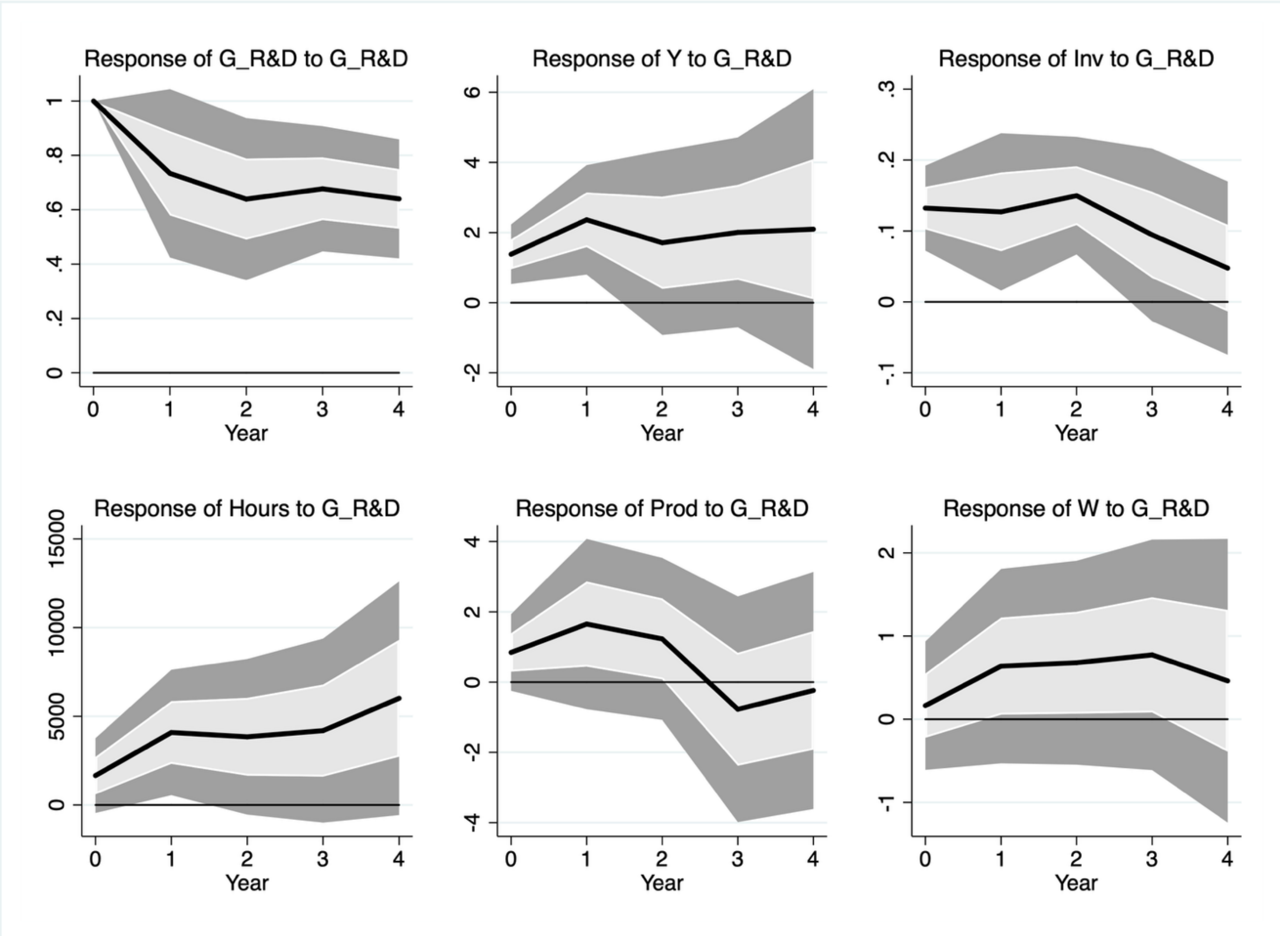

Figure B2. Robustness checks. Impulse Response Functions. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Shaded areas depict 68% and 95% confidence intervals. All Sectors.

	Government R&D Investment – $G\_R\&D$						
	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Y	**1.38**	**2.16**	**2.30**	**2.44**	**2.59**	2.17	2.00
Inv	**0.13**	**0.15**	**0.17**	**0.17**	0.15	0.15	0.15
$Hours$	**1657.20**	**3313.49**	**4041.21**	**4519.08**	**5366.07**	3779.41	6017.6
$Prod$	**0.84**	**1.44**	**1.57**	0.97	0.74	1.11	1.65
W	0.16	**0.46**	**0.62**	**0.74**	0.74	0.55	0.77

Table B2. Robustness checks. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Cumulative effects. Significant estimates are in bold (68%). All Sectors.

For Y, Inv, and $Hours$ cumulative multipliers we compute cumulative multipliers, which indicate the change in the outcome variable following an increase in government R&D expenditure ($G\_R\&D$). In the case of $Hours$ the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod$ and W, we estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t+h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots .4$.

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
All sectors							
Emp	**0.78**	**1.48**	**1.73**	**1.84**	**2.24**	1.61	2.35
Prod_2	**491.10**	**830.86**	**1081.41**	980.70	**998.59**	876.53	1036.4
W_2	35.77	169.84	115.49	177.39	56.94	111.09	247.40

Table B3. Cumulative effects. Significant estimates are in bold (68%). Full Sample.
In the case of Emp the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod\_2$ and W_2, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t+h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots . 4$.

