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The regulatory precondition to sovereign risk transmission

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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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Abstract

This paper examines the role of regulation on how sovereign risk shocks affect bank balance sheets using a panel local projection approach and a newly created dataset of sovereign risk shocks for a sample of Eurozone banks. The empirical results show the existence of a regulatory precondition to sovereign risk transmission: banks that receive a favorable regulatory treatment in the form of a zero percent risk weight tend to increase home sovereign debt holdings and decrease lending in response to sovereign risk shocks. In contrast, comparable banks that face a stricter regulatory treatment, which requires them to calculate positive risk weights, do not exhibit this behavior. The results suggest that reforming the regulatory treatment of sovereign debt could mitigate the transmission of sovereign risk to bank balance sheets.

Keywords: Banks, Government Policy and Regulation, Sovereign Debt
JEL Codes: G21, G28, H6

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1 Introduction

The transmission of sovereign risk to bank balance sheets played a key role in the dynamics of the European sovereign debt crisis. The literature has identified several sovereign risk transmission channels, but has not addressed whether the regulatory treatment of sovereign debt impacts the transmission of sovereign risk to bank balance sheets. This paper seeks to address this question. With banks holding a more substantial share of sovereign debt, it is essential to have a sound understanding of how regulatory policies could minimize the sovereign-bank nexus.

The literature has identified several ways banks respond to higher home sovereign risk and yields by buying more home sovereign debt. One finding is that sovereigns may engage in moral suasion to incentivize banks to purchase sovereign debt [Acharya and Steffen 2015] [Acharya and Rajan 2013], especially when governments have some control over the bank [Altavilla et al. 2017] [Ongena et al. 2019][Horvath et al. 2015] and [Becker and Ivashina 2017]. Additionally, banks may reach for yield offered by risky sovereign debt without bearing the consequences of such investments (i.e., a sovereign default), also labeled "risk shifting" [Diamond and Rajan 2011] [Crosignani 2021] [Acharya and Steffen 2015] [Farhi and Tirole 2017]. Finally, carry trades, enabled by long term refinancing operations, can also play a role [Acharya and Steffen 2015].

The literature has established that lending to sovereigns crowds out lending to the real economy [Popov and Van Horen 2013] [Altavilla et al. 2017] [De Marco 2019] [Acharya et al. 2018]. These studies find that increases in sovereign stress reduce lending by banks. The transmission of risk to bank balance sheets operates through multiple channels. Popov and Van Horen [2013] and De Marco [2019] find that it operates through the impairment of sovereign debt, where reductions in the value of the sovereign debt reduce lending. Popov and Van Horen [2013] show convincingly that this is not due to reductions in credit demand or borrower quality. De Marco [2019] shows that unrealized losses on sovereign debt result in crowding out effects.

However, these explanations pay little attention to the role of regulation: Could regulation reduce the transmission of sovereign risk to bank balance sheets? This paper argues that regulation plays a critical enabling role in the transmission of sovereign risk to bank balance sheets.

To study the impact of regulation, this study compares two groups of banks. One group is subject to a favorable treatment in the form of zero percent risk weights on sovereign debt. The other group has to calculate positive risk weights on sovereign debt. The group with the unfavorable treatment are so-called "IRB banks" that use internal models to calculate capital requirements for most exposures, including sovereign exposures. The group with the favorable treatment are so-called "PPU banks" that use internal models to calculate capital requirements for most exposures, just like IRB banks, but benefit from an exemption ("permanent partial use"; PPU) that allows them to apply a zero percent risk weight to their sovereign exposures.

To identify sovereign risk, I construct a novel dataset of sovereign risk shocks. These shocks are identified by taking changes in the sovereign credit rating or rating outlook and measuring the change in the 10-year government bond spread vs. Germany in a 1-day window after the rating / outlook change. The spread is an indicator of sovereign risk, because it reflects the additional risk premium demanded by market participants above the German government bond yield. This response reflects the news embedded in the rating or outlook change. This identification approach is analogous to identification in the monetary policy literature [Altavilla et al. 2019, Jarociński and Karadi 2020].

These sovereign risk shocks enter a panel local projection, where the sovereign risk shock is interacted with the regulatory treatment of each bank to identify how the transmission of sovereign risk depends on the regulatory treatment over the 2009-2022 period.

The impulse responses from the local projections show that banks on the PPU treatment respond to increases in sovereign risk by increasing sovereign debt as a share of total assets. Additionally, PPU banks respond to increases in sovereign risk by reducing loans to euro area customers as a share of assets. Both effects are statistically significant. On the other hand, IRB banks do not show this behavior: there is no increase in the amount of sovereign debt as a share of assets, and there is no reduction in the amount of euro area loans as a share of assets. The point estimates of the impulse response of IRB banks actually show the opposite: they decrease sovereign debt and increase lending, but these effects are not statistically significant.

Together, these effects make up the core finding of this paper: sovereign risk transmission to bank balance sheets occurs when a bank meets the "regulatory precondition". Only if the bank uses a favorable regulatory approach to calculate risk weights on sovereign debt (i.e. the PPU approach), then it responds to sovereign risk shocks by buying sovereign debt and crowding out lending. In practice, banks that are exempted from calculating positive risk weights on (home) sovereign deb and are allowed to calculate a 0% risk weight transmit sovereign risk to their balance sheets. Banks that calculate positive risk weights using internal models do not show this transmission. This study concludes that a favorable regulatory treatment is a precondition to sovereign risk transmission.

These results hold up under a variety of robustness checks. I show that the results do not change when including macroeconomic variables and argue that changes in macroeconomic conditions, such as decreases in loan demand, should affect IRB and PPU banks similarly. Several econometric concerns are also shown to not materially change the baseline result, including alternative definitions of the dependent variable, alternative sample definitions, and the possibility of the results being caused by a few banks that switch approach. Some smaller samples reduce the significance to the 10% level.

The rest of the paper is structured as follows. Section 2 discusses the regulatory treatment of sovereign debt in the EU. Section 3 discusses identification, data and specification. Section 4 goes into the core result of this paper. Section 5 presents the robustness checks. Section 6 concludes and discusses the policy implications.

2 The regulatory treatment of sovereign debt

It is common knowledge that banks can apply a zero percent risk weight to sovereign debt. What is less commonly known is that this does not hold for all banks. Banks that operate internal models to calculate risk weighted assets – so-called "internal rating based approach" (IRB) banks – have to calculate **positive risk weights for sovereign debt**. For example, some banks in Italy, Germany, France, and the Netherlands calculate positive risk weights on their sovereign portfolios.[1]

IRB banks are different from banks on the standardized approach. Under the standardized approach, the bank does not use an internal model but instead selects "standard" risk weights prescribed by regulation to calculate capital requirements. For most credit assets besides sovereign debt, the standardized approach risk weights are significantly higher than those of the internal models operated by IRB banks.

An advantage of using the IRB approach is that it translates to considerable capital savings. A significant disadvantage that inhibits banks from moving to IRB is the substantial cost of building and operating a set of internal models. So banks with smaller asset bases or who could not expect significant capital savings tend to remain on the standardized approach. Nevertheless, for the banks that have moved to IRB, the capital savings are clear; based on the sample used in this study[2] asset densities, measuring risk weighted assets as a share of total assets, are 11.7% lower for IRB banks on average, and average equity-to-asset ratios are 3.88% lower for IRB banks than SA banks. Please refer to Table 8 depicted in Section 4.2 for more background to these figures. Under Basel II, it became possible to move to IRB, so the larger banks moved approach in 2007-08. Smaller banks remained on the standardized approach. A total of 3 banks upgraded from SA to IRB during the sample period.

[1] Note that IRB banks are not evenly distributed over all countries; the questions this raises with regards to the impact of sample selection on the core result is checked for as part of the robustness analyses under in Section 5.

[2] These data were sourced from the EBA transparency exercise, and therefore have a smaller coverage than the IBSI data. At best, the data span the 2014-2022 period. Some variables, such as capital ratio's, are available less frequently and were collected manually in the course of other research.

	IRB	PPU	SA
AT	0	2	0
BE	1	2	1
DE	3	8	4
ES	0	5	4
FI	0	0	1
FR	0	5	3
IE	0	2	1
IT	1	4	2
NL	3	1	1
PT	0	2	2

Table 1: Approach frequency by country in 2014-12

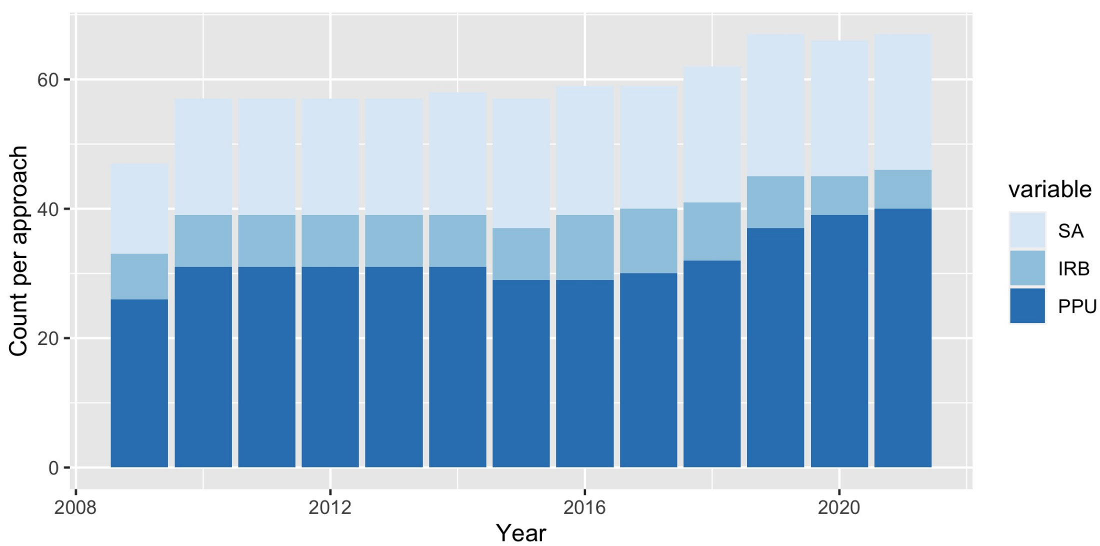

Figure 1: Regulatory treatment over time

The crucial detail is that IRB banks can apply for permission to apply standardized approach (SA) risk weights to their sovereign portfolio. This exemption is called "permanent partial use" (PPU). Banks with PPU can apply a zero percent risk weight to sovereign debt while still using IRB for other portfolios. This makes PPU banks similar to IRB banks, except for how they treat sovereign exposures. For SA banks, such a comparison is not valid, since how SA banks calculate risk weights for nearly all exposures differs from those of IRB / PPU banks. As I show Subsection 4.2, these SA banks differ on many other characteristics. Most crucially, SA banks are highly capitalized.

