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JEL codes: E62, H50, H63, O38

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Abstract

This paper examines the effects of shrinking fiscal space and the resulting fiscal consolidation on private and public expenditure in research and development (R&D). In a sample of OECD countries, we find R&D expenditure strongly influenced by the available fiscal space, with this relationship being particularly pronounced in less innovative countries. To better understand this relationship, we further explore a potential transmission channel: fiscal consolidation. Our analysis shows that the spending cuts in public allocations to R&D driven by fiscal adjustments are more pronounced in less innovative countries, suggesting the presence of a doom loop between consolidations and low domestic R&D intensity. Finally, the composition of consolidations matters: tax-based adjustments have a significantly negative impact on total domestic R&D spending, primarily due to the sharp contraction they induce in business R&D investments.

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1 Introduction

In this paper we shed light on the relation between fiscal space, fiscal policy, and investment in research and development (R&D).

Recent policy debates have increasingly focused on the challenge of enhancing national competitiveness by advancing economies toward the technological frontier. This imperative is driven by long-term trends such as population ageing, climate change, and the digital transition, all of which require substantial and timely investment in research and development (R&D). As Mario Draghi emphasised, achieving this requires countries to mobilise an "*enormous amount of money in a relatively short time*" (Financial Times, 2024). However, the fiscal space available for such interventions varies significantly across countries and has been further constrained by state interventions, notably those aimed at mitigating the effects of the energy crisis.

Tight fiscal space might lead to lower public investment, as found by Larch et al. (2024), and possibly affect private investment too. Several governments are indeed facing the need to undertake fiscal consolidation to rebuild fiscal space. When facing this trade-off, innovation-enhancing fiscal policies such as spending on R&D tend to often be the first to be cut, thereby undermining the parallel objective of improving competitiveness. Understanding how fiscal space and fiscal consolidations interact with R&D spending (both publicly and privately funded) is therefore a timely and policy-relevant question. Using narrative-identified fiscal consolidation episodes and local projection methods, we establish causal effects of fiscal adjustments on R&D spending.

This study focuses on the flexibility of R&D spending in response to fiscal constraints. We explore how the share of primary expenditure allocated to R&D adjusts across different country groups when fiscal space tightens. In particular, we investigate whether the starting level of R&D spending matters for maintaining a stable R&D investment as a share of government spending when consolidating. Understanding whether diverging patterns emerge across countries is crucial for assessing both the risks of pro-cyclical R&D cuts and the potential for an innovation "doom-loop" in relatively less innovative economies. Finally, we investigate whether the composition of fiscal consolidation — expenditure- or tax-based — differentially affects public and private R&D spending. In fact, beyond leading to a possible reduction in public investment in research and innovation, fiscal consolidation may hinder private investment in the same area. This effect has the potential to be even more disruptive for a country's innovative capacity, since private investment constitutes by far the largest share of total R&D spending, while public investment accounts for a smaller fraction.

We focus specifically on the innovation channel of fiscal space for several reasons: first, business and public sector investment in R&D activities and intangible assets have emerged as one of the main drivers of long-term growth and productivity, and thus competitiveness. Second, the digital and green transitions bring risks and opportunities through the need to develop and deploy new technologies in a relatively short time: R&D is key in harnessing the benefits and mitigating risks. Lastly, as we document below, R&D expenditure displays pro-cyclical behaviour, which has complicated sustained large-scale investments over a protracted period of time, as currently needed. We address these questions in a sample of OECD countries over a 40-year period.

Indeed, we find that public and higher education R&D exhibits pro-cyclical behaviour. Similarly to Larch et al. (2024) on overall public investment, our analysis shows that an increase in public debt and the consequent reduction in available fiscal space are associated with a decrease in public spending on research and development. This result is robust to employing different indicators used in the literature to capture different definitions of fiscal space (Kose et al., 2022), since the literature does not agree on a single definition.

A decrease in fiscal space is positively correlated with a subsequent decline in public and higher education R&D. Public R&D expenditure also displays a high correlation with fiscal space when measured as a share of total primary expenditure, highlighting how R&D spending is more responsive to decreases in fiscal space than other types of government expenditure. Moreover, this correlation is stronger and more significant for countries marked by lower capacity for innovation. We examine heterogeneities across countries grouped by innovation performance, as measured by the Global Innovation Index. When focusing on highly innovative countries, fiscal space does not correlate with either government budget allocations on R&D or public sector-performed research.

These results open the door to a possible innovation doom loop where countries that are already less innovative curb their R&D expenditure more than their more innovative peers, further widening the innovation gap. To better disentangle the mechanisms behind these correlations, we then turn our analysis to more explicit policy choices, focusing on fiscal consolidation. A shrinking fiscal space increases the need for fiscal adjustments, which could include cuts to public allocations on R&D, making fiscal space and public R&D positively correlated. The impact of consolidation on business R&D could go in either direction, depending on which transmission channel will prevail. Crowding-in and crowding-out effects coexist; moreover, fiscal consolidations can directly affect private R&D, through cuts in subsidies or tax increases, or indirectly via changes in aggregate demand, interest rates, corporate income and profits, thereby affecting investment decisions.

Our results show that public sector R&D and university-performed R&D decline sharply after a consolidation shock, both in absolute value and as a percentage of primary expenditure. The effects of consolidation on business R&D, estimated on the whole sample, are negative and significant. Overall domestic research, which includes private, public, and higher education research, undergoes a significant fall, mainly driven by the response of business R&D.

When focusing on the innovation performance of the country, we see again how in less innovative countries consolidations are followed by a larger drop in public research compared to highly innovative ones. The effects of consolidation on private R&D also differ strongly across the two groups, where innovation leaders do not experience a reduction in this item after a consolidation shock, but on the contrary experience a slight increase, suggesting the private sector's ability to fill in the gap left by public cuts. Certainly, among the various factors that may influence these results is also a form of non-monetary (and hard-to-quantify) public support to private R&D, such as the regulatory framework and other institutional conditions. In our analysis, we do not consider this dimension directly among the variables potentially affected by fiscal space and fiscal consolidation, but it is nevertheless embedded in the Global Innovation Index and therefore indirectly reflected in the classification between more and less innovative countries.

Our analysis then turns to investigate the effects of different policy choices behind the consolidation plans: tax-based adjustments significantly reduce private and overall domestic R&D. Results on the composition of fiscal consolidation are consistent with a substantial body of literature (Alesina et al., 1998, 2015), indicating that tax-based and expenditure-based consolidations yield contrasting effects on several macroeconomic variables, such as business investment. This heterogeneity is therefore of key relevance for our work. While expenditure-based plans do not have clear effects on R&D, tax-based plans lead to a reduction in business R&D and, consequently, on domestic overall research. In light of current needs to rebuild fiscal space and achieve fiscal consolidation, while simultaneously mobilising the substantial resources for technological advancement emphasised by Mario Draghi, our results flag how fiscal consolidations should be accompanied by reforms increasing a country's ability to attract capital and to foster private R&D.

Our analysis bears strong policy implications for the design of adjustment plans. Fiscal adjustments usually entail large political costs, which might influence the choice of consolidation measures. Certain tax categories may be more amenable to increases than others, just as specific spending categories are more susceptible to cuts (Munoz and Olaberria, 2019). From our analysis R&D emerges as part of the latter group. Therefore, even though a fiscal consolidation plan might need to address urgent issues, it is essential that it includes medium to long-term assessments preserving those types of expenditure capable of ensuring growth, competitiveness, and long-term fiscal sustainability itself. Moreover, less innovative countries face the danger of falling into a 'low-R&D trap', or doom loop where a low level of domestic innovation is associated with larger cuts to (already low) public R&D investment. The greater propensity of this group of countries to cut public R&D investments is confirmed by its larger reduction relative to total public spending following fiscal adjustments.

The rest of the paper is structured as follows: Section 2 illustrates the data and the related literature. Section 3 presents the results of the partial correlation analysis between fiscal space and R&D spending and the local projection analysis of the effects of fiscal consolidations on R&D. Section 4 concludes.

2 Data and Literature

In this section, we present the data behind our analyses and some main characteristics of the relation between fiscal space, fiscal consolidations, and R&D, in the context of the current literature.

2.1 R&D

A large branch of literature on endogenous growth and technological progress has highlighted the fundamental role that R&D plays in sustaining long-term growth. The role of knowledge in fostering long-term growth can be found in seminal papers by Romer (1986) and Lucas (1988). Later on, Aghion and Howitt (1992) explicitly introduced the R&D component in their model, where a competitive research sector is the source of endogenous growth. More recently, Kung and Schmid (2015) found that R&D drives a persistent component in the growth rate of productivity, therefore triggering persistent swings in the growth rate of output.

Empirical studies such as Moretti et al. (2023) and Guellec and Van Pottelsberghe de la Potterie (2004), also confirm these results: an increase in R&D expenditure leads to an increase in the growth rate of total factor productivity.

Building on this literature, we use R&D data from the OECD Main Science and Technology Indicators. These indicators show that, long before the establishment of the EU Single Market in 1992, European countries displayed significant heterogeneity in their industrial models and in the extent to which each country's private sector invested in R&D (Figure 1). Yet, while deeper integration should have made capital more readily available to firms, the level of business R&D investment did not converge towards the higher level displayed by the US. Only Germany managed to keep pace; other countries, while increasing their expenditure on R&D, did not manage to ramp up expenditure enough to fill the initial gap. Outside the EU, Chinese firms started rapidly expanding R&D expenditure from 2000 onwards, overtaking the US and Germany as a share of GDP.

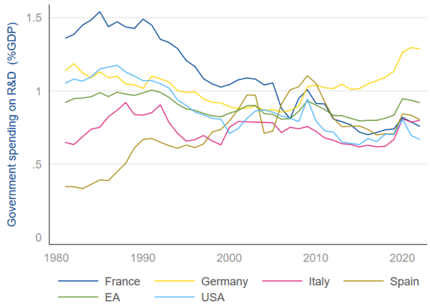
The sluggish growth in business R&D was not compensated by additional funds from the public sector. In fact, France lost its status as a leader in government intramural expenditure in R&D (public research) to China, even though Germany, in this case, has significantly increased its expenditure. Other EU Member States for which data is available display different dynamics, with Italy decreasing its expenditure, and Spain increasing it. A similar dynamic can be observed in total government allocations for R&D, which include both public research and government financial support to research activities performed outside the public sector (primarily businesses and higher education). Finally, higher education R&D expenditure shows a fairly stable growth rate over the years for all the selected countries.

Several works have explored the relationship between public and private R&D, as well as the relationship between fiscal policy and private investment in R&D.

