Innovation, Public Debt and Monetization: an Empirical Analysis

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3 June 2023

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June 3, 2023

Abstract

This paper explores the relationship between public debt and technological innovation through panel threshold regressions on a sample of 15 industrialized countries from 2000 to 2019. It also asks what impact debt monetization (expressed as the amount of debt held at the central bank) has on this nexus.
Our results show strong nonlinearities in the sense that an increase in debt above a certain threshold negatively impacts the rate of innovation, while below it has positive effects. Monetizing debt contributes positively to innovation if it is below the "debt turning point", while this becomes detrimental for debt-to-GDP ratios above the threshold. The same inverted-U-shaped relationship is found between the monetization rate and innovation rate.

Keywords: Public debt, Innovation, Debt monetization, Panel threshold regression

JEL Codes: C23, O47, H60, E58, O00

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1 Introduction

Over the past 15 years, data show an increasing trend in the public debts of major advanced economies, due both to the financial crisis of the years 2007-2008 and more recently to the pandemic crisis triggered by Covid-19. According to data provided by the International Monetary Fund, this phenomenon has not only impacted European economies, but excessive debt growth also characterizes the public accounts of other countries belonging to the G20, such as the United States, Japan, Korea, Australia, and Canada.

In addition, a solution to the problem of fiscal consolidation (debt repayment policies) alternative to decreasing government spending and increasing taxes is recently making its way into the scientific and policy debate: debt monetization. A clear definition and current framing of the problem is presented by Andolfatto (2018). To summarize, government liabilities are composed of money, central bank reserves, and Treasury debt. When debt is converted into money, that is, when fiscal and monetary policy act together, it is monetized. Technically, debt is monetized if it is financed through currency or reserves at central banks. Strictly speaking, Japan's Quantitative Easing is an attempt to monetize debt, as it has no quantitative limits and is implemented to keep rates at the desired level, while the ECB's, being part of a temporary unconventional monetary policy, does not fall under the above definition. In a broader sense, as a proxy for monetized debt, one could use the percentage of public debt held at the Central Bank of the economies under consideration.

In this sense, IMF data indicate different trajectories. In some countries, such as Sweden, Norway, Ireland, Italy, Portugal, and the United States, the percentage of public debt held at the central bank increased (if only temporarily) following the sovereign debt crisis (2011), while the reverse trend was followed in, for example, Japan, Germany, Belgium, Korea, and Slovenia.

Analyzing World Bank data, there is an increasing trend in the innovation rate (calculated as the ratio of the number of patent applications filed with the relevant authority to the resident population) in Korea since the 1990s. In 2020, there were 35 patent applications per 10,000 population in Korea, while in Japan, where a decrease in the variable has been observed, there were 18 in the same year. This is followed by the United States, with 8 applications, and the highest value for European countries belongs to Germany, which submitted 5 applications.

Given this background, in this paper, we ask a research question that, to the best of our knowledge, has never before been addressed empirically. We propose an analysis of the relationship between public debt and innovation capacity in advanced economies. The data described so far would seem to show a negative relationship, but our objective is to verify whether this relationship is linear or not, and what is the role of debt monetization on innovation capacity. In fact, at the theoretical level, it is assumed that greater monetization reduces the cost of debt on the government balance sheet and allows a greater share of government spending to be invested in research and development, fostering innovation. To summarize, we therefore ask how and to what extent the issuance of new debt impacts the rate of innovation in advanced economies and whether and to what extent it is worthwhile to use monetization to finance debt and incentivize technological innovation.

As already pointed out, the main novelty of the paper is that this is the first empirical work that delves into the research question just described, so we are unable to cite similar work in the literature. Moreover, no research analyzes what is the optimal share of monetized debt such that it provides the highest rate of innovation. Our research question could pave the way for a different strand of the literature since no empirical paper has focused on the relationship between public debt and the innovation rate. For completeness, we cite some theoretical papers that address this issue, developing models of endogenous growth. A first attempt was provided by Ferraro and Peretto (2020), through a one-sector Schumpeterian general equilibrium model of innovation-driven growth (which improves products and quality) with endogenous technological change and public debt as a source of financing in the fiscal rule. In this model, it is assumed that once a government deficit is produced, fiscal consolidation will be required to bring the budget back into balance. The necessary condition to avoid explosive paths is that the growth rate of the economy is higher than the interest rate on the debt. Several scenarios can be distinguished. In the Ricardian regime, the government can impose non-distortionary flat taxes each year to adjust the budget balance. Government debt is then neutral because it does not affect household behavior and the transitory dynamics are stable on the saddle path. In contrast, in the non-Ricardian regime, to ensure debt sustainability, the government must adjust government spending or the labor tax rate, and the system goes into explosive dynamics if the interest rate on debt exceeds the growth rate of output. In the case where debt stabilization is immediate (the private sector is displaced), financing through reduced government spending improves welfare (ratio of consumption to output) compared with the taxation channel. If, on the other hand, the implementation of the fiscal consolidation plan is postponed in time, the private sector anticipates the government's moves due to the perfect rationality hypothesis. In this case, if the government intervenes through government spending, consumption is set on an unstable trajectory and losses are greater than with fiscal consolidation. Therefore, to achieve equilibrium, it is necessary to specify the date when the ratio of debt to output will be stabilized and to announce the instruments used. A second benchmark paper is Huang et al. (2021), in which the authors develop a Schumpeterian model of endogenous growth in which money is included as cash-in-advance, and thus enters both household balance sheets and firms' investment decisions. In this model, however, the effects of government debt are not considered.

At the empirical level, a couple of papers can be mentioned that estimate the link between public debt and innovation rate. Coccia (2013), analyzing partial coefficients and multiple regression analysis results on a sample of 27 European countries from 1995 to 2009, estimates positive returns of R&D intensity and public education spending on the employment rate, which is negatively correlated with public debt. According to the aforementioned study, fiscal consolidation should be implemented with GDP growth rather than following balanced budget rules or increasing taxation. This paper comes close to the proposed research question, but has two drawbacks: the dependent variable is employment, while our target variable is the rate of innovation; moreover, this is measured as government R&D spending, and government spending on education is also used, while it would be preferable to use the number of patents earned, as a proxy for actual innovative R&D spending. A second study that is useful for these purposes, but in which micro-level data are also used, is Croce et al. (2019). Specifically, based on a combination of U.S. macroeconomic data, information on stock returns, and firm-level accounting data from 1975 to 2013, the authors predict that (innovative) high R&D firms are riskier and more exposed to debt policy shocks. When government debt increases, these firms pay higher expected returns because their risk premium and cost of capital increase. This leads to a decrease in investment in innovative firms, whose cost of capital is more sensitive to the dynamics of government debt than low R&D-intensive firms. The authors also developed a stochastic endogenous growth model to respond to these empirical results.