	Bank	New approach	Old approach
1	Banca Monte dei Paschi di Siena S.p.A.	PPU	IRB
2	Banco BPM S.p.A.	PPU	IRB
3	BPER Banca S.p.A.	PPU	IRB
4	Deutsche Pfandbriefbank AG	PPU	IRB
5	ING Groep N.V.	PPU	IRB
6	SFIL	PPU	IRB
7	Banca Monte dei Paschi di Siena S.p.A.	IRB	PPU
8	Société générale	IRB	PPU
9	Banca Popolare di Sondrio, Società Cooperativa per Azioni	PPU	SA
10	Mediobanca – Banca di Credito Finanziario S.p.A.	PPU	SA

Table 2: Banks that have switched approach

PPU needs to be granted by the supervisor after a request by the bank. Some supervisors granted PPU immediately upon the arrival of Basel II and to all the banks in their remit. For example, in Spain and Portugal, all IRB banks consistently benefit from PPU for all periods. However, supervisors did not allow PPU in other countries, such as in The Netherlands, where no bank had initially applied for or been granted PPU. Note that after the ECB took over supervision for many of the largest institutions, it also started to allow PPU applications from 2019 onwards, resulting in one Dutch bank changing its approach from IRB to PPU. In other countries, such as Germany, France, and Italy the approaches are mixed: some banks use IRB for their sovereign portfolio, while others use PPU. As a result, it is rare for banks to switch approaches. Table 2 shows the banks that have changed approach. 9 switches occurred, of which 5 banks moved from IRB to PPU. One bank moved from PPU to IRB. Three banks moved from SA to PPU, reflecting their adoption of internal models. As a result, regulatory approaches are highly stable. Nevertheless, as a robustness check, the results are reproduced excluding these switchers, see Subsection 5.4.

A key element of the identification strategy is that banks using the PPU approach are similar to those using the IRB approach regarding the transmission of sovereign risk, besides the regulatory approach on their sovereign portfolio. After applying a large set of controls, one can conclude that the regulatory approach drives the results. While under Section 5 I show how the specification is robust to differences between banks, an analysis of the bank

	mean	median	sd	max	min	nonna
Log(Total assets)	11.79	11.60	1.10	14.19	9.48	5299.00
Log(Equity)	9.13	9.18	1.33	11.56	5.38	5299.00
Equity to asset ratio	8.06	7.16	4.45	25.52	1.60	5299.00
Home sovereign debt to equity	0.66	0.48	0.83	8.79	-0.06	5299.00
Home sovereign debt to assets	4.26	3.92	3.51	19.92	-0.24	5299.00
Loans to assets	71.23	72.19	10.54	97.44	31.95	5299.00
Shock	-0.01	0.00	0.52	7.52	-8.90	5299.00

Table 3: Descriptive statistics for PPU banks

	mean	median	sd	max	min	nonna
Log(Total assets)	12.33	12.18	1.00	14.08	9.44	1319.00
Log(Equity)	9.45	9.35	0.97	10.79	5.38	1319.00
Equity to asset ratio	6.16	5.66	2.81	20.63	0.67	1319.00
Home sovereign debt to equity	0.48	0.37	1.15	36.69	-0.13	1319.00
Home sovereign debt to assets	2.78	1.93	2.96	49.41	-0.58	1319.00
Loans to assets	78.91	79.58	8.50	98.90	40.32	1319.00
Shock	-0.00	0.00	0.21	2.70	-2.96	1319.00

Table 4: Descriptive statistics for IRB banks

balance sheet ratios already demonstrates the absence of major differences between IRB and PPU banks. Table 3 and Table 4 show different bank balance sheet numbers for PPU and IRB banks, respectively. IRB and PPU banks are comparable in size, with Log(Total Assets) on average at 11.75 for PPU banks and 12.39 for IRB banks. Log(Equity) is, on average, 9.19 for PPU banks and 9.49 for IRB banks. The median values are closer together than the averages, reflecting that there are a few large banks in the IRB bucket. The equity-to-asset ratio is lower for IRB banks, with 5.86% for IRB vs. 8.12% for PPU banks. This is partially driven by country location; as you can see from Table 1 there are relatively more IRB banks in countries with low asset densities (such as NL, DE), resulting in lower equity-to-asset ratios on average compared to PPU banks. Note that the specification includes the SA banks as well, but I delegate the discussion of these banks to a robustness analysis under Section 4.2.

3 Empirical approach

3.1 Data

The empirical approach of this paper relies on three components: a set of exogenous country-level shocks, a panel of bank balance sheet variables, and a set of dummy variables identifying the regulatory approach the bank is on (IRB, PPU, SA). Together these form the basis for a panel local projection set-up. Below, I describe the data components and then proceed with outlining the specification.

3.1.1 Sovereign risk shocks

First, I identify exogenous shocks to sovereign risk, analogous to the event study identification approach in the monetary policy literature [Altavilla et al. 2019, Jarociński and Karadi 2020]. I track the change in the 10-year government bond yield versus Germany (labeled "the spread" throughout this paper) the one day window after a change in the credit rating or credit outlook of a sovereign.[3] These shocks are considered exogenous since each shock reflects an unexpected change in the spread after a change in the credit standing of a sovereign.

The shock is measured as the change in the spread, not the rating change itself. This is a key distinction since rating changes are often anticipated by market participants. Rating agencies usually follow one another when updating credit standing, suggesting that only the first mover presents news to the market resulting in a shock to the yield. The response is a measure of the degree to which the rating agency presents new information. While banks engage in bond-buying

With regard to the exogeneity of the shock, a concern is that the definition of the shocks way be dependent on the dependent variable. The reason is that based on the literature we know that banks buy home sovereign bonds when sovereign risk increases, and so when there

[3]Rating changes are typically announced outside trading hours, and so the delta between the day of the rating announcement and the day after the rating change will incorporate the rating change news.

		Count
1	# Total changes	193
2	# Rating changes	103
3	# Positive rating changes	73
4	# Negative rating changes	30
5	# Outlook changes	131
6	# Positive outlook changes	63
7	# Negative outlook changes	68

Table 5: Breakdown of frequency of rating and outlook changes

is a change in sovereign risk through a rating or outlook change, banks buy home sovereign bonds and affect the government yield and therefore the spread. However, this concern is not valid for two reasons. First, while the bond-buying mechanism is clearly present - and also again shown to exist in this study - this would actually dampen the size of the shock. More demand for sovereign bonds from banks will increases the bond price and decreases the yield. Second, in addition to the dampening effect, it is clear that the overall correlation between the yield and the shocks is low. This suggests the aggregate demand and supply dynamics in the market for sovereign bonds are therefore not associated with the shocks, suggesting that the impact of bank bond buying behavior in response to shocks has a limited impact on the yield, if any. All in all, this suggests that the concern of banks intervention in the sovereign bond market after a rating or outlook change is likely to dampen shock size; even then, there is little association between the shocks and the overall yield level.

I collect a panel of 103 rating changes, consisting of 73 upgrades 30 rating downgrades. There are a total of 131 outlook changes, made up of 63 outlook upgrades and 68 outlook downgrades. The total of 193 changes is lower than the sum of rating and outlook changes separately due to overlap between the two. Please refer to Table 5. The number of shocks varies over time, peaking at 35 changes in 2011, and decreasing to as little as a single shock in 2020. The shock descriptives, as per Table 6, show a varying number of shocks varies between countries. Countries that experiences sovereign stress (IE, IT, PT, ES) have a larger number changes, and the average shock tends to be larger with a larger standard deviation.

	Count	Mean	Median	Std.Dev
AT	10	-0.01	0.19	0.56
BE	14	-0.16	0.00	1.30
DE	4	0.00	0.00	0.00
ES	32	-0.05	-0.02	1.15
FI	9	-0.05	-0.10	0.23
FR	12	-0.10	-0.16	0.57
IE	40	-0.06	0.09	2.11
IT	25	-0.21	-0.30	1.35
NL	8	-0.04	-0.07	0.18
PT	39	-0.11	0.28	2.33

Table 6: Shocks by country

The daily shocks are aggregated to the monthly level through summation, since the balance sheet variables are available at a monthly frequency. Visual inspection of the shock series shows that is reasonable to expect the shocks to be serially correlated. The autocorrelation is 0.202 for the first lag. Such serial correlation is possible and common in the literature, according to Alloza et al. [2019]. The presence of serial correlation is not an issue per se, but it can affect the estimated impulse response. To deal with this, I follow the proposal from Alloza et al. [2019] and include leads of the shock in the local projection, as shown in the next section.[4]

3.1.2 Regulatory approach data

The regulatory approach is inferred from the EBA transparency exercise data. This data shows which banks calculate credit risk weighted assets using IRB , as it includes the total amount of RWA calculated under IRB. It also shows a portfolio breakdown and the amount of RWA per approach (IRB, SA). From this, it follows whether (i) a bank is on the IRB approach and (ii) on what approach the sovereign portfolio is. Note that the regulatory treatment was

[4]Alloza et al. [2019] distinguish between two types of IRF: one that shows the "most likely dynamic response of a variable to a shock based on historical data", and another one that shows "the response of the shock as if the shocks were uncorrelated". Since the paper already relies on high frequency identification of shocks, which makes the economic magnitude of the IRF less relevant, I show the second definition of the impulse response. This means I include leads of the shock up to $t + h - 1$ to ensure the serial correlation in the shocks does not affect the results.

