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Risk weighting, private lending and macroeconomic dynamics

Michael Donadelli
(University of Brescia)

Marcus Jüppner
(Deutsche Bundesbank and Goethe University Frankfurt)

Lorenzo Prosperi
(Toulouse School of Economics and Prometeia SpA)

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

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Non-technical summary

Research Question

According to existing rules, the regulatory treatment of sovereign exposures is more favourable than for any other asset in the European Union. Legislation assigns zero risk weights on EU government bonds regardless of how they are rated. Existing research focuses on the effect of banking rules on excessive domestic bond holdings and the sovereign-bank-nexus as a source of instability during a crisis. However, a zero risk weight policy may also have effects on the business cycle during tranquil periods when there is no government default risk, since it affects the costs of private lending relative to holding sovereign debt.

Contribution

We study the macroeconomic effects of (favourable) risk weighting of government bonds within a standard real business cycle model with financial intermediation during normal times. For this purpose, we consider an extreme case where there is no possibility of countries or firms defaulting. In our model, there are two types of assets held by banks in their portfolios. These are loans to firms for the purpose of producing output and sovereign debt to finance government expenditure. Banks are subject to regulatory capital requirements and are penalised if they move below the target capital ratio.

Results

We show that during normal times, favourable risk-weighting of sovereigns reduces banks' incentives to engage in private lending, as it makes loans to firms more costly relative to government bonds. Also, the zero risk policy reduces banks' flexibility in reacting to negative economic shocks as they can only deleverage by reducing private lending. A policy introducing positive risk weights on government bonds has both long run effects and stabilising properties with respect to the business cycle. It stimulates private lending and hence investment and output in the long run by reducing the lending spread. Furthermore, the policy stabilises the lending spread, leading to a lower volatility of investment and output.

Nichttechnische Zusammenfassung

Fragestellung

Bei der Bankenregulierung in der Europäischen Union erfahren Staatsanleihen gegenüber anderen Anlagegütern eine bevorzugte Behandlung. So müssen Banken für Anleihen von EU-Staaten per Gesetz kein Risikokapital hinterlegen. Die Forschung konzentriert sich bisher auf die Auswirkungen dieser Regelungen auf die übermäßige Akkumulation von Staatstiteln und den Risikoverbund von Banken und Staaten als Gefahr für die wirtschaftliche Stabilität in Krisenzeiten. Die Nullgewichtung von Staatsanleihen bei der Berechnung der aufsichtsrechtlichen Eigenmittelerfordernisse kann allerdings auch konjunkturelle Effekte in Zeiten ohne Risiko eines Staatsbankrotts haben, da diese Ungleichbehandlung die relativen Kosten der privaten Kreditvergabe und des Erwerbs von Staatsschulden beeinflusst.

Beitrag

Dieses Papier untersucht die makroökonomischen Folgen der (vorteilhaften) Risikogewichtung von Staatsanleihen unter normalen Wirtschaftsbedingungen mithilfe eines Real-Business-Cycle-Modells mit Bankensektor. Wir betrachten dazu den Extremfall ohne Ausfallrisiko von Banken und Unternehmen. Im Modell gibt es zwei Arten von Anlagegütern, welche Banken in ihrem Portfolio halten. Diese sind Kredite an Unternehmen für die Güterproduktion und Staatsschuldentitel, welche zur Finanzierung von öffentlichen Ausgaben dienen. Banken sehen sich regulatorischen Eigenmittelanforderungen gegenüber und werden sanktioniert, wenn ihre aufsichtsrechtliche Eigenmittelausstattung unter den gegebenen Zielwert fällt.

Ergebnisse

Die Ergebnisse zeigen, dass die vorteilhafte Behandlung von Staatsanleihen unter normalen Wirtschaftsbedingen Anreize für Banken zur Vergabe von Krediten an den privaten Sektor verringert, da Firmenkredite im Vergleich zu Staatsanleihen verteuert werden. Darüber hinaus wird der Handlungsspielraum von Banken in Folge eines negativen konjunkturellen Schocks verringert, da diese den Verschuldungsgrad nur senken können, indem sie die private Kreditvergabe zurückfahren. Eine Politikmaßsnahme, welche das Hinterlegen von Risikokapital für Staatsanleihen erforderlich macht, fördert durch günstigere Finanzierungskonditionen bei der privaten Kreditvergabe Unternehmensinvestitionen und damit die gesamtwirtschaftliche Produktion. Des Weiteren werden über eine geringere Volatilität der Kreditzinsen konjunkturelle Schwankungen abgeschwächt.

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Risk weighting, private lending and macroeconomic dynamics*

Michael Donadelli
University of Brescia

Marcus Jüppner
Deutsche Bundesbank and Goethe University Frankfurt

Lorenzo Prosperi
Toulouse School of Economics and Prometeia SpA

Abstract

According to current regulation, European banks can apply zero risk weights to sovereign exposures in their balance sheet, irrespective of the assigned rating. We show that a zero risk weighting of sovereign bonds has implications by distorting banks' asset allocation decisions. Due to the lower regulatory cost of sovereign bonds, banks invest more in those bonds at the expense of lending to the real sector. To quantify the effect of this distortion, we build a standard RBC model featuring financial intermediation and a government sector calibrated to the euro area economy. Financial regulation is introduced via a penalty function that punishes banks if they deviate from the target capital ratio. We study the zero risk weight policy during normal times when there is no sovereign default risk and find that a policy introducing positive risk weights on government bonds has both long-run effects and stabilising properties with respect to the business cycle. This policy makes the steady state lending spread on loans to firms decline, stimulating investment and output. Also, it stabilises the lending spread, leading to a lower volatility of investment and output.

Keywords: Sovereign bonds, risk weighting, RBC, lending

JEL classification: E44, E32, G21, G32.

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*Contact address: Michael Donadelli, University of Brescia, Department of Economics and Management, Via S. Faustino 74/b, 25122 Brescia, Italy. Email: michael.donadelli@unibs.it, marcus.jueppner@bundesbank.de, lorenzo.prosperi@tse-fr.eu. The authors acknowledge helpful discussions with Christian Hellwig, Patrick Fève, Marcella Lucchetta, Christian Schlag and Satyajit Chatterjee. Moreover, we would like to thank the seminar participants at TSE. The views expressed in this paper are those of the author(s) and do not necessarily coincide with the views of the Deutsche Bundesbank or the Eurosystem and Prometeia SpA.

1 Introduction

Since the financial crisis, policy makers have started an intensive reform of banking regulation, with the ultimate goal of strengthening the banking system and disincentivising risk-taking behaviour. So far, this process has not involved a comprehensive reform of the regulatory treatment of sovereign exposures, which has remained broadly unchanged from the Basel I framework (BCBS, 2017). According to existing rules, the regulatory treatment of sovereign exposures is more favourable than for any other asset. In particular, risk weights are assigned to different types of assets in order to adequately measure the risk contained in banks' balance sheets and to evaluate their capital position. However, at national discretion, banks are allowed to assign zero risk weights to government debt denominated in domestic currency, regardless of the default risk of a country. Even considering only those assets with an investment grade rating, risk weights for other types of exposures (including loans) are usually positive. This implies that sovereign debt receives a more favourable regulatory treatment compared to private lending, even among the highest rated assets, which may encourage banks to accumulate public debt (Nouy, 2012).