Moreover, there is consensus in the literature on the positive relationship between R&D investment, innovation, TFP growth, and output growth, yet it has not yet been clarified how much and how public debt impacts economic growth (Heimberger (2021), Saungweme and Odhiambo (2018)). Other existing empirical papers are limited to analyzing the relationship between public debt (sometimes including foreign debt) and economic growth (citing some of the leading papers, Reinhart and Rogoff (2010a), Reinhart and Rogoff (2010b), Abbas and Christensen (2010), Cordella et al. (2010), Afonso and Jalles (2011), Checherita-Westphal and Rother (2011), Minea and Parent (2012), Kourtellos et al. (2013), Szabó (2013), Panizza and Presbitero (2014), Égert (2015), Woo and Kumar (2015), Bökemeier and Clemens (2016)), but innovation rate is never considered as a dependent variable.

From the methodological point of view, the objective here is to estimate the relationship between innovation rate, public debt, and debt monetization rate, controlling for other explanatory variables (human capital, initial GDP per capita, trade openness, and inflation). Because we rely on already developed empirical strategies, we perform several panel threshold regressions with Fixed Effects. Our sample consists of 15 industrialized countries (European and non-European) from 2000 to 2019, who compose our panel dataset. Regarding this analysis, we follow the empirical approach to panel estimation proposed by Roodman (2009). Concerning the construction of the panel data and the econometric techniques to be used, being dataset agnostic, a paper with a methodology similar to the one we implement is Carvelli and Trecroci (2021).

The main findings of the paper are as follows. First, analyzing the sample of 15 industrialized countries from 1989 to 2019, we find that both the relationship between public debt and innovation and the relationship between monetization rate and innovation are nonlinear. Modeling this nonlinearity with threshold regressions, we also find that a 1 p.p. increase in public debt pushes innovation by 0.02 p.p. when public debt is less than 109.6% of GDP, while it leads to a 0.10 p.p. reduction in innovation if the debt/GDP ratio exceeds the critical threshold.

When the debt-to-GDP ratio exceeds the 109.6% threshold, however, we find that one tool (alternative to increasing debt) for increasing innovation is debt monetization. In fact, for debt/GDP levels less than 144%, a 1 p.p. increase in the monetization rate results in a 0.03 p.p. increase in the innovation rate. While for debt levels greater than the latter threshold, an increase in the monetization rate may also be detrimental to innovation growth: a 1 p.p. increase in the monetization rate corresponds to a 0.17 p.p. decrease in the innovation rate.

Finally, we find a final constraint on the use of monetization to finance debt if the ultimate goal is to push innovation. In fact, our results show that the nonlinearity in the relationship between monetization and innovation consists of an inverted U-shaped relationship, where the critical threshold of the monetization rate is 16.61%. For initial levels less than this, increasing the monetization rate by 1 p.p. increases the innovation rate by 0.06 p.p., while above the threshold this decreases by 0.06 p.p..

In addition to being unique in the literature analyzing public debt, this paper can provide preliminary policy implications on the management of debt monetization. From this work, countless ad hoc studies can be developed for individual economies, including testing what is the best instrument or mix of instruments to finance the debt and thus boost innovation and economic growth.

The rest of the paper proceeds as follows. In Section 2, we present the empirical methodology implemented. The data used are described in Section 3, while results are shown in Section 4. Finally, Section 5 concludes.

2 Empirical Methodology

In this work, we study the relationship between innovation rate, public debt, and debt monetization rate firstly estimating a Fixed Effects (FE, hereinafter) panel model specification. The theoretical model is the following:

$$Y_{it} = \alpha + \sum_{j=1}^{J} \beta_j X_{jit-1} + \sum_{k=1}^{K} \delta_k Z_{kit-1} + \sum_{\ell=1}^{N-1} \mu_\ell D_{\ell i} + \sum_{s=t_0}^{t_{T-1}} \tau_s D_{st} + \epsilon_{it}, \tag{1}$$

where $i = 1, ..., N$ is the country index, $t = t_0, ..., t_T$ is the time index, X_j is the j-th regressor and Z_k is the k-th control variable. Moreover, we have $N-1$ individual dummies, as $D_{\ell i} = 1$ if $i = \ell$ and $D_{\ell i} = 0$ if $i \neq \ell$, and $t_T - t_1$ temporal dummies, as $D_{st} = 1$ if $s = t$ and $D_{st} = 0$ if $s \neq t$. This specification can also be written as follows:

$$Y_{it} = \alpha + \mu_i + \tau_t + \sum_{j=1}^{J} \beta_j X_{jit-1} + \sum_{k=1}^{K} \delta_k Z_{kit-1} + \epsilon_{it}. \tag{2}$$

Thus, we assume that both the regressors and the control variables are strictly exogenous conditional on the unobserved individual and time effects μ_i and τ_t (Chamberlain (1984))[1].

The dependent variable Y for our purposes is the innovation rate, the regressors X_j are public debt, the square of public debt, and the monetization rate of public debt, while we use human capital, trade openness, inflation and GDP per capita as control variables Z_k. We will estimate several regressions by combining these variables in Section 4 with FE and robust standard errors. By adding this option, we assume that errors are only correlated within individuals and not across them.

In a second step, we estimate the regression just described using the single-threshold panel fixed

[1] When we turn to sample estimation in Section 4, we will remove the time dummies from the specification in (1) and (2), as they do not turn out to be significant from statistical tests.

effects method[2], as follows:

$$Y_{it} = \alpha + \mu_i + \sum_{j=1}^{J} \beta_{1j} X_{jit-1}(q_{it} < \gamma) + \sum_{j=1}^{J} \beta_{2j} X_{jit-1}(q_{it} \geq \gamma) + \sum_{k=1}^{K} \delta_k Z_{kit-1} + \epsilon_{it}, \tag{3}$$

where the β_1 and β_2 coefficients depend on the threshold parameter γ estimated for the threshold variable q_{it} (Hansen (1999)). We use both the public debt and the debt monetization rate as threshold variables (estimating separate regressions). In other words, by estimating (3), we assume that the generic β coefficient associated with the X_{jit} regressor changes whether the threshold variable q_{it} is greater or less than a certain threshold parameter γ.
Alternatively, this model can be written as follows:

$$Y_{it} = \alpha + \mu_i + \sum_{j=1}^{J} \beta_j X_{jit-1}(q_{it}, \gamma) + \sum_{k=1}^{K} \delta_k Z_{kit-1} + \epsilon_{it}, \tag{4}$$

where

$$X_{jit-1}(q_{it}, \gamma) = \begin{cases} X_{jit-1} I(q_{it} < \gamma) \\ X_{jit-1} I(q_{it} \geq \gamma) \end{cases} . \tag{5}$$

In some regressions that we will present in Section 4, the threshold variable q_{it} coincides with the X_{jit} regressor (e.g., public debt), while in others they may not coincide (e.g., if we place government debt as the threshold variable q_{it} and the monetization rate as the X_{jit} regressor). In each case, we assume that the coefficients associated with the control variables Z_{jit} are fixed, regardless of the values assumed by the threshold variables q_{it}.