Appendix C

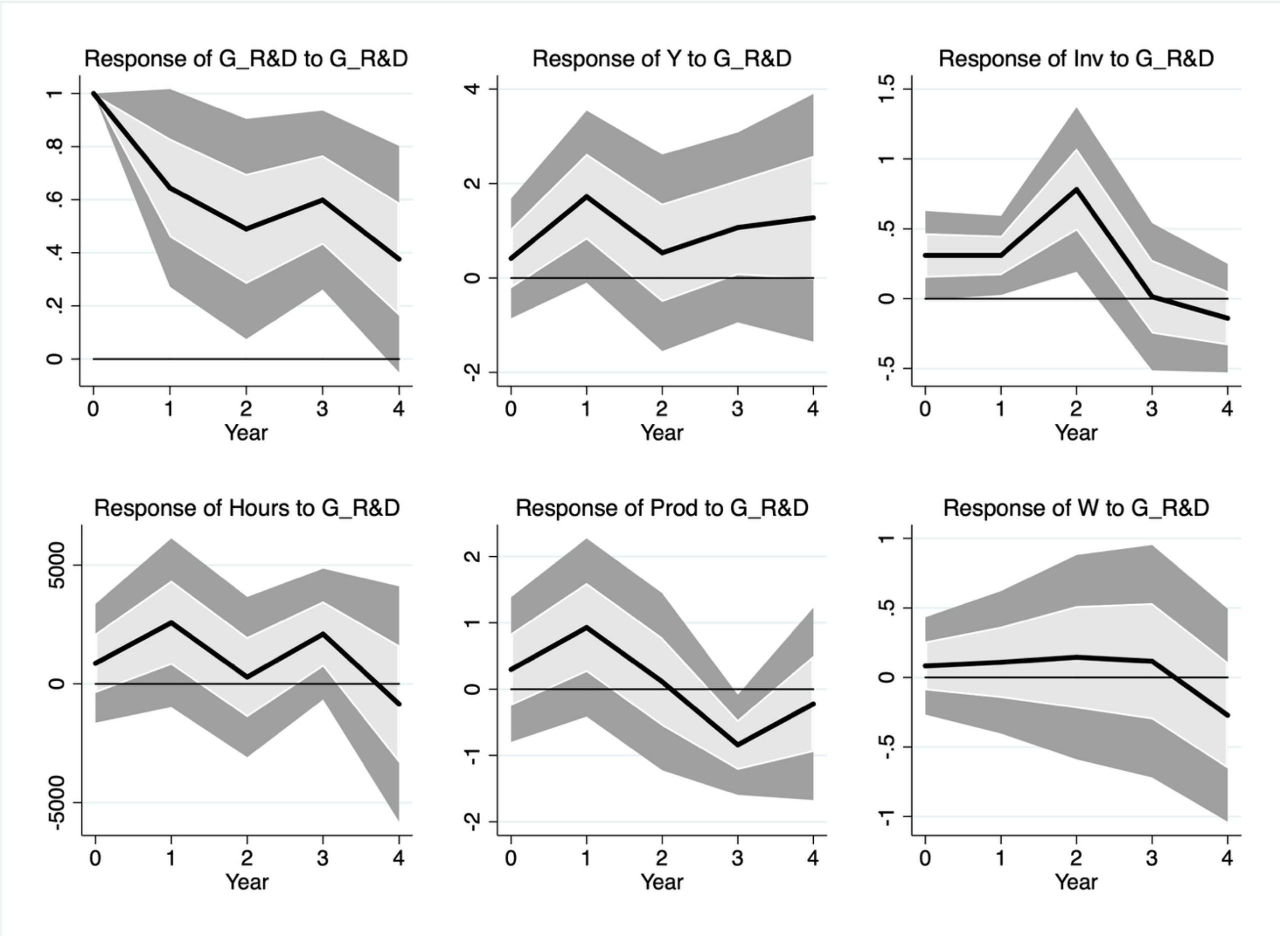

Figure C1. Robustness checks. Impulse Response Functions. Excluding countries with the larger number of regions (DE and UK). Shaded areas depict 68% and 95% confidence intervals. Industry.

