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Government Debt and Growth: The Role of R&D

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ABSTRACT: Economic growth in the advanced economies (AEs) has been slowing down since the early 2000s, while government debt ratios have been rising. The recent surge in debt at the onset of the Covid-19 pandemic has further intensified concerns about these phenomena. This paper aims to offer insight into the high-debt low-growth environment in AEs by exploring a causal link from government debt to future growth, specifically through the impact of debt on R&D activities. Using data from manufacturing industries since the 1980s, it shows that (i) government debt leads to a decline in growth, particularly in R&D-intensive industries; (ii) the differential effect of government debt on these industries is persistent; and (iii) more developed or open financial systems tend to mitigate this negative impact. These findings contribute to our understanding of the relationship between government debt and growth in AEs, given the role of technological progress and innovation in economic growth.

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1. Introduction

Government debt ratios have been increasing in the advanced economies (AEs) since the 2000s, and reached uncharted levels in the wake of the Covid-19 pandemic. This surge and the resulting levels of government debt put the issue at the epicenter of policy debate, elevating concerns about future economic performance (Adrian et al. 2024, ECB 2024, IMF 2024a). Moreover, economic growth has shown a downward trend across AEs since the early 2000s, which was largely driven by the slowdown in productivity growth (Adrian et al. 2024, IMF 2024b, 2024c). This paper connects these two phenomena, offering insight into the high-debt low-growth environment in AEs. In particular, it attempts to build causality in the government debt and growth nexus by identifying a specific mechanism shaping this association, i.e., the R&D channel of government debt. It shows that high levels of government debt hinder R&D activities in AEs, which has implications for the long-term economic performance given the role of innovation and technological progress in productivity growth.

The analysis is based on industry-level data from 2-digit manufacturing industries in AEs over the last four decades. It exploits the differences in industries' reliance on R&D activities within countries. The results show that higher levels of government debt lead to a decline in growth, particularly in industries that heavily rely on R&D activities. The differential effect of government debt on R&D-intensive industries is persistent for upwards of 10 years. This offers an explanation for the observed pattern of weak economic performance following the episodes of surges in government debt, given the role of technological progress and innovation in long-term economic growth. It also suggests that rising government debt levels in AEs have likely posed a drag on productivity growth by suppressing R&D, and thus, contributing to the declining trend in growth. The results also show that more developed or open financial systems seem to mitigate the negative effect of government debt on R&D activities to some extent. To the best of my knowledge, this is the first study attempting to establish causality in the government debt and growth nexus identifying the effect of debt on innovative activities relying on granular data in a cross-country setting.

The effects of government debt on macroeconomic outcomes have been a longstanding issue in the literature (e.g., Domar 1944, Meade 1958, Diamond 1965), and raised concerns in policy circles (e.g., Cottarelli 2011, IMF 2012, Arslanalp and Eichengreen 2023). The theory suggests that high levels of government debt can reduce future economic growth through various channels, including crowding-out of private investment, constraining the country's ability to implement countercyclical fiscal policy, leading to distortionary taxes, generating issues related to debt overhang, and affecting expectations, inflation and interest rates (see Panizza and Presbitero 2013 for a review). The majority of empirical literature consistently documents a negative association between government debt and future growth, albeit with some heterogeneity in this relationship, making it important to understand the underlying mechanisms driving the effects of government debt on growth. Moreover, the causal evidence has remained scarce, since it is challenging to address the issues of (i) reverse causality (i.e., lower GDP growth increases the debt-to-GDP ratio), and (ii) omitted variables (i.e., other country-level factors can jointly drive lower GDP growth and high government debt) using macro-data.

This paper uses granular data on industry panels from AEs to overcome these issues and offer an explanation for the association between government debt and future growth, as opposed to the previous literature that mainly use macro-data. It argues that high levels of government debt likely have a disproportionate impact on innovative activities, and hypothesizes that the decline in growth due to government debt should be larger in industries that rely more on R&D, compared to others. By adopting industry-level data and exploiting within country variation in industries' R&D intensity, it makes one step forward toward identifying a causal link between government debt and growth by showing evidence on the differential impact of debt on R&D activities.

A potential mechanism through which high levels of government debt can have a disproportionately large effect on R&D activities is uncertainty. High levels of government debt are associated with higher uncertainty surrounding economic policies and prospects, and political environment (e.g., Cochrane et al. 2011b, Baker et al. 2016, Croce et al. 2019, Yared 2019, Ahir et al. 2022, Ben-Nasr and Boubaker 2024, Hong et al. 2024).[1] Rising uncertainty can be detrimental for innovative activities due to their peculiar nature. First, R&D investment generally yields outcomes with a longer delay, and is riskier, compared to the standard investment. Thus, investment decisions in R&D can be more responsive to the overall uncertainty. Second, innovative activities typically require lumpy and larger scale initial investment. In the periods of high uncertainty, firms may defer such investment, and save, or use, those funds for other purposes. Third, R&D activities entail highly specialized investment with high irreversibility and low redeployability, making it hard to tap into those assets, in case of a short-term needs to survive the periods with high uncertainty. Hence, instead of investing in R&D during those periods, firms may reallocate their investment to the projects that are more redeployable, reversible, and hence, cashable. Consistent with these considerations, there is extensive evidence showing that these features of R&D investment make it more prone to increased uncertainty (e.g., Goel and Ram 2001, Czarnitzki and Toole 2011, Bhattacharya et al. 2017, Kim and Kung 2017, Choi et al. 2018a, Fich et al. 2020, Li et al. 2022).

Another channel through which high levels of government debt can undermine innovative activities is its role in the confidence of the agents. Various fiscal policy choices leading to, or resulting from, high debt levels can hamper consumer and investor confidence (e.g., Konstantinou and Tagkalakis 2011, Beetsma et al. 2021, Jia et al. 2022, Kim et al. 2023). As a result, consumption can decrease, which likely affects the demand for high-tech products more, compared to that of some low-tech products (e.g., food and textiles). Moreover, investors tend to perceive the periods of high government debt as bad times, and become hesitant to allocate funds for longer term and riskier R&D projects, even when they have adequate financial resources, but instead relocate funds to short-term low-risk projects (Croce et al. 2019).

A few theoretical studies in the literature establish a link between government debt and R&D activities. Croce et al. (2019) proposes a model showing that movements in government debt affect tax dynamics, and ultimately obstruct firms' innovative activities. In a production-based asset pricing model with fiscal policy shocks, where Ricardian equivalence does not hold,[2] the government finances its expenditures by debt and distortionary taxes on firms' profits. As debt levels increase, uncertainty about future tax rates rises increases. The value of innovative firms is mainly driven by the present value of volatile monopolistic rents, and thus, riskier R&D-intensive firms become more exposed to the surges in cash flow uncertainty compared to others. Spikes in government debt, in the model, lead to a decline in the overall investment in physical capital, while also triggering a reallocation of investment to standard activities, thereby particularly hindering investment in R&D and firms' incentives to innovate (via depressing patent valuations). Ferraro

[1] I also illustrate some suggestive evidence for this pattern in the Appendix (Figure A1), i.e., economic uncertainty appears to be higher in countries and years with relatively high government debt.

[2] Under Ricardian equivalence, debt levels do not have much effect on growth. This requires several strong assumptions, such as lump-sum taxes, forward-looking households with intergeneration altruism, and perfect capital markets (Barro 1974).

and Peretto (2020) instead introduces a theoretical model in which labor taxes to offset an increase in government debt distort households' work incentives and firms' incentives to innovate.

If some of these channels are at play, i.e., if government debt has a disproportionate impact on R&D activities, its growth effect should be more pronounced in industries which typically use R&D activities more intensely. To test this hypothesis, I use industry-level data from the UNIDO (United Nations Industrial Development Organization) covering 2-digit manufacturing industries (ISIC Rev. 3, 15-36) from 36 AEs over the period 1980-2022. The empirical strategy exploits within-country variation in R&D intensity across 2-digit manufacturing industries, following an approach similar to Rajan and Zingales (1998). In the baseline, R&D intensity for each industry is calculated using data on R&D expenditures of large, listed firms from a benchmark country with highly developed financial markets and a strong institutional framework (i.e., the US). Similar to the macro-finance literature pioneered by Rajan and Zingales (1998), I assume that this industry-level measure for R&D intensity is likely to capture the inherent differences in the production processes across industries, rather than being influenced by financial frictions or appropriability problems. Another advantage of benchmarking industry R&D intensity based on data from the US is that it is not affected by the changes in debt levels in AEs in the sample, which would lead to endogeneity otherwise. To the extent that industries' relative R&D intensity, based on the data from the US, carries over other AEs, industry-level data allows me to identify the effect of government debt on growth varying with cross-industry differences in R&D intensity.

A major advantage of using industry-level data is that, as opposed to macro-data, growth pattern of a 2-digit manufacturing industry is not likely to have a large impact on government debt level in a country, alleviating reverse causality. Moreover, it allows me to control for the effects of underlying factors that a granular level, mitigating the issue of omitted variables to a large extent. In particular, country-industry fixed effects in the estimation isolate the underlying variation in industry growth in a country arising from some inherent characteristics which work against, or in favor of, a specific industry. The effects of country-specific shocks which are common across industries in each country-year pair are accounted by country-year fixed effects. Finally, the variation in growth arising from industry-specific global conditions, trends, or growth opportunities, is absorbed by industry-year fixed effects.