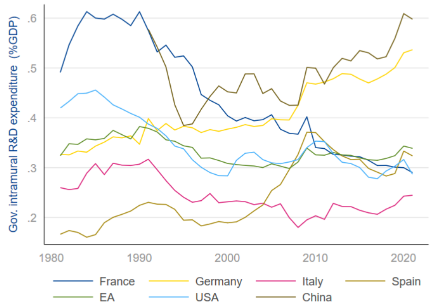
Reductions in direct (government funding of business-performed R&D) and indirect (tax incentives) support to business-performed research motivated by a consolidation plan, are accompanied by a decrease in public sector and higher education-performed research. Since crowding-in and crowding-out effects coexist (Guellec and Van Pottelsberghe De La Potterie, 2003; Moretti et al., 2023), the overall effect on business R&D is undetermined. Consequently, only some firms might be able to (partially or fully) compensate for the lack of public research by increasing the amount of private resources invested in R&D activities. At the same time, fiscal consolidation directly affects private R&D. Expenditure cuts and tax increases impact aggregate demand, corporate income and profits, changing the full amount of resources available for investment (Alesina et al., 2015).

Finally, micro-studies such as Croce et al. (2019) and Peia and Romelli (2022) show that high-R&D firms are more exposed to government debt and have higher expected returns. The impact of fiscal consolidation on business-performed R&D is expected to be positive through this channel: fiscal consolidation is primarily aimed at reducing budget deficits and government debt. Consequently, it should result in a lower risk factor priced into stock returns and benefit high-R&D firms more than low-R&D ones, thereby influencing R&D expenditure.

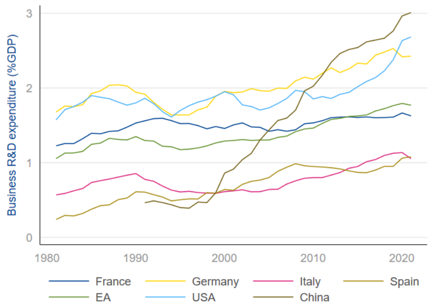
Figure 1 – R&D expenditure dynamics in selected countries



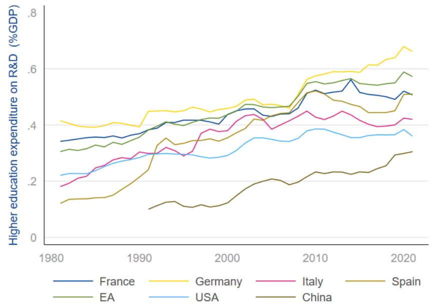
(a) Gov. total allocations on R&D



(b) Gov. intramural R&D expenditure



(c) Business R&D expenditure



(d) Higher education R&D expenditure

2.2 Fiscal Space

When approaching our research question on the ties between fiscal space and competitiveness in the context of the euro area, we must first define fiscal space.

Different studies rely on different definitions of fiscal space depending on what they want to capture. Fiscal space can in fact be understood as in Heller (2005): 'the ability of the sovereign to borrow without undermining the sustainability of its financial position or the stability of the economy'. The complexity - or fuzziness - of the concept is well exemplified by the vast cross-country database presented in Kose et al. (2022), consisting of 30 different indicators, grouped into four categories: debt sustainability, balance sheet vulnerability, external and private sector debt-related risks as potential causes of contingent liabilities, and market access. Some of these indicators overlap with other concepts, such as the vulnerability in the private sector's balance sheet, and capture the tight relation between private and public indebtedness that can arise especially during turbulent times.

As our analysis looks at the relation between fiscal space and R&D, with R&D being one of the main engines of competitiveness, it is important to recall that under different definitions of competitiveness, the relation between fiscal space and competitiveness might change. Darvas (2013) notes how gaining fiscal space and competitiveness might be conflicting objectives for high-debt countries in a monetary union. While high unexpected inflation might lower the debt burden and free some fiscal space, this would worsen competitiveness by increasing relative prices. A low-inflation environment on the other hand, while potentially pushing exports through lower relative prices, would result in a reduction in fiscal space (Darvas, 2013). These conflicting objectives also motivate our choice not to investigate price competitiveness, but to look at the capacity of a country to invest and reach the edge of the technological frontier.

The primary indicator of fiscal space used in our analysis is the (inverse) ratio between general government debt and tax revenues. This measure is widely adopted in the literature. For instance, Aizenman and Jinjarak (2012) analyse the effects of fiscal stimuli on exchange rates, depending on the fiscal space in the domestic economy. By expressing government debt as a share of tax revenue, the authors capture the tax capability of the country and its ability to repay debt. Institutional weakness may hinder government's ability to collect taxes, thereby affecting their capacity to repay debt in the short term and the long-term sustainability of government debt.

This principle also guides our choice of variable, as we aim to capture the "room for manoeuvre" that governments have to promote R&D and other policies. Similarly, Bergant and Forbes (2023) use this measure, among others, to investigate the determinants of policy responses to the Covid-19 pandemic. In the first step of our dynamic analysis, we will demonstrate how changes in fiscal space available at time $t-1$ are strongly correlated with R&D investments in the subsequent period. Using the first difference of our fiscal space indicator as the explanatory variable, we will repeat the analysis with an alternative variable commonly employed for such evaluations: the cyclically adjusted primary balance (CAPB).

An increase in CAPB at time $t-1$, similar to a positive change in the tax revenue-to-debt ratio, leads to an improvement in fiscal space in the following period. The distinctive feature of CAPB is that it is generally regarded as a measure of discretionary policy, as it is adjusted for cyclical effects (as well as interest payments on debt). In contrast, the tax revenue-to-debt ratio can be influenced by factors entirely unrelated to discretionary policy decisions by policymakers, but still able to affect the fiscal space available.

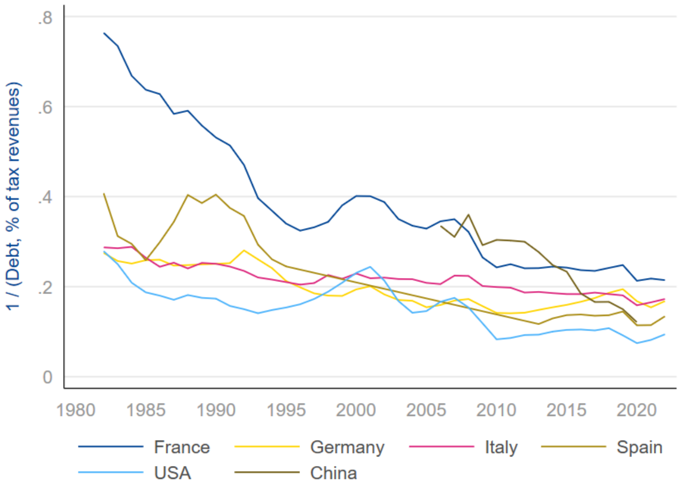
Figure 2a illustrates the dynamics of the fiscal space indicator for the same sample of countries used in the R&D analysis. The index decreases as fiscal space shrinks, covering the period from 1980 to 2022. The figure shows a converging and decreasing trend, indicating that all sample countries have a smaller fiscal space at the end of the period. Additionally, the initial heterogeneity across countries has narrowed. The dynamics of the CAPB are shown in Figure 2b, revealing significant heterogeneities across countries. Among the most notable aspects are the substantial primary surpluses achieved by Italy in the period preceding its entry into the euro area and following the Global Financial Crisis (GFC). After the GFC, Germany also recorded primary surpluses, whereas during the same period, the United States and Spain experienced very negative CAPB levels. Primary deficits were observed in all the countries shown following the COVID-19 crisis.

2.3 Fiscal Consolidations

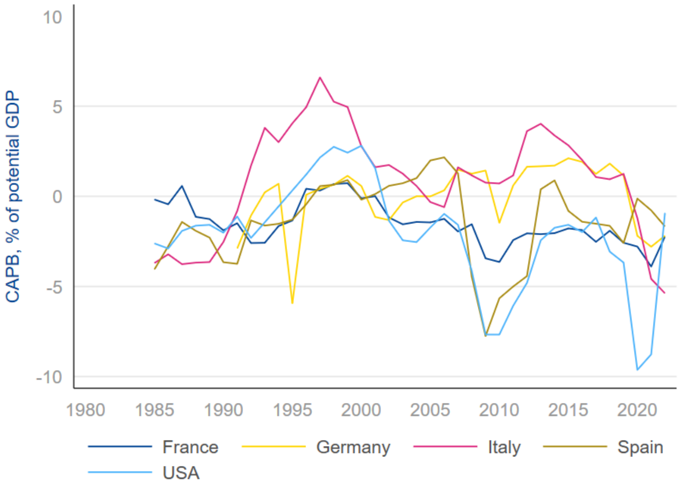
Since this paper aims to disentangle the relationship between public and private R&D expenditure and fiscal policy choices, we rely on the literature that studies the effects of exogenous fiscal consolidation episodes on the economy to better pinpoint the causal relation between the two. We therefore focus on how these exogenous policy changes, which increase fiscal space, affect public and private R&D spending.

Over the years, several works have tried to identify fiscal shocks to assess the effects of consolida-

Figure 2 – Fiscal space indicators in selected countries



(a) Tax revenues as % of debt



(b) Cyclically adjusted primary balance

tions on GDP. Initially, fiscal adjustments were identified quantitatively, looking at changes in the cyclically adjusted primary balance (CAPB) (Alesina and Ardagna, 2013), which should exclude the automatic effects of the business cycle. However, the exogeneity of the measures constructed using this strategy has been called into question. The main critique focuses on how changes in the CAPB do not rule out changes in fiscal policy changes aimed at responding to cyclical fluctuations. Moreover, the cyclical adjustment applied to derive the CAPB has been shown to suffer from measurement errors correlated with economic developments (Pescatori et al., 2011).

To address these shortcomings, Pescatori et al. (2011) developed an alternative identification approach. Specifically, they propose a narrative methodology that identifies consolidation episodes as fiscal measures primarily aimed at reducing the budget deficit, based on an in-depth analysis of policy documentation. Alesina et al. (2019) follow this methodology and extend the dataset to 2014, covering 16 OECD countries.

In our analysis, we utilise the recently developed dataset from Adler (2024), which builds upon the two previous works and extends the identification of consolidation episodes from 1978 to 2020.

This dataset includes all fiscal measures "motivated primarily by the desire to reduce the budget deficit and not by a response to prospective economic conditions."

This identification strategy results in episodes with both positive and negative signs, with positive ones largely dominating the set. Tax hikes and expenditure cuts aimed at reducing the budget deficit are basic examples of positive adjustments. The presence of negative signs in the calculation of fiscal consolidation measures arises from the need to record the net sum of both consolidation measures aimed at deficit reduction and other fiscal actions (when implemented) that, although potentially opposing the consolidation effort, are not driven by cyclical factors but are instead motivated by long-term supply-side considerations. For example, in the case of France in 2018, while expenditure cuts aimed at reducing the deficit were implemented, they were partially offset by a tax cut designed to provide long-term tax relief and enhance business competitiveness. This offset is included in the overall calculation, reflecting the simultaneous occurrence of fiscal adjustments and other policy actions.