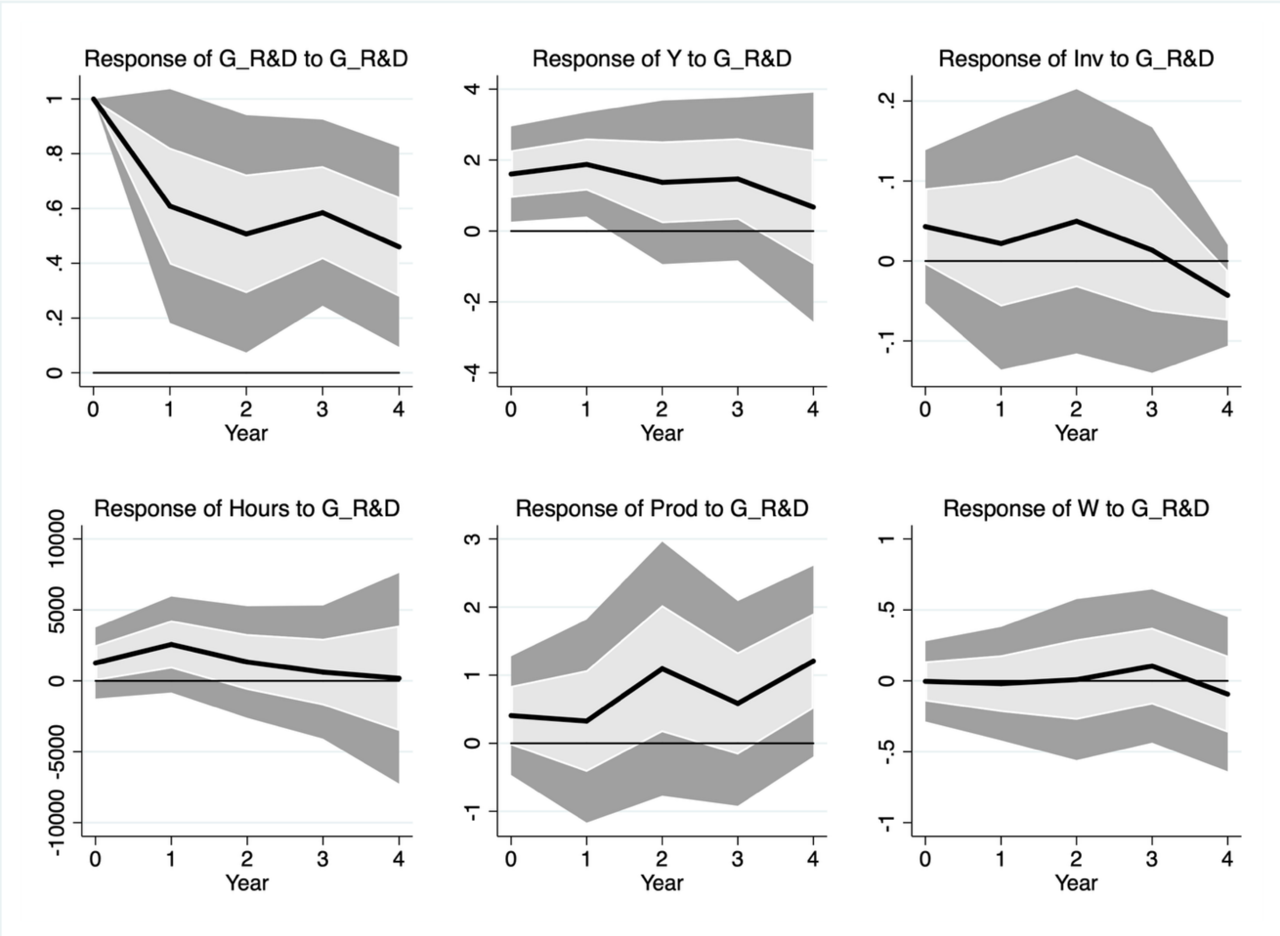

Figure C2. Robustness checks. Impulse Response Functions. Excluding countries with the larger number of regions (DE and UK). Shaded areas depict 68% and 95% confidence intervals. Construction.