	Mean	Median	Std. Dev.	Max	Min	NxT
Home Sovereign Debt / Assets	4.71	3.58	4.69	49.41	-0.58	9724
Euro Area Loans / Assets	62.21	64.43	15.99	100.16	0.17	9724
Sovereign risk shock	-0.01	0.00	0.50	7.52	-8.90	9724
Yield on 10yr g. bond	1.81	1.39	1.96	16.14	-0.71	9724
Equity / Assets	8.34	6.85	6.80	76.84	0.04	9724
Log(Total Assets)	11.61	11.42	1.12	14.19	6.62	9724
Log(Industrial Production)	0.18	0.10	4.36	54.53	-28.20	9724
Unemployment Rate	9.07	7.90	5.22	26.40	2.90	9724
Inflation	0.17	0.13	0.75	4.43	-2.49	9724

Table 7: Descriptive statistics

not always available from 2009 onward; the regulatory treatment was backfilled. This is not an issue as switches occur rarely, and is expected to be low during this period given that banks had to select an approach just two years earlier. Note that the regulatory data is at a biannual or quarterly frequency. This resulted in imputation between those periods to arrive at the monthly frequency at which I observe the balance sheet variables. This could impact the timing of the approach switch for banks that switched approach. Therefore, for the banks that have changed approach, the annual reports and disclosures were checked to obtain the accurate transition dates; please refer to Subsection 7.1 in the Annex.

3.1.3 Bank balance sheet variables

The second component consists of bank balance sheet items; I expect these to be affected by sovereign risk. Two key bank balance sheet variables are sourced from the Individual Balance Sheet Item (IBSI) statistics: home sovereign debt as a share of total assets and loans to euro area customers as a share of total assets. Together, these make up 70% of the bank balance sheet on average. I come to a total of 9891 observations, with an average time series of 143 for a sample of 69 banks. The descriptive statistics of the variables are displayed in Table 7.

3.2 Panel local projections specification

I investigate the relationship between the sovereign risk shocks, the regulatory approach through a panel local projection specification [Jordà 2005], that is to study the impact of shocks identified through an event study methodology [Kho 2024, Kloosterman et al. 2022, Jarociński and Karadi 2020, Altavilla et al. 2019]. The shocks should affect PPU, IRB and SA banks differently, which is why the regulatory approach is interacted with the shock.

The dependent variable is a bank balance sheet ratio at $h = 0, 1, 2, 3, \ldots, H$ steps into the future with $H = 11$ to allow for projections one year out. The panel local projection is then saturated with a large number of controls. All in all, this takes the following form:

$$Y_{ijt+h} = \alpha_{ij}^h + \gamma_t^h + \beta_1^h IRB_{ijt-1} * Shock_{jt} + \beta_2^h PPU_{ijt-1} * Shock_{jt} + \beta_3^h SA_{ijt-1} * Shock_{jt} + \omega^h Q_{ijt} + \epsilon_{ijt} \quad (1)$$

The dependent variable, Y_{ijt+h}, is either the home sovereign debt to asset ratio, $(\frac{HSD}{TA})_{ijt+h}$, or the euro area loans to asset ratio $(\frac{EAL}{TA})_{ijt+h}$. These variables indicate the share of the balance sheet the bank is allocating to sovereign debt and loans to euro area customers, respectively. [5] In the specification, $i = 1, 2, 3, ..., N$ indexes the banks, $j = 1, 2, 3, ..., J$ indices the country (sovereign) units, and $t = 1, 2, 3, ..., T$ months. The specification includes bank fixed effects (α_{ij}^h) and time fixed effects (γ_t^h). The standard errors are corrected for temporal and cross-sectional dependence using the method proposed by Driscoll and Kraay [1998]. The local projections are estimated using OLS.[6] The regulatory approach variables

[5] Note that non-euro area loans, total loans and other forms of real sector lending were included in the initial analysis as well. However, the baseline result is euro area loans since this is the economically most relevant effect at the highest aggregated level.

[6] Herbst and Johannsen [2024] point out that the time dimension of most local projections is significantly smaller than needed for unbiased inference, such as used by Jordà [2005]. This could be relevant here as the time dimension averages to 143. However, this is nto a concern for the results, as the core finding of Herbst and Johannsen [2024] is that the coefficient is biased *downwards* and so do not invalidate the outcomes. Rather, in the absence of an implementation of the bias corrected estimator of Herbst and Johannsen [2024], it should be noted that a removal of the bias would increase the point estimate and make the results

$[IRB_{ijt-1}; PPU_{ijt-1}; SA_{ijt-1}]$ are lagged one period, but that this does not materially affect the results.

A large set of controls is included and summarized in the control vector, Q_{ijt}, for the sake of brevity. Note that the control vector is extensive, as nearly all controls are interacted with the approach dummies, resulting in a large number of variables. The control vector includes three lags of the dependent variable.[7] For every $h > 0$, the shocks occurring in the period $[0; h-1]$ are included. For example, for period $h = 3$, the following shocks are included: $[Shock_{jt}, Shock_{jt+1}, Shock_{jt+2}]$. Including leads of the shock is necessary to control for any shocks that may also affect the outcome variables. Three lags of the shock are included as well, following [Alloza et al. 2019, Kloosterman et al. 2022, Montiel Olea and Plagborg-Møller 2021, Plagborg-Møller and Wolf 2021]. Dummies for the SA and PPU approaches are included separately as well. Three lags of industrial production, unemployment, inflation, the government bond yield, and the equity-to-asset ratio are included. Note that in the preferred specification, these controls are all interacted with the regulatory treatment to allow them to attain different values depending on the approach.

4 Results

4.1 PPU vs. IRB banks

To show how bank balance sheet variables respond to sovereign risk shocks, dependent on regulatory treatment, I depict the impulse response function (IRF) for the two dependent variables, HSD/TA and EAL/TA. The impulse responses are simply a collection of the coefficients of interest on the approach dummy interacted with the shock, reflecting a 1% sovereign risk shock, surrounded by a 95% confidence interval.

The first core result of this paper follows from Figure 2: PPU banks significantly increase

potentially more significant. Also, the results I present rely on a comparison of IRB and PPU. The bias of Herbst and Johannsen [2024] affects both parameters equally and so would not materially affect the results.

[7] Alternative lag structures were also employed, but this does not alter the outcomes of the result.

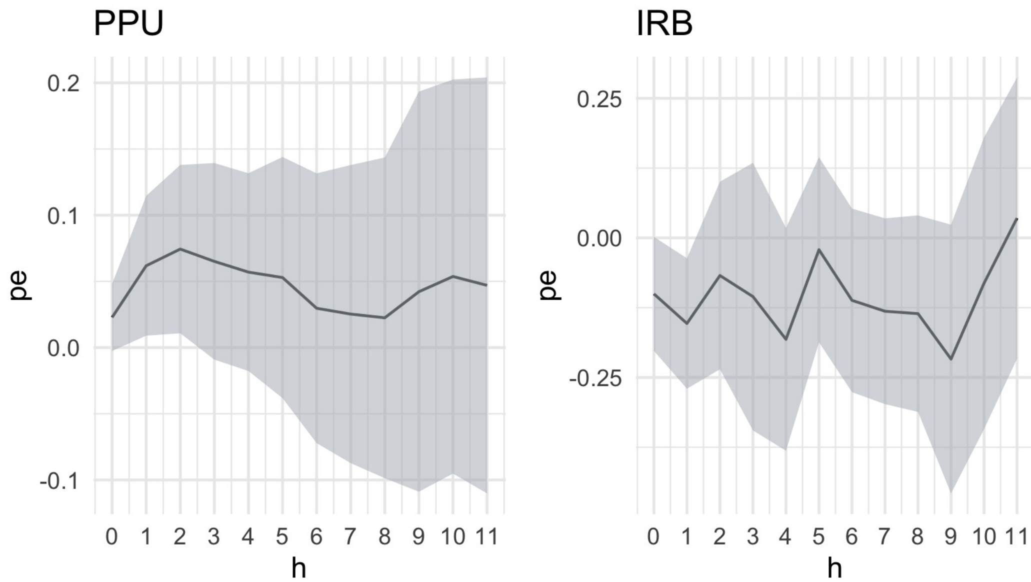

Figure 2: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{HSD}{TA}$)

the home sovereign debt to asset ratio in response to a sovereign risk shock, whereas IRB banks do not show an increase of the home sovereign debt to asset ratio. The results are reflected in the significance levels: PPU banks significantly increase home sovereign debt, while for IRB banks, the results are mostly not significantly different from zero (except for one period). However, the point estimates show stronger effects: whereas PPU banks increase sovereign debt as a share of assets, IRB banks tend to decrease sovereign debt.

To compare the response of bank balance sheets to sovereign risk, I conduct a number of coefficient tests to establish (in)equality. Coefficient tests for the hypothesis that the response to shocks, $\beta_1 = \beta_2$, are significant at the 5% level for periods $h = 0, 1$ for home sovereign debt to total assets. The difference is substantial for euro area loans to total assets at the $h = 1, 2, 3$ horizon. These results indicate that the coefficients are not only substantially different from zero but that the PPU and IRB banks are significantly different from each other. Towards the one-year horizon, there is less statistical evidence for differences in the response. This is not due to the point estimates since these do not seem to converge, but rather due to the widening of the confidence intervals. Such a result should not be surprising, as a one-day change in the government bond yield is unlikely to have effects a year out.