Figure A1 in the Appendix illustrates the composition of fiscal consolidations over time for a sample of 15 OECD countries. Each bar shows the sum of expenditure-based and tax-based consolidation measures, as % of GDP, across all countries. Three prominent periods of substantial consolidation emerge: the early 1980s, the early 1990s (which spans a longer duration), and the aftermath of the financial and sovereign debt crises.

The originality of our paper stems from the use of consolidation episodes to identify the effects of fiscal adjustment on the overall research and development expenditure. This approach allows us to explore a channel through which the reconstruction of fiscal space might affect long-term growth. The decrease in domestic R&D due to a reduction in public allocations may either be exacerbated by a subsequent decline in business R&D investments or (partially or fully) offset by a positive response from private R&D. The overall effect will contribute to determine the long-term impact of fiscal consolidation.

3 Analysis

3.1 R&D and fiscal space

We start our analysis by investigating how R&D expenditure responds to the available fiscal space, controlling for the business cycle. By understanding how flexible R&D is, we can assess how easily it can be adjusted in response to changes in fiscal policy.

Hp1: Does R&D expenditure respond to a change in fiscal space?

To answer this question, we investigate the partial correlation between fiscal space and R&D expenditure using a set of unit and time fixed effects regressions. This approach allows us to highlight significant differences across countries. The benchmark models are:

$$\Delta y_t = \beta_0 + \beta_1 \Delta y_{t-1} + \beta_2 \Delta ln(FS)_{t-1} + \beta_3 \mathbf{X}_t + \mu_i + \gamma_t + \epsilon_t \quad (1)$$

$$\Delta y_t = \beta_0 + \beta_1 \Delta y_{t-1} + \beta_2 CAPB_{t-1} + \beta_3 \mathbf{X}_t + \mu_i + \gamma_t + \epsilon_t \quad (2)$$

Here, Δy_t is the logarithmic change in different R&D spending categories, as defined by the OECD. These categories include: total government allocations for R&D ($GBARD$); government intramural expenditure on R&D ($GOVERD$); higher education expenditure on R&D ($HERD$); R&D tax incentives ($GTARD$); and business-performed R&D financed by the public sector ($BERD_{PUB}$). FS captures our main measure of fiscal space, the inverse of general government gross debt over tax revenues, while $CAPB$ is our second definition, capturing the cyclically-adjusted primary balance as a share of potential GDP.[1]

The set of control variables $\mathbf{X}_t$, includes the change in primary expenditure over GDP (to control for fluctuations in the overall government spending), lagged long-term interest rate (to capture financial conditions), real GDP growth (to capture business cycle fluctuations), and inflation. Finally, μ_i and γ_t are the coefficient for country and time fixed effects, respectively.

We estimate the benchmark models using data for 32 OECD countries, spanning over the period from 1980 to 2020.[2] Finally $\Delta ln(FS)$ and CAPB are interacted with dummy variables capturing the country's innovation performance, following the approach of Pellens et al. (2024). These dummy variables categorise countries into three groups, depending on whether the country displays a high, medium, or low level of innovation, based on the Global Innovation Index (GII) ranking. The GII captures a country's innovation capacity across several dimensions and then ranks them based on their performance.[3] In this work, we use the GII as a proxy of the country's innovative status to capture heterogeneity in R&D spending across country groups.

In each table, we report the coefficients estimated from Equation 1 and 2 for each dependent variables - so using the first definition of (change in) fiscal space $\Delta ln(FS)$ in the columns labelled as (1), and, next to them in columns labelled as (2), the coefficients estimated from equation 2, using CAPB as alternative measure of fiscal space variation.

Table 1 highlights a pronounced procyclical behaviour across most R&D categories, though with notable variations in magnitude and statistical significance. Government R&D allocations ($GBARD$) and intramural spending ($GOVERD$) exhibit strong procyclical patterns, with statistically significant positive correlations with GDP growth, as evidenced by the positive and statistically significant correlation between the variables and GDP growth in every specification. Higher education R&D ($HERD$) shows a more moderate procyclical relationship, with a significant coefficient only when using the $CAPB$ measure of fiscal space. In contrast, public funding for business-performed R&D ($BERD_{PUB}$) displays no significant correlation with GDP growth, suggesting that somehow the public sector continues to finance private sector research investment during downturns. Tax incentives for R&D ($GTARD$) also show no significant relationship with economic cycles. These results are in line with the main findings in Pellens et al. (2024), while revealing that cyclical sensitivity is strongest for direct government R&D activities rather than higher education or public support to private sector research.

As for the response of these spending categories to a change in fiscal space in the previous

[1] See Appendix A2 for a more detailed list of variables.
[2] List of countries available in Table A1
[3] GII rank available in Table A1, Appendix

year, when capturing it as the ratio of tax revenues to debt (odd-numbered columns), fiscal space improvements show positive associations across the three main public R&D categories ($GBARD$, $GOVERD$, $HERD$), but only higher education R&D spending exhibits a statistically significant response. This could point to a higher sensitivity of university research to fiscal constraints, compared with other government R&D programmes. When looking at more private-sector oriented types of R&D financing, tax incentives seem to be negatively correlated with fiscal space, while no significant relationship emerges for public-funded R&D performed by private firms.

Table 1 – Responses of R&D expenditure categories to changes in fiscal space

Δy_t	$GBARD$		$GOVERD$		$HERD$		$GTARD$		$BERD_{PUB}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δy_{t-1}	-0.139*	-0.092	-0.142***	-0.098***	0.032	0.012	0.037	0.056	-0.173***	-0.140*
	(0.069)	(0.090)	(0.043)	(0.031)	(0.042)	(0.040)	(0.036)	(0.041)	(0.019)	(0.073)
$\Delta ln(FS)_{t-1}$	0.014		0.061		0.072**		-0.447**		0.116	
	(0.040)		(0.064)		(0.027)		(0.196)		(0.144)	
$CAPB_{t-1}$		0.349***		-0.082		0.211		-0.866		0.836
		(0.107)		(0.276)		(0.147)		(0.883)		(0.706)
$LTinterest_{t-1}$	0.000	0.000	0.006	0.006	-0.001	-0.001	-0.021*	-0.023*	-0.016	-0.012
	(0.004)	(0.004)	(0.003)	(0.004)	(0.002)	(0.003)	(0.011)	(0.012)	(0.015)	(0.009)
$\Delta ln(GDP)$	0.633**	0.492*	0.877*	0.767*	0.443	0.421*	1.341	0.994	-0.170	0.314
	(0.236)	(0.267)	(0.436)	(0.407)	(0.260)	(0.225)	(1.012)	(1.159)	(1.002)	(0.703)
$\Delta(Pr.Exp./GDP)$	0.004**	0.002	0.003	0.003	0.003**	0.003**	0.008	0.008	0.013	0.015
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.006)	(0.006)	(0.015)	(0.012)
CPI	0.000	0.002	0.007	0.005	-0.005*	-0.004	-0.015	-0.017	-0.004	-0.004
	(0.003)	(0.003)	(0.006)	(0.005)	(0.003)	(0.002)	(0.021)	(0.019)	(0.018)	(0.016)
N	737	774	737	774	737	774	300	315	729	766
R^2	0.121	0.127	0.056	0.075	0.122	0.105	0.118	0.093	0.085	0.089

Standard errors in parentheses
Country FE, YES, Time FE, YES
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

An improvement in fiscal space at $t-1$, now captured by a positive $CAPB$ (even-numbered columns), is significantly and positively correlated with an increase in total public R&D expenditure in the subsequent period.

Having examined the correlations between fiscal space and R&D expenditure, we now test whether public R&D spending is more sensitive to fiscal constraints than total primary spending. This analysis aims at revealing the relative responsiveness of R&D expenditure within the broader government budget. We thus extend the analysis beyond growth rates to examine spending composition effects, assessing how different expenditure categories adjust relative to each other when fiscal space changes. Results are reported in Table 2 and are consistent with our previous findings.

When looking at the partial correlation with the change in fiscal space, captured by the ratio of tax revenues to debt, in the previous year (odd columns), we find a positive association for total government allocations to R&D ($GBARD$), higher education expenditure on R&D ($HERD$), and government-funded business R&D ($BERD_{PUB}$), although none of the results are statistically significant. For tax incentives ($GTARD$), we find the same significant, negative correlation as in Table 1. When shifting our focus to our second definition of fiscal space, we see that after an improvement in the $CAPB$ in the previous period, both government allocations and higher education R&D make up a higher share of primary expenditure. Conversely, a deterioration in the $CAPB$ will be followed by a decrease in the share of R&D expenditure. This result suggests that R&D spending is more flexible compared to other components of primary expenditure.

Table 2 – Responses of R&D expenditure categories (as a share of primary expenditure) to changes in fiscal space

$\Delta(Y_t/Pr.Exp)$	$GBARD$		$GOVERD$		$HERD$		$GTARD$		$BERD_{PUB}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δy_{t-1}	-0.120**	-0.050	-0.186***	-0.182***	-0.075	-0.062	0.182**	0.185**	0.033	0.059
	(0.055)	(0.073)	(0.036)	(0.033)	(0.086)	(0.081)	(0.086)	(0.078)	(0.095)	(0.094)
$\Delta ln(FS)_{t-1}$	0.018		-0.007		0.039		-0.047***		0.010	
	(0.056)		(0.021)		(0.032)		(0.015)		(0.016)	
$CAPB_{t-1}$		0.614***		-0.097		0.367**		-0.088		0.090
		(0.177)		(0.180)		(0.138)		(0.091)		(0.072)
$LTinterest_{t-1}$	0.002	0.002	0.003	0.002	-0.002	-0.003	0.001	0.001	-0.002	-0.002
	(0.004)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\Delta ln(GDP)$	-0.381	-0.608*	-0.261	-0.326	-0.518***	-0.656***	0.097	0.136	-0.085	-0.095
	(0.268)	(0.312)	(0.321)	(0.296)	(0.172)	(0.174)	(0.182)	(0.225)	(0.097)	(0.098)
$\Delta(Pr.Exp./GDP)$	-0.027***	-0.030***	-0.009**	-0.009***	-0.018***	-0.019***	-0.004**	-0.004**	-0.002	-0.002*
	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
CPI	-0.006	-0.002	-0.000	-0.000	-0.005*	-0.004	-0.001	-0.002	-0.001	-0.001
	(0.003)	(0.004)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
N	691	733	706	748	608	644	449	469	640	687
R^2	0.315	0.282	0.171	0.182	0.368	0.357	0.096	0.087	0.075	0.078

Standard errors in parentheses
Country FE, YES, Time FE, YES
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

It is worth noting, however, how government intramural expenditure on R&D ($GOVERD$), which primarily consists of public sector salary expenditures, shows a negative and not significant correlation. We attribute this finding to the composition of the variable, as wages are generally harder to adjust, especially in the short term.