In academic research, the special regulatory treatment of sovereign debt that assigns a zero risk weight (ZRW) to government bonds in capital adequacy rules and its effect during normal times has not received much attention yet. Most of the papers in this field focus on the effect of banking rules on excessive domestic bond holdings and the sovereign-bank nexus as a source of instability during a crisis. With this paper, we aim to fill this gap and show the financial and macroeconomic effects of relaxing the zero risk weight rule on sovereigns in the extreme case of a riskless scenario with no possibility of countries or firms defaulting.[1] We argue that the ZRW rule favours capital allocation of banks towards government securities and "crowds out" the provision of credit to the private sector by distorting the marginal cost of holding these assets. We study the macroeconomic implications of varying the regulatory risk weights on government bonds within a standard DSGE framework in which banks are subject to regulatory capital requirements. As in most of real business cycle (RBC) models with banking sectors, financial regulation is specified via a penalty function that punishes banks if they deviate from the target capital ratio. In our model, regulation has no beneficial effects for the economy as it only absorbs aggregate resources. This framework is extended by a government sector that finances its expenditures by levying taxes on households and issuing bonds that are held by domestic banks.

We show that removing zero risk weights on sovereigns would increase the flexibility of banks, since they can accommodate a reduction of risk-weighted assets by changing the composition of the balance sheet. In particular, if, after a shock, the capital ratio falls below the regulatory threshold, the bank can now sell bonds and loans (and not only loans) to reduce risk-weighted assets. As a result, loans are less penalised by regulation compared to sovereign bonds and for this reason interest rates on loans carry a lower marginal cost from banking regulation. We embed this mechanism in our model and calibrate it to the euro area economy to quantify the effects of removing these zero risk weights.

[1] We acknowledge that this is a rather unrealistic assumption, as firms may also default during normal times.

We find that increasing the risk weights on sovereign bonds in the capital adequacy ratio of banks has important stabilising properties and stimulates investment in the long run. Due to the relatively lower risk weight on loans to firms, the lending spread in the steady state decreases, increasing the marginal profitability of investment and thus long-run output. When looking at the volatility of the business cycle, we find that this policy stabilises the lending rate on loans, reducing the variability of investment and output. As investment is financed via loans provided by banks, this also implies a lower volatility of the bank's balance sheets.

These results may look surprising. Increasing sovereign risk weights tightens an unnecessary constraint (capital regulation) and absorbs aggregate resources. One might therefore expect negative effects on the economy from this policy scenario. However, penalising bond holdings reduces the distortion on loans induced by regulation, which would boost investment and output, compensating the negative effects from tighter capital conditions.

Since regulation is introduced in a reduced form, our model does not consider some of the possible costs that may arise from this policy. For example, bonds have no real use in our economy even though in practice, banks use them for different purposes such as liquidity management[2], credit risk mitigation and profitable investments (BCBS, 2017). Moreover, for the purpose of this paper, we do not factor in the implications of sovereign default risk. Indeed, while removing zero risk weights might potentially lower lending rates, we show that it has the opposite effect on government bond rates. This might create concerns on fiscal sustainability, since public debt would be larger in the long run to cover interest expenses. Moreover, increased sovereign default risk can potentially trigger defaults in the banking sector, a channel that is not explicitly modelled in our framework. Nevertheless, since this policy increases long-run output, the government can increase tax revenues and counteract the rise in sovereign debt induced by larger bond yields. To conclude, we do not provide a complete argument in favour of or against this policy. Importantly, due to the limitations of our analytical framework, results should be treated with caution, as it is uncertain if they still hold in a model with sovereign and firm default risk.

Our results shed new light on the ongoing policy debate on banks' exposure to sovereigns. According to the literature, excessive bond holdings can be problematic during a crisis, as occurred in 2012. However, according to our findings, they also have implications for the marginal cost of investment for banks, even in tranquil periods. In particular, whenever zero risk weighting is in place, banks invest relatively more in government bonds compared to loans to firms. Importantly, while reducing domestic sovereign exposure is clearly an important goal for financial stability, the distribution of debt across countries is not relevant in our set-up. Regardless of the nature of the sovereign debt, bonds are simply considered as an alternative investment opportunity for banks. Therefore, even if caps on domestic exposures are imposed (De Groen, 2015; Véron, 2017), banks in the euro area will likely buy sovereign debt issued by other European countries, thus keeping aggregate sovereign exposure unchanged.

The remainder of the paper is structured as follows. In Section 2, we review the

[2]Since sovereign bonds are the most liquid assets, they are used as required collateral for interbank lending and to access monetary policy financing. Moreover, banking regulation requires banks to hold a buffer of liquid assets.

related literature. Section 3 recaps (briefly) the current banking regulation under Basel III and the policy discussion on Basel IV about sovereign exposures, and relates them to the results of our analysis. In Section 4, we present the general equilibrium model. Section 5 presents our benchmark calibration and discusses the main quantitative results. Robustness checks are provided in Section 6. Section 7 concludes.

2 Related Literature

Since the global financial crisis, a large number of DSGE models featuring a banking sector have been developed in order to analyse the role of bank capital and leverage constraints in the propagation of shocks through the banking sector. In these models, bank capital is motivated either by mitigating moral hazard problems in financial contracts (see e.g. Meh and Moran, 2010; Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011; Gertler, Kiyotaki, and Queralto, 2012) or by exogenous regulatory requirements (see e.g. Van den Heuvel, 2008; Gerali, Neri, Sessa, and Signoretti, 2010; de Walque, Olivier, and Rouabah, 2010; Pariès, Sørensen, and Rodriguez-Palenzuela, 2011). The latter is justified by the concern that monetary policy may be insufficient in addressing financial imbalances, and that other instruments such as regulatory tools might therefore be necessary (see Blanchard, Dell'Ariccia, and Mauro, 2010). A large number of studies evaluate macroprudential policies such as the Basel (I-III) capital requirements, and compute optimal capital regulation.[3] While most of these papers focus on the effects of minimum capital requirements (such as the 8% rule) or risk-sensitive or countercyclical capital buffers, we are among the first to study the implications of zero sovereign risk weights under the current regulatory regime.

This paper introduces bank capital requirements in a DSGE framework as an exogenous penalty which reduces bank profits when the bank is not sufficiently capitalised. The main advantage of this approach is the possibility of applying perturbation methods and solving large scale DSGE models. For this reason, it has been largely adopted in the past (see e.g. Gerali et al., 2010; Kollmann et al., 2011; Kollmann, 2013; Lambertini and Uysal, 2014; Fève, Moura, and Pierrard, 2019; Lozej, Onorante, and Rannenberg, 2017). Alternatively, instead of using the penalty approach to prevent banks from falling below the target capital ratio, Abad (2018) assumes that the banks' leverage constraint is always binding, since equity issuance is more costly than deposit financing. However, this modelling assumption is not supported by the data, since banks usually operate above the minimum requirements. In our case, we target average capital ratios among European banks.

Since the onset of the European debt crisis, research devoted much attention to the negative feedback loop between banks and sovereigns and its implications for macroeconomic activity.[4] Bocola (2016) shows that government default risk has adverse effects

[3]See e.g. Gerali et al. (2010), Covas and Fujita (2010), Cúrdia and Woodford (2010), de Walque et al. (2010), Pariès et al. (2011), Gertler and Karadi (2011), Kollmann, Enders, and Muller (2011), Angeloni and Faia (2013), Agénor, Alper, and da Silva (2013), Cecchetti and Kohler (2014), Christiano, Motto, and Rostagno (2014), Quint and Rabanal (2014), Angelini, Clerc, Cúrdia, Gambacorta, Gerali, Locarno, Motto, Roeger, den Heuvel, and Vlček (2015), Benes and Kumhof (2015), and Brzoza-Brzezina, Kolasa, and Makarski (2015).