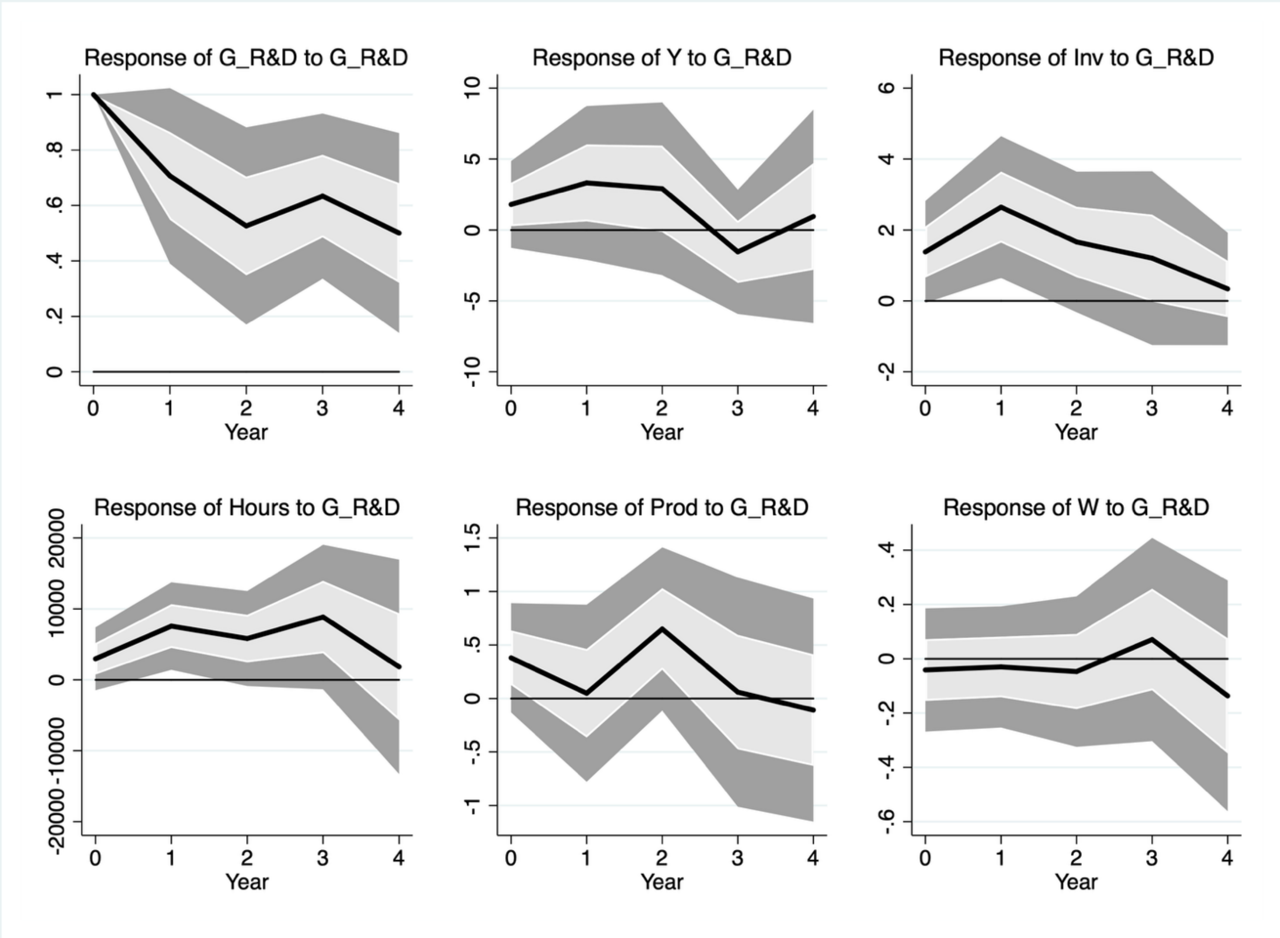

Figure C3. Robustness checks. Impulse Response Functions. Excluding countries with the larger number of regions (DE and UK). Shaded areas depict 68% and 95% confidence intervals. Market services.

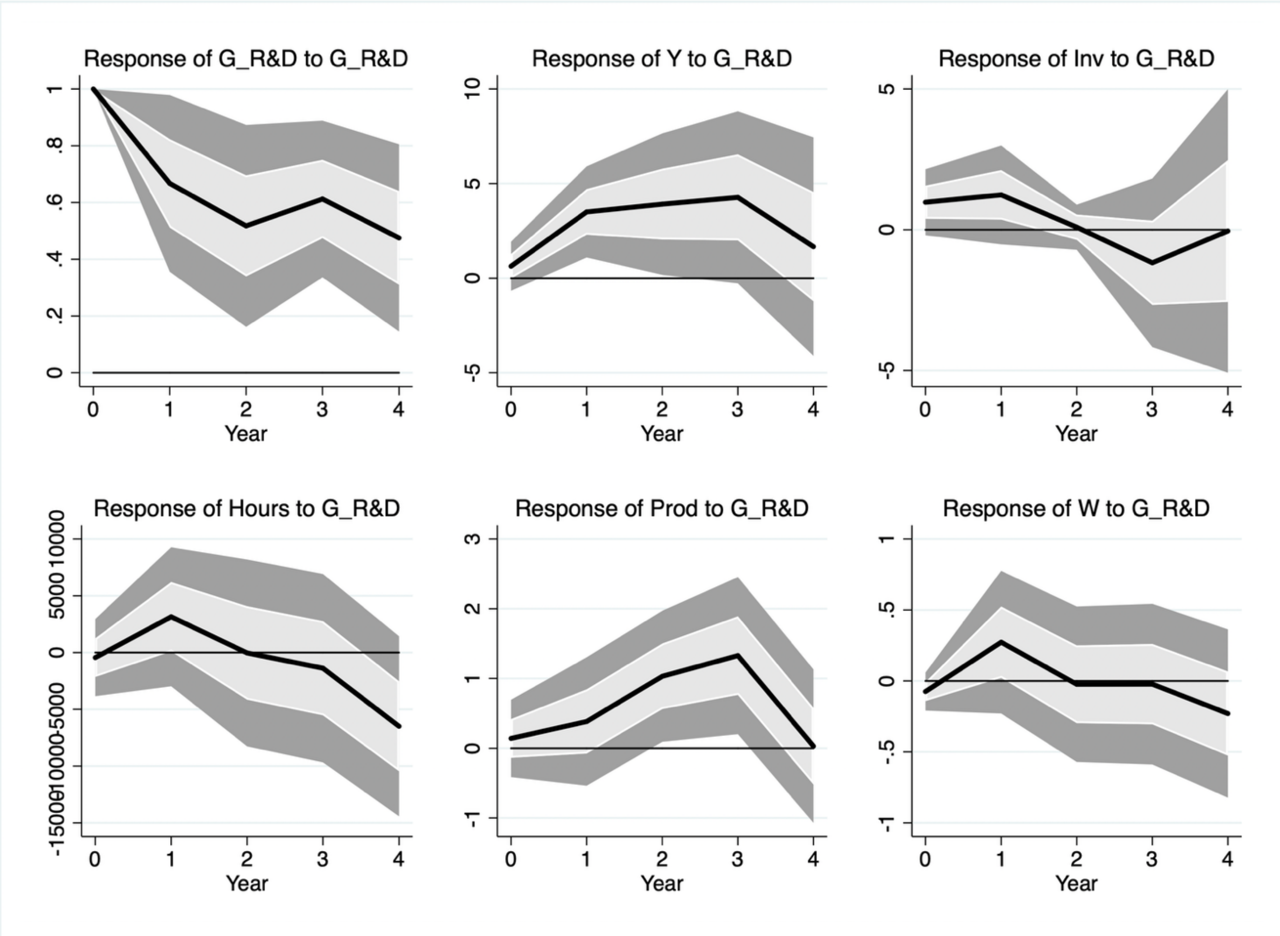

Figure C4. Robustness checks. Impulse Response Functions. Excluding countries with the larger number of regions (DE and UK). Shaded areas depict 68% and 95% confidence intervals. Finance.