In Table 3, we continue our analysis assessing the role that country-level heterogeneities might play in determining the size and direction of the partial correlation between fiscal space and R&D, and the relative flexibility of the latter. We focus in particular on the innovation ranking of the countries in our sample. To do so, we interact our measures of fiscal space with the innovative status of each country, summed up by whether a country belongs to one of three categories: $Lead$ (Innovation leader, high innovation); $Foll$ (Innovation follower, medium innovation); and Mod (Moderate innovator, low innovation).

Our analysis does find significant heterogeneities across country groups. Total government allocations for R&D ($GBARD$), public-sector performed research ($GOVERD$) and higher education research expenditure ($HERD$) responses to changes in both definitions of fiscal space are much larger in countries with the relatively weaker innovation performance, classified as *Moderate* innovators. For *Moderate* innovators, a shrinking fiscal space implies a significant reduction in government allocations on R&D, in public and higher education R&D. Conversely, in countries with a higher R&D track record, classified as *Followers*, and even more so in *Leaders*, these expenditure categories appear largely uncorrelated with the available fiscal space, with a few exceptions. The lack of correlation implies a stronger stability of these types of spending in countries that have already performed relatively better at innovating. Countries that lagged behind display cyclicality in R&D expenditure. Results for tax incentives ($GTARD$), show a negative correlation for *Follower* and *Moderate* innovators. This might be due to a cut of R&D tax incentives when countries decide to gain fiscal space by increasing revenue. When looking at government funding of business-performed R&D, results are not significant.

Table 3 – Responses of R&D expenditure categories to changes in fiscal space by innovation status

Δy_t	$GBARD$		$GOVERD$		$HERD$		$GTARD$		$BERD_{PUB}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δy_{t-1}	-0.144*	-0.096	-0.146***	-0.097***	0.027	0.012	0.036	0.056	-0.174***	-0.143*
	(0.070)	(0.089)	(0.039)	(0.031)	(0.041)	(0.040)	(0.039)	(0.041)	(0.019)	(0.079)
$\Delta ln(FS)_{t-1}^{Lead}$	-0.046		-0.007		0.058**		-0.612		-0.045	
	(0.039)		(0.055)		(0.022)		(0.537)		(0.164)	
$\Delta ln(FS)_{t-1}^{Foll}$	-0.001		-0.021		0.049		-0.216**		0.234	
	(0.037)		(0.048)		(0.036)		(0.094)		(0.159)	
$\Delta ln(FS)_{t-1}^{Mod}$	0.266*		0.656*		0.217***		-1.171**		0.053	
	(0.137)		(0.362)		(0.066)		(0.529)		(0.169)	
$CAPB_{t-1}^{Lead}$		0.210		-0.195		0.256*		-0.780		0.336
		(0.135)		(0.353)		(0.115)		(3.080)		(0.473)
$CAPB_{t-1}^{Foll}$		0.224		-0.331		0.040		-0.976		1.558
		(0.195)		(0.391)		(0.213)		(0.756)		(1.605)
$CAPB_{t-1}^{Mod}$		0.751***		0.501*		0.445*		-0.703		0.261
		(0.262)		(0.290)		(0.257)		(1.319)		(0.735)
$LTinterest_{t-1}$	0.000	-0.000	0.006*	0.006	-0.001	-0.001	-0.021*	-0.023*	-0.016	-0.011
	(0.003)	(0.004)	(0.003)	(0.004)	(0.002)	(0.002)	(0.010)	(0.011)	(0.015)	(0.010)
$\Delta ln(GDP)$	0.543**	0.463*	0.680	0.732*	0.406	0.46*	1.370	1.00	-0.254	0.293
	(0.219)	(0.257)	(0.412)	(0.394)	(0.256)	(0.233)	(1.147)	(1.138)	(1.046)	(0.693)
$\Delta(Pr.Exp./GDP)$	0.003*	0.002	0.002	0.003	0.003*	0.003**	0.007	0.008	0.012	0.014
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.006)	(0.006)	(0.015)	(0.011)
CPI	0.001	0.002	0.008	0.006	-0.005*	-0.003	-0.023	-0.017	-0.004	-0.005
	(0.003)	(0.003)	(0.007)	(0.005)	(0.003)	(0.003)	(0.024)	(0.020)	(0.018)	(0.015)
N	737	774	737	774	737	774	300	315	729	766
R^2	0.133	0.130	0.081	0.078	0.127	0.108	0.129	0.093	0.086	0.094

Standard errors in parentheses
Country FE, YES, Time FE, YES
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Finally, similar results emerge when examining the cross-country heterogeneity in research spending as a percentage of primary expenditure (Table 4). The fiscal space coefficients are larger in absolute value and often significant for countries classified as *Moderate* innovators. In this context, observing the behaviour R&D expenditure as a share of primary expenditure is particularly important: in fact, classifying countries into three groups may capture different propensities for cutting or expanding overall public expenditure. This, in turn, could obfuscate specific effects of these cuts on research and development expenditure. Both measures of fiscal space suggest once again that, in countries classified as *Moderate*, the share of public expenditure allocated to R&D is more volatile than other types of primary expenditure, and it is highly dependent on the available fiscal space. In more innovative countries, such a correlation is not found. For *Leaders*, the share of government intramural expenditure on R&D ($GOVERD$), is even negatively correlated with available fiscal space, suggesting these countries might relatively preserve this spending item when fiscal space shrinks. When looking at results for tax incentives ($GTARD$) and business-performed R&D ($BERD_P$), results are almost never significant.

3.2 R&D and fiscal consolidations

3.2.1 Baseline

While we did confirm the presence of a partial correlation between fiscal space and research expenditure, this does not address two underlying issues central for policymakers and for the competitiveness of a country. First, there could be simultaneity between investment in R&D and the measures of fiscal space chosen: more R&D can increase the overall level of productivity of a country and then increase its fiscal space in the long run. While this potential simultaneity is unlikely to be significant in the very short term (the time unit of our models), we cannot rule it out in principle.

Table 4 – Responses of R&D expenditure categories (as a share of primary expenditure) to changes in fiscal space by innovation status

$\Delta(Y_t/Pr.Exp.)$	*GBARD*		*GOVERD*		*HERD*		*GTARD*		$BERD_{PUB}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δy_{t-1}	-0.124**	-0.052	-0.191***	-0.182***	-0.077	-0.060	0.182**	0.184**	0.032	0.0583
	(0.054)	(0.074)	(0.035)	(0.032)	(0.085)	(0.081)	(0.086)	(0.078)	(0.095)	(0.093)
$\Delta ln(FS)^{Lead}_{t-1}$	0.052		-0.020		0.040		-0.048		-0.006	
	(0.095)		(0.023)		(0.036)		(0.031)		(0.019)	
$\Delta ln(FS)^{Foll}_{t-1}$	-0.032		-0.031		-0.005		-0.044***		0.025	
	(0.053)		(0.030)		(0.045)		(0.015)		(0.017)	
$\Delta ln(FS)^{Mod}_{t-1}$	0.181		0.143***		0.178***		-0.058		-0.023	
	(0.143)		(0.042)		(0.049)		(0.054)		(0.027)	
$CAPB^{Lead}_{t-1}$		0.560		-0.234		0.296		-0.180		-0.020
		(0.300)		(0.150)		(0.161)		(0.291)		(0.085)
$CAPB^{Foll}_{t-1}$		0.388		-0.253		0.229		-0.107		0.099
		(0.263)		(0.336)		(0.165)		(0.076)		(0.121)
$CAPB^{Mod}_{t-1}$		1.068***		0.349**		0.633***		0.001		0.188
		(0.360)		(0.144)		(0.237)		(0.203)		(0.119)
$LTinterest_{t-1}$	0.002	0.001	0.003 *	0.002	-0.002	-0.003	0.001	0.001	-0.002	-0.002
	(0.004)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
$\Delta ln(GDP)$	-0.396	-0.633*	-0.302	-0.360	-0.662***	-0.662***	0.097	0.136	-0.086	-0.113
	(0.253)	(0.299)	(0.318)	(0.290)	(0.168)	(0.174)	(0.189)	(0.222)	(0.099)	(0.099)
$\Delta(Pr.Exp./GDP)$	-0.027***	-0.030***	-0.009**	-0.009***	-0.018***	-0.019***	-0.004***	-0.004**	-0.002	-0.002*
	(0.005)	(0.004)	(0.003)	(0.003)	(0.026)	(0.003)	(0.001)	(0.001)	(0.001)	(0.001)
CPI	-0.005	-0.002	-0.000	0.000	-0.005	-0.003	-0.001	-0.002	-0.002	-0.001
	(0.003)	(0.004)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
N	691	733	706	748	608	644	449	469	640	687
R^2	0.316	0.282	0.178	0.190	0.375	0.361	0.096	0.087	0.077	0.079

Standard errors in parentheses
Country FE, YES, Time FE, YES
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

A partial correlation analysis can provide an interesting picture concerning the relation between R&D and fiscal space, but the results obtained so far cannot be interpreted in causal terms: they cannot be seen as the effect of specific policy decisions aimed at countering or leveraging the changes in available fiscal space. Moreover the business cycle might not be fully captured by the control variables, and some other excluded or unobserved variables - such as (not) forward-looking government decisions - could be relevant drivers of both research spending and fiscal space, leading to a co-movement between the two variables.

To identify and disentangle the channel driving a potential underlying causal relationship between fiscal space and the role of government expenditure in R&D, we use a dataset of exogenous changes in fiscal policy, specifically looking at exogenous fiscal consolidations. This allows us to determine the effects of explicit policy choices, without the risk of other factors influencing the causal relationship.

The definition of these episodes allows us to identify a specific transmission channel: changes in taxes and government spending included in the dataset have to be primarily aimed at rebuilding the fiscal space to become more sustainable in the long run. Therefore, we can expect that the correlation between fiscal space and R&D spending is (at least partially) driven by fiscal consolidation: a shrinking fiscal space triggers fiscal adjustments, which in turn have a direct effect on public and private spending.[4]

We thus aim at addressing a set of questions over the relation between fiscal consolidation and R&D:

[4]From an empirical perspective, to support this logical connection, Appendix A presents an estimation of the correlation between consolidation episodes at time t and the change in available fiscal space in the preceding period, $t-1$. The results confirm the significance of this dynamic relationship. A reduction in fiscal space at time $t-1$ is significantly associated with both a larger magnitude of consolidation and a higher probability of implementing consolidation at time t.

Hp2: Does fiscal consolidation affect public and private R&D spending?

Hp3: Are these effects heterogeneous across countries?

Hp4: Do expenditure-based and tax-based consolidations have different effects on R&D expenditure?