3 Data

Observations from 15 countries from 1989 to 2019 are collected in our original unbalanced panel dataset. We use the innovation rate as the dependent variable, while our main reference regressors are the public debt and the public debt monetization rate. We add human capital, trade openness, inflation, and GDP per capita as control variables to our dataset. The variables used as proxies, the source and time coverage are shown in Table 1.
Table 2 shows the summary statistics for our sample. Here, we report the mean, the standard deviation, the minimum, and the maximum values, both for the overall dataset, for the cross-section dimention[3] and for the time-series dimention[4]. For all the variables, except the monetization rate and inflation, the between variability is greater than the within variability. This means that the variability across countries is more important than the variability in time.

[2]We introduce this type of nonlinearity because, as outlined in Section 4, public debt squared turns out to be a significant variable.

[3]Every observation is the average value per country, in the "between" rows.

[4]Every observation is the average value per year, in the "within" rows.

Table 1: Dataset

Variable name	Definition	Measure	Source	Time coverage
Innovation Rate	Patent applications, residents	% of Total Population[a]	World Bank	1980-2020
Public Debt	Public debt	% of GDP	IMF	1989-2021
Monetization Rate	Government debt hold by Central Banks	% of Total Debt	IMF[b]	1989-2021
TFP	TFP level at current PPPs	USA=1	PWT 10.0[c]	1954-2019
Human Capital	Human capital index, based on years of schooling and returns to education	Index	PWT 10.0	1950-2019
Trade Openness	Goods And Services (BPM6): Sum of Exports and Imports, Goods And Services	% of GDP	World Bank	2005-2020
GDP per Capita	GDP per capita, PPP	constant 2017 international $	World Bank	1990-2020
Inflation	GDP deflator	%	World Banks	1961-2020
Population[d]	Total population	unit of people	World Bank	1960-2020

This table shows the variables used in the estimated regressions, the definition, measure, time coverage and source

[a] This is calculated as the number of patent applications per 10,000 population.
[b] Arslanalp and Tsuda (2014).
[c] Feenstra et al. (2015).
[d] This variable is used to scale the number of patents to build the proxy for the innovation rate.

Moreover, in Table 3, we report the contemporaneous correlations among variables. Public debt and the innovation rate are highly correlated (72.4%). The monetization rate is also very correlated with public debt (48.2%), while it has a not very high correlation with the innovation rate (39.4%). In Figure 1, we plot the time series of innovation rate for each country. Japan's innovation rate is much higher than the rest of the sample over the time horizon considered, although the series shows a downward trend since 2000. The lowest value for this country (about 20%, in 2019) is more than double the highest value for the second country in the sample (less than 10%, United States, 2019). In contrast, it is worth noting the increasing trend followed by the United States since 1989. The third country by innovation rate is Germany, which has maintained a stable value of around 6% since the 2000s. All other countries follow a stable dynamic throughout the time horizon, with rates ranging between 0 and 4%.

Figure 2 shows the time series of public debts in our sample. In most of the countries considered, public debt shows a downward trend until 2007, then increases and tends to fall back to pre-crisis values toward the end of the sample. Two important exceptions are the leading innovating countries. Japan follows an increasing trend, starting from a public debt of 50% of GDP in 1989 to 200% in 2019. In contrast, the United States follows the dynamic described for the rest of the sample, with higher values (in fact, they peak at 150% in the early 1990s).

Table 2: Summary Statistics

Variable		Mean	Std. Dev	Min	Max	Observations
Innovation Rate	overall	4.349	6.035	0.105	30.539	N=450
	between		6.054	0.657	25.356	n=15
	within		1.137	-1.574	9.532	T-bar=30
Public Debt	overall	63.316	33.777	8.400	203.000	N=459
	between		28.367	23.432	131.557	n=15
	within		19.594	-19.137	134.759	T-bar=30.6
Monetization Rate	overall	6.264	7.349	0.010	42.472	N=354
	between		4.293	1.536	15.924	n=15
	within		5.945	-5.241	32.812	T-bar=23.6
HC	overall	3.265	0.357	1.911	3.774	N=464
	between		0.344	2.244	3.614	n=15
	within		0.130	2.895	3.553	T-bar=30.9333
Trade Openness	overall	82.363	40.322	24.615	173.181	N=224
	between		41.308	27.864	157.557	n=15
	within		6.418	55.768	103.465	T-bar=14.9333
ln(GDP pc)	overall	10.643	0.185	9.975	11.045	N=438
	between		0.135	10.324	10.839	n=15
	within		0.133	10.293	10.888	T-bar=29.2
Inflation	overall	2.005	1.775	-2.311	11.670	N=449
	between		0.831	-0.010	3.777	n=15
	within		1.592	-2.802	10.772	T-bar=29.9

This table shows the summary statistics for the panel variables. We report the mean, standard deviation, minimum value, maximum value and sample size. These statistics are reported for the entire sample, cross-sectional dimension (between) and time dimension (within).

Table 3: Contemporaneous Correlations

Variable	Inn. Rate	Public Debt	Mon. Rate	HC	Trade Openness	ln(GDP pc)	Inflation
Innovation Rate	1.000						
Public Debt	0.724	1.000					
Mon. Rate	0.394	0.482	1.000				
HC	0.197	0.286	0.227	1.000			
Trade Openness	-0.462	-0.139	-0.265	-0.193	1.000		
ln(GDP pc)	-0.233	-0.044	-0.050	0.348	0.200	1.000	
Inflation	-0.410	-0.520	-0.135	-0.152	0.054	0.081	1.000

This table shows the contemporaneous correlations between the panel variables.

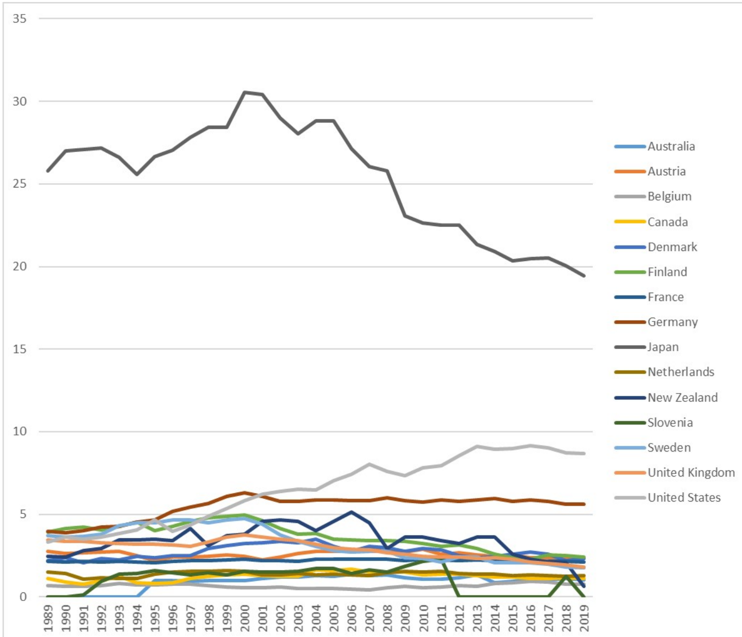

Figure 1: Innovation Rates

This figure shows the time series of the innovation rate for the 15 countries in the sample from 1989 to 2019.