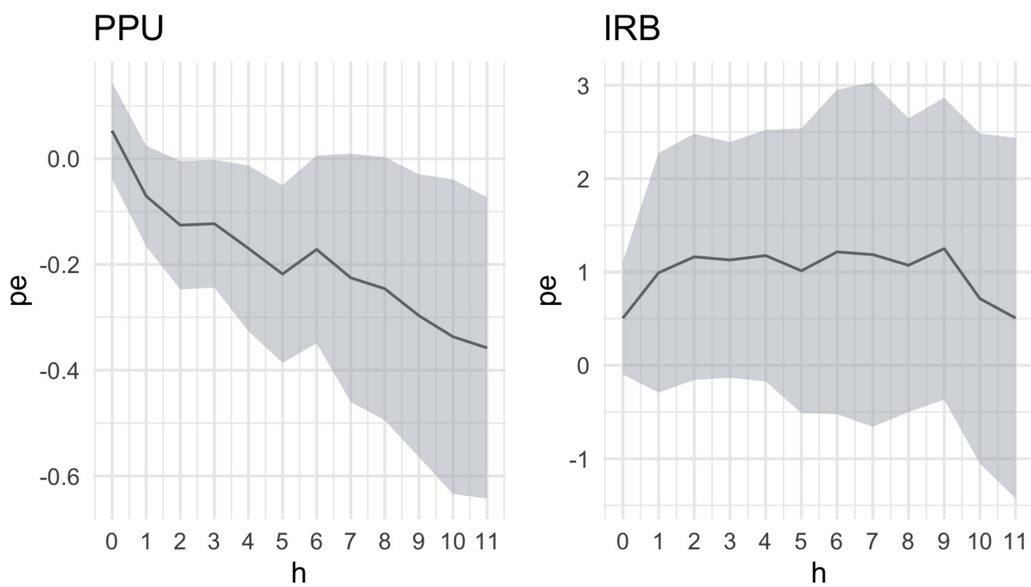

Figure 3: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{EAL}{TA}$)

The second core result follows from Figure 3, and shows that PPU banks decrease loans to euro area customers, while IRB banks do not show such behavior. This is statistically significant. PPU banks significantly decrease lending, while there is no statistically significant result for IRB banks. Coefficient tests for the hypothesis that the response to shocks, $\beta_1 = \beta_2$, are significant at the 5% level for periods $h = 1, 2, 3, 10$ for euro area loans to total assets. The point estimates show a striking difference. PPU banks reduce lending and do this at all $h > 0$, suggesting that lending by these banks persistently goes down and remains down for an extended period. However, IRB banks extend *more* lending, suggesting that these play a more supportive role. The total effect decreases in the last two periods. Nevertheless, the effect remains persistent over the full horizon. Such persistence is concerning as it may also suggest a confounding variable, but in Robustness Section 5.5 discusses why this persistence emerges.

Taken together, these results indicate the existence of a ”regulatory precondition” to sovereign risk transmission: only if the bank can use a lax regulatory treatment to calculate risk weights on sovereign debt (i.e. the PPU approach), then it responds to sovereign risk shocks by buying sovereign debt and crowding out lending. In contrast, IRB banks do not show this behavior. This suggests the mechanisms found in the literature such as risk shifting, moral suasion, carry trade incentives [Acharya and Steffen 2015] operate that when the regulatory precondition is met. Only when the regulatory precondition is there do sovereign exposures crowd out real sector lending as found in earlier studies [Popov and Van Horen 2013, Altavilla et al. 2017, De Marco 2019, Acharya et al. 2018].

Overall, the magnitude of the effects is small. A 1% increase in spread, which is quite a shock, would increase the amount of sovereign bonds as a share of total assets by 0.075 percentage points for PPU banks. Given an average home sovereign debt to asset ratio of 4.71%, this translates to a 1.5% increase in the amount of sovereign bonds for the average bank. Such a small magnitude is the result of the study design which attempts to identify causal effects. The estimation attempts to identify the "pure" effect of a single shock, controlling for future and lagged shocks and lagged shocks, which also means that any statistical persistence is excluded. Since this paper tries to identify the causal effect of a single shock and so needs to expunge potential serial correlation from the shock series, the IRF does not describe the most likely path of home sovereign debt to assets as "the most likely" IRF would include the statistical persistence - see for a more thorough discussion [Alloza et al. 2019].

4.2 SA vs. PPU banks

The dataset and baseline specification also includes the banks on the standardized approach. The reason for this is that banks switch approaches now and then, and would therefore decrease the sample size. Additionally, including these banks helps estimate estimate the unit and fixed time effects. When excluding the SA banks from the sample and re-estimated the baseline results, the impulse response function of PPU banks remains largely unchanged, but the confidence interval widens and so the results become less significant. At $h = 2, 3$ the coefficients are significant at the 10% level. Given the large drop in the sample size (ca. 31%) this is not surprising. Nevertheless, the hypothesis that IRB and PPU are equal to

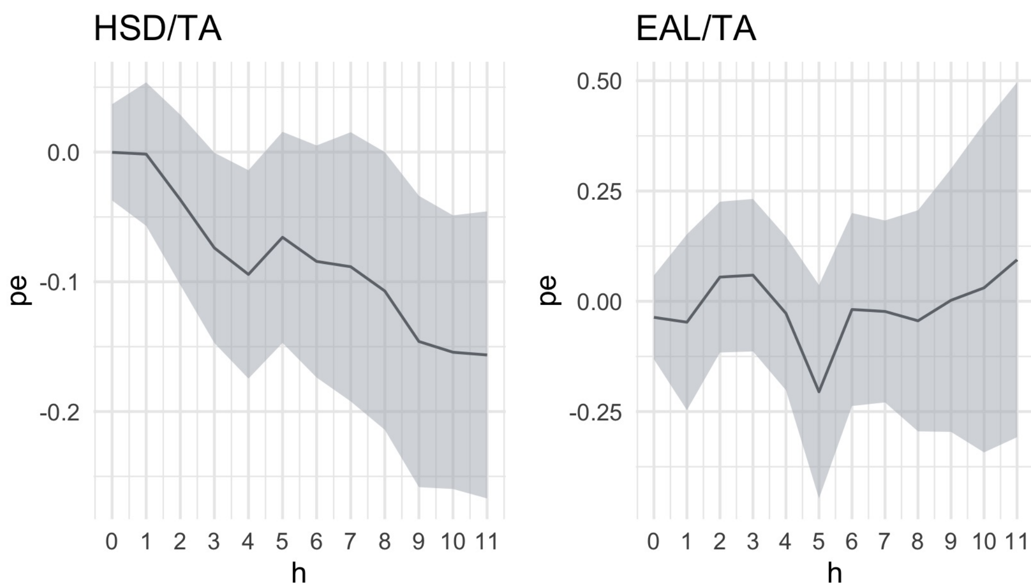

Figure 4: Impulse Response Function based (95% CI, 1% shock) on for SA banks with the left hand side showing ($\frac{HSD}{TA}$) and the right hand side showing ($\frac{EAL}{TA}$)

each other is rejected at a high level of confidence at several horizons (for $h = 1$ at the .05 level, for $h = 2$ at the .01 level, and $h = 3$ at the .1 level). As such, the conclusion remains that PPU banks respond to increases in sovereign risk by buying more sovereign debt than IRB banks.

SA and PPU banks benefit from the same treatment of sovereign debt, i.e., the zero percent risk weight. Therefore, one might expect SA and PPU banks to behave similarly: both apply a zero percent risk weight to sovereign exposures, so the same regulatory precondition is met. However, when looking at the IRFs from SA banks, they do not respond to sovereign risk shocks by buying more sovereign debt. They also do not decrease lending to euro area customers. Please refer to Figure 4 for the IRFs from the two baseline specifications. The fundamental question is: Would this not invalidate the regulatory precondition?

This argument hinges on the comparability of SA banks to PPU banks, which, in short, are not comparable: SA banks operate with a much higher capitalization. SA banks are similar in their approach to sovereign debt but differ in the risk weights for all their other exposures. The result is that they have much higher capital ratios, leverage ratios, and

	IRB	PPU	SA
CET1 ratio FL	15.34	14.87	28.01
Total Capital ratio TR	19.22	17.65	28.15
Leverage ratio FL	5.30	5.52	11.47
Asset density	31.72	37.40	43.38
TSCR+CBR CET1	9.69	8.91	8.74
TSCR CET1	6.56	6.09	6.08

Table 8: Average for prudential ratios by regulatory treatment

asset densities. SA banks' fully loaded CET1-ratio averages 28%, while PPU banks average slightly below 15%. They also have higher leverage ratios: where PPU banks have an average leverage ratio of 5.5%, SA banks operate with an 11.5% leverage ratio on average. These stylized facts align with the work of Crosignani [2021], who argues that highly capitalized banks have no interest in holding home sovereign debt. In contrast, low-capital banks tend to invest more in home sovereign debt when risk is high due to risk-shifting motives. This suggests that the high capitalization of SA banks should lead one to expect no response to sovereign risk shocks in the observed results.

5 Robustness

This section presents a variety of robustness analyses with regard to the key result. Some detailed analyses are delegated to the Annex, but summarized below.

5.1 Macro-financial conditions

The current state of the macro-economy is a function of sovereign risk shocks, and so affects banks through their operating environment. The core of this concern is that we might not be observing the effect of sovereign risk, but the effect of macroeconomic conditions, resulting from sovereign risk, on bank balance sheets. For example, decreases in lending could be the result of changes in loan demand, instead of crowding out behavior of banks. Macroeconomic conditions could, as such, be a confounding variable.

However, these confounding variables are already included in the baseline specification, measured through industrial production, unemployment, and inflation. Effects running from the shock to these variables should, therefore, be controlled for. Additionally, time fixed effects also control for common shocks. Finally, the IRB and PPU banks operate in identical environments; macroeconomic shocks do not explain why PPU banks behave differently from IRB banks. For example, a change in loan demand should affect IRB and PPU banks similarly, while the empirical results show a differentiated response.

Another channel is that of a "yield channel": sovereign risk shocks could drive up the yield on government bonds. Banks could be responding to changes in the yield and not so much to changes in sovereign risk. For example, one could imagine that banks have a proprietary assessment of sovereign risk and attempt to harvest "irrationally" high yields, defined as yields that diverge from their sovereign risk assessment. Especially in a crisis, it is possible for markets and banks to have differentiated views about the true level of risk.

However, the empirical results are robust to the inclusion of the yield. First, the results already control for any effects of the yield as yields enter baseline specification directly. Second, the correlation between sovereign yields and sovereign risk is low (Pearson's: -0.088, Kendall: -0.031).[8] Since the sovereign risk is a one-day response to a rating change and the yield is measured at a monthly frequency, such discrepancies are very well possible and show that the shocks are not necessarily related to the level fo the yield.