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Industry							
Y	0.41	**1.30**	1.25	**1.37**	**1.61**	1.19	1.72
Inv	**0.31**	**0.38**	**0.66**	0.52	0.41	0.45	0.78
$Hours$	865.10	**2091.00**	1744.56	**2129.49**	1598.55	1685.74	2572.50
$Prod$	0.30	**0.75**	0.63	**0.18**	0.09	0.39	0.93
W	0.08	0.12	0.16	0.17	0.06	0.12	0.15
Construction							
Y	**1.61**	**2.16**	**2.29**	**2.34**	2.21	2.12	1.88
Inv	0.04	0.04	0.05	0.05	**0.03**	0.04	0.04
$Hours$	**1255.70**	**2372.59**	2430.77	2132.36	1879.72	2014.23	2561.8
$Prod$	0.41	0.45	**0.86**	0.89	**1.15**	0.75	1.21
W	0.00	-0.01	-0.01	0.03	0.00	0.00	0.10
Market services							
Y	**1.80**	**3.00**	**3.60**	2.26	2.21	2.57	3.32
Inv	**1.38**	**2.36**	**2.55**	2.40	2.15	2.17	2.64
$Hours$	**2970.60**	**6178.97**	**7332.51**	**8798.85**	8034.29	6663.04	7576.90
$Prod$	**0.38**	0.25	**0.48**	0.40	0.31	0.36	0.65
W	-0.04	-0.04	-0.05	-0.02	-0.05	-0.04	-0.13
Finance							
Y	**0.63**	**2.48**	**3.68**	**4.40**	4.27	3.09	4.20
Inv	**0.98**	**1.33**	1.05	0.40	0.33	0.82	1.24
$Hours$	-445.80	**1623.70**	1223.50	462.76	**-1588.89**	255.05	-6493.2
$Prod$	0.14	0.31	**0.71**	**1.03**	0.89	0.62	1.33
W	-0.07	**0.12**	0.08	0.05	-0.02	0.03	0.27

Table C1. Robustness checks. Excluding countries with the larger number of regions (DE and UK). Cumulative effects. Significant estimates are in bold (68%). Four sectors.

In the case of Emp the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod\_2$ and W_2, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t+h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots . 4$.

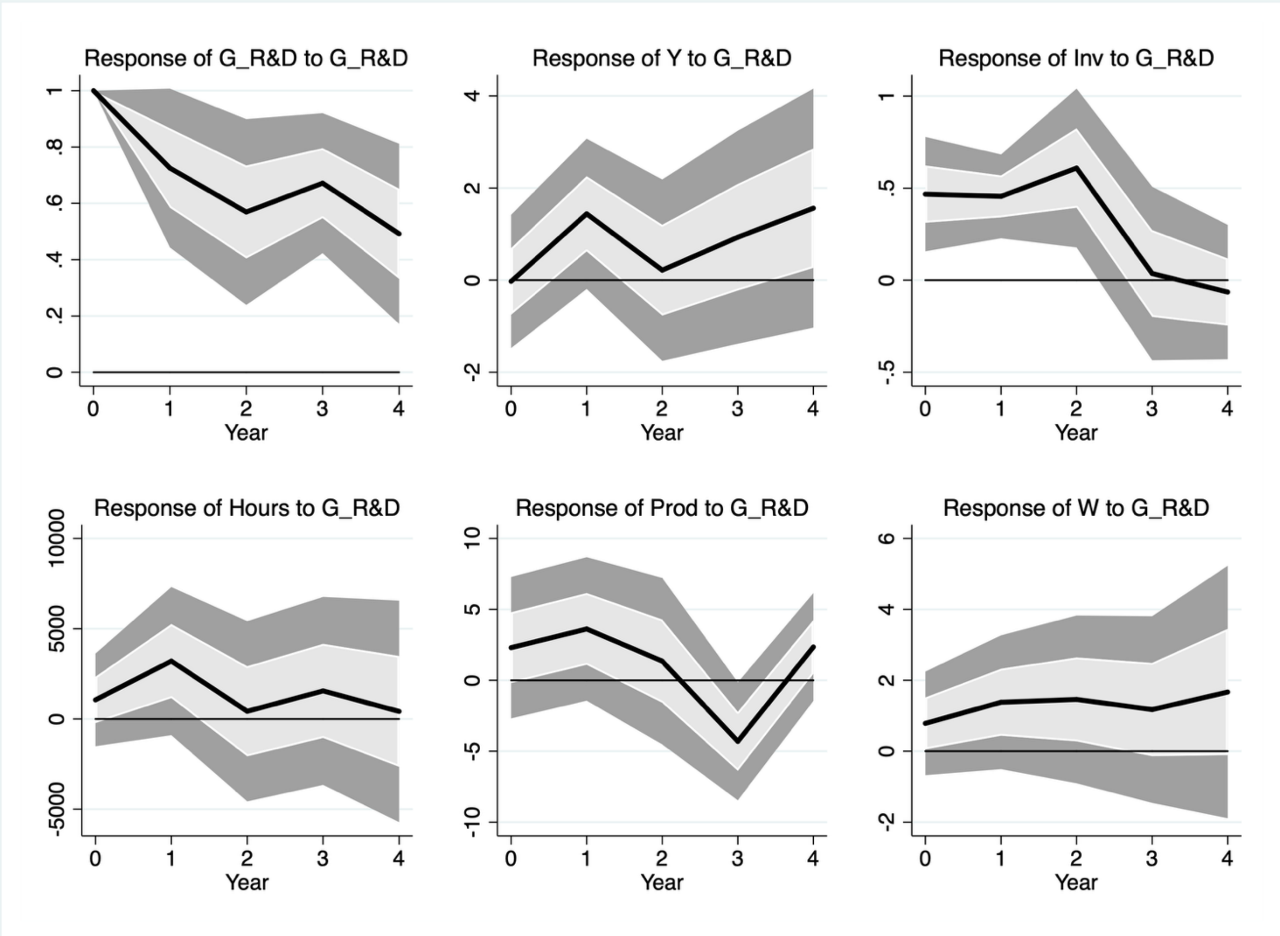

Figure C5. Robustness checks. Impulse Response Functions. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Shaded areas depict 68% and 95% confidence intervals. Industry.