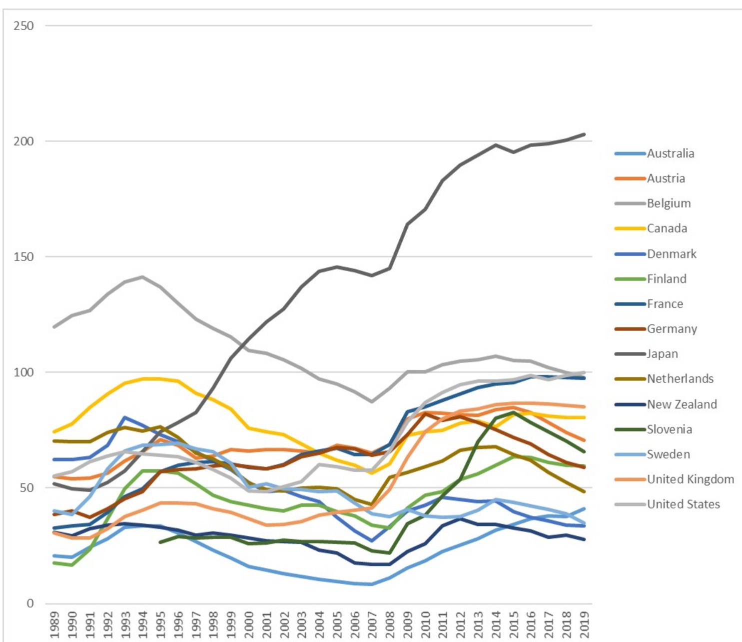

Figure 2: Public Debts

This figure shows the time series of public debt-to-GDP ratios for the 15 countries in the sample from 1989 to 2019.

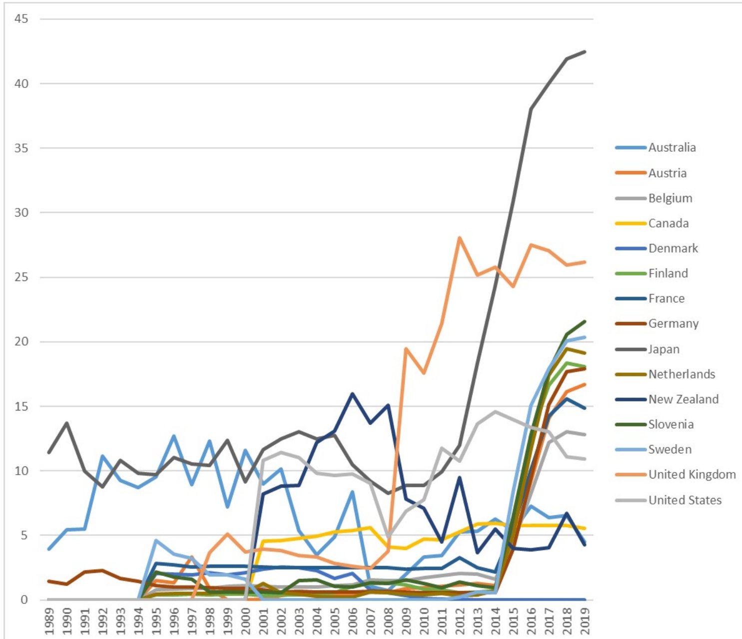

Figure 3: Debt Monetization Rates

This figure shows the time series of the monetization rate for the 15 countries in the sample from 1989 to 2019.

Regarding the monetization rate, the dynamics are very heterogeneous among countries, as shown in Figure 3. European countries have been monetizing their public debt since 2015, following an increasing trend with values ranging from 12 to 22% in 2019. In contrast, New Zealand peaked at around 15% in 2006, after which the monetization rate gradually declines over time. Japan has a more or less constant monetization rate of around $9-14\%$ until 2012, then follows a strongly increasing trend until 2019, reaching around 42%. A similar dynamic is followed by the United Kingdom, with average values stable below 5% until 2008 and following an increasing trend until the end of the sample (26%). Finally, the United States have a monetization rate of 11% in 2000 and 2019, with a lower peak of 5% in 2008 and a higher peak of 15% in 2014.

The data just described can be summarized by looking at Figures 4 and 5, in which the averages by year and country for the three variables of interest are plotted, respectively. Concerning Figure 4, it can be seen that the average innovation rate over time remained constant, at around 5%, while the average innovation rate increased from 2013-2014 (probably as a result of debt monetization of European countries), reaching 15% at the end of the sample. In contrast, the average public debt reached a first high in 1994 (65%), following a downward trend until the years of the financial crisis. Following this, since 2007, the average public debt of the countries considered increased rapidly, reaching nearly 80% in 2014, and falling back to less than 75% in 2019, following various policies to contain it.

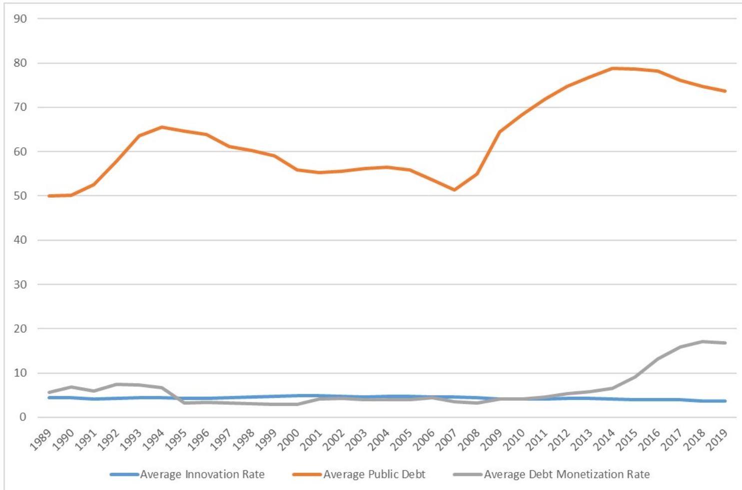

Figure 4: Average Values by Year

This figure shows the time series of the average value for each year of the innovation rate, the debt-to-GDP ratio and the monetization rate from 1989 to 2019.

Figure 5 shows the average values for each country. The countries are sorted in descending order from left to right according to the average innovation rate. It can be seen immediately that Japan's average rate (25.4%) is about four times the average rate of the second-largest innovator country, the United States (6.5%). The average innovation rate of other countries ranges from 5.5% (Germany) to 1.1% (Australia). The only country with an innovation rate below 1% is Belgium (0.7%). Regarding average public debt, the top 4 countries are Japan (131.6%), Belgium (110.6%), Canada (78.7%), and the United States (71.2%). Of these, the first and last are the leading innovators, while the others are among the bottom 3 in average innovation rate. Thus, based on this raw data visualization, it is not straightforward to interpret the relationship between public debt and innovation rate. Among the countries considered, only two have public debt less than 30%: Australia (23.4%) and New Zealand (28.8%). As for the average debt monetization rate, countries belonging to the European Union, except Sweden (7.1%), maintain a value of less than 5%. The country with the highest average rate is still Japan (15.9%), followed by the United Kingdom (14.0%) and the United States (10.8%).