The findings show that government debt hinders growth, particularly in industries that rely heavily on R&D activities, relative to others. The estimated disproportionate effect of debt on growth in R&D-intensive industries is economically important. For instance, growth rate of machinery industry (a high-tech industry, at the 75th percentile of R&D intensity) becomes 0.5 percentage points lower compared to paper products (a low-tech industry, at the 25th percentile of R&D intensity), when they are located in a country with high government debt (at the 75th percentile of the sample) rather than in a country with a lower level of debt (at the 25th percentile of the sample). As an alternative, when estimated similarly, the additional forgone growth in the top 5 industries with the highest R&D intensity due to higher debt, compared to the decline in growth in the bottom 5 industries, is 2 percentage points per annum. These are sizable, considering that the average industry growth rate in the sample is 2.9 percent per annum, on average. It is worth noting that, in the context of the Rajan and Zingales (1998) approach, this is only the additional growth loss in high-tech industries relative to low-tech industries, due to higher debt level (rather than being the overall impact).

Moreover, the disproportionate effect of government debt on R&D-intensive industries is long-lasting for upwards of 10 years. The absence of evidence for recovery in R&D-intensive industries implies that firms do not simply delay some innovative projects to relaunch them in the short-term following the periods of high government debt, but some productivity-enhancing activities are either canceled, or at least, shelved for a long period.[3] It is also important that the negative effect of government debt on high-tech industries' growth exhibits some nonlinearity, with the impact being more pronounced at higher debt levels. Interestingly, the R&D channel of government debt appears to be specific to AEs, i.e., it is not pronounced in the emerging markets (EMs).

Next, focusing on a financial channel, I examine whether the measure of R&D intensity is indeed a proxy for industries' sensitivity of the availability of finance. First, to the extent that government debt hinders capital accumulation in general (via crowding-out of funds), the previous result can be explained by the physical capital channel, rather than R&D. Next, high-tech industries may rely more on external finance, or liquidity, since R&D investment typically has longer gestation lags and yields output with a delay (Rajan and Zingales 1998, Raddatz 2006). Moreover, R&D investment typically has lower tangibility, and thus, is less collateralizable, resulting in greater vulnerability to financing frictions (e.g., Braun and Larrain 2005, Hall and Lerner 2010, Ahn et al. 2020, Hardy and Sever 2021). Hence, if higher government debt soaks up available finance, an underlying financial channel can undermine the R&D channel. Relatedly, the availability of financing options at the macro-level (proxied by the degree of financial development or openness) may be the factors driving the results (rather than debt itself). However, accounting for these explanations does not alter the baseline result. This points to a link between government debt and growth, which works specifically via the impact of debt on R&D activities. On the other hand, it does not mean that finance has no role to play in the interplay between government debt and innovative activities. Indeed, the results show that the negative impact of government debt on growth in R&D-intensive industries is mitigated in countries with more developed or open financial systems, consistent with those financing-related considerations.

The results stay similar in a large set of additional checks. First, accounting for several other country-level factors (i.e., macroeconomic or structural features) does not undermine the previous findings. The disproportionate effect of debt on R&D-intensive industries is not likely to be driven by outliers, or a few countries that are relatively richer or poorer. In addition, I check the results by dropping the US from the sample to address endogeneity concerns, given that the R&D intensity measure is calculated based on the data from the US. Using weighted regressions, I show that it is not larger or smaller industries driving the results. The former mitigates, if any, concerns about reserve causality, since growth patterns of smaller manufacturing industries have an even smaller effect on government debt. Finally, the results are not only driven by some large shocks, i.e., they remain similar when tested in the pre- or post-Global Financial Crisis periods, or the pre-Covid-19 period.

[3] To the extent that R&D investment need continuity to bear fruit, disruptions in R&D activities can also undermine long-term growth through skills of capital depreciation, even if firms relaunch those projects after some years (Ahn et al. 2020).

1.1. A Brief Review of the Literature

The theoretical literature with the "conventional view" of public debt finds that government debt is associated with lower economic growth, particularly in the long-term, consistent with neoclassical and endogenous growth models (e.g., Diamond 1965, Saint-Paul 1992).[4] This view emphasizes that while the positive aggregate demand impact of debt in the short-term may be prevalent, crowding-out effects hinder economic activity in the long-term by depressing private investment (e.g., Elmendorf and Mankiw 1999).[5] The negative impact of government debt can be even larger, and also materialize in the short-term, if it leads to distortionary taxes or debt overhang problem; and affects uncertainty, expectations, sovereign risk, and interest rates (e.g., Dotsey 1994, Codogno et al., 2003, Laubach, 2009, Cochrane 2011a, 2011b). Several theoretical studies also discuss that the effects of government debt on growth can depend on some factors including the public to private capital ratio or the current state of the economy (e.g., Checherita-Westphal et al. 2014, Aloui and Eyquem 2019).

Empirical evidence generally supports this view. The extant literature using cross-country data at the macro-level documents a negative association between government debt and future economic growth, while several influential studies point to some nonlinearity and heterogeneity in this association, e.g., showing that government debt predicts lower growth after a threshold, or that country-specific factors play a role in the link between debt and growth (among many others, see Caner et al. 2010, Checherita-Westphal and Rother 2010, Reinhart and Rogoff 2010, Cecchetti et al. 2011, Kumar and Woo 2010, Pattillo et al. 2011, Eberhardt and Presbitero 2015, Jalles and Medas 2022).[6] Nonetheless, the vast majority of the literature on the association between government debt and growth fails to establish causality, since (i) lower GDP growth can lead to higher government debt as percent of GDP, thereby leading to reverse causality (Easterly 2001), and (ii) there can be other country-level factors jointly driving lower growth and high government debt (the issue of omitted variables).

There are a few exceptions though. Ash et al. (2017) uses forward (rather than contemporary) growth rates, instruments current public-debt ratio with its lag, and also controls for lagged GDP growth rates, aimed at alleviating the issues of endogeneity and reverse causality. The authors confirm the bi-directional relationship between government debt and growth, raising concerns about reverse causality in the earlier literature.[7] In an attempt to tackle reverse causality, De Soyres et al. (2022) focuses on "exogenous shocks" in government debt levels relying on forecast errors from the vintages of the IMF World Economic Outlook. The authors find that unanticipated increases in government debt reduce future growth, with this effect being larger in countries with initially high levels of debt.

On the other side, Panizza and Presbitero (2014) aims to alleviates the issue of endogeneity by proposing an instrument for public debt relying on the fact that, when countries have foreign currency debt, changes in a country's exchange rate have a mechanical effect on the debt ratio. Using data on the currency composition of debt and matching it with bilateral exchange rates to establish a variable capturing the

[4] See Panizza and Presbitero (2013), Kobayashi (2015), Salmon (2021), and Heimberger (2023) for detailed reviews of the literature on the relationship between government debt and growth.

[5] However, it is worth noting that some theoretical models suggest that an increase in the fiscal deficit leading to a higher public debt level may also increase the long-term growth, for instance, via hysteresis channel (Delong and Summers 2012).

[6] Also see Egert (2015) which raises some concerns about the threshold effects of debt as found by the earlier literature.

[7] In this literature, several papers adopt GMM approach by using macro-data and instrumenting government debt with its lags, but this approach is open to some criticism (see Panizza and Presbitero 2013).

valuation effects brought about by exchange rate movements, they find that the negative association between government debt and growth fades in a sample of OECD countries. As their results do not reject the null hypothesis that debt has no effect on growth, they conclude that “the case that debt has causal effect on growth in advanced economies still needs to be made”.

This paper fills this important gap in the literature by attempting to establish causality in the government debt and growth nexus. It identifies a specific mechanism to explain the effect of government debt on economic growth, i.e., its impact on R&D activities. As opposed to the previous cross-country studies, it makes a step forward to overcome the aforementioned challenges related to reverse causality and omitted variables by using granular data, and adopting an identification strategy as proposed by Rajan and Zingales (1998), which has been widely used in the macro-finance literature to identify the effect of financial development on growth. For this purpose, it uses data on industry panels from AEs, and exploits variation in R&D intensity across industries within countries, which makes it possible to identify the differential effect of government debt on growth in high-tech industries, relative to others. To the best of my knowledge, this is the first study attempting to establish causality for the negative association between government debt and growth, and identifying the R&D channel of debt in a cross-country setting using industry-level data.[8]

A closely related study to the present one is by Croce et al. (2019) presenting evidence on the R&D channel of government debt in the US using firm-level data, consistent with the findings from AEs in this study. The authors exploit the cross-section of stock returns in the US, and show that (i) R&D-intensive firms are more exposed to government debt and pay higher expected returns than others, (ii) high levels of government debt are associated with higher risk premiums for those firms, and (iii) increases in the cost of capital for R&D-intensive firms predict declines in future growth. To provide a theoretical explanation for these observations, they introduce a production-based asset pricing model with endogenous innovation and fiscal policy shocks. In their model, the government finances expenditures by debt and distortionary taxes on corporate profits. As debt levels increase, uncertainty about future tax rates is elevated. As the value of innovative firms is mainly driven by the present value of volatile monopolistic rents, R&D-intensive firms become more exposed to surges in cash flow uncertainty than their peers, which reduces innovative investment and future growth. Another closely related study by Fan et al. (2022) focuses on the crowding out effects of debt, and shows that local government debt reduces firms’ innovative activities in China, particularly for the firms that are financially more constrained.