5.2 Valuation effects

One concern is that "valuation effects" could produce similar results. Such a valuation effect could occur because the balance sheet records a market value, and the market value of bonds responds to yields - when yields go up, the market value of a bond declines. The dependent variable measures the amount of home sovereign debt at market value compared to assets. When interest rates rise, the price of bonds declines and so would the amount of sovereign

[8]A similar picture arises when looking at first differenced yields: Pearson's: 0.072, Kendall: .036

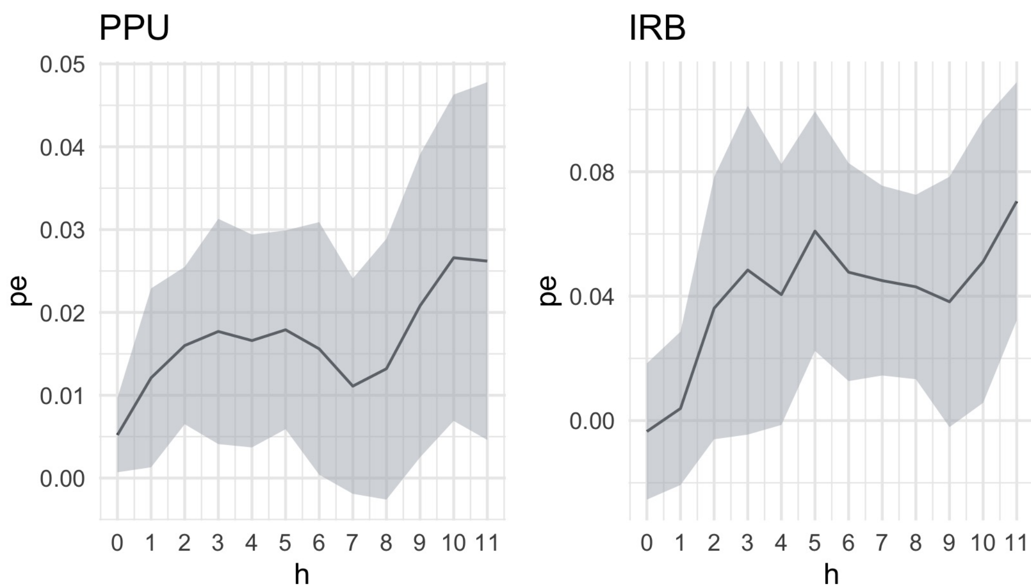

Figure 5: Impulse Response Function (95% CI, 1% shock) with dependent variable $ln(\frac{IndexHSD}{IndexTA})$

debt reported in the IBSI statistics. As the model relates home sovereign debt to sovereign interest rate shocks, this could introduce measurement issues. One could argue valuation effects contaminate the current results.

To remedy this, I rely on indices of notional stocks that are also part of the IBSI statistics. Such indices are cleaned of valuation effects and reflect the underlying notional amounts of debt instruments. Because these are indices, dividing the index of notional stocks of home sovereign debt by total assets will not create a meaningful variable since it does not contain information about the relative amounts of home sovereign debt to total assets. Minor changes may appear large when the notional amount is small, and large changes may appear small when the notional amount is substantial. This also introduces a measurement issue because the true notional amount is unobservable. The final measurement of the variable of interest settles on the log of the home sovereign debt to total assets, measured through indices of notional stocks. This variable is clean of valuation effects, and the impulse response reflects changes in home sovereign debt compared to the change in the asset base. The ratio is defined as follows: $ln(\frac{IndexHSD}{IndexTA})$.

The results are displayed in Figure 5. The IRF shows that PPU banks increase the notional amount as well. So, actual purchases occur and suggest that the valuation effects mute the significance of the baseline dependent variable defined in market value terms. There, thus, is a degree of a "technical" effect in the measurement of the dependent variable, which may also be driving the results from previous studies [Altavilla et al. 2017]. In the right-hand panel, one can see that IRB banks increase the amount of sovereign debt. However, at the same time, we know from the baseline specification that there is an (insignificant) decrease in market value. Decreases in market value and notional increases are not mutually exclusive. Sovereign debt purchases in notional terms are more than fully offset by decreases in market value. Such behavior is commensurate with banks targeting a minimum amount of sovereign debt on the balance sheet defined in market terms, such as required by the Liquidity Coverage Ratio: when there is a decrease in market value, banks buy more of it but this does not result in increases in the amount of sovereign debt measured in market terms. There is evidence that banks have incentives to hold a certain amount of sovereign debt [Bonner 2016].

5.3 Alternative dependent variables

The dependent variables are defined as a share of total assets. However, these could also be described in alternative ways. To that end, Figure 6 shows the results from Specification 1 with the dependent variable defined as the log of home sovereign debt, $Log(HSD)$. The overall trajectory of the results is confirmed, but the confidence interval widens. The IRF of the PPU banks is still positive for a sovereign risk shock, while the IRF is negative for IRB banks. The confidence interval, however, widens. The results are therefore no longer significant at the 5% level, but only at the 10% level. A similar IRF is shown in Figure 7: the general pattern is confirmed, but the results are less significant. Please refer to subsection 7.6 in the Annex for the IRF of a specification with $ln(TotalAssets)$ as the dependent variable; essentially, the IRF hovers around zero.

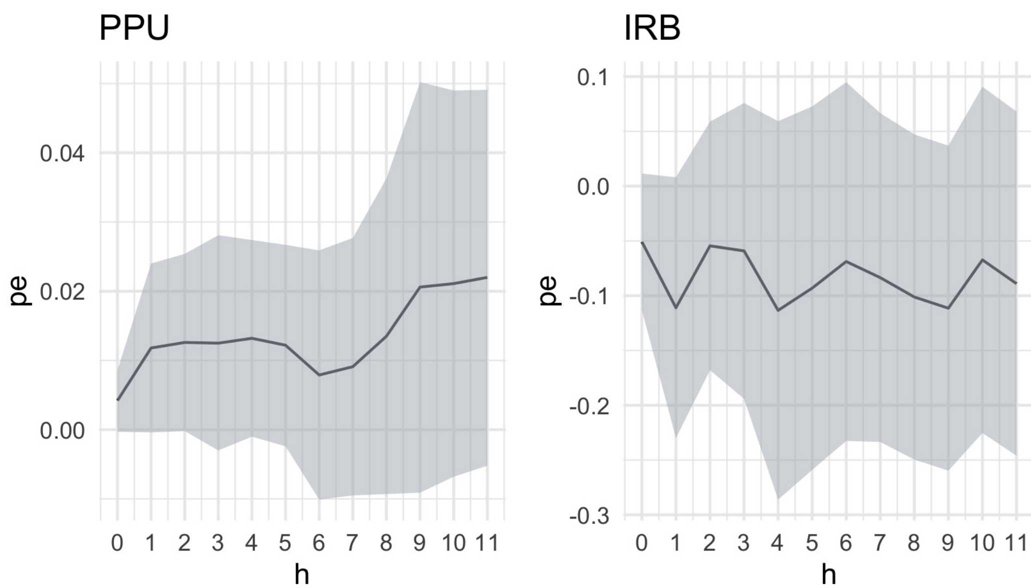

Figure 6: Impulse Response Function (95% CI, 1% shock) with dependent variable $ln(HSD)$

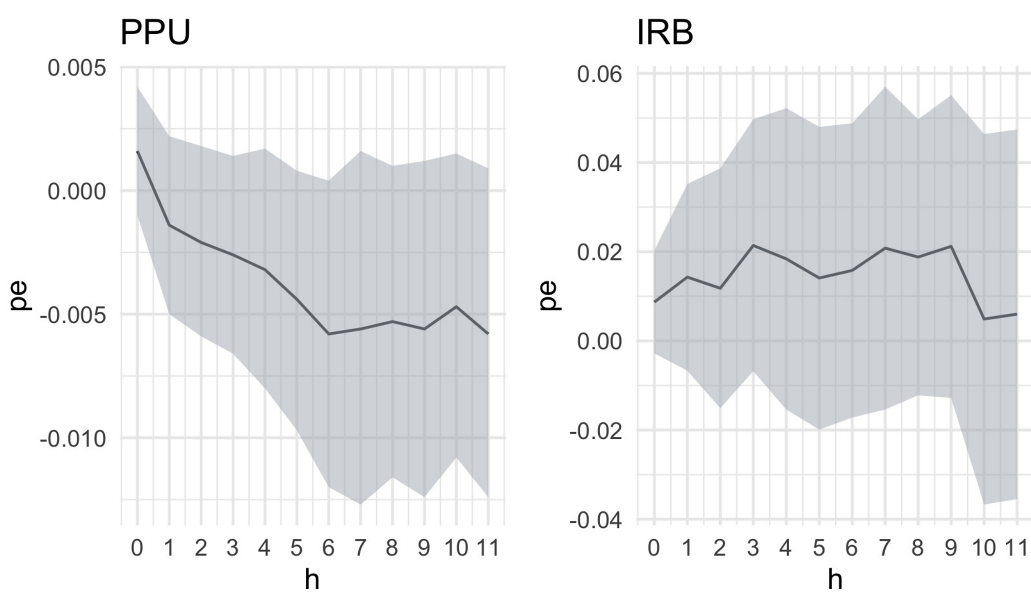

Figure 7: Impulse Response Function (95% CI, 1% shock) with dependent variable $ln(EAL)$

5.4 Alternative samples

The sample is restricted in several ways to show that the results remain valid even when excluding specific groups of banks from the estimation. For brevity, the detailed results are delegated to the Annex. Three checks were done. First, banks that have switched approach are excluded from the sample; this does not affect the result, showing that the identification of the effect is not due to the "switchers". Second, countries that do not have IRB and PPU banks are excluded from the sample, resulting in the exclusion of banks from Austria, Spain, Finland, Ireland, and Portugal. Excluding these countries from the sample does not affect the results materially. Third, I dropped Germany from the sample since this country has several IRB banks but does not experience any sovereign risk shocks, as the spread is, by definition, equal to zero.[9] None of these exclusions result in a material difference in the results.