To answer them, we rely on local projections (Jordà, 2005), since the method allows us to look at the effects of exogenous fiscal consolidations on public and private R&D spending over a 4-year horizon.

The local projections framework is:

$$y_{t+h} - y_{i,t-1} = \beta_{0s} + \beta_{1s} * e_t^{FC} + \beta_{2s} * \mathbf{X}_t + \beta_{3s} * \Delta y_{t-1} + \gamma_t + \mu_i + \epsilon_{t+s} \quad (3)$$

$$\begin{aligned} y_{t+h} - y_{i,t-1} = I_i[\beta_{INN,0s} + \beta_{INN,1s} * e_t^{FC} + \beta_{INN,2s} * \mathbf{X}_t + \beta_{INN,3s} * \Delta y_{t-1}] + \\ +(1-I_i)[\beta_{MOD,0s} + \beta_{1s} * e_t^{FC} + \beta_{MOD,2s} * \mathbf{X}_t + \beta_{MOD,3s} * \Delta y_{t-1}] + \alpha_{i,h} + \gamma_t + \mu_i + \epsilon_{t+s} \end{aligned} \quad (4)$$

$$y_{t+h} - y_{i,t-1} = \beta_{0s} + \beta_{1s} * e_t^{EB\_FC} + \beta_{2s} * e_t^{TB\_FC} + \beta_{3s} * \mathbf{X}_t + \beta_{4s} * \Delta y_{t-1} + \gamma_t + \mu_i + \epsilon_{t+s} \quad (5)$$

$$for\ s = 0, 1, 2, 3, 4$$

Where $\mathbf{X}_t$ is a vector of control variables: $\Delta ln(GDP)_{t-1}$, $\Delta(Primary\_expenditure/GDP)_t$, $LTinterest_{t-1}$, $\Delta Debt/GDP_{t-1}$ and CPI_{t-1}.

The R&D spending categories, used as dependent variables in logarithmic form, are therefore the same as in the previous section (i.e., those that are entirely or predominantly public in nature), plus three additional ones: government budget allocations for R&D ($GBARD$), government intramural expenditure on R&D ($GOVERD$), higher education expenditure on R&D ($HERD$), and government-funded business R&D ($BERD_{PUB}$). To these, we add total business-performed R&D expenditure ($BERD$), the share of it financed by the private sector ($BERD_{BUS}$) — which represents the vast majority — and, finally, total domestic R&D expenditure ($GERD$).

I_i is an indicator function that takes the value of 1 when Country i is classified as a leader in innovation and 0 when identified as a moderate innovator. Like in our previous analysis, we classify the countries in our sample based on the GII ranking, yet due to having to limit the number of countries in this sample, we group them into two categories rather than three. Consequently, $\beta_{INN,1s}$ and $\beta_{MOD,1s}$ represent the responses of R&D expenditure in leading innovative countries and moderate innovators, respectively.[5]

Consistently with the first part of our analysis, we show the cumulative impulse responses of the growth rate for all R&D spending categories, and the change as a share of primary expenditure for categories that are public in nature. We expect to see the results from Section 3.1 for public R&D confirmed by this analysis. This would imply a larger and more significant correlation between fiscal space and public R&D in less innovative countries, reflecting an higher propensity in R&D cuts during consolidation.

[5]The list of countries used in this analysis and their GII classification available in Table A1 in the appendix

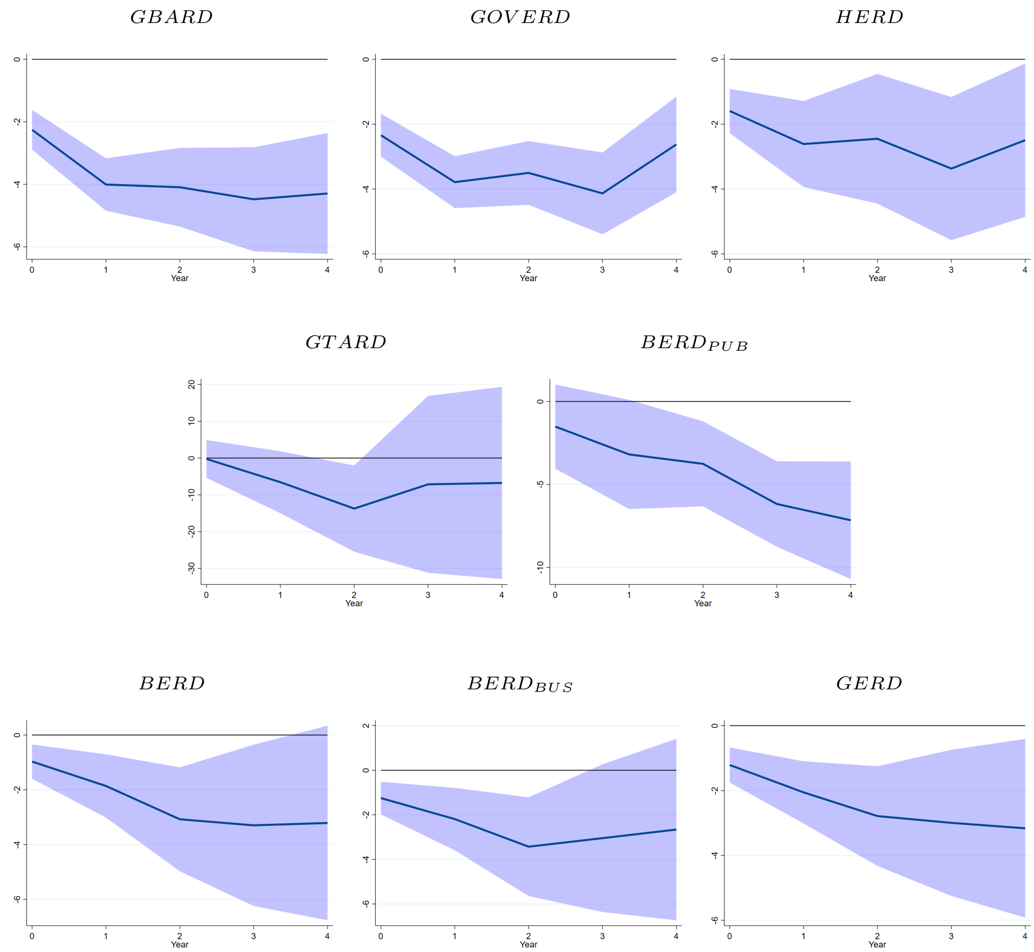
While the partial correlation analysis did not yield clear results over the cyclicality of business R&D with respect to fiscal space, we exploit this causal framework to further our understanding of how private research, and then overall domestic research, react to fiscal adjustments.

Figure 3 plots impulse responses to a consolidation shock over the entire sample. The behaviour of public R&D is in line with expectations: total government allocations for research, public research and higher education research are cut during consolidation times. Following a consolidation shock of 1% of GDP, we observe on impact a reduction of approximately 2% in total government allocations and public research. In the following periods, both spending categories experience a further decline and then stabilise at levels approximately 4% lower than their pre-shock values, respectively. University research (HERD) exhibits a similar pattern, decreasing by nearly 2% on impact and by more than 3% after three years. Significant reductions are also observed for government-funded business-performed R&D, which, although not affected on impact, declines by up to 7% four years after the fiscal consolidation shock. More ambiguous results, due to high volatility, are found for GTARD, which nonetheless appears to decrease significantly two years after the shock. Finally, focusing on total R&D expenditure performed by the private sector, the share financed by firms themselves, and total domestic R&D expenditure, the results are clear and consistent. Following a fiscal consolidation episode equivalent to 1% of GDP, private-sector-performed research declines by about 1% on impact and by up to 4% four years after the shock. A very similar pattern is observed for the share of this research financed by the private sector, as this represents by far the main source of funding. Finally, total domestic R&D expenditure (GERD) follows an almost identical trajectory, since business-performed R&D constitutes the overwhelming majority of total domestic research spending.

A fiscal consolidation usually implies a reduction in overall primary expenditure, where some spending items are cut more significantly than others. To explore the flexibility of public R&D components compares to overall spending, Figure 4 shows the impulse responses as a percentage of primary expenditure. The results show very similar dynamics across the R&D spending categories considered. Total government allocations for R&D, public-sector-performed R&D, and higher education R&D are the most affected by fiscal consolidation on impact and in the following year than overall primary expenditure, as reflected in the significant reduction of their share relative to primary spending. This decline in the ratio of R&D to primary expenditure is largely absorbed after about two years for all three categories. The reduction in tax incentives, however, appears to take longer to recover. Finally, public support for business-performed R&D seems to remain broadly in line with primary expenditure, showing no significant deviation from it.

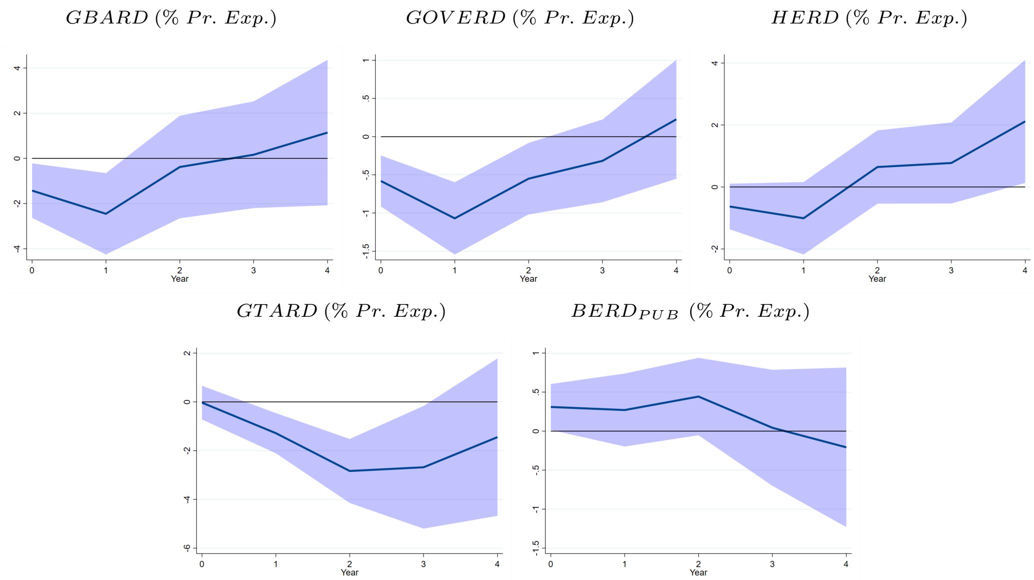
The results seem to overall point to a tendency to sacrifice R&D during consolidation episodes, with some lasting effects even four years after the consolidation took place. The sacrifice seems to affect R&D disproportionately, as it is cut more than overall primary expenditure. Yet, our previous analysis shows how, in line with the literature, differences in the policy mix and in country characteristics can affect the outcome of a policy choice. We thus turn our analysis to two important types of heterogeneity are at play: country heterogeneity and consolidation-plan heterogeneity.