This paper is also broadly related to the literature on the role of innovative activities in productivity and economic growth. The theoretical and empirical strands of the literature find that innovation is a key for sustained improvements in productivity and long-term growth (among many others, see Romer 1990, Aghion and Howitt 1992, Grossman and Helpman 1993, Kogan et al. 2017, Hardy and Sever 2021, 2023). Several studies document the slowdown in productivity growth in AEs since the early 2000s as an important driver of declining trend in economic growth (e.g., Fernald 2015, Adler et al. 2017, Jones 2017, Fernald et

[8] It is worth mentioning a few empirical studies which use granular data to explore the link between government debt and growth by focusing on crowding-out effects. Huang et al. (2018) shows that government debt hinders growth in industries with higher dependence on external finance using data from 73 economies over the 2000s. Huang et al. (2020) shows that local public debt in China crowds out private firm’s investment by tightening funding constraints. In this paper, I instead find evidence on the R&D channel of government debt, which is robust to accounting for such financing-related considerations.

al. 2023, IMF 2024b, 2024c). The finding on the impact of government debt on R&D activities, as shown by this paper, contributes to the understanding of the high-debt and low-growth environment observed in AEs.

The rest of this paper is organized as follows. Section 2 introduces the data. Section 3 presents the empirical methodology. Section 4 documents the stylized facts. Section 5 illustrates the results. Section 6 concludes.

2. Data

2.1. Industry-level Data

Industry-level data is from the UNIDO database, which is compiled mainly based on industrial surveys. The database provides information on productive activities for 2-digit manufacturing industries, as listed in Table 1 (ISIC Rev. 3, 15-36). I use industry value added and output (both in USD), as well as the number of employees. Industry labor productivity is the ratio of value added to the number of employees. Growth rates of industry value added, output and labor productivity are the log difference, multiplied by 100, and winsorized at the 2.5th and 97.5th percentile levels to reduce the influence of outliers in the results. Industry value added share in total manufacturing (a control variable in the estimation) is the ratio of industry value added to total value added in manufacturing in each country-year cell (in percent). Summary statistics of the variables as used in the analysis are presented in the Appendix (Table A1).

2.2. Industry R&D Intensity and Other Characteristics

The goal is to explore the disproportionate effect of government debt on growth in industries which heavily engage in R&D activities. For this purpose, I follow an approach in the spirit of Rajan and Zingales (1998). In their seminal work, the authors discuss that some industries need more external finance than others for some underlying reasons. Their hypothesis is that the impact of financial development on growth should be larger in industries with greater reliance on external finance, compared to others. To examine the differential effect of financial development across industries, they introduce a proxy for external finance dependence of industries, which is calculated based on data from large, listed firms in the US. Similarly, in this paper, I adopt a measure of industries' R&D intensity, and examine the differential impact of government debt by exploiting the cross-industry variation in this feature.

In the baseline, I adopt a proxy for industries' R&D intensity based on R&D spending data from publicly listed firms in the US, following the previous literature (e.g., Ilyina and Samaniego 2011, Brown et al. 2017). There are various reasons why using data on R&D expenditures from the listed firms in the US is a reasonable measure to proxy for the innate differences in R&D intensity across industries. First, highly developed financial markets in the US alleviate financing-side distortions that can generate underinvestment in R&D otherwise. Next, a favorable legal framework and strong enforcement institutions, such as intellectual property protection, or lower levels of corruption, impose fewer bottlenecks on firms' innovative activities by mitigating appropriability problems. Third, the US has one of the most advanced technology markets with a large technology consumption market. Fourth, large and listed firms in the US likely (i) have easier access to capital markets, (ii) are better equipped to protect the intellectual property in case of breaches, and (iii) can take advantage of the market opportunities and the technology frontier.

Hence, a proxy for industries' R&D intensity, as calculated based on those firms in the US, offers a reasonable benchmarking for inherent differences across industries. Nonetheless, it does not necessarily mean that this measure pinpoints the "correct" level of R&D activities, but instead, it is likely to reflect differences in R&D intensity across industries, driven by underlying differences production processes (rather than by financing-related and institutional frictions).

Lastly, benchmarking industries' R&D intensity from the US addresses endogeneity. Detailed industry-level data on R&D investment generally is not available for many countries, and going back to the 1980s. However, even if it were available, it would lead to endogeneity, since industries' R&D intensity (when the measure is calculated based on the data from countries in the sample) can be shaped by country-specific developments or shocks. Thus, this approach ensures that industry R&D intensity is exogenous to the changes in the country-specific factors in the sample.

A potential concern about benchmarking industries' R&D intensity using data form the US can be that the intensity of industries' innovative activities may differ across countries, to the extent that the production processes vary, for instance, due to different local conditions. However, this is not likely to change the results, as long as the ordering of industries based on R&D intensity remains similar across AEs. That is, if computing machinery production requires more R&D than the leather industry across AEs (in line with the ordering in the US), this phenomenon does not likely generate a significant bias. Furthermore, to address any remaining concerns, I use various alternative proxies for industries' R&D intensity in robustness.

In the baseline, I use the share of R&D expenditures in overall capital expenditures as a proxy for R&D intensity in 2-digit manufacturing industries, in line with Ilyina and Samaniego (2011). It is adopted from Igan et al. (2022). The measure is calculated using data from publicly listed companies in the US from the Compustat database. This ratio is averaged over the period 1980–1999 for each firm to smooth out temporal fluctuations. The median value across the firms in each 2-digit industry is adopted as a proxy for R&D intensity (RDI) for that industry (to prevent large firms from overshadowing the information from small firms).

The first column in Table 1 illustrates RDI for manufacturing industries. Chemicals industry has the highest RDI (ISIC 24), followed by medical instruments, office and computing machinery, communication equipment, electrical and machinery industries (ISIC 33, 30, 32, 31 and 29, respectively). Wearing apparel industry has the lowest RDI (ISIC 18), where coke, wood, basic metal, food and paper product industries follow (ISIC 23, 20, 27, 15 and 21, respectively). There exists variation across industries' RDI, with a mean value of 0.97 and a standard deviation of 1.34 (as shown in Table A.1 in the Appendix). The two-digit industries at the 75th and 25th percentiles of RDI are machinery (ISIC 29) and paper products (ISIC 21), respectively. This means that the former typically requires more R&D (a relatively high-tech industry), while the latter operates with lower levels of R&D activities (a relatively low-tech industry).

In robustness, I take other industry characteristics into account to examine whether they undermine the role of RDI in the interplay between government debt and industry growth, i.e., to test whether RDI is indeed as a proxy for those industry characteristics. For this purpose, I account for physical capital intensity, asset tangibility, dependence on external finance and liquidity needs (Table 1). They are adopted from Igan et al. (2022). Asset tangibility is the share of net property, plant and equipment in total book-value of firm assets, as with Braun and Larrain (2005). Dependence on external finance is as the share of firm's capital expenditures which are not financed with cash flow from operations, following Rajan and Zingales (1998).

The proxy for liquidity needs is the ratio of a firm's total inventories to annual sales, as proposed by Raddatz (2006). Similar to the baseline measure for RDI, these measures are first calculated at the firm level by averaging the annual shares over the period 1980-1999 to smooth out temporal fluctuations. Then, the median value across firms within each industry is used as a proxy for that industry. Finally, physical capital intensity is the total real capital stock as share of value added in each industry from the NBER-CES Manufacturing Industry Database, as with Nunn (2007) and Ciccone and Papaioannou (2009).

I also adopt three alternative proxies for RDI in the robustness checks. First, the ratio of R&D expenditures to sales for the median US firm in each 2-digit industry over the period 1990-2000, as calculated using data from large and listed firms from the Compustat database, is adopted from Brown et al. (2017). Second, I use data from the OECD countries over the period 1995-2005 to proxy for RDI (i.e., the ratio of R&D expenditures to production in each industry based on the OECD-STAN database), instead of the US, as adopted from Seitz and Watzinger (2017). Finally, I adopt the measure of RDI, as listed by Choi et al. (2018b), which is calculated similar to the baseline measure but over the period 1970-2000. For the identification, it is encouraging that the correlations between those different proxies are high (Table A2).

Table 1: Industry-level measures

Industry	ISIC	R&D intensity (RDI)	Physical capital intensity	Asset tangibility	Dependence on external finance	Liquidity needs
Food and beverages	**15**	0.180	1.466	0.363	-0.309	0.102
Tobacco products	**16**	0.402	1.047	0.219	-2.897	0.252
Textiles	**17**	0.349	1.287	0.329	-0.157	0.178
Wearing apparel, fur	**18**	0.000	0.440	0.116	-0.298	0.213
Leather, leather products and footwear	**19**	0.554	0.630	0.128	-0.735	0.219
Wood products (excl. furniture)	**20**	0.164	1.126	0.293	-0.250	0.114
Paper and paper products	**21**	0.266	1.674	0.510	-0.385	0.116
Printing and publishing	**22**	0.602	0.911	0.267	-0.752	0.069
Coke, refined petroleum, nuclear fuel	**23**	0.062	2.496	0.617	-0.236	0.076
Chemicals and chemical products	**24**	5.456	1.768	0.206	3.868	0.141
Rubber and plastics products	**25**	0.368	1.253	0.363	-0.273	0.126
Non-metallic mineral products	**26**	0.337	1.600	0.421	-0.350	0.145
Basic metals	**27**	0.168	2.272	0.397	-0.210	0.168
Fabricated metal products	**28**	0.351	1.137	0.278	-0.566	0.178
Machinery and equipment n.e.c.	**29**	0.926	0.995	0.216	-0.431	0.203
Office, accounting, computing machinery	**30**	2.845	0.752	0.133	1.056	0.190
Electrical machinery and apparatus	**31**	1.245	0.938	0.245	-0.025	0.194
Radio, TV, communication equipment	**32**	2.353	1.108	0.179	0.317	0.194
Medical, precision, optical instruments	**33**	3.168	0.549	0.155	1.241	0.235
Motor vehicles, trailers, semi-trailers	**34**	0.441	1.365	0.270	-0.140	0.142
Other transport equipment	**35**	0.614	0.914	0.250	-0.248	0.213
Furniture; manufacturing n.e.c.	**36**	0.511	0.764	0.204	-0.337	0.176

Notes: The measures are adopted from Igan et al. (2022). R&D intensity is the ratio of R&D expenditure to capital expenditure. Physical capital intensity is the total capital stock as the share of value added. Asset tangibility is the share of net property, plant and equipment in total book-value of assets. Dependence on external finance is the share of capital expenditures which are not financed with cash flow from operations. The measure on liquidity needs is the ratio of total inventories to annual sales. The industry-level proxies are based on the data from the US.