5.5 Persistence of the EALTA IRF

The baseline result shows a high persistence of the effect of sovereign risk on EALTA, which is a cause for some concern, but additional checks show that this persistence can adequately be explained. A question raised by the persistence of the effect on lending to euro area customers is whether a one-day shock can have such persistent effects. An easier explanation is that some confounding variable here at work. Additional IRFs, not displayed here, that project beyond the $h = 11$ horizon show this persistent effect continuing beyond the 18 month horizon. To tease out the nature of this effect, I exclude the leads from the local projection, which shows that without including leads of the shock the IRF stabilizes at $h = 10$. This suggests that we are observing a peculiar case of dynamic IRFs Alloza et al. [2019]. Recall that we included the leads to show the effect of a single shock, and to ensure we are not conditioning on historical most likely trajectory of a shock that may include serial

[9]Note that Germany experienced only four rating changes in the entire dataset. It is not simply that the spread vs. Germany is zero by definition, using alternative definitions (such a s change in yield) would not result in significantly more shocks for Germany.

correlation, in line with Alloza et al. [2019]. However, contrary to the expectation that serial correlation leads to more pronounced IRFs, in this case excluding the leads results in less persistent effects instead of more persistent effects. This suggests there is some negative correlation between the shocks. When looking at correlation of the historical shocks, we see some small but negative correlations emerge after $h = 10$, suggesting that there is some cause of expecting negative serial correlation. Intuitively, this means that if a government continues to operate with a higher level or sovereign risk, loans to euro area customers exhibit a downward trend. In practice, governments aim to neutralize (the effects of higher) sovereign risk, which can explain a negative serial correlation between the shocks at higher horizons.

6 Conclusion

This paper explores the transmission of sovereign risk to bank balance sheets. Previous studies have found that increases in sovereign risk cause banks to buy sovereign bonds, which crowds out lending. As such, the transmission of sovereign risk to bank balance sheets has negative consequences for the real economy. But is there something that policy makers could do about this transmission? Empirical research into the role of regulation in the transmission of sovereign risk to bank balance sheets has not received similar attention.

This study finds that regulation plays a critical enabling role in the transmission of sovereign risk to bank balance sheets: a ”regulatory precondition” exists that determines whether sovereign stress affects bank balance sheets. Banks subject to a favorable treatment in the form of zero percent risk weights on sovereign debt, while using IRB for all other exposures, tend to engage in bond-buying and crowding out behavior in response to sovereign stress. Banks that are required to calculate risk weights using internal models for their sovereign debt show the opposite behavior.

These findings have policy implications. If policymakers want to avoid the negative consequences of sovereign risk shock transmission to bank balance sheets, banks should not be allowed to use the PPU approach. Alternatives, such as imposing positive risk weights on sovereign exposures as part of the standardized approach or requiring IRB banks to develop models for sovereign risk, could stem the transmission of sovereign risk. Essentially, positive capital requirements for sovereign debt would ensure that banks cannot load up on risk indefinitely while also ensuring bank owners have skin in the game.

However, policy has taken the opposite approach, making PPU mandatory for all banks relying on internal models. Under the new Basel reform, banks can no longer calculate risk weights for sovereign debt using internal models. This means banks are required to rely on the standardized approach, even if banks use internal models for their other exposures.[10] Essentially, the newest Basel reform entails that all banks will be put on the PPU approach, which, according to the results of this study, may increase the transmission of sovereign risk shocks to the real economy. The empirical evidence presented in this paper suggests that adjusting the regulatory treatment of sovereign debt could reduce the transmission of sovereign risk to bank balance sheets.

[10]This is the result of the new principle that banks should only use internal models if they have access to proprietary data on defaults and recoveries. For sovereigns, banks cannot have such proprietary data as sovereign defaults are widely available to the public.

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7 Annex

7.1 Manual adjustments for treatment switchers

The regulatory treatment is not directly observed in all periods. It is observed at a semi-annual or quarterly frequency, while government debt holdings are observed at the monthly frequency. As the regulatory treatment changes infrequently, the interpolation for the months within half a year not too problematic. However, it does introduce some mismeasurement for some periods when a specific institution switches. To address these mismeasurements the disclosures of switching banks were searched to pin down the transition dates and ensure that the portfolio type is accurate. This results in the following adjustments. Note that for one institution, Societe Generale, no information was found on the exact dating of the switch that occurred from PPU to IRB.

- **Banca Popolare di Sondrio**. The switch from SA to PPU did not occur in 2019-04 but per 2019-06 as per the following statement: "On 27 May 2019, the European Central Bank authorised the Banca Popolare di Sondrio Group to adopt its internal rating models for the purpose of determining the amount of capital requirements for credit risk (Advanced IRB Approach - A-IRB) relating to "Corporate" and "Retail" regulatory portfolios, with effects starting from the supervisory reporting at 30 June 2019."

- **Banco BPM** The switch from IRB to PPU for it sovereign portfolio occurred not 2018-10 but in 2018-03: "On 16 February 2018 Banco BPM S.p.A. received authorisation to use internal models to calculate capital requirements for the post-merger Banco BPM portfolio. This authorisation includes, in addition to the updated PD model, a new EAD retail model, and the ELBE and LGD Defaulted Asset model. Following the authorisation, Banco BPM must use the Add-ons (LGD parameter multipliers) until all the findings outlined by ECB in the authorisation letter have been resolved. These models have been used to calculate capital requirements starting from the reports issued on 31 March 2018"

- **ING** A ING credit update shows that the switch from IRB to PPU occurred in the third quarter, so the dataset was changed to reflect the change not per changed 2020-07 but per 2020-09.

- **Mediobanca** The switch from SA to PPU occurred because Mediobanca became an IRB bank in the first quarter of 2018, but only adopted the models in Q1-2019. This is shown by the following statement: ""As part of authorization process to use AIRB models in order to calculate the regulatory capital requirements for credit risk (the "Roll Out Plan"), following the authorization for the Mediobanca and Mediobanca International corporate lending portfolios, on 12 December 2018, CheBanca! received authorization to use internal PD and LGD models to calculate the credit risk deriving from its Italian mortgage loans. The adoption of the models for reporting purposes is conditional upon the PD metrics being revised for certain sub-portfolios. Actual usage of the models will therefore begin from 1Q 2019; the estimated saving in terms of RWAs is in the region of €1.4bn (average weighting for mortgages is below 20

- **Unicaja** The change from SA to PPU was reflected in the dataset not per 2021-04, but per 2021-06, per the following statement from an ad hoc disclosure: "The Governing Council of the European Central Bank has granted Unicaja Banco the authorisation to apply the A-IRB models to the calculation of credit risk capital requirements for its retail portfolio (not SMEs), which the bank had requested in January 2020. This authorisation will allow Unicaja Banco to apply these models by the end of June 2021. The bank estimates that this implementation will reduce its Risk Weighted Assets (RWAs) by around 3 billion euros and it will have a positive impact of approximately 200 bps on its Capital and CET1 Fully Loaded ratios. At 31 March 2021, the Capital and CET1 Fully Loaded ratios were 16.72% and 15.14% respectively Ad hoc disclosure".

7.2 Banks switching approach

Some banks switch approach over time. One concern is that the specification picks up mostly the effects of banks switching, and so does not provide a lot of information on the banks that remain steadily on a single approach. To show that this is not a concern, the baseline specifications are estimated on a sample that excludes the banks that have switched approach. Please refer to Table 2 for an overview of the banks that have switched. Figure 8 shows the IRF from the baseline specification estimated on this restricted sample. Clearly, there is no substantial impact of this more restricted sample. For euro area loans to total assets, based on the baseline specification, and depicted in Figure 9 there there is no substantial impact on the size or significance of the IRF.

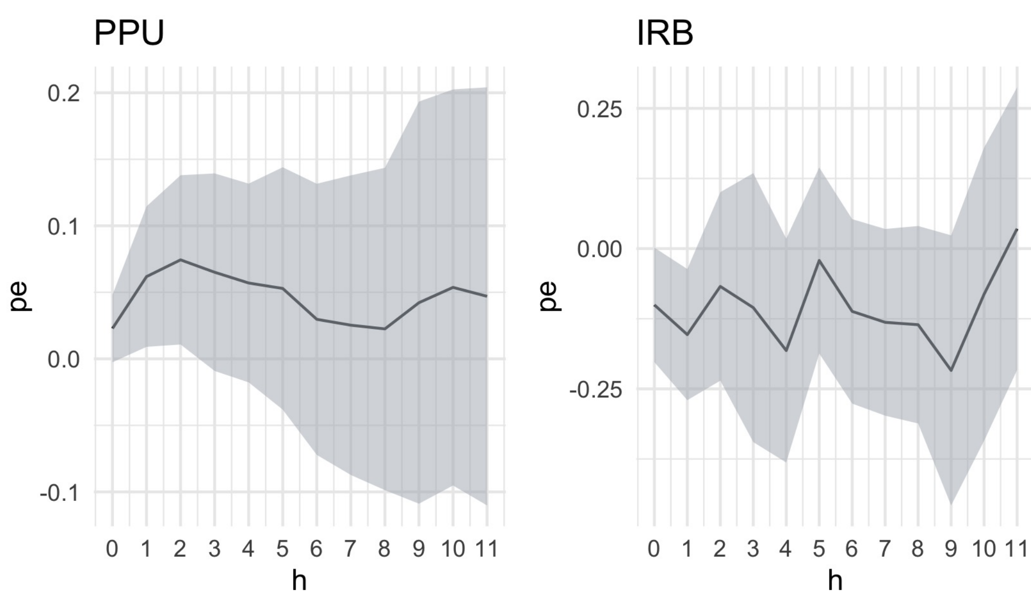

Figure 8: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{HSD}{TA}$) estimated on a sample that excludes banks that have switched approach