Figure 3 – Responses to a consolidation shock, growth rates



Note: Cumulative impulse responses to a consolidation shock of 1% of GDP. The dependent variables are expressed as the growth rate of each item. The shaded area represents the 90% confidence interval.

Figure 4 – Responses to a consolidation shock, percentage of primary expenditure



Note: Cumulative impulse responses to a consolidation shock of 1% of GDP. The dependent variables are expressed as a percentage of primary spending.

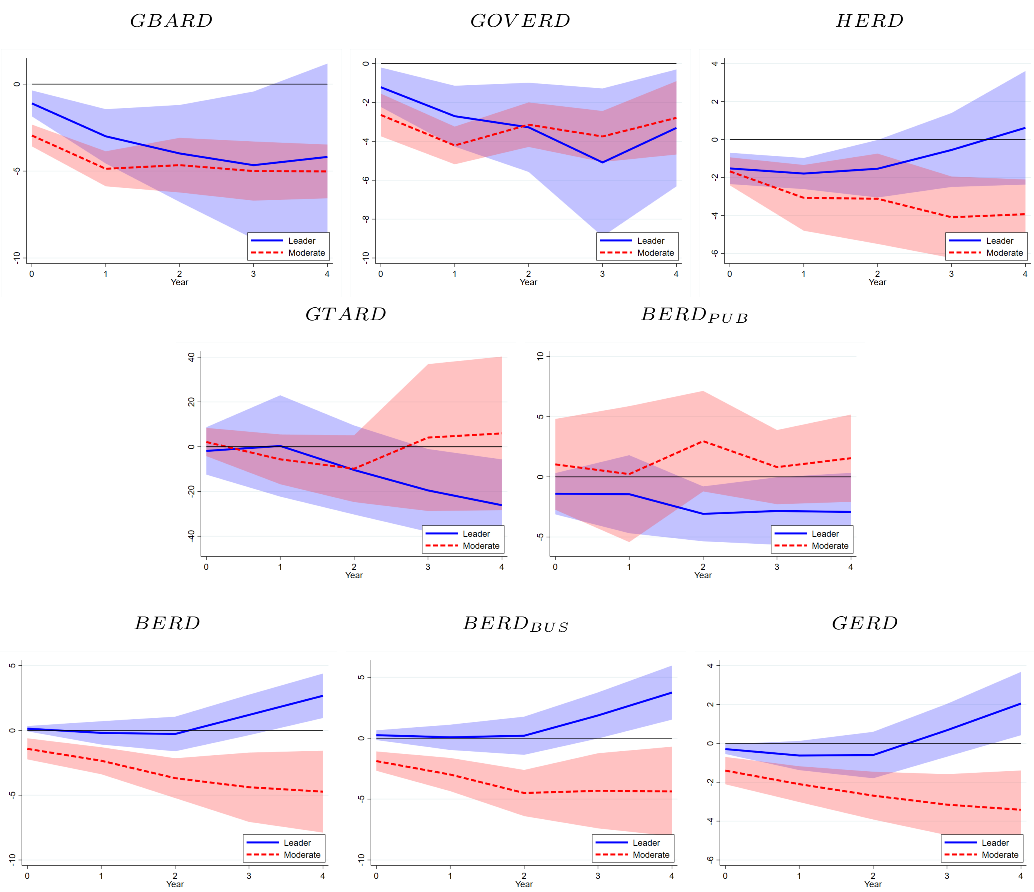
3.2.2 Country heterogeneities

Different countries might have a different capacity and propensity to innovate, and this might affect the way they treat R&D spending during a fiscal consolidation. To account for this heterogeneity, we split the sample into highly innovative and less innovative countries and assess whether this might result in heterogeneous effects of consolidation.

Figure 5 shows cumulative impulse responses of various R&D spending categories to a consolidation shock in the two groups. Impulse responses were estimated using state-dependent local projections as per Equation (4).

In moderate innovators, consolidation shocks lead to a reduction in total government allocations on R&D ($GBARD$), of about 3% on impact, which stabilises at around -5% after four years. Innovation leaders, on the contrary, do not face drastic cuts in government allocations to R&D on impact, but experience a significant decrease over time, reaching approximately -4% . Yet, after four years, the wide confidence intervals result in statistical insignificance. A similar pattern emerges for public-sector-performed R&D, which declines sharply in countries classified as moderate innovators, while experiencing a much smaller contraction in innovation leaders. Only in the medium term—around four years after the shock—do the effects appear to converge.

Figure 5 – Responses to consolidation shock by innovation status, growth rates



Note: Cumulative impulse responses to a consolidation shock of 1% of GDP. Dependent variable: R&D spending growth. Heterogeneity across countries.

The effect of a consolidation in university research ($HERD$) is initially similar between the two groups of countries, with an overall decrease in the growth of this item. Yet, it then evolves according to an entirely different dynamic: in moderate innovators, this spending category stabilises at a level lower than its pre-shock value, whereas the contraction is fully offset in more innovative countries. When it comes to tax incentives ($GTARD$), we can see that while they seem to be unchanged in moderate innovators, their growth rate at the end of the period is lower in innovation leaders, after a consolidation shock. Finally, regarding public support for private-sector research, no clear results emerge, as the difference between the two groups is not statistically significant. Turning now to research performed by the private sector ($BERD$) and financed by it ($BERD_{BUS}$), the analysis reveals the most striking difference between the two groups. Innovation leaders do not experience a reduction in private R&D following a consolidation shock; on the contrary, they appear to exhibit a slight but significant increase in the years after the shock, suggesting the private sector's ability to absorb resources withdrawn from the public sphere. Conversely, business R&D undergoes a sharp contraction when moderate innovators consolidate, decreasing by up to 5% four years after the shock. When looking at gross domestic research, we see it follows the same pattern, driven by business R&D.

These results show how a consolidation episode in the two group of countries lead to diverging R&D spending growth rates. The most direct consequence is an increasing divergence in the innovative status of countries following a fiscal adjustment, driven by a doom loop between R&D cuts and low R&D intensity in less innovative countries. Furthermore, this again underlines how crucial cross-country heterogeneity can be, as it encompasses numerous factors that can significantly affect future investment dynamics. Even the nature of the research carried out in different countries may matter: in more innovative economies, research activities are often both fundamental and applied, whereas in technologically lagging countries, they tend to be predominantly applied. This distinction may further contribute to the heterogeneous responses of private investment to external shocks.

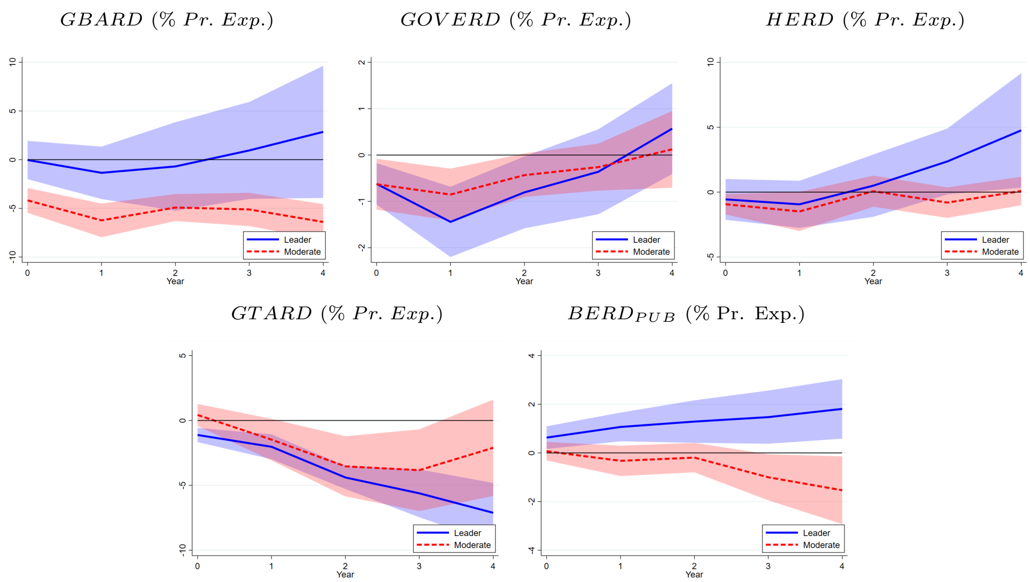
Innovation leaders and moderate innovators might experience consolidation episodes of different frequencies and magnitudes. To rule out any size effects, we estimate—just as we did earlier for variables directly linked to public spending—the impulse responses of government allocations for R&D, public-sector research, higher education research, tax incentives, and direct funding to firms, expressed as percentages of primary expenditure. These dynamics, illustrated in Figure 6, are crucial to fully understanding the flexibility of R&D. Overall government allocations to R&D ($GBARD$) shows a dramatically different dynamics across country groups, with innovation leaders not altering the share of primary expenditure dedicated to it, and a dramatic, persistent decrease for moderate innovators. When it comes to HERD, the dynamics are less pronounced but still evident. In both groups of countries, this spending category appears to move in line with overall primary expenditure. However, innovation leaders tend to increase the share of spending devoted to research and innovation in higher education a few years after the consolidation shock, while in moderate innovators, it stabilises at the level of total primary spending even several years after the shock. The responses of government intramural R&D ($GOVERD$), on the other hand, do not differ significantly between the two groups.

Finally, when interpreting the change in the share of public expenditure devoted to indirect

($GTARD$) and direct ($BERD_{PUB}$) support to firms, the results are highly significant. Regarding tax incentives, this category of spending proves to be extremely flexible in both groups of countries, showing a sharp and nearly identical decline in the years following the shock—although innovation leaders appear to display greater persistence in this adjustment.

The most notable difference, however, emerges for government funding of business-performed R&D, which increases relatively in innovation leaders but declines among less innovative countries. This response—combined with the weaker ability of the private sector in these countries to offset fiscal consolidations through their own R&D spending—highlights the key reasons behind the sharp contraction in private-sector research following a consolidation shock.