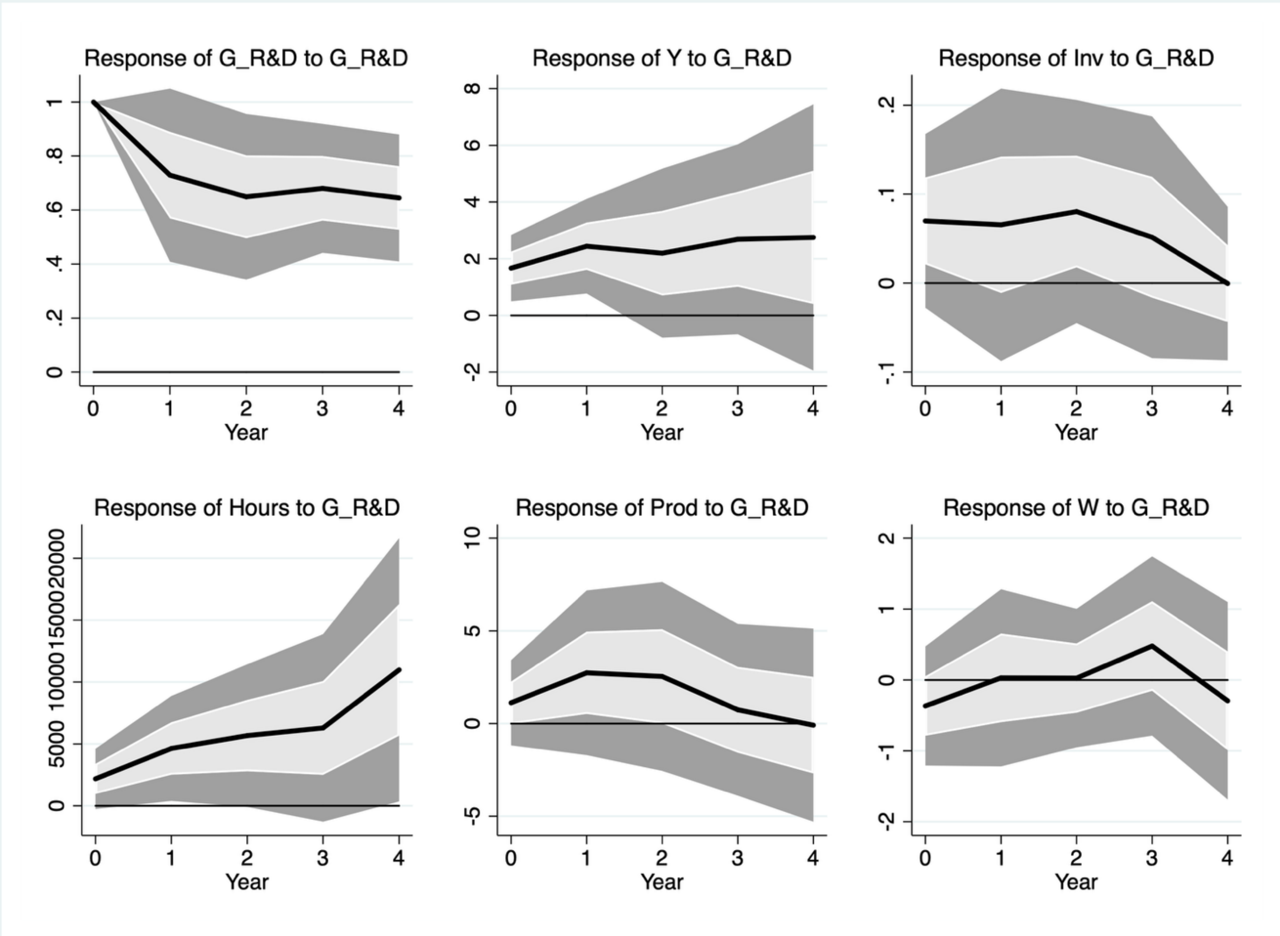

Figure C6. Robustness checks. Impulse Response Functions. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Shaded areas depict 68% and 95% confidence intervals. Construction.