[4]See Abad (2018) for a detailed review of the literature.

on the funding ability of banks and it raises the risks associated with lending to the private sector. Abad (2018) shows that the possibility of a sovereign default acts as an important source of systemic risk, by which an initial shock to a small fraction of banks translates into system-wide instability. Most of these papers claim that zero risk weights exacerbate the negative feedback loop between banks and sovereigns in times of stress by incentivising banks to hold an excessive amount of bonds. In his quantitative study, Abad (2018) provides a counterfactual exercise showing that introducing capital requirements for banks' sovereign exposures reduces banks' endogenous exposure to sovereign risk and makes banks effectively safer and, consequently, helps mitigate the feedback effects between banking and sovereign crises and their negative spillovers on economic activity. The empirical study by Acharya and Steffen (2015) finds that undercapitalised banks with high risk-weighted returns undertook long peripheral sovereign bond positions to earn higher and riskier returns on their diminished capital while still meeting regulatory capital requirements. Also in our study, zero risk weighting induces excessive bond holdings, but because default risk is not explicitly modelled, it has no effect on the solvency of banks and governments or on macroeconomic stability. However, even in the absence of default risk, we show that zero risk weights have detrimental effects on private lending and macroeconomic activity in normal times.

Finally, our paper is in line with the capital taxation literature. The distortion from differential risk weighting in our framework with costly regulation is similar to having a higher tax on loans to firms than on government bonds. This translates into a higher tax on physical capital, as loans to firms are used for capital formation. When removing this distortion, we find that the level of output and the capital stock increases in the steady state. Hence, our results are in line with the findings of Judd (1985) and Chamley (1986), who find that in models of exogenous economic growth, where capital and output in units of effective labour stay constant in the steady state and savings only finance the formation of fixed capital, taxes on capital and capital income have detrimental effects on capital stock and output levels. However, they find that economic growth is unaffected by these taxes. In a recent study, Bösenberg, Egger, and Zoller-Rydzek (2018) examine the effects of broad capital taxation on the capital stock, output, and welfare within a dynamic model of small open economies, fitting data on 79 countries over the period 1996-2011. The authors find that capital tax reductions induce economically significant positive effects on output and the capital stock (per unit of effective labour). Effects on welfare instead may be positive or negative for a country, as a reduction in tax revenues reduces consumption in the short run and raises it in the long run, which means that welfare outcomes depend on the net effect of this tax policy. That transition phases may often overturn positive long-run welfare gains is often found in the literature. Russo (2002) finds negative welfare effects along the transition to the new steady state in an exogenous growth model.

3 Banking regulation

Before presenting our model framework, we briefly recap the current regulation scheme in the banking sector in order to provide a better understanding of both the current debate on the regulatory treatment of government bonds and the insights of our model. Introduced in 2013, the Basel III accord is supposed to maintain banks' solvency by strengthening regulation, supervision, and risk management. More precisely, these frameworks impose capital adequacy requirements which limit the amount of assets (including loans) that a bank may hold relative to its own capital, with the goal of ensuring that losses may be absorbed without prejudicing the rights of creditors and depositors. From the capital side, the bank should hold assets of a particular quality and type in sufficient quantities to absorb losses. On the assets side, the bank must calculate the value of all assets in the balance sheet by weighting each asset according to its riskiness. In particular, banks are required to satisfy

$$\frac{Capital}{RWA} > 8 + CAPB + CCYCB\%$$

where RWA are risk weighted assets, $CAPB$ is the capital conservation buffer and $CCYCB$ is the countercyclical buffer[5]. The rule requires that banks should have total regulatory capital not lower than a given threshold (from 8% to 13% according to the buffers) of RWA. Risk weighted assets are simply a weighted sum of assets where weights are assigned according to different asset categories and riskiness. Focusing on sovereign exposures, under the standardised approach of Basel III, risk weights should be applied to these assets based on external ratings. These weights are summarised in Table 1. If we compare these weights with the ones associated with other counterparties, we find that government bonds usually receive favourable treatment. For instance, AAA sovereign exposures attract a zero per cent risk weight while AAA corporate exposures attract a twenty per cent risk weight (see Table 2).

Table 1: Risk weights for sovereigns (standardised approach)

Credit rating	AAA	A	BBB+	BB+	below B-	unrated
RW	0	0.2	0.5	1	1.5	1

Table 2: Risk weights for private loans and assets (standardised approach)

Categories	Banks	Firms	Equity	Retail	Residential mortgages
RW	0.2-1.5	0.2-1.5	1-2.5	0.75	0.35

Moreover, under current regulations, the treatment of sovereign debt denominated in domestic currency is subject to national discretion.[6] In Europe, the Capital Requirement Directives (CRD) transpose Basel rules into European legislation and assigns a zero risk weight to all sovereign exposures, regardless of their ratings.

[5]The capital conservation buffer is intended to be large enough to enable banks to maintain capital levels above the minimum requirement throughout a significant sector-wide downturn. The countercyclical buffer is an additional requirement which will be implemented by national supervisors when there is excess credit growth in the economy, with the intention of dampening such credit growth.

[6]See Basel II (comprehensive version published in June 2006): "At national discretion, a lower risk weight may be applied to banks' exposures to their sovereign (or central bank) of incorporation denominated in domestic currency and funded in that currency. Where this discretion is exercised, other national supervisory authorities may also permit their banks to apply the same risk weight to domestic currency exposures to this sovereign (or central bank) funded in that currency."

Banking regulation is evolving and different rules on risk weights on private assets have been established and will likely be incorporated into the finalised version of Basel IV accord. However no agreement has been reached on a possible change in sovereign risk weighting. The banking sector's sovereign exposure is still very large in the euro area and, most importantly, this exposure is subject to a strong domestic bias. According to policy makers and academics, the bank-sovereign nexus is at the core of the European debt crisis. The home-bias phenomenon is one of the main obstacles in reaching the completion of the banking union and an agreement on the European deposit insurance scheme (Véron, 2017).

However the policy change is contested for different reasons. Firstly, increasing risk weights would be very costly for the banking sector in countries with lower credit ratings. Second, limiting banks' holdings of sovereign bonds would constraint their ability to stabilise the sovereign debt market. Since 2012, in case of distress, a sovereign has had the opportunity to apply to an ESM programme and activate ECB outright monetary purchases. However, this option is politically costly and governments are usually reluctant to go down that path. Third, governments are aware that such a change would very likely increase interest rates of sovereign bonds in the long run.

For these reasons, alternative policies have been proposed to limit banks' exposure to sovereign bonds. An option is to set a common cap on holdings in relation to each sovereign issuer (De Groen, 2015). A second recent proposal is to apply concentration charges on domestic sovereign holdings above a certain threshold: 33% of Tier 1 capital (Véron, 2017). A common argument of these alternative proposals is that excessive domestic bond holdings is a potential source of distress during a crisis. These alternative proposals go in the direction of redistributing holdings across different banking sectors, but the overall exposure to sovereigns in the euro area might remain unchanged, as well as the risk weights. As a result, if these policies are implemented, the banking sector would still be highly exposed to European sovereign debt benefiting from a favourable treatment in terms of risk weights.

While domestic exposure is certainly an issue, we show that ignoring this special regulatory treatment for the whole asset class has negative macroeconomic implications. Firstly, risk weighting has implications for the marginal cost of investments by the banking sector. When risk weights on sovereigns are greater than zero, the bank can divest both loans and bonds for the purpose of deleveraging, but this is not the case in the current regulatory environment. This has two potential effects. When risk weights on sovereigns are zero, lending rates are larger and sovereign bond rates are lower compared to a case without this special treatment for bonds. This has negative effects on output and investments in the long run for the economy. Secondly, when a shock hits the economy, banks' profitability and asset quality are usually also hit severely, inducing the bank to deleverage to prevent the capital ratio from falling below the 8% threshold. With zero risk weighting, deleveraging is realised only through loans, with investments declining more intensively, resulting in a long lasting recession in the economy. We argue that removing this special treatment for sovereign bonds would improve the resilience of output and investments to a capital quality shock.

Removing zero risk weights has potential positive effects for private lending and negative effects for government financing. Indeed, the policy change would likely increase interest rates on government bonds in the long run since the marginal cost stemming from regulation would increase. This might create concerns with regard to fiscal sustainability, with public debt increasing to cover interest expenses. However, if this policy has positive effects on output, fiscal policy can be more restrictive and counteract the increase in sovereign debt.