2.3. Country-level Data

Data on government debt is from the IMF's Global Debt Database. It is the total stock of debt liabilities issued by the central or general government (as percent of GDP) in different tests (see Mbaye et al. 2018 for details).

In robustness, I account for various macroeconomic, financial, institutional and structural variables to address concerns about whether government may be a proxy for those factors (i.e., to rule out alternative several explanations). For this purpose, I use real GDP per capita (constant in US dollars and used in logarithm) as a proxy for economic development, and trade (as percent of GDP) as a proxy for trade openness. I account for the size of the economy with real GDP (constant in USD and used in logarithm). I obtain data on inflation rate (CPI), and use the ratio of older dependents (people older than 65) to the working-age population (ages 15-64) as a proxy for population aging. They are from the World Bank's World Development Indicators (WDI) database.

I use the index on financial development from the IMF. It is a composite index which accounts for the multidimensional nature of financial development by incorporating information on financial markets and institutions regarding depth, access and efficiency. Financial institutions include banks, mutual funds, insurance companies and pension funds. Financial markets include bond and stock markets. It is defined as a combination of depth (size and liquidity of markets), access (ability of individuals and firms to access financial services), and efficiency (ability of institutions to provide financial services at low cost and with sustainable revenues, and the degree of activity of capital markets). The index is calculated based on a principal component analysis (see Svirydzenka 2016). It is between 0 and 1, higher values indicating greater financial development.

I also adopt the index from Chinn and Ito (2006) as a proxy for the level of financial openness. It is a de jure measure of capital account openness, ranging between 0 and 1. Higher values of the index indicate more open financial systems. Finally, as a proxy for institutional quality, I use the polity index from the Polity V dataset from Center for Systemic Peace. It ranges between -10 and 10, higher values indicating greater institutional quality.[9]

To observe the patenting trends across countries in the stylized facts, I adopt data on the number of patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office (based on the World Intellectual Property Organization) from the WDI.

2.4. Sample

The main analysis (both at the industry-level and country-level) is based on data from AEs with available data over the period 1980-2022. The main sample consists of 36 AEs: Australia, Austria, Belgium, Canada, Hong Kong SAR, Taiwan Province of China, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, New Zealand, Norway, Portugal, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK, USA. In robustness, I also test the results by dropping the US from the sample to address any concerns

[9] I fill in the 2022 values from 2021 for the Chinn-Ito index, and the period 2019-2022 from 2018 for the polity index, since these datasets stop at 2021 and 2018, respectively. However, the associated results below are not affected by this step.

about endogeneity (since RDI is calculated using data from the US). I also test the results in the sample consisting of EMs (63 countries).

3. Methodology

The objective is to investigate the differential effect of government debt levels on growth based on the variation in industries' RDI. For this purpose, I follow a methodology similar to Rajan and Zingales (1998), which examines the effect of financial development on industry growth by exploiting within country differences across industries' dependence of external finance. In this study, I instead investigate the differential effect of government debt levels on industries with different RDI. The hypothesis is that if high government debt levels hinder innovative activities, the growth impact of debt should be more pronounced in industries which heavily rely on R&D activities. The main specification is as follows:

$$\Delta \log(VA_{c,j,t}) = \alpha\ VA\ share_{c,j,t-1} + \beta\ RDI_j \times Government\ debt_{c,t-1} + \theta_{c,t} + \theta_{c,j} + \theta_{j,t} + \epsilon_{c,j,t} \qquad \mathbf{(1)}$$

where c, j and t stand for countries, 2-digit manufacturing industries, and years, respectively. The dependent variable $\Delta \log(VA_{c,j,t})$ is the growth rate of industry value added at year t (in percent). The variable RDI_j is a proxy for industry's R&D intensity, allowing a comparison across 2-digit manufacturing industries within countries. $Government\ debt_{c,t-1}$ is the central government debt as share of GDP at year t-1. The lagged value of the value added share of each industry in total manufacturing value added in its country ($VA\ share_{c,j,t-1}$) serves as a control variable.

The main focus of this paper is the interaction term between RDI and government debt. The coefficient estimate β will gauge the degree to which the impact of government debt on growth depends on industries' RDI. A negative estimate will suggest that government debt leads to a decline in growth, particularly in R&D-intensive industries.

For the identification to hold, there are two implicit assumptions, similar to the empirical literature pioneered by Rajan and Zingales (1998). First, I assume that some industries inherently and persistently rely more on R&D activities than others, mainly driven by differences in their production methods and processes. Next, these differences carry over AEs, such that an industry's RDI as adopted from the US serves as a good proxy for its RDI in other AEs.

The inclusion of country-year ($\theta_{c,t}$), country-industry ($\theta_{c,j}$) and industry-year ($\theta_{j,t}$) fixed effects is also important for identification. Country-year fixed effects absorb the underlying variation in industry growth that is common across manufacturing industries in a country in a year. In particular, they control for the impact of all common time-variant economic, political and institutional developments, as well as country-specific shocks (including in demand or supply sides), on industry growth. Country-industry fixed effects account for the underlying reasons which can lead to a lower, or higher, growth in an industry in a country, on average. This set of fixed effects accounts for, for instance, whether industries with higher technological intensity on average grow less, or more, in some countries due to some unobserved, but persistent factors. Finally, industry-year fixed effects absorb the roles of industry-specific global developments, shocks, trends, or growth opportunities, in growth at an annual frequency. Thus, by allowing to control for the effects of a large set of factors, the use of industry-level data mitigates concerns about omitted variables.[10]

Country-year and industry-year fixed effects are also important to isolate the role of inflation dynamics in the estimation. Industry-year fixed effects eliminate the influence of a common global (US dollar) inflation for each industry during a year. For many cases, assuming a common global inflation for each industry is sensible, since the manufacturing goods are tradable, and thus, producers generally see global common prices (Rodrik 2013). However, in practice, there may be some reasons why domestic prices may change differently compared to world prices, even in the case of tradables. To the extent this is an issue, country-year fixed effects absorb the role of the component of inflation which is country-specific, but common across industries in a year.

While the three types of fixed effects control for the impacts of a large set of factors, they cannot account for the relative size of industries. In particular, industries that are initially larger compared to their peers may have less room, or have limited additional resources or new opportunities, to grow faster. Thus, it is important to control for the lagged value of the value added share of each industry in total manufacturing value added in its country ($VA\ share_{c,j,t-1}$). Standard errors are clustered at the country-industry level.[11]

Using industry-level data to identify the effect of government debt on growth also has the advantage of mitigating reverse causality. In particular, as opposed to macro-data, it is not likely for the growth dynamics of a R&D-intensive (2-digit) manufacturing industry to significantly alter the pattern of government debt level in a country.

I also use a version of the specification in (1) to test whether the differential effect of government debt on R&D-intensive industries' growth is long-lasting. For this purpose, I run local projections regressions focusing on the cumulative changes in industry value added over a 10-year period (Jorda 2005). In particular, the left-hand side variable is the cumulative change of value added (in percent) from year *t-1* to *t, t-1* to *t+1*, …, and finally, *t-1* to *t+10*, in different regressions. I report the coefficient estimate of the interaction term from those regressions.

[10] Nonetheless, in the context of the Rajan and Zingales (1998) approach, there is a trade-off between identifying the causal effect of government debt and assessing its aggregate impact. While the inclusion of country-year fixed effects is crucial for identification, this allows me to observe the differences in each country-year cell. Therefore, it is not possible to measure the effects of debt on aggregate R&D activities (since the overall effects are captured by the fixed effects).

[11] The results stay virtually the same, if the standard errors are (i) not clustered but robust to heteroskedasticity, (ii) three-way clustered (at the country-industry, country-year and industry-year levels), (iii) two-way clustered with any combinations of those three levels, or (iv) one-way clustered at the country-year or industry-year levels.

Next, I examine whether RDI can indeed be a proxy for some other industry characteristics. For this purpose, I extend the specification in (1) by including the interaction term between other industry characteristics and government debt, as follows:

$$\Delta \log\left(VA_{c,j,t}\right) = \alpha\, VA\ share_{c,j,t-1} + \beta\, RDI_j \times Government\ debt_{c,t-1} + \gamma\, I_j \times Government\ debt_{c,t-1} + \theta_{c,t} + \theta_{c,j} + \theta_{j,t} + \epsilon_{c,j,t} \quad (\mathbf{2})$$

where I_j represents industry's physical capital intensity, asset tangibility, dependence on external finance and liquidity needs. The coefficient estimate γ captures those alternative channels through which government debt can affect industry growth. If those do not undermine the R&D channel, I expect the coefficient estimate β from this analysis to be similar to the one estimated by the first specification.