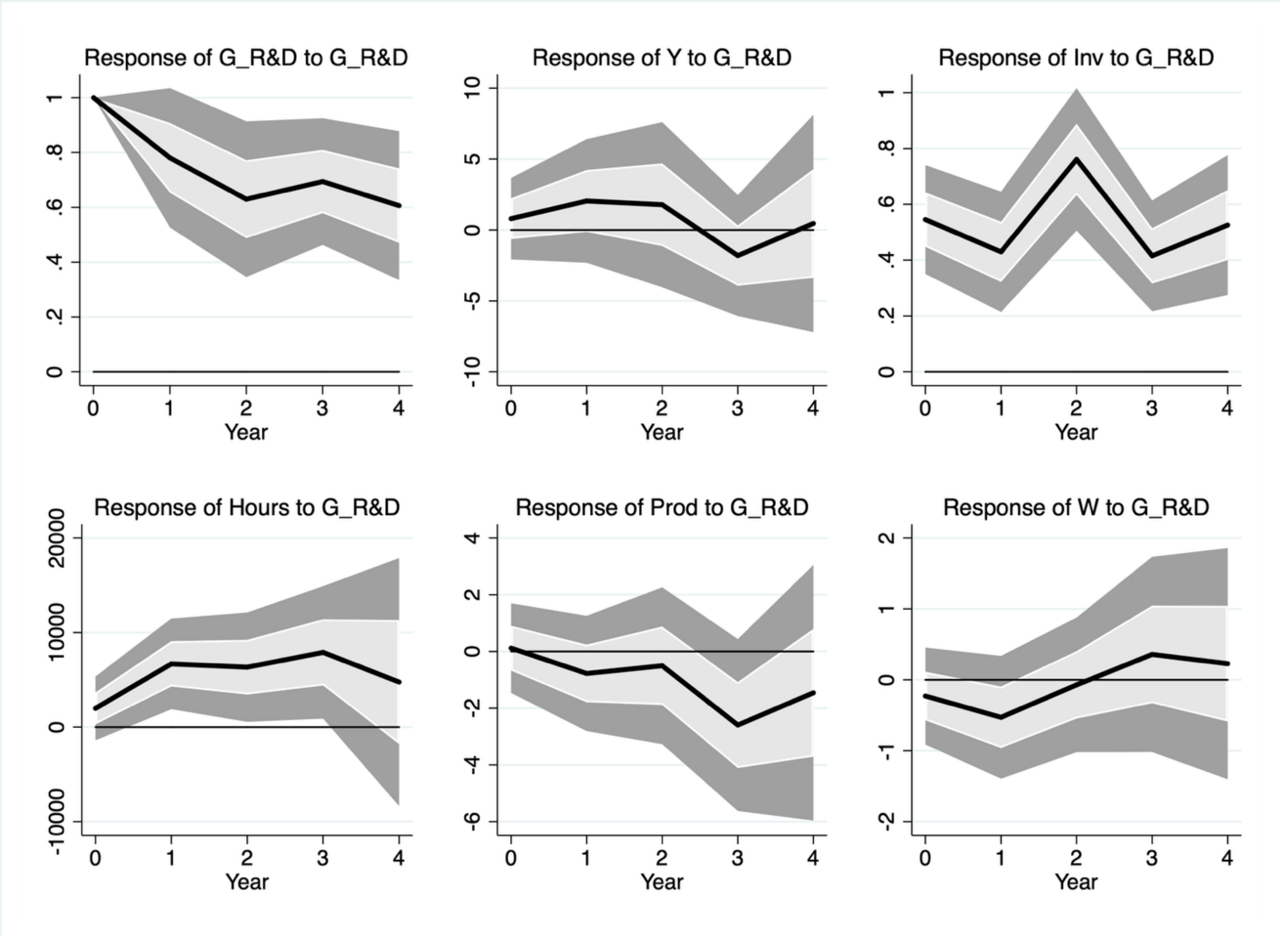

Figure C7. Robustness checks. Impulse Response Functions. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Shaded areas depict 68% and 95% confidence intervals. Market services.