Our model accounts for regulation by applying a penalty function approach.[7] With our choice of the penalty function, we explicitly take into account the potential benefit that arises when the bank has several assets in its portfolio and can change the asset composition for deleveraging. In particular, according to our penalty function, loans and sovereign bonds are substitutes as long as there is no special treatment in terms of RWA for public debt. This implies that when banks increase holdings of one asset, it reduces the marginal cost of the other. Our novel economy featuring non-zero risk weight on sovereigns is described in the next section and its macroeconomic implications are discussed in Section 5.

4 Model Description

Our model builds on the work of Gertler and Kiyotaki (2010) and Lambertini and Uysal (2014), and features households, firms, government and banks. Households supply labour, demand consumption goods and save in deposits supplied by banks. Perfectly competitive firms produce the consumer good using labour and capital. The latter is produced by capital producers subject to investment adjustment costs. To purchase capital, firms need to take loans from financial intermediaries. In the financial sector, banks use deposits and own net worth to provide loans to firms and buy government debt. In addition to domestic banks that make optimal portfolio decisions, we introduce an exogenous external sector that also provides funds to firms in order to match the balance sheet structure of European banks. Finally, the government issues debt and imposes taxes on households to finance government spending. The model is calibrated to match macroeconomic and financial data for the Euro area.[8] Let us stress that our main goal here is to maximise insight into the relationship between different risk weights, sovereigns, lending activity, and the macroeconomy, and to avoid tangential complications. We therefore strive to keep the model as simple as possible, while still matching key RBC features. For this reason, we follow Gertler and Kiyotaki (2010) and Lambertini and Uysal (2014) and deliberately exclude a role for a monetary authority and potential interaction with macroprudential policies. Given that in our framework banks accumulate net worth as a result of regulatory requirements that are implemented by means of a penalty function, as in Lambertini and Uysal (2014), regulation is costly and has no beneficial effects. We therefore do not take welfare considerations into account.

[7]This approach has been widely employed by the recent literature (see, among others, Gerali et al., 2010; Lambertini and Uysal, 2014; Fève et al., 2019).

[8]In contrast to our approach, Lambertini and Uysal (2014) calibrate the model on the US economy and model the Basel II and III regimes. Furthermore, they assume that the government cannot issue debt to finance government expenditures. Therefore, concerns about the regulatory treatment of government bonds by bank capital regulation are absent. Finally, we introduce an external sector that provides funds to firms.

4.1 Households

Households' utility is characterised by CRRA preferences and habit formation of the form

$$U_t = \sum_{t=0}^{\infty} \beta^t \mathbb{E}_0 \left[\frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \nu \frac{L_t^{1+\varphi}}{1+\varphi} \right], \tag{1}$$

where C_t is consumption, L_t is labour, β is the discount factor, σ is the coefficient of relative risk aversion, φ is the inverse Frisch elasticity of labour supply, ν is the weight of labour in the utility function and h is the parameter capturing habit persistence. Infinitely lived households maximise utility subject to the following budget constraint:

$$C_t + D_t = L_t W_t + R_{D,t-1} D_{t-1} + \Pi_t - T_t, \tag{2}$$

where D_t are deposits, $R_{D,t-1}$ is the predetermined return on deposits, W_t is the wage received, and T_t are taxes levied by the government to finance government expenditure. Π_t are distributed profits from banks and capital-producing firms and transfers from old bankers to new bankers.

The optimal choice of consumption leads to the stochastic discount factor (SDF):

$$M_{t,t+1} = \beta \left[\frac{(C_{t+1} - hC_t)^{-\sigma} - \beta h \mathbb{E}_{t+1}[(C_{t+2} - hC_{t+1})^{-\sigma}]}{(C_t - hC_{t-1})^{-\sigma} - \beta h \mathbb{E}_t[(C_{t+1} - hC_t)^{-\sigma}]} \right]. \tag{3}$$

The household chooses deposits, D_t, optimally, such that

$$\frac{1}{R_{D,t}} = \mathbb{E}_t[M_{t,t+1}]. \tag{4}$$

4.2 Capital producers

Competitive capital-producing firms buy capital from goods-producing firms and then repair depreciated capital and build new capital, subject to adjustment costs. The net profit is given by

$$NP_{CP,t} = Q_t I_t - \left[1 + f\left(\frac{I_t}{I_{t-1}} \right) \right] I_t, \tag{5}$$

where Q_t is the relative price of capital and adjustment costs are defined as

$$f\left(\frac{I_t}{I_{t-1}} \right) := 0.5\chi \left(\frac{I_t}{I_{t-1}} - 1 \right)^2, \tag{6}$$

with $f' > 0$, $f'' > 0$. Hence, capital producers produce new capital at unitary cost $1 + f$, which is then sold to output-producing firms at the price Q_t. Maximising present and future expected profits, the firms optimally choose investment I_t such that

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}} \right) + f'\left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} - \mathbb{E}_t \left[M_{t,t+1} f'\left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right], \tag{7}$$

which is the standard equation that defines Tobin's Q.

4.3 Firms

Output is produced by perfectly competitive firms according to the following production function:

$$F_t = C_t + G_t + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{8}$$

where A_t is the level of total factor productivity (TFP), K_t is the capital stock, and L_t denotes labour supply. At the end of period t, the representative firm purchases capital K_{t+1} from capital producers for production purposes in the following period. To finance the acquisition of capital, the firm receives loans $Q_t S_t$ from the banking sector at the lending rate $R_{K,t+1}$. More specifically, the firm issues S_t claims that are equal to the number of units of capital acquired K_{t+1} and prices each claim at the price of a unit of capital Q_t. Before production, the firm also pays the wage rate W_t for labour supplied by workers. After the output is produced, the firm sells the depreciated capital to capital-producing firms at price Q_t. Consequently, the firm's net profit is given by

$$NP_{F,t} = F_t - W_t L_t - R_{K,t} Q_{t-1} S_{t-1} + Q_t S_t - Q_t I_t. \tag{9}$$

The capital stock evolves according to:

$$S_t = (1-\delta) K_t + I_t, \tag{10}$$

$$K_{t+1} = \Psi_{t+1} S_t, \tag{11}$$

$$S_t = S_t^b + S_t^x, \tag{12}$$

where the amount of claims S_t issued are bought by domestic banks (S_t^b) and the external sector (S_t^x). The depreciation rate of capital is defined by δ, and Ψ can be interpreted as a capital quality shock. According to the zero-profit condition, the return on capital is given by:

$$R_{K,t+1} = \Psi_{t+1} \frac{\alpha \frac{F_{t+1}}{K_{t+1}} + (1-\delta) Q_{t+1}}{Q_t}, \tag{13}$$

and excess return for capital is given by

$$ExR_{K,t} = R_{K,t} - R_{D,t-1}. \tag{14}$$

TFP evolves according to the exogenous AR(1) process

$$\log A_t = \rho_a \log A_{t-1} + \epsilon_{a,t}, \tag{15}$$

where $0 \leqslant \rho_a < 1$ and $\epsilon_{a,t} \sim N(0, \sigma_a^2)$. The capital quality shock evolves according to the AR(1) process

$$\log \Psi_t = \rho_\Psi \log \Psi_{t-1} + \epsilon_{\Psi,t}, \tag{16}$$

where $0 \leqslant \rho_\Psi < 1$ and $\epsilon_{\Psi,t} \sim N(0, \sigma_\Psi^2)$.