Figure 6 – Responses to consolidation shock by innovation status, percentage of primary expenditure



Note: Cumulative impulse responses to a consolidation shock (1% GDP). Dependent variable: R&D spending as % of primary spending. Heterogeneity across countries

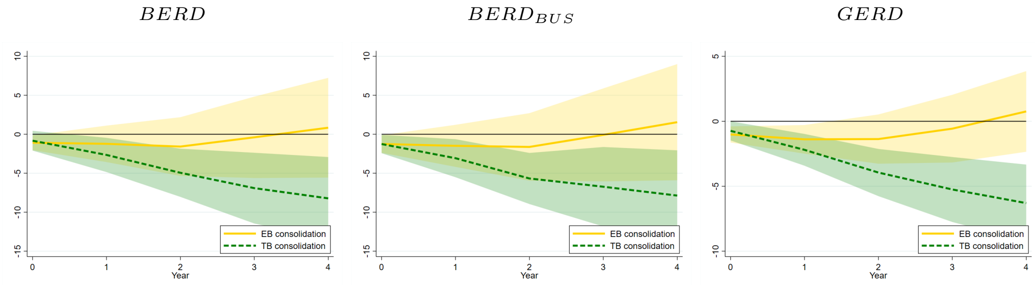
Once again, the path for business R&D ($BERD$) is clearly divergent across country groups: moderate innovators significantly and persistently reduce the total share of public spending allocated to research and development following consolidation, while the same variable shows an increase for innovation leaders. These results further consolidate our previous finding of an innovation doom loop.

3.2.3 Types of consolidation

The second heterogeneity we explore is based on the different composition of consolidation plans. As mentioned, the dataset we use categorises each consolidation plan either as tax-based or expenditure-based. Model 5 allows us to estimate the effects of unanticipated consolidation episodes differentiating between tax-based and expenditure-based plans.

The impulse responses for public R&D spending categories are reported in Appendix A2, as the reductions in these categories do not differ significantly — except in a few isolated cases —across the two types of consolidation plans. This suggests that, whether the adjustment relies primarily on spending cuts or mainly (though not exclusively) on tax increases, these expenditure categories are consistently subject to reductions of comparable magnitude.

Figure 7 – Responses to consolidation shock by plan composition



Cumulative impulse responses to a consolidation shock of 1% of GDP. Dependent variable: R&D spending growth. Consolidation plan heterogeneity

Business R&D responses are in line with the main findings of the fiscal consolidation literature. Alesina et al. (2015) show that private fixed-capital formation strongly decreases after a tax-based consolidation shock, while the effects of an expenditure-based adjustment are essentially insignificant. Our work focuses on research spending but results do not change. Neither expenditure-based nor tax-based consolidations have a significant effect, on impact, on private R&D, but tax-based consolidations do decrease R&D by the end of the time horizon. This is mainly due to the inherent characteristics of this spending item, which is marked by high adjustment costs and is hence a slow-moving variable. The response to an expenditure-based consolidation shock is insignificant through the entire horizon. The effects on gross domestic research are relevant: a tax-based consolidation leads to a persistently negative growth rate of overall domestic research. Four years after a tax-based consolidation shock, business investment on research is significant lower by about 5%. In conclusion, the composition of the consolidation plan does matter for total domestic research expenditure.

4 Conclusions

This paper estimates the sensitivity of R&D to changes in fiscal space and to fiscal adjustment. Despite the relevant role of research and development as a powerful driver of innovation, competitiveness, and productivity growth, we find, in a sample of 32 OECD countries, that a reduction in available fiscal space is strongly correlated with lower public R&D spending. These results shed light on the volatility of this spending item and governments' inability to preserve it when fiscal spaces shrink.

Correlation between public research and fiscal space hides large differences in this relation across countries. Less innovative countries show a significant positive relation between fiscal space and research spending: in countries that are already lagging on the innovation front, R&D spending moves together with the availability of fiscal room-to-manoeuvre. On the contrary, the relation is non-significant for medium and highly innovative countries: where countries have a more solid R&D track record, spending does not change when fiscal space changes. This partial correlation result shows that the propensity to cut research spending when facing a constrained fiscal space is different across countries, with those already lagging behind being more likely to reduce their R&D expenditure when fiscal space decreases, making this crucial expenditure item cyclical.

We further explore the channel linking innovation and fiscal space, using a dataset of exogenous fiscal consolidation episodes to have a clearer view over causality. Using local projections, we derive impulse responses for total government allocations for R&D, public research and higher education research after a consolidation shock. Less innovative countries cut public research more than innovation leaders, both in absolute terms and as a share of total primary expenditure, following a consolidation episode. We thus find a confirmation of a doom loop between having relatively low R&D expenditure and being prone to cutting it in response to the need to consolidate the public finance.

Moreover, the response of business enterprise expenditure on R&D strongly differs between the two groups of countries. Private research in less innovative countries decreases over time following a consolidation episode. On the other hand, business R&D is largely unaffected in innovation leaders following a fiscal consolidation. We also find strong evidence of strong heterogeneities in the effects of consolidation on domestic research: fiscal adjustment reduces overall research in moderate innovators and has non-negative effects for innovation leaders.

Since the type of policy mix might also affect the response of R&D expenditure, we differentiate between tax- and expenditure-based consolidations. We find that gross domestic research and business R&D do respond to tax-based consolidations much more than to expenditure-based ones. Business expenditure on R&D is significantly lower after 4 years following a tax-based consolidation, while an expenditure-based plan has no clear effects on it. These results lead to divergent overall effects on domestic R&D: in the aftermath of an expenditure-based adjustment, domestic R&D spending fully recovers to its pre-consolidation levels, and while tax-based consolidation reduces both private and total R&D expenditure, its overall effect is negative.

To conclude, governments do not preserve public research spending following a fiscal adjustment. This result is mainly driven by less innovative countries cutting research expenditure more than innovation leaders. The direct consequence is a doom loop between R&D cuts and low-R&D intensity, which will result in a divergent innovation gap. This follows the trend of decreasing fiscal space available to countries and their attempts to rebuild it. Furthermore, the composition of fiscal adjustment matters: tax-based consolidations have a negative effect on business investment in research, resulting in a decrease of the overall domestic R&D investment.

The policy implications of these findings are stark: consolidation plans, such as those foreseen under the new European economic governance review, should account for the doom loop between low R&D intensity and the propensity to cut this spending. While preserving fiscal space is also key in maintaining R&D expenditure, and hence proximity to the technological frontier, its rebuilding should not come at the expense of innovation and hence long-term growth. In this context, the design and composition of the consolidation plan become critically important.

References

Adler, G. (2024). An Updated Action-based Dataset of Fiscal Consolidation. *IMF Working Papers*, 2024(210):1.

Aghion, P. and Howitt, P. (1992). A Model of Growth through Creative Destruction. *Econometrica*, 60(2):323–351.

Aizenman, J. and Jinjarak, Y. (2012). The fiscal stimulus of 2009–2010: trade openness, fiscal space, and exchange rate adjustment. *NBER International Seminar on Macroeconomics*, 8(1):301–342.

Alesina, A. and Ardagna, S. (2013). The design of fiscal adjustments. *Tax Policy and the Economy*, 27(1):19 – 68.

Alesina, A., Favero, C., and Giavazzi, F. (2015). The output effect of fiscal consolidation plans. *Journal of International Economics*, 96:S19–S42. 37th Annual NBER International Seminar on Macroeconomics.

Alesina, A., Favero, C., and Giavazzi, F. (2019). *Austerity: When It Works and When It Doesn't*. Princeton University Press.

Alesina, A., Perotti, R., Tavares, J., Obstfeld, M., and Eichengreen, B. (1998). The political economy of fiscal adjustments. *Brookings Papers on Economic Activity*, 1998(1):197–266.

Bergant, K. and Forbes, K. (2023). Policy packages and policy space: Lessons from covid-19. *European Economic Review*, page 104499.

Croce, M., Nguyen, T. T., Raymond, S., and Schmid, L. (2019). Government debt and the returns to innovation. *Journal of Financial Economics*, 132(3):205–225.

Darvas, Z. (2013). The euro area's tightrope walk: Debt and competitiveness in italy and spain. Bruegel Policy Contribution 2013/11, Bruegel, Brussels.

Financial Times (2024). Europe faces 'competitiveness crisis' as us widens productivity gap. Accessed: October 27, 2025.

Guellec, D. and Van Pottelsberghe De La Potterie, B. (2003). The impact of public r&d expenditure on business r&d. *Economics of innovation and new technology*, 12(3):225–243.

Guellec, D. and Van Pottelsberghe de la Potterie, B. (2004). From r&d to productivity growth: Do the institutional settings and the source of funds of r&d matter? *Oxford Bulletin of Economics and Statistics*, 66(3):353–378.

Heller, P. (2005). Back to basics-fiscal space: what it is and how to get it. *Finance and Development-English Edition*, 42(2):32–33.

Jordà, O. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182.

Kose, M. A., Kurlat, S., Ohnsorge, F., and Sugawara, N. (2022). A cross-country database of fiscal space. *Journal of International Money and Finance*, 128:102682.

Kung, H. and Schmid, L. (2015). Innovation, growth, and asset prices. *The Journal of Finance*, 70(3):1001–1037.

Larch, M., Claeys, P., and van der Wielen, W. (2024). Scarring effects of major economic downturns: The role of fiscal policy and government investment. *European Journal of Political Economy*, page 102509.

Lucas, R. J. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, 22(1):3–42.

Moretti, E., Steinwender, C., and Van Reenen, J. (2023). The Intellectual Spoils of War? Defense R&D, Productivity, and International Spillovers. *The Review of Economics and Statistics*, pages 1–46.

Munoz, E. and Olaberria, E. (2019). Are Budget Rigidities a Source of Fiscal Distress and a Constraint for Fiscal Consolidation ? Policy Research Working Paper Series 8957, The World Bank.

Peia, O. and Romelli, D. (2022). Did financial frictions stifle r&d investment in europe during the great recession? *Journal of International Money and Finance*, 120:102263.

Pellens, M., Peters, B., Hud, M., Rammer, C., and Licht, G. (2024). Public r&d investment in economic crises. *Research Policy*, 53(10):105084.

Pescatori, M. A., Leigh, M. D., Guajardo, M. J., and Devries, M. P. (2011). A New Action-Based Dataset of Fiscal Consolidation. IMF Working Papers 2011/128, International Monetary Fund.

Romer, P. M. (1986). Increasing Returns and Long-run Growth. *Journal of Political Economy*, 94(5):1002–1037.