The Figures just described allow us to better visualize what we have already shown in Table 2, namely, that differences between countries in the rate of innovation are much more important than the temporal variability of the series. We, therefore, expect that the best specification of the panel model to be estimated will include individual fixed effects, but reject time dummies[5].

[5]This hypothesis is verified with statistical tests reported in Section 4 and in Appendix.

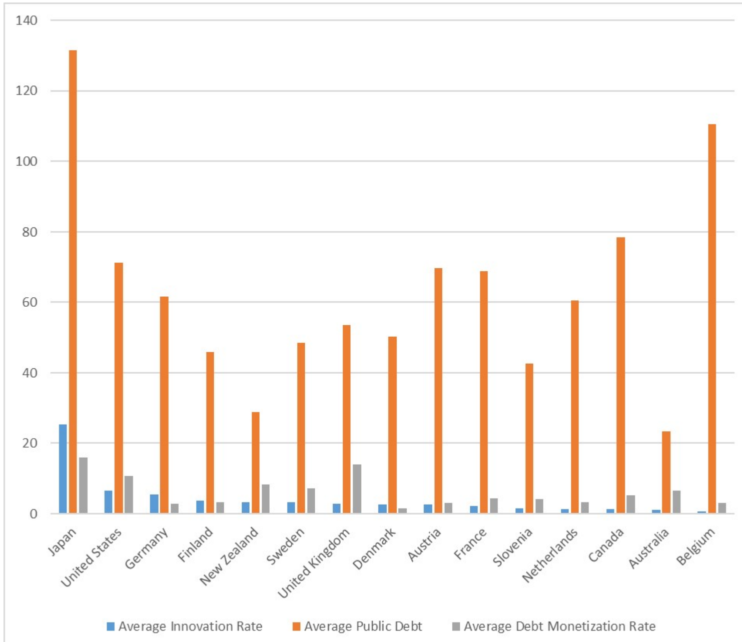

Figure 5: Average Values by Country

This figure shows the average values by country of the innovation rate, the debt-to-GDP ratio and the monetization rate.

4 Results

We estimate 2 using the panel dataset described in Section 3. For robust standard errors, we use the Eicker/Huber/White sandwich estimator of variance (Eicker (1967), Huber et al. (1967), White (1980), White (1982)). Our estimates cover the same sample of 15 countries with 3 different time horizons: 1989-2019, 1996-2019, and 2000-2019. Since public debt and the monetization rate are highly correlated (Table 3), we regress the innovation rate on public debt and the monetization rate separately. Furthermore, given the individual and temporal dummy tests in Table 7 in the Appendix, the best specification to be estimated includes only individual and not temporal effects. In Table 4, we report the results of our estimates with the sample from 1989 to 2019. We present 5 different specifications. The dependent variable is the innovation rate, while lagged public debt and lagged squared public debt are the regressors in specifications 1 and 2 (columns 2 and 3), and the lagged monetization rate and its squared value are the regressors in specifications 3, 4, and 5 (columns 4, 5, and 6). In specifications 2 and 4 we include lagged human capital, lagged trade openness, and lagged inflation as control variables, while in specification 5 we also include lagged GDP per capita as control variable[6]. We report the coefficients and the robust standard errors in parenthesis. At the bottom lines, the Table shows the number of observations, the R-squared, the p-value of the Hausman test, the number of countries, and if country and time FE are included in the regressions. The same

[6]This control variable is not included in the regression where public debt is among the explanatory variables, as there may be a mathematical correlation between the two variables. Public debt is in fact scaled with respect to GDP.

regressions are estimated with the sample starting in 1996 and in 2000 in Tables 8 and 9 in Appendix[7].

Table 4: Panel Estimations 1989-2019 (No Time Dummies)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate	(4) Innovation Rate	(5) Innovation Rate
$PublicDebt_{t-1}$	0.0628**	0.0558***			
	(0.0263)	(0.0186)			
$SquaredP.Debt_{t-1}$	-0.000433***	-0.000370***			
	(0.000116)	(6.61e-05)			
HC_{t-1}		-6.257**		-6.869**	-7.085**
		(2.480)		(2.326)	(2.654)
$TradeOpenness_{t-1}$		0.0146		0.00896**	0.00800
		(0.00860)		(0.00398)	(0.00619)
$Inflation_{t-1}$		0.00370		-0.0766	-0.0783
		(0.0340)		(0.0620)	(0.0676)
$MonetizationRate_{t-1}$			0.0898***	0.0853***	0.0849***
			(0.0265)	(0.0136)	(0.0139)
$SquaredMon.Rate_{t-1}$			-0.00607***	-0.00354***	-0.00355***
			(0.000708)	(0.000278)	(0.000295)
$ln(GDPpercapita)_{t-1}$					0.682
					(2.523)
Constant	2.636**	22.46***	4.880***	26.53***	20.02
	(1.091)	(7.245)	(0.115)	(7.682)	(23.43)
Observations	432	202	328	189	189
R-squared	0.408	0.614	0.313	0.448	0.449
Hausman p-value	0.000	0.000	0.002	0.004	0.008
Number of countries	15	15	15	15	15
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for five different specifications for the sample 1989-2019. The output variable is the innovation rate. In specifications 1 and 2, the variable is regressed on the lagged public debt and its squared value. In specifications 3, 4 and 5, the variable is regressed on the lagged monetization rate and its squared value. In specifications 2 and 4, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 5, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the p-value of the Hausman test, the number of countries, and whether country or year Fixed Effects are considered are reported.

[7] Because there are many missing data for the control variables, regressions that include them for the three time horizons produce the same results.

Table 5: Panel Estimations Threshold Regression 2000-2019 (Threshold on Public Debt)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate	(4) Innovation Rate	(5) Innovation Rate
HC_{t-1}		-4.894***		-4.442***	-5.360***
		(0.671)		(0.743)	(0.995)
$TradeOpenness_{t-1}$		0.00204		0.00589**	0.00487*
		(0.00177)		(0.00241)	(0.00252)
$Inflation_{t-1}$		0.0827***		0.0252	0.0278
		(0.0287)		(0.0377)	(0.0376)
$PublicDebt_{t-1}(d < d*)$	-0.00161	0.0199***			
	(0.00299)	(0.00383)			
$PublicDebt_{t-1}(d > d*)$	-0.117***	-0.105***			
	(0.00472)	(0.00462)			
$MonetizationRate_{t-1}(d < d*)$			0.000683	0.0273**	0.0286***
			(0.00968)	(0.0108)	(0.0108)
$MonetizationRate_{t-1}(d > d*)$			-0.204***	-0.173***	-0.173***
			(0.0127)	(0.0125)	(0.0125)
$ln(GDPpercapita)_{t-1}$					1.437
					(1.038)
Constant	6.027***	20.65***	4.672***	18.76***	6.514
	(0.182)	(2.088)	(0.0760)	(2.478)	(9.182)
Observations	247	247	247	247	247
R-squared	0.725	0.788	0.539	0.622	0.625
Number of countries	13	13	13	13	13
Threshold Variable	Public Debt	Public Debt	Public Debt	Public Debt	Public Debt
Threshold value	109.6	109.6	144.0	144.0	144.0
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for five different specifications for the sample 2000-2019. The output variable is the innovation rate. The threshold variable is public debt. In specifications 1 and 2, the variable is regressed on the lagged public debt. In specifications 3, 4 and 5, the variable is regressed on the lagged monetization rate. In specifications 2 and 4, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 5, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the number of countries, the threshold value, and whether country or year Fixed Effects are considered are reported.