4.4 Government

Government expenditures, G_t, evolve according to the exogenous AR(1) process

$$\log G_t = \rho_G \log G_{t-1} + (1 - \rho_G)\bar{G} + \epsilon_{G,t}, \tag{17}$$

where $\bar{G}$ are government expenditures in the steady state, $0 \leqslant \rho_G < 1$, and $\epsilon_{G,t} \sim N(0, \sigma_G^2)$. The government's budget constraint reads

$$G_t + R_{G,t-1}B_{t-1} = B_t + T_t, \tag{18}$$

where B_t are government bonds and $R_{G,t-1}$ is the return on government bonds. Following Leeper, Plante, and Traum (2010), we express the tax rate on output τ_t as

$$\tau_t = \kappa_b B_{t-1} + \kappa_y Y_{t-1}. \tag{19}$$

Total government revenues are given by $T_t = \tau_t Y_t$ (see Section 4.8 for our formal definition of GDP, Y_t). Importantly, in our model, taxation adjusts in response to a deterioration in the business cycle and for stabilization purposes. This is a relevant ingredient in the model, since the policy change we are analysing has a positive long-run effect on output that will make fiscal policy more restrictive.

4.5 Banks

Banks provide loans to firms using both external and internal funds. The former are deposits purchased by households while the latter are the banks' net worth. According to the banks' balance sheet constraint, the value of loans, $Q_t S_t^b$, provided to firms and government bonds, B_t, held each period is equal to the sum of deposits, D_t, and banks' net worth, N_t. Formally,

$$\underbrace{Q_t S_t^b + B_t}_{Assets_t} = N_t + D_t. \tag{20}$$

The bank's net worth at time t is defined as retained earnings which are given by interest received on assets (loans and government bonds) less the interest that has to be paid on liabilities (deposits) and other costs:

$$N_t = R_{K,t}Q_{t-1}S_{t-1}^b + R_{G,t-1}B_{t-1} - R_{D,t-1}D_{t-1} + \mathcal{P}_{t-1}. \tag{21}$$

$\mathcal{P}_{t-1}$ is a penalty that is associated with financial regulation in the form of minimum capital requirements. The penalty function representing capital requirements reads as follows:

$$\mathcal{P}_t = \bar{\mathcal{P}} + \phi \log\left(\frac{RAT_t}{\gamma}\right), \tag{22}$$

where RAT_t is the risk weighted capital ratio, γ is the target capital ratio, and $\bar{\mathcal{P}}$ is a scaling parameter. The sensitivity of the penalty to deviations from the regulatory target is measured by ϕ. Supposing $\bar{\mathcal{P}} = 0$, if its regulatory capital ratio falls below a specified threshold, the bank will pay a certain penalty imposed by the regulatory authority ($\mathcal{P}_t < 0$). However, if the bank has more capital than required, it will be rewarded ($\mathcal{P}_t > 0$).[9] To avoid a counterintuitive creation of aggregate resources when $RAT > \gamma$, we calibrate $\bar{\mathcal{P}}$ to ensure that the penalty is always negative in our simulation. While this calibration helps to interpret regulation in our model as a cost for the economy, it has very limited quantitative effects. Formally, the risk weighted capital ratio is defined as

$$RAT_t = \frac{N_t}{\underbrace{Q_t S_t^b + \theta B_t}_{RWA_t}}, \tag{23}$$

where θ can be interpreted as the relative risk weight of government bonds with respect to private loans. The penalty function that we propose satisfies some relevant properties that have been previously stated in Kollmann (2013). Defining excess capital as $X_t = N_t - \gamma RWA_t$, we can show that

- $\mathcal{P}(\cdot) < 0 \Leftrightarrow X_t < 0$,
- $\mathcal{P}''(\cdot) < 0$,
- $\mathcal{P}(0) = 0$.

Moreover, important properties of the penalty function can be shown by looking at its first derivatives

$$\frac{\partial \mathcal{P}_t}{\partial RWA_t} = \frac{\partial \mathcal{P}_t}{\partial Q_t S_b^t} = -\phi RWA_t^{-1}, \qquad \frac{\partial \mathcal{P}_t}{\partial N_t} = \phi N_t^{-1}, \qquad \frac{\partial \mathcal{P}_t}{\partial B_t} = -\phi\theta RWA_t^{-1}, \tag{24}$$

which imply that the marginal cost of an additional unit of risk-weighted assets negatively depends on the amount of risk-weighted assets and the marginal benefit of an additional unit of bank capital negatively depends on the amount of bank capital. Finally, the derivatives of the penalty function do not depend on the regulatory capital ratio γ. The black line in Figure 1 represents this penalty function. Importantly, since the first derivative with respect to an asset is a decreasing function of RWA, the first derivative with respect to private loans is also a decreasing function of sovereign bond holdings and vice versa (if $\theta > 0$). This implies that government bonds and loans are substitutes; when the banks increase holdings of one asset, it reduces the marginal cost of the other, and the degree of substitution increases with θ.[10]

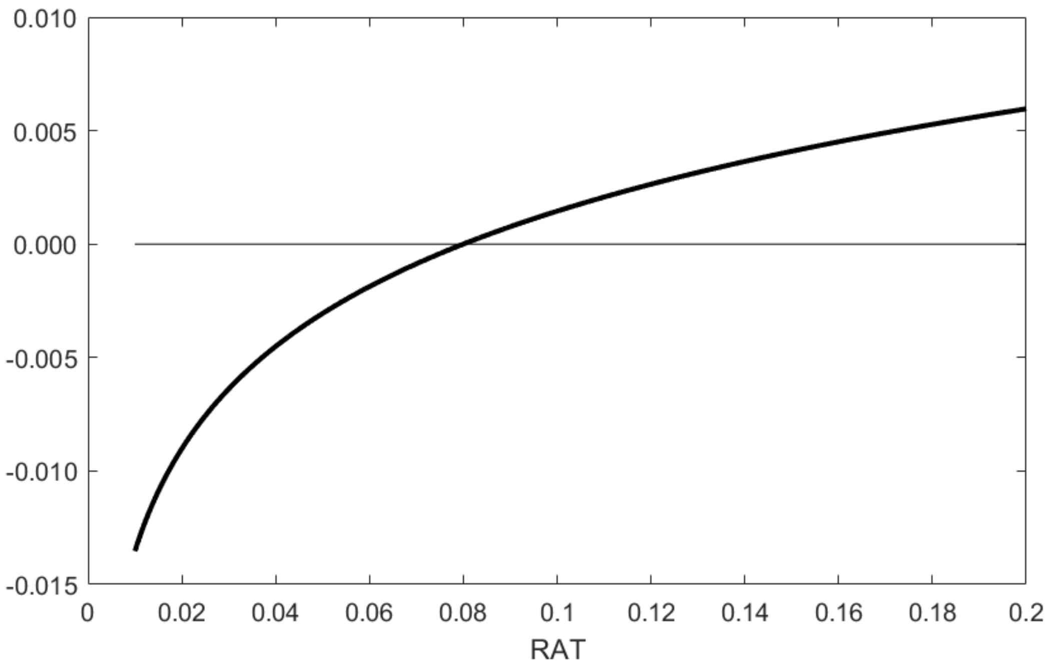
Combining the bank's net worth and its balance sheet constraint yields the following law of motion for net worth

$$N_{t+1} = [R_{K,t+1} - R_{D,t}]Q_t S_t^b + [R_{G,t} - R_{D,t}]B_t + R_{D,t}N_t + P_t. \tag{25}$$

[9] Another example of this penalty approach using a different functional form is provided by Kollmann (2013), Gerali et al. (2010), Fève et al. (2019), and Lozej et al. (2017).

[10] Besides ensuring substitutability between loans and bonds, the penalty function allows us to calibrate in the steady state both a positive lending spread on loans and the banks' average regulatory capital ratio from the data which is above the minimum threshold. This is not possible using the adjustment cost approach in Gerali et al. (2010).

Figure 1: Capital requirements penalty function



Note: The penalty function is calibrated using the following set of parameters: $\phi = 0.0065$, $\bar{\mathcal{P}} = 0$, $\gamma = 0.08$.