Then, I account for the differential effects of some other country-level variables on industry growth based on RDI. In particular, while country-year fixed effects absorb the common impact of all country-level variables on growth, it is still important to test whether those country-level variables can have a disproportionate impact on growth in R&D-intensive industries, possibly undermining the effect of government debt. Hence, these tests check whether government debt may indeed be a proxy for those county-level factors, and the latter can be an alternative explanation for the previous findings. The specification is as follows:

$$\Delta \log\left(VA_{c,j,t}\right) = \alpha\, VA\ share_{c,j,t-1} + \beta\, RDI_j \times Government\ debt_{c,t-1} + \gamma\, RDI_j \times X_{c,t-1} + \theta_{c,t} + \theta_{c,j} + \theta_{j,t} + \epsilon_{c,j,t} \quad (\mathbf{3})$$

where $X_{c,t-1}$ represents various country-level variables as mentioned above (i.e., GDP, GDP per capita, trade, inflation, and proxies for institutional quality, financial development, financial openness and population aging). The coefficient estimate γ captures the differential impact of those country-level variables on R&D-intensive industries, if any. To the extent that government debt does not simply act as a proxy for those country-level factors, I expect the coefficient estimate β from this specification to remain similar to the estimate from the first specification.

Finally, I explore whether finance plays a role in the impact of government debt on R&D-intensive industries. The specification is as follows:

$$\Delta \log\left(VA_{c,j,t}\right) = \alpha\, VA\ share_{c,j,t-1} + \beta\, RDI_j \times Government\ debt_{c,t-1} + \gamma\, RDI_j \times Z_{c,t-1} + \lambda\, RDI_j \times Government\ debt_{c,t-1} \times Z_{c,t-1} + \theta_{c,t} + \theta_{c,j} + \theta_{j,t} + \epsilon_{c,j,t} \quad (\mathbf{4})$$

where $Z_{c,t-1}$ represents proxies for financial development or openness. If the coefficient estimate β is negative, a positive coefficient estimate of the triple interaction term (λ) will imply that financial development, or openness, mitigates the impact of government debt on R&D-intensive industries.

4. Stylized Facts

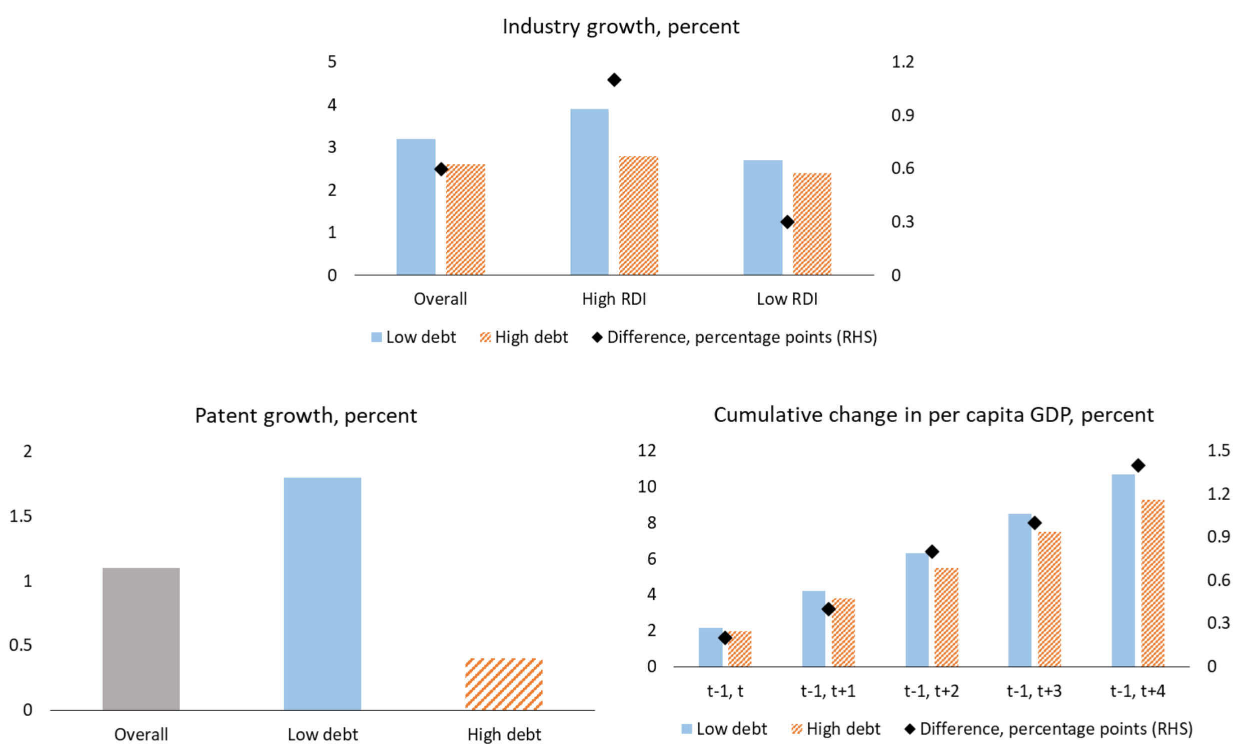
In this section, I explore (i) whether industry growth appears to be different in aftermath of the years with high government debt based on industries' RDI, and (ii) government debt seems to drag patenting and growth outcomes at the macro-level. Figure 1 illustrates the findings.

The chart on the first row reports the average growth rate in industries following the years of high versus low levels of government debt (based on the sample median of debt). The first two bars show that industry growth is about 3.2 percent, on average, in cases where government debt is low, while it decreases to 2.6 percent when government debt is high. The next two bars repeat the same exercise, but only focusing on the half of the 2-digit industries with relatively high RDI (based on the median of this measure as shown in Table 1). Average growth rates are 3.9 versus 2.8 percent for these industries following the years of low and high government debt, respectively. Finally, the last two bars show that growth rates become 2.7 and 2.4 percent for the industries with low RDI, following the years with low and high government debt, respectively. Importantly, the differential growth rate based on government debt (i.e., the difference between average growth rates of 3.9 and 2.8 percent) is 1.1 percentage points in R&D-intensive industries, whereas this difference is only about 0.3 percentage points in industries with low RDI. This points to that high government debt levels tend to hinder growth, particularly in industries with greater use of R&D. In the next section, I test this relationship in a formal setting.

Then, I explore whether a consistent pattern is reflected in the patenting outcomes at the macro-level. For this purpose, the left-hand side chart on the second row uses data at the country-level, and documents the average growth rate of the number of patent applications at year *t*, in the overall sample, as well as in the two subsamples with low versus high government debt at year *t-1* (based on the sample median of debt). It shows that the average growth rate of the number of patents is about 1.1 percent per annum in the overall sample. However, it seems to be higher (1.8 percent) following the years with relatively low levels of government debt, while it remains at about 0.4 percent when debt is high. This suggests that high government debt predicts a lower growth rate in patenting, in line with the industry-level pattern above.

Finally, in the right-hand side chart on the second row, I focus on the per capita GDP dynamics following the years of high versus low government debt. If high levels of government debt are associated with lower innovative outcomes (i.e., patenting growth) as shown before, it can be expected that the periods with relatively high debt will be followed by durably low economic growth, considering the role of innovation in long-term economic performance. To observe whether this is the case, I similarly divide the sample into two subsamples based on the median value of government debt at year *t-1*. Then, I report the sample average of the cumulative change in real per capita GDP over 1-, 2-, …, and 5-year periods from *t-1*. In the first year (the first bar representing the period of *t-1* and *t*), the average change in per capita GDP in the countries with low debt is about 2.2 percent, whereas it is 2.0 percent in the ones with high debt. This divergence becomes more pronounced over the years. For instance, at the end of the fifth year (as shown by the last 2 bars), the cumulative change in per capita GDP becomes 10.7 percent in countries with initially low debt versus a cumulative growth rate of 9.3 percent in others, making the accumulated gap across those subsamples 1.4 percentage points. This implies that high government debt levels are associated with persistently weaker economic performance in the macro-level.

Figure 1: Government debt, R&D and growth in AEs



Notes: The chart on row 1 reports average industry growth rates in (i) the overall sample, (ii) the subsample consisting of industries with high R&D intensity (RDI), and (iii) the subsample consisting of industries with low RDI, at year t. In each of those three exercises, the samples are divided into two subsamples based on the median level of government debt at year t-1 (low versus high debt). Industry subsamples with high and low RDI are based on the median value of RDI in Table 1. The left-hand side chart on row 2 documents the growth rate of the number of patents at the macro-level at year t in the overall sample and the two subsamples based on the median level of government debt at year t-1 (low versus high debt), averaged in the corresponding samples. Right-hand side chart (row 2) reports the growth rate of real per capita GDP for the indicated periods, averaged in the subsamples of low and high government debt (divided based on the median level of government debt at year t-1). In all charts, growth rates are in percent, and difference is in percentage points. The samples consist of AEs and 2-digit manufacturing industries, over the period 1980-2022, as listed in Section 2.