A

Table A1 – Countries use in the analysis and their classification based on innovation status

Country	**GII (fiscal space sample)**	**GII (fiscal consolidation sample)**
Denmark	Innovation leader	Innovation leader
Finland	Innovation leader	Innovation leader
France	Innovation leader	Innovation leader
Germany	Innovation leader	Innovation leader
Canada	Innovation leader	Innovation Leader
Japan	Innovation leader	Innovation leader
Netherlands	Innovation leader	
Sweden	Innovation leader	Innovation leader
Switzerland	Innovation leader	
United Kingdom	Innovation leader	
United States	Innovation leader	Innovation leader
Australia	Innovation follower	Moderate innovator
Austria	Innovation follower	Moderate innovator
Belgium	Innovation follower	Moderate innovator
Israel	Innovation follower	
Estonia	Innovation follower	
Iceland	Innovation follower	
Ireland	Innovation follower	Moderate innovator
Italy	Innovation follower	Moderate innovator
Luxembourg	Innovation follower	
Norway	Innovation follower	
New Zealand	Innovation follower	
Colombia	Moderate innovator	
Czechia	Moderate innovator	
Greece	Moderate innovator	
Hungary	Moderate innovator	
Mexico	Moderate innovator	
Spain	Moderate innovator	Moderate innovator
Poland	Moderate innovator	
Portugal	Moderate innovator	Moderate innovator
Slovak Republic	Moderate innovator	
Slovenia	Moderate innovator	

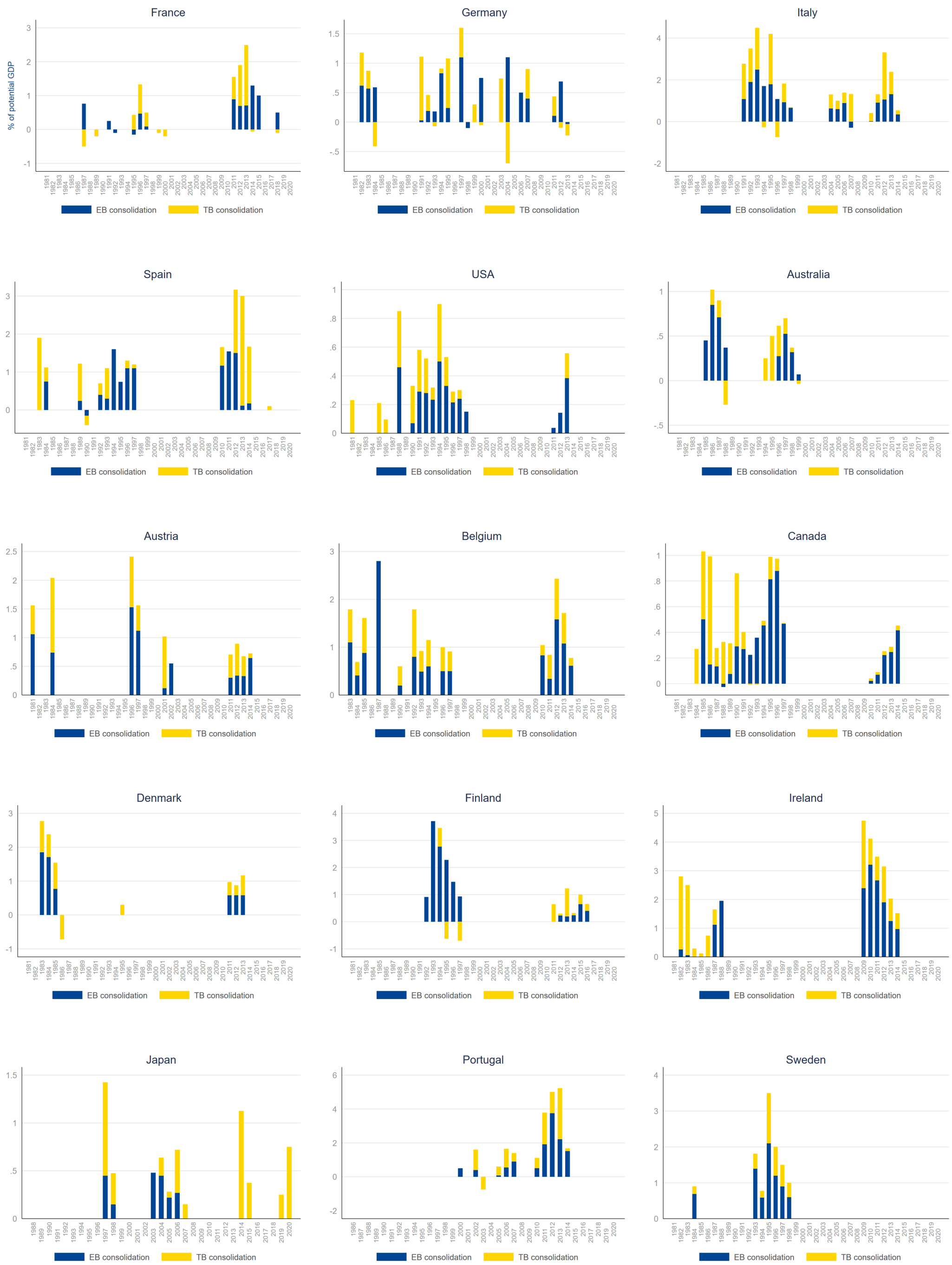
Table A2 – R&D Variables and Abbreviations

Abbreviation	**Full Name**	**Description**
GBARD	Government Budget Allocations for R&D	Total government allocations for research and development
GOVERD	Government Intramural Expenditure on R&D	Government intramural expenditure on R&D (primarily public sector salary expenditures)
HERD	Higher Education Expenditure on R&D	Higher education expenditure on research and development
$BERD$	Business-performed R&D	Business enterprise expenditure on research and development
$BERD_{BUS}$	Business-performed R&D financed by the private sector	Business enterprise expenditure on research and development (private R&D spending)
$BERD_{PUB}$	Business R&D Financed by Government	Business R&D expenditure that is financed by government funding
GTARD	Government Tax Relief for R&D	Government tax relief/incentives for R&D activities
GERD	Gross Domestic Expenditure on R&D	Total domestic research expenditure (includes private, public, and higher education research)

Table A3 – Consolidations by composition and country type

		Tax-based	Expenditure-based	Ratio
Innovation leaders	Number of episodes	95	90	
	Mean (% of GDP)	0.29	0.58	0.5
Moderate innovators	Number of episodes	84	84	
	Mean (% of GDP)	0.75	0.93	0.76
Ratio		0.38	0.62	

Figure A1 – Exogenous consolidation episodes as share of GDP



A.1 Correlation between change in fiscal space and consequent need to consolidate

Table A4 presents the regression results for the fiscal consolidation variable, identified narratively from fiscal documents and expressed as a percentage of GDP, on various macroeconomic variables. The findings highlight that GDP growth, changes in available fiscal space, and long-term interest rates at time $t-1$ are significant predictors of fiscal consolidation episodes at time t. Specifically, a decline in GDP and an increase in interest rates, both (potential) indicators of worsening economic conditions and tighter credit acces, are associated with greater fiscal consolidation in the subsequent period.

As discussed in the main text, a deterioration in fiscal space at time $t-1$ is also correlated with greater consolidation in the following period. This estimate provides important empirical support for the link between fiscal space and fiscal consolidation, confirming that fiscal adjustment is a viable policy option for addressing a shrinking fiscal space.

Finally, inflation does not appear to be significantly correlated with the dependent variable, which, however, exhibits a strong degree of autocorrelation.

Table A5 has a dummy as dependent variable. Consolidation dummy takes the value of 1 if consolidation value, as % of GDP, is greater than 0. Otherwise, the dummy is equal to 0. Consequently, the coefficients can be interpreted as the effect on the probability of undertaking a fiscal consolidation. The results are very similar to the previous model, although GDP growth at time $t-1$ is no longer statistically significant. Nevertheless, the change in fiscal space remains a significant and relevant predictor: a deterioration in this variable is associated with a higher probability of consolidation in the subsequent period.

Table A4 – Partial correlation between change in fiscal space (t-1) and consolidation (t)

	(1) Consolidation measure	(2) Consolidation measure
$Cons_{t-1}$	0.402***	0.333***
	(0.043)	(0.064)
$\Delta ln(FS)_{t-1}$	-1.558**	
	(0.681)	
$CAPB_{t-1}$		-6.560***
		(1.068)
$\Delta ln(GDP)_{t-1}$	-2.495**	-6.031***
	(1.102)	(1.093)
$LTinterest_{t-1}$	0.130***	0.144***
	(0.030)	(0.046)
CPI	-0.050	-0.035
	(0.035)	(0.048)
N	460	504
R^2	0.575	0.567

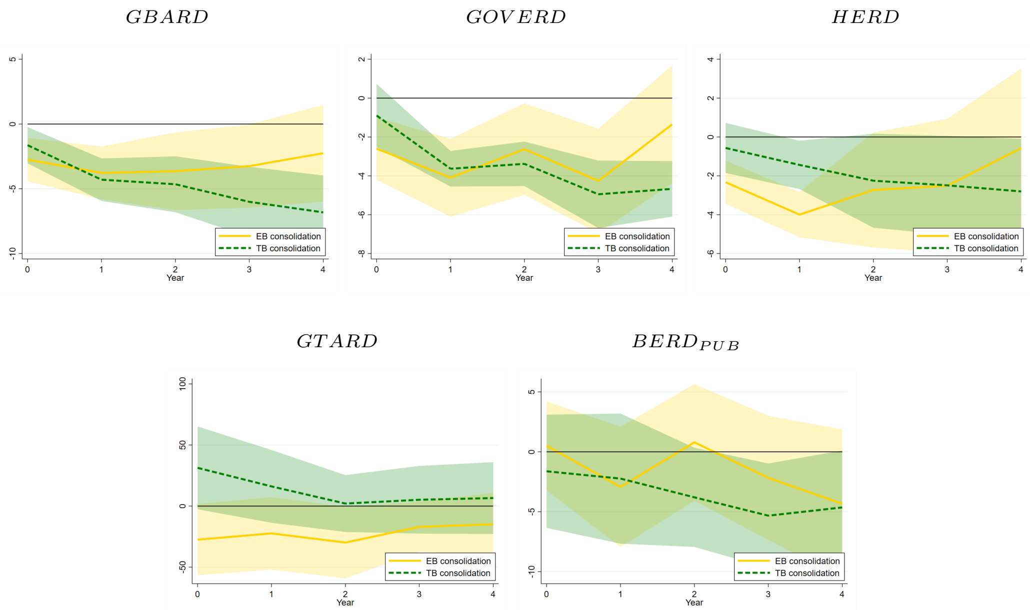
Standard errors in parentheses
Country FE, YES
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5 – Partial correlation between change in fiscal space (t-1) and probability to consolidate (t)

	(1) Consolidation dummy	(2) Consolidation dummy
$Cons\_dummy_{t-1}$	2.813***	2.504***
	(0.288)	(0.266)
$\Delta ln(FS)_{t-1}$	-6.926***	
	(1.636)	
$CAPB_{t-1}$		-35.449***
		(6.665)
$\Delta ln(GDP)_{t-1}$	0.844	-6.284
	(6.829)	(5.744)
$LTinterest_{t-1}$	0.154***	0.237***
	(0.051)	(0.049)
CPI	-0.077	-0.144
	(0.101)	(0.101)
N	458	504
R^2		

Standard errors in parentheses
Country FE, YES
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure A2 – Responses to a consolidation shock, growth rates



Note: Cumulative impulse responses to a consolidation shock of 1% of GDP. The dependent variables are expressed as the growth rate of each item. The shaded area represents

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