To ensure that banks rely on external financing to provide loans and buy government debt, it is assumed that banks exit the economy with constant probability $1 - \epsilon$ in every period. Therefore, the value of a bank satisfies the Bellman equation

$$V_t(Q_t S_t^b, B_t, N_t) = \max_{Q_t S_t^b, B_t} \Big\{ (1-\epsilon) N_t + \epsilon \mathbb{E}_t [M_{t,t+1} V_{t+1}(Q_{t+1} S_{t+1}^b, B_{t+1}, N_{t+1})] \Big\}. \tag{26}$$

The optimal choices of $Q_t S_t^b$ and B_t imply, respectively,

$$\mu_{s,t}(Q_t S_t^b + \theta B_t) = \phi \mathbb{E}_t [M_{t+1} \Omega_{t+1}], \tag{27}$$
$$\mu_{b,t}(Q_t S_t^b + \theta B_t) = \phi \theta, \tag{28}$$

and the envelope condition with respect to N_t reads:

$$\Omega_t = 1 - \epsilon + \epsilon \mu_{n,t}, \tag{29}$$

where

$$\Omega_t := V_{N_{t+1}}, \tag{30}$$
$$\mu_{s,t} := \mathbb{E}_t \Big[M_{t,t+1} \Omega_{t+1} (R_{K,t+1} - R_{D,t}) \Big], \tag{31}$$
$$\mu_{b,t} := (R_{G,t} - R_{D,t}), \tag{32}$$
$$\mu_{n,t} := \mathbb{E}_t \Big\{ M_{t,t+1} \Omega_{t+1} \Big[R_{D,t} + \frac{\phi}{N_t} \Big] \Big\}. \tag{33}$$

Rearranging optimality conditions yields

$$\mathbb{E}_t\Big[M_{t,t+1}\Omega_{t+1}(R_{K,t+1}-R_{D,t})\Big] = -\frac{\partial \mathcal{P}_t}{\partial Q_t S_t^b}\mathbb{E}_t[M_{t+1}\Omega_{t+1}], \tag{34}$$

$$R_{G,t}-R_{D,t} = -\frac{\partial \mathcal{P}_t}{\partial B_t}. \tag{35}$$

Equations (34) and (34) determine the spread between interest rates on loans and government bonds versus the deposit rate. In the absence of regulation, the interest rate on sovereign debt should be equal to the deposit rate (i.e. the inverse of the discount factor), while the expected discounted spread on loans should be equal to 0.

The transfers that new banks receive by households are equal to a fraction ω of the returns to loans of existing bankers

$$\omega R_{K,t} Q_{t-1} S_{t-1}^b. \tag{36}$$

Hence, the evolution of aggregate net worth can be written as

$$N_t = \epsilon\Big\{[R_{K,t}-R_{D,t-1}]Q_{t-1}S_{t-1}^b + [R_{G,t-1}-R_{D,t-1}]B_{t-1} + R_{D,t-1}N_{t-1} + P_{t-1}\Big\} + (1-\epsilon)\omega R_{K,t}Q_{t-1}S_{t-1}^b. \tag{37}$$

For calibration purposes, we define return on assets, ROA_t, as the ratio of net interest income to total assets:

$$ROA_t = \frac{R_{K,t}Q_{t-1}S_{t-1}^b + R_{G,t-1}B_{t-1} + D_t - Q_t S_t^b - B_t - R_{D,t-1}D_{t-1}}{Q_t S_t^b + B_t}. \tag{38}$$

4.6 External sector

In addition to domestic banks, we assume the existence of an external sector that exogenously provides funds to goods-producing firms. The amount of claims, S_t^x, bought by the external sector at price Q_t is constant over time. Since we introduce this sector as external to the model, we do not specify a budget constraint.

4.7 Labor market

The firm's optimal labour allocation leads to

$$W_t = (1-\alpha)\frac{F_t}{L_t}, \tag{39}$$

and the workers' optimal labour allocation implies

$$W_t = \frac{\nu L_t^{\varphi}}{(C_t - hC_{t-1})^{-\sigma} - \beta h \mathbb{E}_t\big[(C_{t+1} - hC_t)^{-\sigma}\big]}. \tag{40}$$

We assume that there is no friction on the labour market.

4.8 Market clearing conditions:

Goods market clearing implies that

$$F_t = C_t + G_t + \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t - \mathcal{P}_{t-1}. \tag{41}$$

As long as $\mathcal{P}_t < 0$, regulation has detrimental effects on aggregate output. We define GDP, Y_t, as

$$Y_t = C_t + G_t + I_t. \tag{42}$$

5 Quantitative analysis

In this section, we present our benchmark calibration and the model results. First we discuss the dynamics of our model by showing impulse responses of key variables to a capital quality shock. Then, we discuss the macroeconomic implications of removing the zero risk weight on sovereigns in banks' regulatory capital ratio by comparing steady states and second moments, respectively, for the different regimes. We also employ a variance decomposition and impulse response analysis in order to show whether the new policy increases the resilience of the economy to specific structural shocks compared to the benchmark.

5.1 Calibration

Our benchmark model requires the specification of 23 parameters. For the sake of clarity, the parameter set is divided into three different categories. Table 3 summarises our parameter choices. The first category includes nine parameters that cannot be easily identified and for this reason are calibrated in line with existing studies (Panel A). In the second category (Panel B), parameters are calibrated to match the steady state values and second moments of a restricted set of variables.[11] The remaining two parameters are set in accordance to the current banking regulation (Panel C).

As pointed out above, the first set of parameters in Panel A is standard in the literature. Importantly, and in line with our main analysis, parameter values employed in these studies are estimated for the euro area. An exception is Lambertini and Uysal (2014), who rely on US data.

The discount factor of households, β, is set to match an annual real interest rate on deposits of 2%. In the literature, alternative choices of β have been proposed, where the real interest rate ranges from 0.5% to 3%. Our calibration is inside this range but larger than the average real deposit rate in the euro area (1%). The shape of the penalty function and the effect of regulation on the economy strongly depend on parameter ϕ. According to Equation (34), the larger the parameter ϕ, the larger the compensation required by the banking sector for lending to the real economy. As a result, the parameter is calibrated to match the spread between the lending rate and the government bond rate, proxied

[11]Details on data are provided in Appendix A.

Table 3: Benchmark calibration

Parameter	**Value**	**Description**	**Note**
Panel A		*calibration from literature*	
σ	2.000	relative risk aversion	
ν	4.000	disutility from work	
h	0.700	habit parameter	CMS, FMS
φ	2.000	inverse elasticity labour supply	CMS, FMS, FP
χ	0.800	firm adjustment cost	
α	0.300	share capital in production	
δ	0.025	capital depreciation	CMS, FMS
ρ_A	0.857	ρ productivity shock	LU
ρ_Ψ	0.880	ρ capital quality shock	LU
Panel B		*calibration from data*	
β	0.995	discount factor of households	Target S.S. $RD = 2\%$
ϕ	0.007	penalty parameters	Target S.S. $R_K - R_D = 0.65\%$
$\bar{S}_x$	18.874	size of external financial sec	Target S.S. $B/(B + S_b) = 35\%$
$\bar{G}$	0.482	gov. expenditure steady state	Target $G/Y = 20\%$
κ_y	0.050	tax response to output	Estimated policy rule
κ_b	0.039	tax response to debt	Target $B/Y = 90\%$
ϵ	0.500	survival rate transfers	Target S.S. $std(ROA) = 0.26\%$
ω	0.114	transfers new bankers	Target $RAT = 11.7\%$
ρ_G	0.844	ρ government spending	AR(1) estimation
σ_G	0.003	σ government spending shock	Target S.S. $std(G) = 0.005$
σ_A	0.005	σ productivity shock	Target S.S. $std(Y) = 0.012$
σ_Ψ	0.002	σ capital quality shock	Target S.S. $std(I) = 0.038$
$\bar{\mathcal{P}}$	-0.004	scaling parameter penalty function	Negative penalty in simulation
Panel C		*calibration from regulation*	
γ	0.080	capital ratio constraint	Basel 3 regulation
θ	0.000	relative risk weight sovereign	Basel 3 regulation