5. Results

5.1. Baseline Results

Table 2 illustrates the baseline results. Column 1 shows the results in the sample consisting of AEs. The negative coefficient estimate of the interaction term implies that higher level of government debt leads to lower growth, particularly in industries which heavily engage in R&D activities. The disproportionate impact of high levels of government debt on growth in high-tech industries is economically sizable. The two-digit industries at the 25th and 75th percentiles of RDI distribution are paper products (ISIC 21) and machinery (ISIC 29), respectively. RDI is 0.266 for paper products, and 0.926 for machinery (Table 1). The country-year observation at the 25th percentile of the distribution of government debt has a debt level of 26.4 percent of GDP, while this is 74.7 percent at the 75th percentile of the sample.

The coefficient estimate of the interaction term (-0.014) suggests that growth rate of machinery industry (high-tech industry) becomes 0.5 percentage points lower compared to paper products (low-tech industry), when they are located in a country with high government debt (at the 75th percentile) rather than in a country with a low level of debt (at the 25th percentile).[12] As an alternative, the similarly calculated growth loss in the top 5 industries with the largest RDI (i.e., ISIC 30-33, 24) due to higher debt, compared to the bottom 5 industries with the lowest RDI (i.e., ISIC 15, 18, 20, 23, 27), is about 2 percentage points on average (calculated using the difference in the average values of the RDI measure across those industries at the top and the bottom of the distribution). These are sizable, considering that the average industry growth in the sample is about 2.9 percent per annum (Table A.1 in the Appendix).

Moreover, in the context of the Rajan and Zingales (1998) approach, this estimated effect is only the additional growth loss in the machinery industry relative to the growth decline in paper products. Hence, it quantifies the differential impact of higher debt levels on growth in industries with relatively higher RDI (rather than being the overall effect).

While it is not the main focus of this study, the negative and statistically significant coefficient of industry's initial value added share suggests that smaller industries tend to exhibit higher growth, pointing to convergence across industries and countries over time (consistent with Rodrik 2013, and Hardy and Sever 2023).

Columns 2-3 show that this pattern does not hold in the sample consisting of EMs, and thus becomes much weaker when tested in the overall sample (consisting of AEs and EMs). These findings, however, do not necessarily suggest that government debt does not affect growth in EMs. They only imply that the R&D channel of government debt is not pronounced in EMs, as opposed to AEs.[13] I use the sample consisting of AEs for the rest of the analysis.

Table 2: Government debt, industry growth and R&D intensity

Variable	AEs	EMs	AEs and EMs
$RDI_j \times Government\ debt_{c,t-1}$	-0.014***	-0.000	-0.005*
	(0.005)	(0.005)	(0.003)
$VA\ share_{c,j,t-1}$	-1.138***	-1.241***	-1.203***
	(0.100)	(0.108)	(0.079)
Country-year F.E.	Yes	Yes	Yes
Country-industry F.E.	Yes	Yes	Yes
Industry-year F.E.	Yes	Yes	Yes
Observations	23,539	27,330	50,877
R-squared	0.470	0.413	0.419

Notes: Results are based on equation 1. Standard errors in parentheses are clustered at the country-industry level. *** p<0.01, ** p<0.05, * p<0.1.

[12] This is calculated by multiplying the estimated coefficient estimate of the interaction term, the difference between the 75th and 25th percentiles of the distribution of RDI, and the difference in the debt levels at the 75th and 25th percentiles of the sample.

[13] A possible explanation may be that EMs are generally subject a wider set of shocks compared to AEs (e.g., Sever 2022, 2024), which can have a larger impact on R&D activities than government debt. For instance, based on a global sample, Sever (2024) shows that violent conflicts hinder R&D activities, with such events being much more relevant for EMs than AEs.

5.2. Accounting for Other Industry Characteristics

In this section, I test whether the measure on RDI may be serving as a proxy for other industry characteristics. Thus, these tests aim to rule out explanations whether the effect of government debt on industry growth materializes through other industry characteristics, rather than RDI. Table 3 illustrates the findings. In column 1, I check whether high-tech industries may be more heavily using physical capital in general, relative to others, i.e., if government debt levels affect industries that rely more on physical as a whole (e.g., via crowding out available funding), rather than the industries that are specifically more dependent on R&D activities. In columns 2, 3 and 4, I test whether RDI may be a proxy for asset tangibility, dependence on external finance, or liquidity needs, respectively. The baseline result remains similar across these tests, even after accounting for such financial channel, thereby eliminating financing frictions as an alternative explanation.[14]

Table 3: Other industry characteristics

Variable	Physical capital intensity	Asset tangibility	Dependence on external finance	Liquidity needs
$RDI_j \times Government\ debt_{c,t-1}$	-0.014***	-0.015***	-0.021**	-0.014***
	(0.005)	(0.005)	(0.009)	(0.005)
$I_j \times Government\ debt_{c,t-1}$	-0.000	-0.026	0.009	-0.014
	(0.011)	(0.043)	(0.010)	(0.105)
$VA\ share_{c,j,t-1}$	-1.138***	-1.138***	-1.137***	-1.138***
	(0.100)	(0.100)	(0.100)	(0.100)
Country-year F.E.	Yes	Yes	Yes	Yes
Country-industry F.E.	Yes	Yes	Yes	Yes
Industry-year F.E.	Yes	Yes	Yes	Yes
Observations	23,539	23,539	23,539	23,539
R-squared	0.470	0.471	0.471	0.470

Notes: Results are based on equation 2. I stands for industry's physical capital intensity (column 1), asset tangibility (column 2), dependence on external finance (column 3), and liquidity needs (column 4). Standard errors in parentheses are clustered at the country-industry level. *** p<0.01, ** p<0.05, * p<0.1.

5.3. Accounting for Other Country-level Factors

Next, I aim to rule out several alternative explanations at the country-level, i.e., whether various macroeconomic, financial, or institutional factors may be driving the results, rather than government debt. This can be the case if those country-level factors have a differential impact on R&D-intensive industries, and are somewhat correlated with debt levels. Table 4 shows the findings. In column 1, I include the interactions between the real GDP per capita (as a proxy for economic development). Column 2 takes the size of the economy into account by including an interaction term with GDP. Column 3 accounts for

[14] I also ran this set of regressions for EMs to explore whether one of these channels may drive the impact of government debt on growth in those countries. But, none of those channels appears to be statistically significant.

institutional quality. Columns 4-5 include financial development and openness, respectively. Columns 6-7 account for trade openness and inflation, respectively. The baseline result remains similar, thereby ruling out alternative explanations whether these country-level variables may be the ones driving the results. Moreover, those factors do not have much effect on R&D-intensive industries. Later, I explore the role of financial variables in the link between government debt and R&D activities.

Finally, I take population aging into account by including an interaction term with RDI and the old-age dependency ratio (column 8). This is sensible to check, particularly if an aging population implies fewer entrepreneurship activities and suppresses R&D, while generating fiscal pressures (e.g., via an upward pressure on pension spending or a decline in tax revenues), and hence, driving government debt levels in some AEs (e.g., Kamiguchi and Tamai 2019, Aksoy et al. 2019, IMF 2019, Honda and Miyamoto 2020). Nonetheless, the main result remains similar, and population aging does not seem to have a differential impact on R&D-intensive industries.

Table 4: Other country-level variables

Variable	GDP per capita	GDP	Polity	Financial development	Financial openness	Trade	Inflation	Aging
$RDI_j \times Government\ debt_{c,t-1}$	-0.013***	-0.012**	-0.013***	-0.014***	-0.014***	-0.014***	-0.015***	-0.016***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$RDI_j \times X_{c,t-1}$	0.781	0.880	-0.014	1.097	0.635	-0.008	0.005	0.042
	(0.768)	(0.683)	(0.045)	(1.545)	(0.628)	(0.007)	(0.006)	(0.041)
$VA\ share_{c,j,t-1}$	-1.174***	-1.177***	-1.218***	-1.168***	-1.216***	-1.167***	-1.171***	-1.169***
	(0.105)	(0.105)	(0.112)	(0.106)	(0.118)	(0.107)	(0.105)	(0.106)
Country-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,877	22,877	21,255	22,877	22,240	22,877	22,877	22,877
R-squared	0.473	0.473	0.499	0.473	0.475	0.473	0.473	0.473

Notes: Results are based on equation 3. X stands for the real GDP per capita (column 1), real GDP (column 2), the polity index on institutional quality (column 3), the index on financial development (column 4), the Chinn-Ito index on capital account openness (column 5), trade as percent of GDP (column 6), inflation rate (column 7) and the old-age dependency ratio (column 8). Standard errors in parentheses are clustered at the country-industry level. *** p<0.01, ** p<0.05, * p<0.1.

5.4. Additional Tests

In this section, I run a large set of additional tests. The results are shown in Table 5. Column 1 in Panel A adopts the RDI measure as winsorized at the 5th and 95th percentile levels to confirm that the results are not solely driven by a few industries with much higher or lower RDI compared to others. Columns 2-4 use the three alternative measures of RDI as explained above, instead of the baseline measure. Columns 5-6 adopt the output growth and labor productivity growth as the left-hand side variable, instead of industry value added growth, respectively. Columns 7-8 use the industry value added growth non-winsorized, or winsorized at the 5th and 95th percentile levels, respectively. The results remain similar.