The Hausman tests in all specifications in Tables 4, 8, and 9 are all significant at $\alpha = 0.01$ level, meaning that Fixed Effects is the right model to estimate. Looking at the results of specifications 1 and 2 of Table (4), we find that both public debt and its square are significant at the $\alpha = 0.05$ level in both estimated regressions. The coefficient associated with public debt is positive, while the coefficient associated with squared public debt is negative, indicating the presence of nonlinearity in this relationship. These results are similar to those obtained in regressions with restricted time samples (Tables 8, and 9), which are still significant at the $\alpha = 0.05$ level. Based on these results, we hypothesize that the nonlinearity is best interpreted by estimating the regression with a threshold on public debt. We expect public debt to positively affect the innovation rate if contained within a certain threshold, beyond which the effect could be negative.

Moreover, regarding the monetization rate, the variable is significant at the $\alpha = 0.01$ level in all specifications and the same nonlinearity just described arises. The same results are obtained in the alternative samples used for robustness checks (Tables 8 and 9). Thus, since the coefficient associated to the monetization rate is positive and the coeffficient associated to its squared value is negative, we decide to model this nonlinearity a regression using a threshold on the monetization rate.

To estimate the regression in 3 we rely on the method developed by Wang (2015). Our sample consists of 13 countries from 2000 to 2019, as this type of model applies only to balanced panels. The list of countries is available in Table 10 in Appendix. Firstly, we use lagged public debt as the threshold variable. The results are shown in Table 5. In specifications 1 and 2, lagged public debt is the nonlinear regressor, while in specifications 3, 4, and 5, it is the lagged monetization rate. As previously described, in specifications 2 and 4, lagged human capital, lagged trade openness, and lagged inflation are used as control variables, while, in specification 5, GDP per capita is also included.

The threshold value on estimated public debt is 109.6. In specification 1, for debt levels below the threshold, the variable is not significant, while it negatively impacts the innovation rate when debt exceeds the threshold. We mainly rely on specification 2, both because we control for the level of human capital, trade opennessm and inflation, and because the R-squared is larger. In this specification, both coefficients associated with public debt are statistically significant at the $\alpha = 0.01$ level. A 1 p.p. increase in the debt-to-GDP ratio leads to a 0.02 p.p. increase in the innovation rate in the following year for debt-to-GDP levels below 109.6%. For debt-to-GDP levels greater than or equal to 109.6%, the same increase leads to a 0.10 p.p. decrease in the innovation rate in the following year. Tables 11 and 13 in Appendix show some robustness checks for these results.

A nonlinearity also emerges when considering the monetization rate. When control variables are not included (specification 3), it is not significant below the critical debt/GDP threshold, while the impact is negative for debt values above the threshold. Again, we prefer specifications 4 and 5, for the reasons already explained. In both, the coefficients associated with the monetization rate are significant at the $\alpha = 0.05$ level. When the monetization rate increases by 1 p.p., the innovation rate increases by about 0.03 p.p., for debt/GDP levels below 144%. Above this threshold, the same increase in the monetization rate leads to a decrease in the innovation rate of 0.17 p.p.

Alternatively, we assume that the threshold variable is the monetization rate. Here we only assume that there is a threshold in the monetization rate such that above or below it an increase in the monetization rate impacts differently on the innovation rate. We do not assume that this nonlinearity impacts the ratio of public debt to innovation. The results of these regressions are presented in Table 6. For robustness checks, in Tables 12 and 14 in Appendix, we perform the same threshold regressions with a sample ending in 2018 and 2017, respectively. In specification 1, we regress the innovation rate only on the lagged monetization rate, while in specification 2 we add lagged trade opennes, lagged human capital, and lagged inflation as control variables. Finally, in specification 3, we also include the logarithm of GDP per capita as a control variable.

Table 6: Panel Estimations Threshold Regression 2000-2019 (Threshold on Debt Monetization Rate)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate
HC_{t-1}		-4.624***	-5.115***
		(0.917)	(1.230)
$TradeOpenness_{t-1}$		0.0127***	0.0122***
		(0.00287)	(0.00300)
$Inflation_{t-1}$		-0.0943**	-0.0934**
		(0.0453)	(0.0454)
$MonetizationRate_{t-1}(m < m*)$	0.0580***	0.0641***	0.0650***
	(0.0195)	(0.0189)	(0.0190)
$MonetizationRate_{t-1}(m > m*)$	-0.0814***	-0.0618***	-0.0615***
	(0.0105)	(0.0115)	(0.0115)
$ln(GDPpercapita)_{t-1}$			0.767
			(1.279)
Constant	4.402***	18.85***	12.32
	(0.113)	(3.054)	(11.32)
Observations	247	247	247
R-squared	0.306	0.427	0.428
Number of countries	13	13	13
Threshold Variable	Monetization Rate	Monetization Rate	Monetization Rate
Threshold Value	16.16	16.61	16.61
Country FE	YES	YES	YES
Year FE	NO	NO	NO

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for three different specifications for the sample 2000-2019. The output variable is the innovation rate. The threshold variable is the monetization rate. In all specifications, the variable is regressed on the monetization rate.In specification 2, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 3, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the number of countries, the threshold value, and whether country or year Fixed Effects are considered are reported.

For all three specifications, the coefficients associated with the monetization rate are significant at $\alpha = 0.01$ level, and are positive for monetization rates below the threshold and negative for monetization rates above the threshold. However, we prefer the specifications with control variables, as the R-squared is higher. Furthermore, the identified threshold value of the monetization rate is 16.61%. The results therefore suggest that, for monetization rates below 16.61%, an increase in the monetization rate by 1 p.p. is associated to an increase in the innovation rate by 0.06 p.p. in the following year. Conversely, for monetization rates above the threshold, an increase of 1 p.p. of this provokes a (mirror-image) decrease of 0.06 p.p. in the innovation rate.

The comparison of the regressions estimated in Tables 5 and 6 thus shows that in order to increase the innovation rate, new public debt can be issued when it does not exceed the critical threshold of 109.6% of GDP. If the debt-to-GDP ratio of the economy under consideration is greater than this threshold, there remains another tool to be used to incentivize innovation, and that is to use an increase in debt monetization, provided that the debt does not exceed 144% of GDP and that the monetization rate is not already greater than 16.61%.