Note: LU: Lambertini and Uysal (2014), FMS: Forni, Monteforte, and Sessa (2009), CMS: Cahn, Matheron, and Sahuc (2017), FP: Fève et al. (2019). S.S.: steady state.

by the AAA Corporate-government bond rate.[12] The effect of sovereign risk weight on lending strongly depends on the size of government debt in the balance sheet of the bank. To measure the share of sovereign bonds in the balance sheet of the banks $\overline{B/Assets}$ we

[12] The spread is defined as the difference between the AAA corporate bond rate and the German government bond rate with the same maturity. Since German bonds also have an AAA rating, the difference between these two rates does not reflect differences in maturity or credit worthiness and is likely to be affected by regulation. While the same spread in the US is above 100 bps in the full sample, for the euro area it is around 60 bps, also due to unconventional monetary policy measures of the ECB in the short sample considered.

proceeded as follows

$$\overline{\left(\frac{B}{Assets}\right)} = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{j\in\mathcal{I}} SOV_{j,t}}{\sum_{j\in\mathcal{I}} SOV_{j,t} + Loans_{j,t}} \quad \mathcal{I} = \{DEU, FRA, ESP, ITA, GRE\}$$

where $SOV_{j,t}$ are domestic sovereign bonds held by the banking sector in country j at time t (source Breughel)[13], and $Loans_{j,t}$ are loans to the private non-financial sector provided by the banking sector in country j at time t (source BIS). Since, in our model, the stock of capital is lent from the financial sector and rolled over every period, the total amounts of loans is much larger than sovereign debt in the model. To target the share of sovereign bond holdings over assets in the data (i.e. 35%), we introduce an exogenous financial sector whose size S_x is calibrated to match this ratio. Note that what is key in this paper are aggregate sovereign holdings held by the banking sector, regardless of whether they are domestic or foreign debt. However, Breughel data offers disclosure of the distribution of holdings only across residents. As a result, we do not know, for example, the size of holdings by German banks of Italian public debt. This implies that a 35% sovereign bond share in banking sector total assets is a conservative estimate.

Government expenditures are calibrated to obtain a share of 20% of output in steady state. To calibrate the tax response to the output gap, we estimate the policy rule in Equation (19).[14] The point estimate of the fiscal multiplier is 0.14, but the parameter is roughly estimated with a standard error of 0.09. Moreover, the model is not converging if we calibrate κ_y as in our point estimate, we set it to 0.05. Instead, κ_b has been set to match 90% debt to GDP in the euro area. As in Fève et al. (2019), we calibrate ω to target the average common equity Tier 1 (CET 1) ratio across European banks ($RAT = 11.7\%$).[15] When the survival rate, ϵ, is zero, bankers will become consumers at the end of the period and they will maximise retained earnings. When ϵ increases, banks care more about the future value of being bankers and less about retained earnings, which become more volatile. As a result to calibrate this parameter we roughly match the standard deviation of return on assets for the euro area banking sector. Equation (17) is then estimated to calibrate the persistence and the standard deviation of government expenditure shocks in the model. Finally, the standard deviation of capital quality and technology shock is calibrated to (roughly) match the standard deviation of investment and output. To ensure that capital regulation is only costly in our model, we calibrate $\bar{\mathcal{P}}$ such that the penalty is always negative in the simulation exercise. According to Basel 2, CET1 should lie above 8%. Therefore, we set $\gamma = 0.08$. In Europe, CRD assigns zero risk weight to sovereign exposures, which implies $\theta = 0$.

The model is solved numerically by a second-order approximation using perturbation methods as provided by the dynare package.[16]

[13] We decided to calculate the statistic on a restricted group of countries for which sovereign holding data is available.

[14] We detrended each series using a "one-sided" HP filter as in Stock and Watson (1999).

[15] We calculate the average CET1 ratio in 2008 for the banking systems of France, Germany, Italy and Spain using data from the IMF.

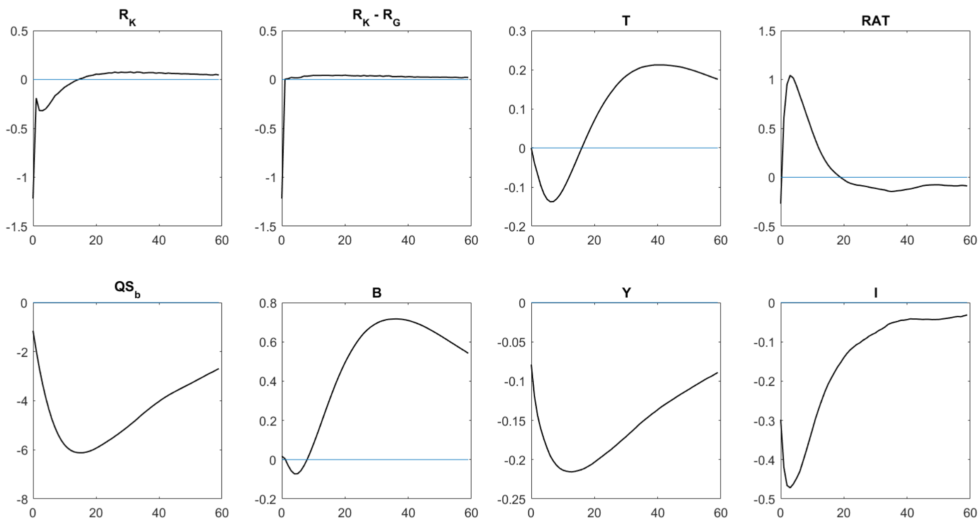
[16] Second-order approximation makes it possible to better capture the nonlinear effects of varying risk weights, given the shape of the penalty function. To highlight the importance of nonlinearities, we present in Section 6 the results from a model solved using first-order approximation around the steady state.

5.2 The response to a capital quality shock

To understand the mechanism of our model, we discuss the responses of endogenous variables to a capital quality shock. Specifically, in Figure 2, we plot impulse responses of various model variables to a negative capital quality shock. When the shock hits the economy, the rate of return on loans is reduced on impact because of the decline in capital productivity. Since the interest rate on deposits falls by a smaller amount, banks' profitability deteriorates. A decline in profitability corresponds to a decline in the capital ratios. Since the return of capital, R_K, is low, and because banks are undercapitalised, the banking sector de-risks by reducing loans to firms. As a result, after the immediate sharp deterioration, the capital ratio rebounds quickly. Due to the process of deleveraging and de-risking, the bank substitutes capital absorbing assets (loans) with bonds. Because of an increase in the demand by banks and a decline in interest rates on sovereigns, the government issues more debt to finance government expenditures. Since fiscal policy is aimed at stabilising public debt, taxes increase.

Five years following the shock, debt to GDP has increased by 0.6% while loans intermediated by banks have declined by 5%. Due to lower productivity of capital and lower supply of loans, investments are negatively affected, declining by -0.4% at their lowest point. Households are negatively affected by the decline in the return of deposits and lower labour income. As a combination of a decline in investment and consumption, output hits a low at almost -0.2%.

Figure 2: Impulse responses to a capital quality shock



Note: Lending rate and spread are annualised. All responses are deviations from the steady state in percentage points.