In Panel B in Table 5, column 1 adopts central government debt winsorized at the 2.5th and 97.5th percentile levels to reduce the influence of outliers in debt. Column 2 uses general government debt instead of central government debt.[15] Column 3 drops the US to alleviate concerns about endogeneity, since RDI is calculated using data from the US. To make sure that it is not a few relatively richer or poorer AEs driving the results, columns 4-5 use weighted regressions where the weights are the logarithm or real GDP per capita, or its inverse, respectively.[16] Columns 6 run a weighted regression where the weights are industry value added shares to make sure that the results are not driven by smaller industries in the sample. Instead, column 7 uses 100 minus industry value added share in the corresponding country as weights, to confirm that it is not larger industries driving the results. It is also important to note that this test mitigates, if any, concerns on reverse causality by reducing the influence of larger industries (whose growth patterns can somewhat be more likely to affect government debt levels, compared to their smaller peers).

Column 8 in Panel B tests the nonlinearity in the previously reported results by focusing on the quartiles of debt. In particular, it includes three interaction terms between the categorical variables indicating the second, third and fourth quartiles of government debt and RDI. The results show that the differential impact of government debt on growth in high-tech industries becomes particularly pronounced at higher levels of debt, compared to lower quartiles, pointing to some nonlinearity.

Finally, Panel C focuses on the time span. Column 1 shows that the result is similar when tested based on the 3-year changes in industry value added (from *t-3* to *t*, and also adopting the right-hand side variables from *t-3*) to smooth out annual variations. Column 2 adopts the average government debt during the last 3 years to test whether durably higher levels of debt generate a similar effect. Columns 3-5 in Panel C shows that the findings remain similar in the pre- and post-GFC periods, as well as over the period 1980-2019 excluding the Covid-19 shock, confirming that those large shocks do not drive the findings. The last column in Panel C shows that the findings are similar, when the analysis is employed over the period 1990-2022, by dropping the 1980s where the data is relatively sparse.

The analysis until now shows that higher levels of government debt have a disproportionately negative impact on R&D-intensive industries compared to other industries, while it is not possible to conclude that the direction of this effect is negative for all industries. In particular, it can be the case that government debt somewhat has a positive effect on growth across all industries, while this positive effect is lower for R&D-intensive industries (leading a negative coefficient estimate for the interaction term between RDI and debt as found above). To provide suggestive evidence on this phenomenon, I drop the country-year fixed effects from the specification in (1), and add the lagged value of government debt in Table 6. Thus, albeit being prone to the problem of omitted variables (arising from the underlying variation in industry growth driven by other country-level factors, given the lack of country-year fixed effects), this alternative approach can offer some insight into the overall direction of the impact. In the last column, the statistically insignificant coefficient estimate of government debt suggests that high levels of debt are not associated with an increase (or a decrease) in industry growth, on average, whereas the negative impact of it varying with industries' R&D intensity survives. This implies that the overall direction of the impact of government debt on growth is likely to be negative, with this effect mainly working through the R&D channel.

[15] The sample shrinks to 34 AEs in this exercise. Data on general government debt is not available for Hong Kong SAR, New Zealand and Singapore, while it becomes available for Netherlands, compared to the main sample consisting of 36 AEs.

[16] In unreported results, I also confirm that it is not a specific country driving this pattern. The coefficient estimate of the interaction term remains similar when one country is dropped at a time. Those results are available upon request.

Table 5: Additional tests

	Panel A							
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
$RDI_j \times Government\ debt_{c,t-1}$	-0.019***	-0.287***	-0.009**	-0.030**	-0.006**	-0.007**	-0.014***	-0.012***
	(0.007)	(0.095)	(0.004)	(0.015)	(0.003)	(0.003)	(0.005)	(0.004)
$VA\ share_{c,j,t-1}$	-1.135***	-1.139***	-1.113***	-1.130***	-0.633***	-0.784***	-1.279***	-0.947***
	(0.100)	(0.100)	(0.102)	(0.100)	(0.065)	(0.078)	(0.114)	(0.082)
Country-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,539	23,539	22,301	23,539	23,292	22,912	23,539	23,539
R-squared	0.470	0.471	0.472	0.470	0.576	0.461	0.442	0.510
	Panel B							
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
$RDI_j \times Government\ debt_{c,t-1}$	-0.019***	-0.015***	-0.013***	-0.014***	-0.014***	-0.014***	-0.014***	
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	
$VA\ share_{c,j,t-1}$	-1.141***	-1.234***	-1.134***	-1.179***	-1.160***	-0.834***	-1.238***	-1.136***
	(0.100)	(0.108)	(0.101)	(0.104)	(0.107)	(0.056)	(0.107)	(0.099)
$RDI_j \times 2nd\ quartile_{c,t-1}$								-0.343
								(0.275)
$RDI_j \times 3rd\ quartile_{c,t-1}$								-0.786**
								(0.394)
$RDI_j \times 4th\ quartile_{c,t-1}$								-1.396***
								(0.533)
Country-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	23,539	22,776	22,731	22,877	22,877	23,539	23,539	23,539
R-squared	0.471	0.478	0.471	0.477	0.468	0.584	0.469	0.470
	Panel C							
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**		
$RDI_j \times Government\ debt_{c,t-1}$	-0.042***	-0.016***	-0.016**	-0.050**	-0.016***	-0.016***		
	(0.013)	(0.006)	(0.007)	(0.020)	(0.005)	(0.006)		
$VA\ share_{c,j,t-1}$	-3.209***	-1.246***	-1.387***	-2.319***	-1.198***	-1.408***		
	(0.292)	(0.117)	(0.181)	(0.429)	(0.106)	(0.118)		
Country-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes		
Country-industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes		
Industry-year F.E.	Yes	Yes	Yes	Yes	Yes	Yes		
Observations	21,895	21,619	14,181	7,418	21,733	20,001		
R-squared	0.585	0.476	0.488	0.433	0.470	0.451		

Notes: Results are based on equation 1. Standard errors in parentheses are clustered at the country-industry level. *** p<0.01, ** p<0.05, * p<0.1.

Panel A. Column 1 adopts the RDI measure winsorized at the 5th and 95th percentile levels. Columns 2-4 use three alternative measures of RDI as adopted from Brown et al. (2017), Seitz and Watzinger (2017) and Choi et al. (2018b), respectively. Columns 5-6 adopt the output growth and labor productivity growth as the left-hand side variable, respectively. Columns 7-8 use the value added growth without winsorization, or winsorized at the 5th and 95th percentile levels, respectively.

Panel B. Column 1 adopts central government debt winsorized at the 2.5th and 97.5th percentile levels. Column 2 uses general government debt. Column 3 drops the US. Columns 4-5 use weighted regressions where the weights are the one-year lagged values of logarithm or real GDP per capita, or the inverse of it, respectively. Columns 6-7 use weighted regressions where the weights are the one-year lagged values of industry value added share, or 100 minus it, respectively. Column 8 includes the interaction terms with the categorical variables indicating the 2nd, 3rd and 4th quartiles of government debt levels.

Panel C. Column 1 presents the result based on overlapping 3-year windows. Column 2 uses the average of debt during the last 3 years. Columns 3-6 show the results based on the periods of 1980-2007, 2011-2022, 1980-2019, and 1990-2022, respectively.

Table 6: Excluding country-year fixed effects

Variable	(1)	(2)
$RDI_j \times Government\ debt_{c,t-1}$		-0.010**
		(0.005)
$VA\ share_{c,j,t-1}$	-0.989***	-0.998***
	(0.095)	(0.095)
$Government\ debt_{c,t-1}$	-0.002	0.006
	(0.005)	(0.006)
Country-year F.E.	No	No
Country-industry F.E.	Yes	Yes
Industry-year F.E.	Yes	Yes
Observations	23,539	23,539
R-squared	0.304	0.304

Notes: Results are based on equation 1, by dropping the country-year fixed effects and adding government debt. Standard errors in parentheses are clustered at the country-industry level. *** p<0.01, ** p<0.05, * p<0.1.

5.5. Heterogeneity of the Effects: The Role of Finance

As discussed above, government debt is argued to reduce investment via crowding-out of available funds, which can be particularly relevant for R&D investment given its sensitivity to the availability of funding. In the previous tests, I show that accounting for such a financial channel separately (i.e., as an alternative explanation) does not change the finding on the disproportionate impact of government debt on R&D activities. I now ask a different question, i.e., whether financial systems play a role in the differential impact of government debt on R&D activities. For this purpose, I use the specification in (4) which includes the triple interaction with proxies of financial development and openness. Table 7 shows the results.

To start with, (i) the coefficient estimate of the main interaction term (between RDI and government debt) remains negative and statistically significant across these tests, i.e., neither financial development nor openness undermines the R&D channel of government debt; and (ii) the interaction terms including financial variables and RDI are statistically insignificant, implying that those financial factors do not have a disproportional impact on R&D activities per se, both being consistent with the findings above. However, the coefficient estimates of the triple interaction terms become positive and statistically significant for the proxies of financial development (column 1) and openness (column 2). These imply that the sensitivity of R&D-intensive industries to government debt becomes lower in countries with more developed or open financial systems. I conclude that the availability of funding mitigates the negative effect of debt on those industries to some extent. Nonetheless, these financial factors do not fully offset the negative impact of government debt in R&D activities for the vast majority of the sample.[17]

Table 7: The role of finance

Variable	Financial development	Financial openness
$RDI_j \times Government\ debt_{c,t-1}$	-0.037***	-0.033***
	(0.013)	(0.008)
$RDI_j \times Z_{c,t-1}$	-0.415	-0.746
	(1.465)	(0.738)
$RDI_j \times Government\ debt_{c,t-1} \times Z_{c,t-1}$	0.036**	0.024***
	(0.017)	(0.008)
$VA\ share_{c,j,t-1}$	-1.175***	-1.222***
	(0.107)	(0.119)
Country-year F.E.	Yes	Yes
Country-industry F.E.	Yes	Yes
Industry-year F.E.	Yes	Yes
Observations	22,877	22,240
R-squared	0.473	0.475

Notes: Results are based on equation 4. Z stands for the index on financial development (column 1) and the Chinn-Ito index on capital account openness (column 2). Standard errors in parentheses are clustered at the country-industry level. *** p<0.01, ** p<0.05, * p<0.1.