5 Conclusion and Further Extentions

This paper provides a first attempt to empirically analyze the relationship between innovation rate, public debt, and monetization. To the best of our knowledge, no similar work exists in the literature. Using a panel of 15 countries from 2000 to 2019, our results are as follows. First, we identify a nonlinear relationship between public debt and innovation rate. When public debt exceeds a certain threshold, it becomes detrimental to technological innovation. The debt turning point is around 110% of GDP. In addition, nonlinearities also characterize the relationship between debt monetization rate and innovation rate: for too high monetization rates, an increase in the share of monetized debt negatively impacts innovation. The same happens when public debt exceeds 144% of GDP.

Several policy implications can be drawn from here. In developed countries, to foster economic growth via technological innovation, public debt could be raised to 110% of GDP. Moreover, the practice of debt monetization is not harmful if it is contained within certain limits. Therefore, to ease the debt burden and boost technological innovation, developed countries could monetize up to 17% of their public debt (understood as the share of debt held with the central bank). However, when the debt-to-GDP ratio exceeds 144%, monetizing further is not recommended, as one would have to act on the markets' confidence in that particular economy or macroeconomic fundamentals. In any case, we do not intend with this paper to delve deeper into the study of the governance and regulation of the public debt monetization process by central banks, given also the different relationships between them and fiscal authorities in the countries considered.

To extend this work, it would first be worthwhile to study the empirical literature and analyze the transmission mechanism of the abovementioned relationships with different empirical methods. We propose to analyze the causal link between an increase in debt and possible channels that could impact the innovation rate, such as increased R&D expenditure or the financial conditions of private companies (Caselli (2019)). This would then require establishing the link between debt and the channel and between the latter and the innovation rate, mapping the nonlinearity that results from this work.

Instead, additional robustness checks could be developed in a companion paper, as the results obtained here are driven by the chosen sample. For example, one could use the method of local projections or construct SVAR models comparing results between countries that can monetize debt (Japan) or not (Eu countries). Finally, one could re-estimate the panel regressions reported here, using a Central Bank Independence Index such as the one developed by Garriga (2016). However, this is only available until 2012, so we also propose to update and nowcast it. Alternatively, one could use the index just updated by Romelli (2022).

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Appendix

Table 7: Test for Individual and Time Effects

Sample	Effects	F	p-value
1989-2019	Individual	844.04	0.00
	Time	0.04	1.00
1996-2019	Individual	622.66	0.00
	Time	0.05	1.00
2000-2019	Individual	521.36	0.00
	Time	0.06	1.00

This table shows the results of the F-test when the innovation rate is only regressed on country dummies or time dummies for the three samples 1989-2019, 1996-2019, and 2000-2019.

Table 8: Panel Estimations 1996-2019 (No Time Dummies)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate	(4) Innovation Rate	(5) Innovation Rate
$PublicDebt_{t-1}$	0.0673**	0.0558***			
	(0.0254)	(0.0186)			
$SquaredP.Debt_{t-1}$	-0.000508***	-0.000370***			
	(9.28e-05)	(6.61e-05)			
HC_{t-1}		-6.257**		-6.869**	-7.085**
		(2.480)		(2.326)	(2.654)
$TradeOpenness_{t-1}$		0.0146		0.00896**	0.00800
		(0.00860)		(0.00398)	(0.00619)
$Inflation_{t-1}$		0.00370		-0.0766	-0.0783
		(0.0340)		(0.0620)	(0.0676)
$MonetizationRate_{t-1}$			0.0862***	0.0853***	0.0849***
			(0.0262)	(0.0136)	(0.0139)
$SquaredMon.Rate_{t-1}$			-0.00587***	-0.00354***	-0.00355***
			(0.000702)	(0.000278)	(0.000295)
$ln(GDPpercapita)_{t-1}$					0.682
					(2.523)
Constant	2.752**	22.46***	4.496***	26.53***	20.02
	(1.168)	(7.245)	(0.114)	(7.682)	(23.43)
Observations	338	202	304	189	189
R-squared	0.565	0.614	0.306	0.448	0.449
Hausman p-value	0.000	0.000	0.000	0.004	0.008
Number of countries	15	15	15	15	15
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for five different specifications for the sample 1996-2019. The output variable is the innovation rate. In specifications 1 and 2, the variable is regressed on the lagged public debt and its squared value. In specifications 3, 4 and 5, the variable is regressed on the lagged monetization rate and its squared value. In specifications 2 and 4, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 5, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the p-value of the Hausman test, the number of countries, and whether country or year Fixed Effects are considered are reported.

Table 9: Panel Estimations 2000-2019 (No Time Dummies)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate	(4) Innovation Rate	(5) Innovation Rate
$PublicDebt_{t-1}$	0.0573**	0.0558***			
	(0.0229)	(0.0186)			
$SquaredP.Debt_{t-1}$	-0.000499***	-0.000370***			
	(7.66e-05)	(6.61e-05)			
HC_{t-1}		-6.257**		-6.869**	-7.085**
		(2.480)		(2.326)	(2.654)
$TradeOpenness_{t-1}$		0.0146		0.00896**	0.00800
		(0.00860)		(0.00398)	(0.00619)
$Inflation_{t-1}$		0.00370		-0.0766	-0.0783
		(0.0340)		(0.0620)	(0.0676)
$MonetizationRate_{t-1}$			0.0845***	0.0853***	0.0849***
			(0.0222)	(0.0136)	(0.0139)
$SquaredMon.Rate_{t-1}$			-0.00532***	-0.00354***	-0.00355***
			(0.000596)	(0.000278)	(0.000295)
$ln(GDPpercapita)_{t-1}$					0.682
					(2.523)
Constant	3.349***	22.46***	4.376***	26.53***	20.02
	(1.119)	(7.245)	(0.102)	(7.682)	(23.43)
Observations	278	202	258	189	189
R-squared	0.603	0.614	0.292	0.448	0.449
Hausman p-value	0.000	0.000	0.000	0.004	0.008
Number of countries	15	15	15	15	15
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for five different specifications for the sample 2000-2019. The output variable is the innovation rate. In specifications 1 and 2, the variable is regressed on the lagged public debt and its squared value. In specifications 3, 4 and 5, the variable is regressed on the lagged monetization rate and its squared value. In specifications 2 and 4, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 5, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the p-value of the Hausman test, the number of countries, and whether country or year Fixed Effects are considered are reported.

Table 10: List of Countries Used in Panel Threshold Regressions

Country name
Australia
Austria
Belgium
Canada
Finland
France
Germany
Japan
Netherlands
New Zealand
Slovenia
United Kingdom
United States

This table shows the list of countries used in the samples for the panel threshold regressions.