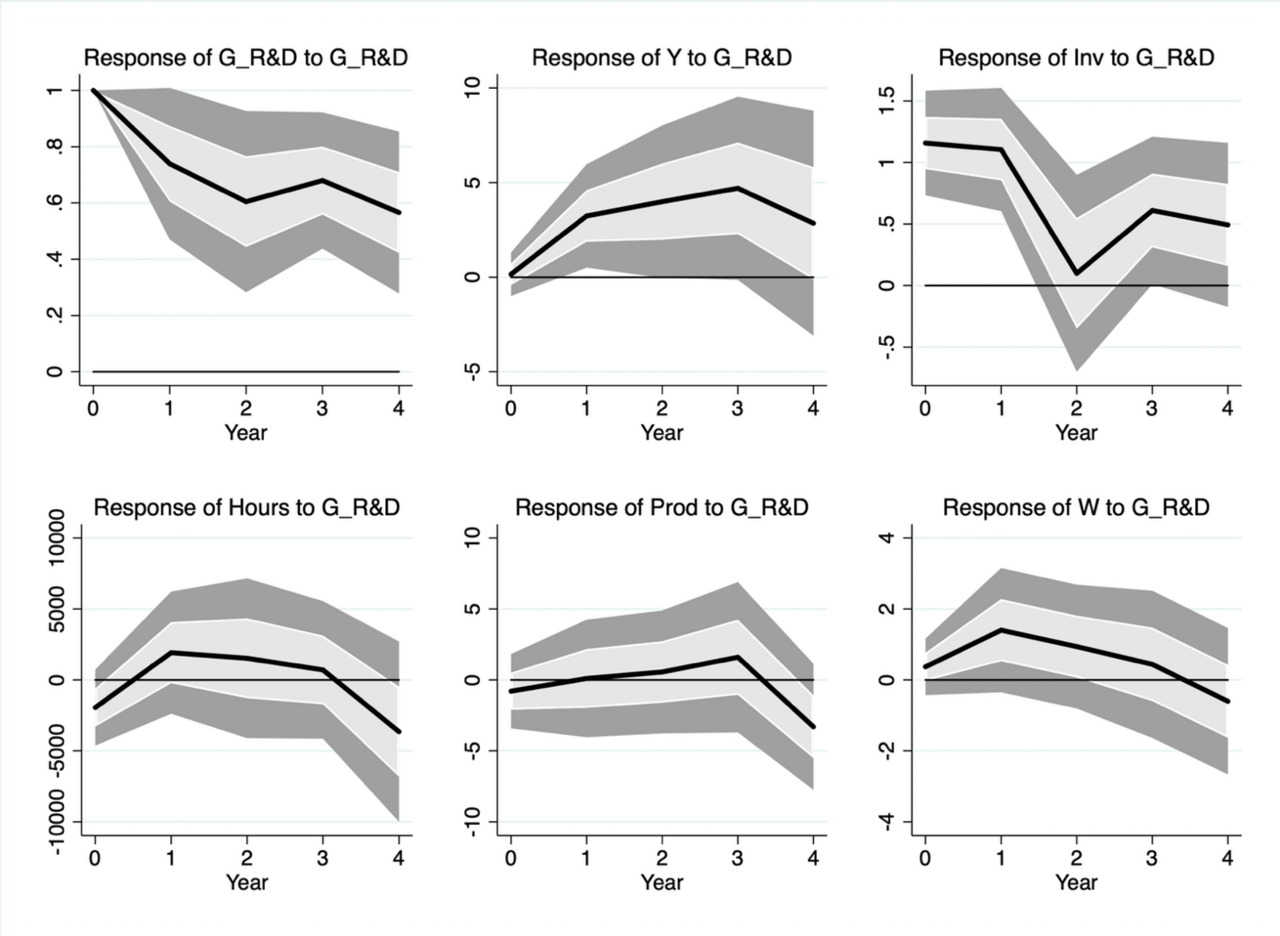

Figure C8. Robustness checks. Impulse Response Functions. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Shaded areas depict 68% and 95% confidence intervals. Finance.

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Industry							
Y	-0.03	**0.82**	0.71	0.86	**1.19**	0.71	1.56
Inv	**0.47**	**0.54**	**0.67**	0.53	0.44	0.53	0.61
$Hours$	1058.00	**2472.35**	2044.38	2105.90	1927.50	1921.63	3206.80
$Prod$	2.30	**3.44**	3.17	**1.01**	**1.54**	2.29	-4.20
W	0.79	**1.26**	**1.58**	1.62	1.87	1.42	1.46
Construction							
Y	**1.67**	**2.38**	**2.65**	**2.94**	**3.17**	2.56	2.75
Inv	**0.07**	0.08	**0.09**	0.09	0.07	0.08	0.08
$Hours$	**2176.30**	**3937.30**	**5247.06**	**6137.31**	**8034.35**	5106.46	10983.3
$Prod$	**1.12**	**2.23**	2.69	2.34	1.90	2.06	2.74
W	-0.37	-0.19	-0.13	0.06	-0.03	-0.13	0.48
Market services							
Y	0.80	1.60	1.92	0.91	0.89	1.22	2.05
Inv	**0.55**	**0.55**	**0.72**	**0.69**	**0.72**	0.65	0.76
$Hours$	**1982.00**	**4869.34**	**6226.71**	**7380.55**	7459.85	5583.69	6690.30
$Prod$	0.12	-0.37	-0.48	**-1.21**	-1.40	-0.67	-2.50
W	-0.23	**-0.42**	-0.34	-0.15	-0.06	-0.24	-0.51
Finance							
Y	0.16	**1.95**	**3.15**	**4.00**	**4.16**	2.68	4.70
Inv	**1.16**	**1.30**	1.01	**0.98**	**0.97**	1.08	1.16
$Hours$	**-1944.70**	-12.94	641.68	730.89	-400.03	**-197.02**	-3646.3
$Prod$	-0.79	-0.40	-0.05	0.49	0.41	**-0.07**	-3.30
W	**0.37**	**1.02**	**1.16**	1.04	0.71	0.86	1.40

Table C2. Robustness checks. Excluding countries with only one or two regions (CY, EE, LT, LU, LV, MT, SI). Cumulative effects. Significant estimates are in bold (68%). Four sectors.

In the case of Emp the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod\_2$ and W_2, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t+h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \dots . 4$.

	Year 0	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Mean*	*Peak*
Industry							
Emp	**0.87**	**1.24**	0.97	0.87	0.70	0.93	1.21
Prod_2	332.70	**1392.14**	897.75	**62.98**	178.52	572.82	1986.6
W_2	**334.90**	517.95	478.26	521.56	330.91	436.72	413.4
Construction							
Emp	**0.89**	**1.61**	**2.14**	**2.50**	**3.39**	2.11	4.36
Prod_2	**897.90**	**1484.20**	**2093.31**	2042.09	**2432.60**	1790.02	2436.2
W_2	289.70	372.73	353.01	354.13	297.10	333.33	330.9
Market services							
Emp	0.42	**1.56**	1.92	2.10	2.32	1.66	1.99
Prod_2	**612.80**	289.62	**597.37**	488.06	442.22	486.01	900.00
W_2	-89.46	-143.82	-195.40	-41.85	-58.15	-105.74	-208.3
Finance							
Emp	**-1.09**	0.23	0.37	0.00	-0.86	-0.27	1.47
Prod_2	102.40	187.76	**754.08**	**1230.41**	853.84	625.70	1882.1
W_2	**-290.70**	**108.08**	83.64	141.92	-24.35	3.72	475.3

Table C3. Robustness checks. Cumulative effects. Significant estimates are in bold (68%). Four sectors.
In the case of Emp the reported multiplier reflects the impact of a €100,000 increase in $G\_R\&D$. For $Prod\_2$ and W_2, we instead estimate and report cumulative elasticities. Cumulative coefficients are obtained by dividing the cumulative response of the outcome variable (y) by the cumulative change in government expenditure ($G\_R\&D$) observed from period t to $t+h$. The mean effect is the average multiplier over this period. The peak effect is defined as the maximum value of $\frac{\Delta y(t+H)}{\Delta G\_R\&D(t)}$ over the horizon $H = 0. \ldots . 4$.