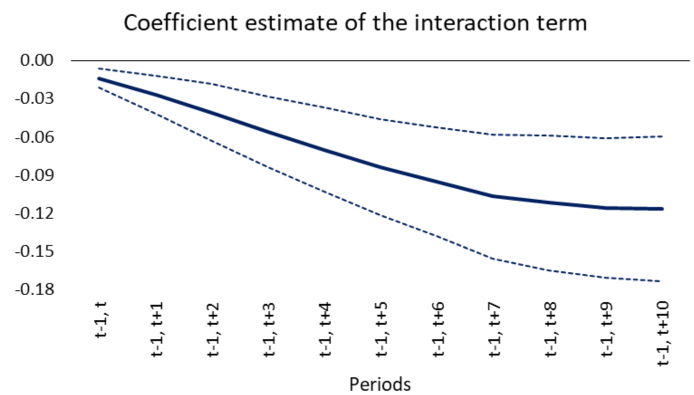
5.6. Durability of the Effects

In this section, I examine whether the differential effect of government debt on R&D-intensive industries is durable. For this purpose, I use the specification in (1), but with local projections over a 10-year period. The results in Figure 2 imply that the impact of debt on R&D-intensive industries is long-lasting for upwards of 10 years. The coefficient estimate in the last period suggests that the accumulated loss in industry value added is 3.7 percentage points larger in machinery compared to paper products, due to high level of debt (comparing the 25^{th} and 75^{th} percentiles of the sample, similar to above). Comparing the losses in the top and bottom 5 industries with the highest and lowest RDI, the accumulated disproportionate effect of government debt on industry value added over a 10-year period becomes 16.4 percentage points. Given that the average decadal change in industry value added in the sample is 30 percent, these estimates are economically important. Moreover, this finding points to that some R&D projects are cancelled or shelved

[17] When jointly assessed, the coefficient estimates of the double interaction (between RDI and debt) and the triple interaction terms in column 1 imply that the impact of debt on R&D-intensive industries becomes statistically insignificant only for the values of the index on financial development above 0.83. The upper bound for the index is 1, and the vast majority of country-year observations in the sample (about 87 percent) has an index below this threshold. When similarly evaluated, the coefficient estimates in column 2 imply that the effect of government debt stays statistically significant (and negative) even for the upper bound of the index on financial openness (which is 1).

for a prolonged time following the periods of high government debt, with no evidence for recovery in the growth loss in high-tech industries.

Figure 2: Differential effect of government debt on R&D-intensive industries over time



Notes: The results are based on equation 1 with local projections. The dependent variable is the cumulative change in industry value added from t-1 to t, t-1 to t+2, …, and t-1 to t+10 in different regressions. The chart reports the coefficient estimate of the interaction term for each regression, as well as the 90 percent confidence interval.

6. Conclusion

Whether government debt poses a drag on future economic growth has been a central question in economics with important policy implications. The increasing trend in debt ratios across AEs since the early 2000s has been coupled with a slowdown in growth, which was largely driven the slowdown in productivity growth. This environment characterized by high government debt ratios and low growth is a cause of concerns for policy makers, entailing risks to macroeconomic prospects. This issue has become particularly relevant for AEs recently, due to the soaring of already-high debt levels in the wake of the Covid-19 pandemic. It is thus important to understand the channels shaping the interplay between rising debt levels and slowing down in growth.

This paper explores the interplay between these two issues, and offers an explanation for the high-debt low-growth environment in AEs with implications for future economic performance. It attempts to build causality in the government debt-growth nexus by showing evidence on a particular mechanism through which government debt affects economic growth, i.e., by its adverse impact on innovative activities. Based on granular data from manufacturing industries in AEs over the period 1980-2022, I show that government debt leads to a decline in growth, particularly in industries which rely heavily on R&D activities. Moreover, this differential effect of debt on R&D-intensive industries is persistent for upwards of 10 years. It is worth noting that this pattern is not only driven by some specific events during the sample period, such as the Global Financial Crisis or the Covid-19 pandemic. Importantly, more developed or open financial systems tend to mitigate the negative impact of debt on innovative activities.

These findings offer a specific explanation for the observed the link between high government debt and low growth in AEs, given the role of technological progress in productivity growth and long-term economic performance. They also highlight a policy trade off: While fiscal stabilization policies as response to economic shocks can help stabilize economies in the short-term, they likely pose a drag on long-term growth, since the resulting high levels of government debt can have an adverse impact on innovative activities. Furthermore, there is suggestive evidence on that policies in favor of financial deepening and openness can help alleviate the adverse effects of debt on future growth.

Nonetheless, another important finding is that this pattern does not hold in EMs, as opposed to AEs. This is not to say that government debt does not affect growth in those economies. It rather suggests that while accumulating more debt hinders growth in AEs through the R&D channel, this specific mechanism does not seem to be at play in other economies. For future research, it remains important to understand which channels are important in EMs for the link the between government debt and growth. In addition, this distinction between AEs and other economies, as found by this study, calls for a theoretical explanation in future research.

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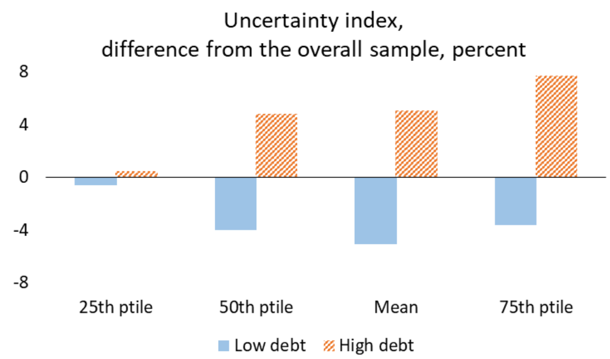
Appendix

Figure A1: Government debt and uncertainty in AEs



Notes: Data on uncertainty is from Ahir et al. (2022). It is an index reflecting the frequency of the word "uncertainty" and its variants in the Economist Intelligence Unit country reports (annual data is the average of the quarterly numbers). It is available for 30 AEs in the sample. The period is 1980-2022, consistent with the regression analysis. The chart reports the 25th, 50th and 75th percentiles, as well as the mean values, of the uncertainty index in two subsamples with low and high government debt (based on the sample median) in comparison to the corresponding values in the overall sample (i.e., the difference between the overall sample and the indicated subsamples, in percent). It shows that uncertainty tends to be higher in countries and years with relatively higher government debt levels. For instance, the third set of bars indicate that the mean value of the uncertainty index is 5 percent higher (lower) in the subsample consisting of the observations with high (low) government debt ratio, compared to the overall sample. Other sets of bars follow the same procedure with the 25th, 50th and 75th percentiles of the distribution of the uncertainty index, comparing them in each subsample.

Table A1: Summary statistics

Variable	Mean	Median	25th ptile	75th ptile
Industry characteristics				
R&D intensity (baseline, Igan et al. 2022)	0.971	0.422	0.266	0.926
R&D intensity (Brown et al. 2017)	0.037	0.012	0.007	0.023
R&D intensity (Seitz and Watzinger 2017)	1.732	0.530	0.360	2.380
R&D intensity (Choi et al. 2018b)	0.170	0.395	0.100	0.810
Physical capital intensity	1.204	1.117	0.911	1.466
Asset tangibility	0.280	0.259	0.204	0.363
Dependence on external finance	-0.096	-0.262	-0.385	-0.140
Liquidity needs	0.166	0.177	0.126	0.203
Industry-level variables				
Value added growth (%)	2.923	3.092	-6.434	12.373
Value added share (%)	5.422	3.850	1.807	7.124
Output growth (%)	3.381	3.339	-5.353	12.400
Labor productivity growth (%)	4.056	3.848	-4.484	12.618
Country-level variables				
Central government debt (% of GDP)	54.215	45.460	26.416	74.717
General government debt (% of GDP)	62.602	56.117	37.149	79.604
GDP per capita (log)	10.302	10.369	9.920	10.671
GDP (log)	26.298	26.252	25.211	27.652
Patent growth (%)	1.095	0.474	-4.971	7.778
Polity (index)	8.956	10	10	10
Financial development (index)	0.583	0.589	0.439	0.740
Chinn-Ito index	0.828	1	0.7	1
Trade (% of GDP)	100.659	71.196	55.389	116.603
Inflation (%)	4.133	2.308	1.249	3.941
Old age dependency (%)	22.422	22.316	18.408	26.161

Table A2: Correlations between R&D intensity (RDI) measures

	RDI (baseline, Igan et al. 2022)	RDI (Brown et al. 2017)	RDI (Seitz and Watzinger 2017)	RDI (Choi et al. 2018b)
RDI (baseline, Igan et al. 2022)	1			
RDI (Brown et al. 2017)	0.981	1		
RDI (Seitz and Watzinger 2017)	0.772	0.718	1	
RDI (Choi et al. 2018b)	0.847	0.771	0.909	1

PUBLICATIONS

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