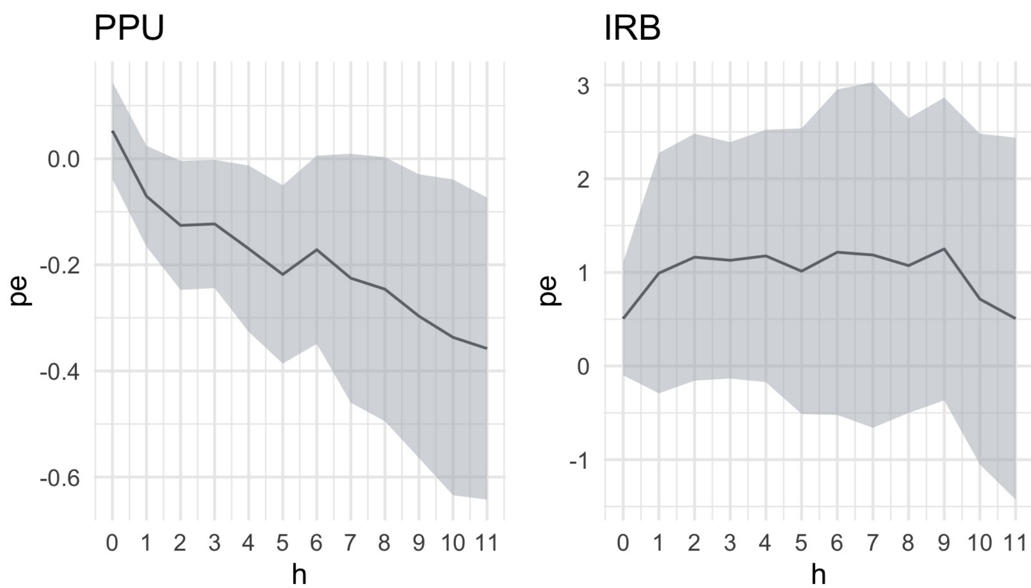

Figure 9: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{EAL}{TA}$) estimated on a sample that excludes banks that have switched approach

7.3 Sample excluding specific countries

A concern is that the bank approaches are not distributed evenly across countries, and that shocks are also not distributed evenly across countries. This could introduce a correlation between regulatory approaches and sovereign risk shocks; countries that only have PPU banks and experience many and / or large shocks could explain the result as well. As there are no IRB banks in these countries, it could very well be that we are observing the response by some banks in some specific countries - correlated with the PPU approach - instead of the "true" PPU response.

To that effect, I exclude countries that have no PPU banks in any of the periods. Therefore, I drop banks from Austria, Spain, Finland, Ireland, and Portugal from the dataset. The results are shown in Figure 10 for home sovereign debt to assets based on the baseline specification and in Figure 11 for euro area loans to assets based on the baseline specification. These figures show that excluding countries without IRB banks does not affect the results materially. There is a decrease in significance, but the overall effects remain highly similar.

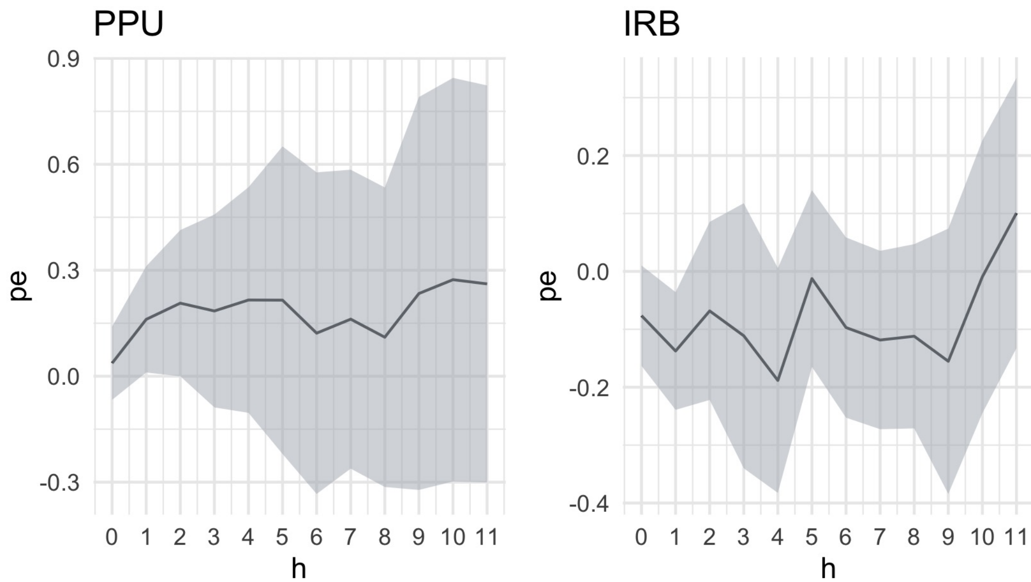

Figure 10: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{HSD}{TA}$) estimated on a sample excluding banks from Austria, Spain, Finland, Ireland, and Portugal

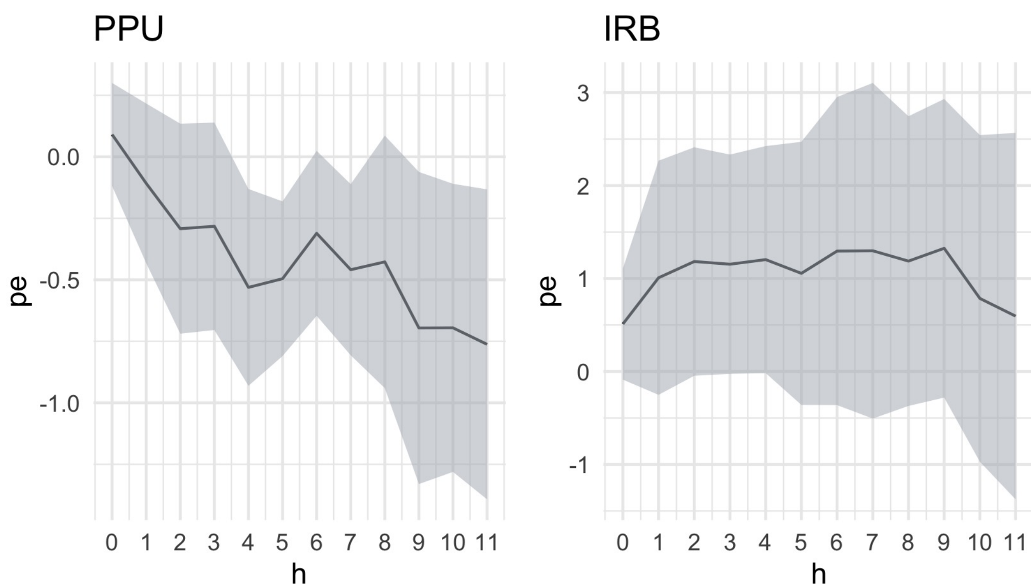

Figure 11: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{EAL}{TA}$) estimated on a sample excluding banks from Austria, Spain, Finland, Ireland, and Portugal

7.4 Excluding Germany

There are no sovereign risk shocks in Germany, as the spread is zero by definition. To provide assurance that this does not affect the results, the baseline specifications are estimated on a sample that excludes Germany. The results are not materially different from the baseline as you can see in Figure 13.

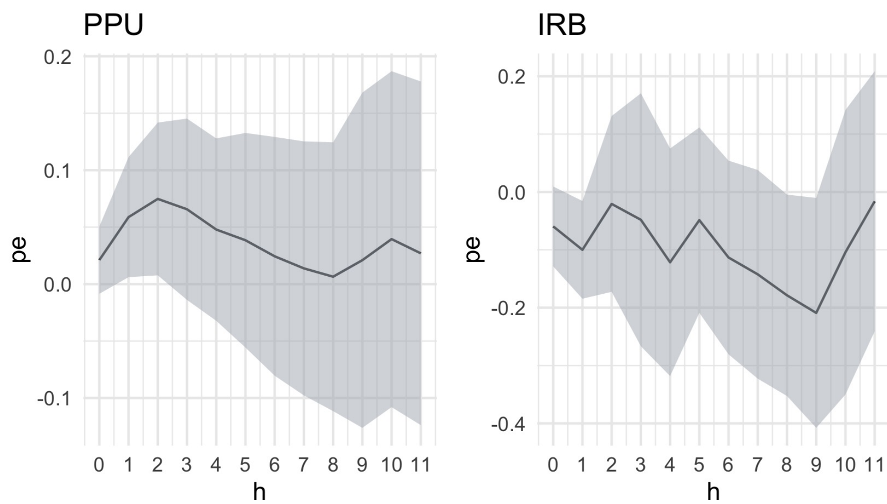

Figure 12: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{HSD}{TA}$) estimated on a sample that excludes German banks

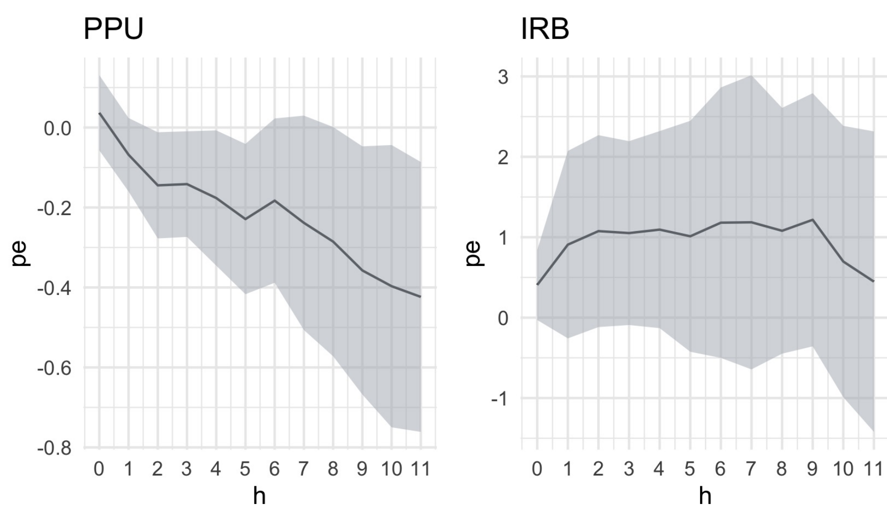

Figure 13: Impulse Response Function (95% CI, 1% shock) with dependent variable ($\frac{EAD}{TA}$) estimated on a sample that excludes German banks

7.5 Excluding SA banks from the sample

The chart below shows the IRF when excluding SA banks from the sample. It shows a decrease in the statistical significance; the 95% CI encapsulates the zero mean. However, such a decrease is also to be expected as the sample gets significantly reduced in size. The significance levels are slightly above the .1 cutoff. Nevertheless, when testing for the difference between IRB and PPU, it is clear that the results are still significant at the .05% level for $h = 1$.