Table 11: Panel Estimations Threshold Regression 2000-2018 (Threshold on Public Debt)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate	(4) Innovation Rate	(5) Innovation Rate
HC_{t-1}		-4.466***		-4.027***	-5.027***
		(0.716)		(0.768)	(1.015)
$TradeOpenness_{t-1}$		0.00181		0.00616**	0.00503**
		(0.00180)		(0.00244)	(0.00255)
$Inflation_{t-1}$		0.0865***		0.0323	0.0359
		(0.0283)		(0.0379)	(0.0379)
$PublicDebt_{t-1}(d < d*)$	-0.000783	0.0188***			
	(0.00297)	(0.00392)			
$PublicDebt_{t-1}(d > d*)$	-0.116***	-0.105***			
	(0.00474)	(0.00471)			
$MonetizationRate_{t-1}(d < d*)$			0.00676	0.0301**	0.0322***
			(0.0110)	(0.0118)	(0.0118)
$MonetizationRate_{t-1}(d > d*)$			-0.214***	-0.183***	-0.183***
			(0.0142)	(0.0140)	(0.0140)
$ln(GDPpercapita)_{t-1}$					1.598
					(1.066)
Constant	5.990***	19.30***	4.667***	17.35***	3.653
	(0.179)	(2.237)	(0.0782)	(2.559)	(9.479)
Observations	234	234	234	234	234
R-squared	0.731	0.787	0.529	0.607	0.611
Number of countries	13	13	13	13	13
Threshold Variable	Public Debt	Public Debt	Public Debt	Public Debt	Public Debt
Threshold Value	109.60	109.60	144.00	144.00	144.00
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for five different specifications for the sample 2000-2018. The output variable is the innovation rate. The threshold variable is public debt. In specifications 1 and 2, the variable is regressed on the lagged public debt. In specifications 3, 4 and 5, the variable is regressed on the lagged monetization rate. In specifications 2 and 4, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 5, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the number of countries, the threshold value, and whether country or year Fixed Effects are considered are reported.

Table 12: Panel Estimations Threshold Regression 2000-2018 (Threshold on Debt Monetization Rate)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate
HC_{t-1}		-4.612***	-4.985***
		(0.944)	(1.254)
$TradeOpenness_{t-1}$		0.0116***	0.0112***
		(0.00293)	(0.00306)
$Inflation_{t-1}$		-0.0876*	-0.0867*
		(0.0455)	(0.0456)
$MonetizationRate_{t-1}(m < m*)$	0.0564**	0.0664***	0.0672***
	(0.0218)	(0.0202)	(0.0203)
$MonetizationRate_{t-1}(m > m*)$	-0.0806***	-0.0660***	-0.0655***
	(0.0121)	(0.0127)	(0.0128)
$ln(GDPpercapita)_{t-1}$			0.593
			(1.310)
Constant	4.423***	18.88***	13.80
	(0.119)	(3.147)	(11.65)
Observations	234	234	234
R-squared	0.266	0.407	0.407
Number of countries	13	13	13
Threshold Variable	Monetization Rate	Monetization Rate	Monetization Rate
Threshold Value	15.99	16.61	16.61
Country FE	YES	YES	YES
Year FE	NO	NO	NO

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for three different specifications for the sample 2000-2018. The output variable is the innovation rate. The threshold variable is the monetization rate. In all specifications, the variable is regressed on the monetization rate.In specification 2, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 3, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the number of countries, the threshold value, and whether country or year Fixed Effects are considered are reported.

Table 13: Panel Estimations Threshold Regression 2000-2017 (Threshold on Public Debt)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate	(4) Innovation Rate	(5) Innovation Rate
HC_{t-1}		-4.232***		-3.699***	-4.758***
		(0.781)		(0.801)	(1.045)
$TradeOpenness_{t-1}$		0.00200		0.00619**	0.00540**
		(0.00189)		(0.00250)	(0.00260)
$Inflation_{t-1}$		0.0876***		0.0485	0.0444
		(0.0291)		(0.0388)	(0.0387)
$PublicDebt_{t-1}(d < d*)$	0.000105	0.0186***			
	(0.00310)	(0.00414)			
$PublicDebt_{t-1}(d > d*)$	-0.116***	-0.106***			
	(0.00497)	(0.00499)			
$MonetizationRate_{t-1}(d < d*)$			0.0166	0.0392***	0.0396***
			(0.0131)	(0.0136)	(0.0136)
$MonetizationRate_{t-1}(d > d*)$			-0.225***	-0.193***	-0.201***
			(0.0162)	(0.0160)	(0.0164)
$ln(GDPpercapita)_{t-1}$					1.725
					(1.102)
Constant	5.956***	18.54***	4.617***	16.18***	1.350
	(0.185)	(2.451)	(0.0836)	(2.673)	(9.870)
Observations	221	221	221	221	221
R-squared	0.724	0.776	0.523	0.597	0.602
Number of countries	13	13	13	13	13
Threshold Variable	Public Debt	Public Debt	Public Debt	Public Debt	Public Debt
Threshold Value	109.60	109.60	145.70	144.00	144.00
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for five different specifications for the sample 2000-2017. The output variable is the innovation rate. The threshold variable is public debt. In specifications 1 and 2, the variable is regressed on the lagged public debt. In specifications 3, 4 and 5, the variable is regressed on the lagged monetization rate. In specifications 2 and 4, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 5, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the number of countries, the threshold value, and whether country or year Fixed Effects are considered are reported.

Table 14: Panel Estimations Threshold Regression 2000-2017 (Threshold on Debt Monetization Rate)

Variables	(1) Innovation Rate	(2) Innovation Rate	(3) Innovation Rate
HC_{t-1}		-5.106***	-5.746***
		(1.005)	(1.325)
$TradeOpenness_{t-1}$		0.0102***	0.00951***
		(0.00310)	(0.00325)
$Inflation_{t-1}$		-0.0896*	-0.0871*
		(0.0471)	(0.0473)
$MonetizationRate_{t-1}(m < m*)$	0.0723***	0.0885***	0.0914***
	(0.0262)	(0.0258)	(0.0262)
$MonetizationRate_{t-1}(m > m*)$	-0.0795***	-0.0550***	-0.0536***
	(0.0147)	(0.0150)	(0.0151)
$ln(GDPpercapita)_{t-1}$			1.029
			(1.386)
Constant	4.367***	20.54***	11.71
	(0.133)	(3.350)	(12.36)
Observations	221	221	221
R-squared	0.237	0.368	0.369
Number of countries	13	13	13
Threshold Variable	Monetization Rate	Monetization Rate	Monetization Rate
Threshold Value	15.99	15.99	15.99
Country FE	YES	YES	YES
Year FE	NO	NO	NO

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

This table shows the estimated coefficients and standard errors for three different specifications for the sample 2000-2017. The output variable is the innovation rate. The threshold variable is the monetization rate. In all specifications, the variable is regressed on the monetization rate.In specification 2, the control variables lagged human capital, lagged trade openness, and lagged inflation are added, while in specification 3, the logarithm of lagged GDP per capita is also used. Finally, the number of observations, the R-squared, the number of countries, the threshold value, and whether country or year Fixed Effects are considered are reported.