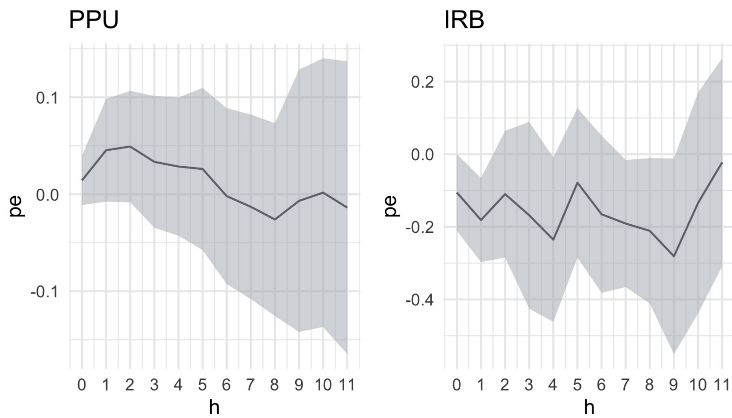

Figure 14: IRF of home sovereign debt to assets to a 1% shock with 95% confidence interval, excluding SA banks

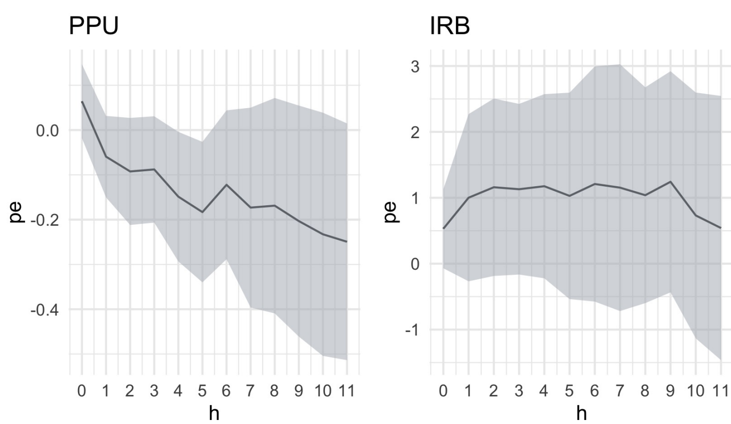

Figure 15: IRF of euro area loans to assets to a 1% shock with 95% confidence interval, excluding SA banks

7.6 IRF with log(TotalAssets) as dependent variable

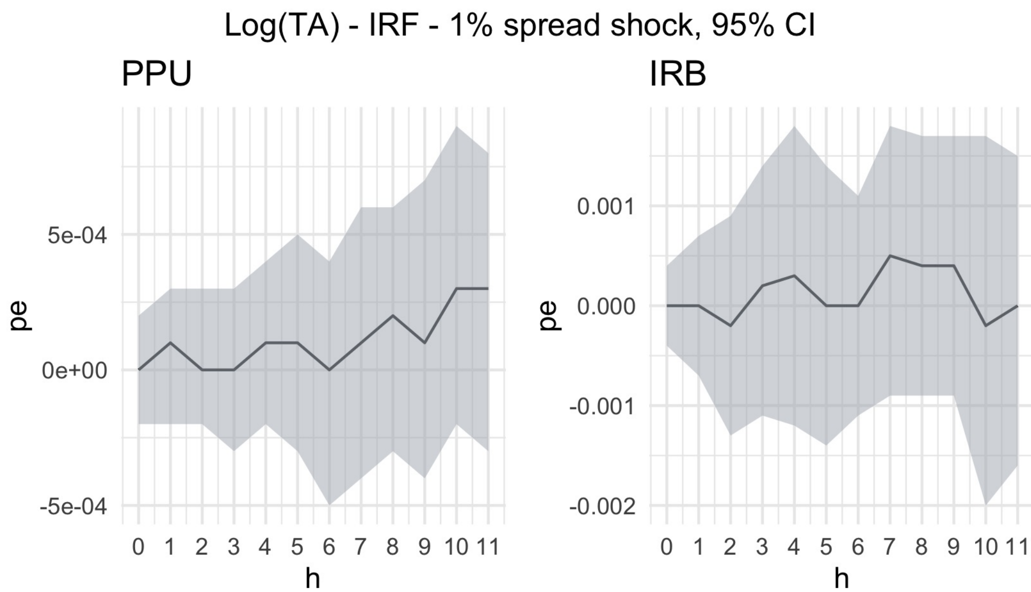

Figure 16: Impulse Response Function (1% shock, 95% CI) with dependent variable $ln(TA)$

7.7 Results from a Panel VAR

The baseline specification is based on a local projection approach. However, to show that the result is not an artefact of the econometric methodology, I produce similar results using an alternative econometric model int eh form of a panel vector autoregression (VAR). To that effect, I estimate a panel VAR based on subsets of the dataset including only IRB or PPU banks. The variables included are the same variables on the right and left hand side of the baseline specification. The model includes two lags. The ordering of the variable matters, where the shock is the first variable, the rate the second, followed by a set of macro and balance sheet variables. The home sovereign debt debt and euro area loans are the last two variables, also in that order. The shock is strictly speaking an exogenous variable. However, there is some persistence in the shock, and to obtain results similar to the local projection where I include leads of the shock, it is more robust to show it as an endogenous variable.

The IRF from the panel VAR for home sovereign debt to assets is shown in Figure 17. Here, a similar result is observed as in the baseline: PPU banks increase their home sovereign debt as a share of assets in response to a sovereign risk shock. IRB banks do not show such behavior. Similarly, for euro area loans, which is shown in Figure 18, PPU banks decrease their loans as a share of assets, while we see no such response in IRB banks. This confirms the baseline results, suggesting that the result applies even when estimated through a different methodology.

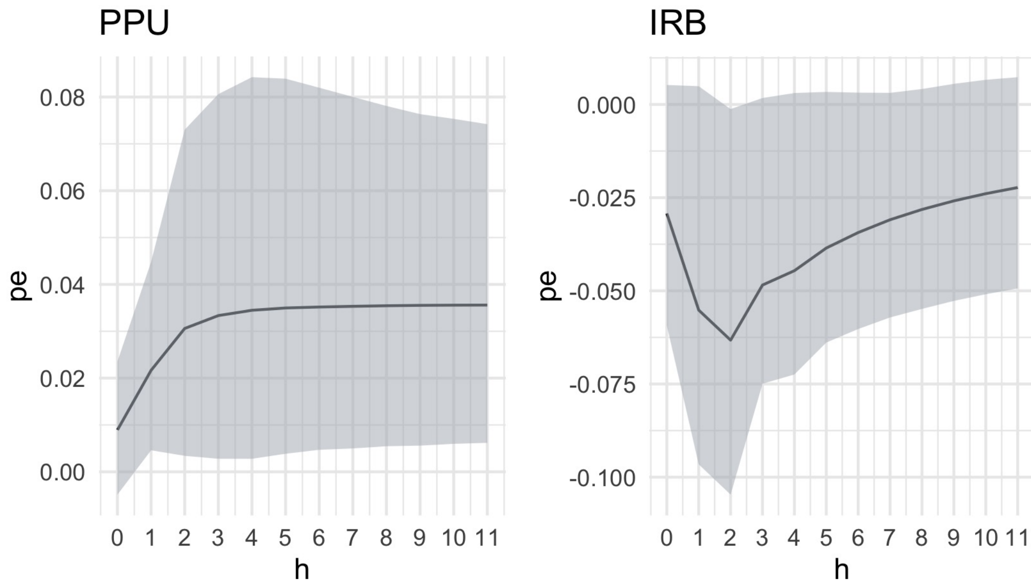

Figure 17: Impulse Response Function (1% shock, 95% CI) for $\frac{HSD}{TA}$ based on a Panel VAR

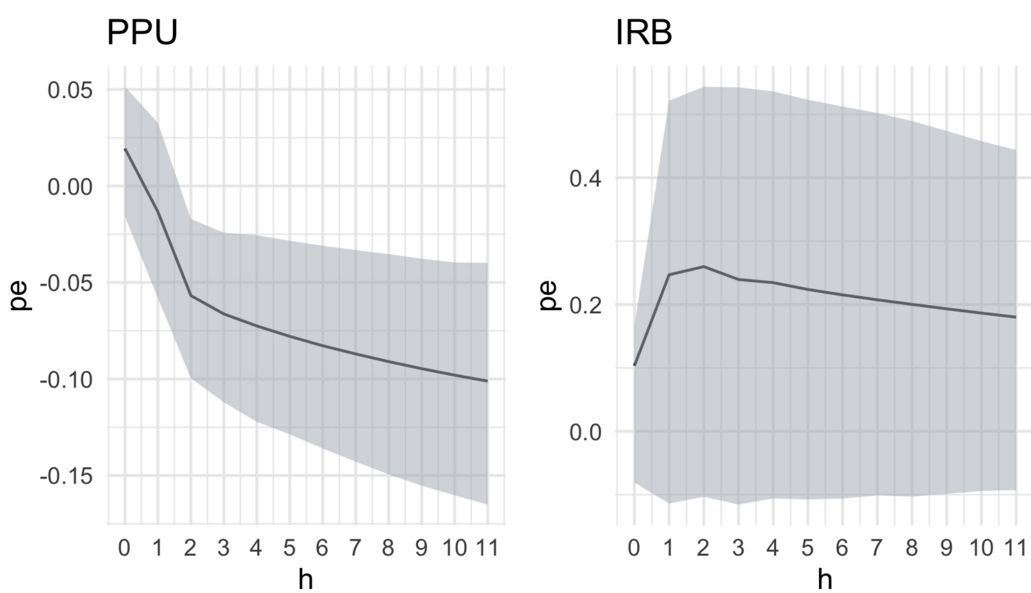

Figure 18: Impulse Response Function (1% shock, 95% CI) for $\frac{EAL}{TA}$ based on a Panel VAR

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