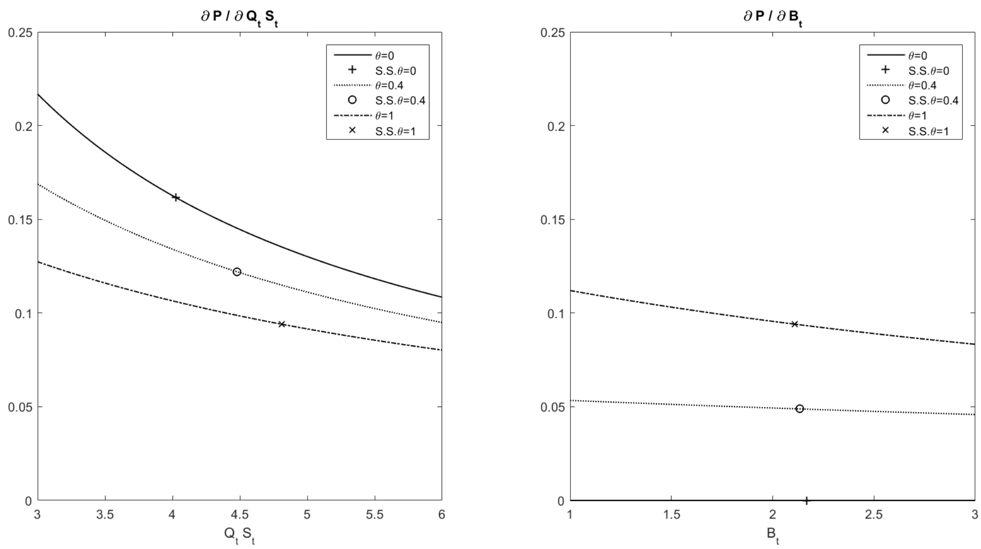
5.3 Steady state effects of increasing risk weights on sovereigns

In the following, we examine the long-run effects of removing favourable risk weighting for sovereigns. In particular, we consider two alternative calibrations of the model

$\theta \in \{0.4, 1\}$, with the remaining parameters left unchanged vis-à-vis the benchmark calibration. The case in which $\theta = 1$ corresponds to the situation in which sovereigns are treated like loans by regulators. In reality, differences in risk weights should also reflect differences in credit worthiness, but in our model there is full commitment to repay the debt even if credit quality depends on the realization of a structural shock.

Increasing risk weights on sovereigns has an important effect on the shape of the penalty function and consequently on interest rates at the steady state. This effect is represented in Figure 3. On the left hand side, the derivative of the penalty function with respect to loans, $-P_L = -\frac{\partial \mathcal{P}}{\partial Q_t S_t^b}$, is presented for different values of θ, while on the right hand side we have the corresponding picture for the derivative with respect to sovereign bonds, $-P_B = -\frac{\partial \mathcal{P}}{\partial B_t}$.[17] When $\theta = 0$, $-P_L$ is positive and decreasing in loans while $-P_B$ is always zero. When θ increases, $-P_L$ declines and $-P_B$ increases. As stated in Section 4.5, this happens essentially because loans and debt are substitutes from a regulatory point of view. When government bonds holdings are included in RWA, loans attract lower regulatory cost. Since higher regulation costs command higher interest rates, and vice versa, an increase in θ reduces the interest rate on loans and increases the interest rate on government bonds. As a result, removing zero risk weight stimulates investment and increase output in the steady state due to lower interest rates on lending.

Figure 3: First derivatives of the penalty function



In Table 4, we present steady state values for different variables of the model for different values of θ. The first three columns present the steady states for $\theta \in \{0, 0.4, 1\}$, while the last two columns present the difference in steady state between $\theta \in \{0.4, 1\}$ and $\theta = 0$. When θ increases from 0 to 1, the interest rate on loans declines by 26 basis points, while interest rates on government bonds increase by 38 basis points. As a result, increasing θ to unity stimulates investments in the steady state by 3% and output by almost 1%. The effect on the public debt to GDP ratio depends on the responses of interest rates and output. On the one hand, larger government bond yields imply

[17] We multiply the derivatives by minus one to interpret them as marginal costs.

a larger level of debt. On the other hand, since output is larger in the steady state, the government relies more intensively on taxation due to the cyclical fiscal policy rule, specified in Equation (19). The latter effect dominates, lowering sovereign debt by almost 3% if $\theta = 1$. This is an important result: a potential risk to removing a zero risk weight on sovereigns might be that public debt increases with larger interest rates, creating concerns about fiscal sustainability. According to our calibration and penalty function specification that implies substitutability across assets, the potential negative effects on debt are more than mitigated if the government commits to the fiscal policy rule that is calibrated in the model. As a result of the change in risk weights, banks recompose their balance sheets by favouring loans to firms (from 65% to almost 70%). Since sovereign bonds are now included in RWA, the regulatory capital ratio RAT declines by 3.6%.

Table 4: Steady states for selected variables of the model for different values of θ

	$\theta = 0$	$\theta = 0.4$	$\theta = 1$	Delta (%) $\theta = 0.4$	Delta (%) $\theta = 1$
Y	2.41	2.42	2.43	0.55	0.96
C	1.35	1.36	1.36	0.20	0.33
K	22.90	23.33	23.64	1.85	3.24
I	0.57	0.58	0.59	1.85	3.24
Assets	6.19	6.57	6.88	6.14	11.00
R_D	1.98	1.98	1.98	0.00	0.00
R_G	1.98	2.06	2.36	0.08	0.38
$R_K - R_D$	0.64	0.49	0.37	-0.15	-0.27
B/A	35.00	32.31	30.63	-2.69	-4.37
S/A	65.00	67.69	69.37	2.69	4.37
RAT	11.70	9.78	8.06	-1.92	-3.64
B	2.17	2.12	2.11	-2.03	-2.85

Note: Interest rates are annualised.

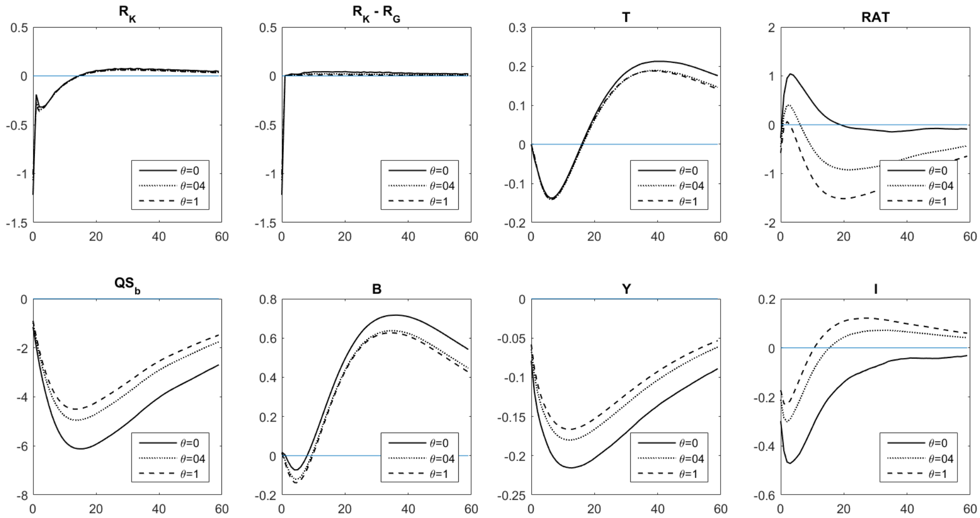
5.4 Effects on second business cycle moments of increasing risk weights on sovereigns

In this section we examine the effects of increasing risk weights on macroeconomic dynamics. We therefore compare impulse responses to a capital quality shock for different values of θ. The idea here is that zero risk weights on sovereigns not only affect the steady state of the model, but also increases the persistence of a negative shock to the economy. Impulse responses for different values of θ are depicted in Figure 4.[18] Upon the realization of a negative capital quality shock, banks de-risk to prevent the capital ratio from falling below the threshold. When sovereign bonds are included in risk-weighted assets, the banks can de-risk by reducing the demand for bonds. As a result, credit supply declines by a lower amount compared to the case in which $\theta = 0$, providing benefits for investment and output.

Increasing risk weights on sovereigns might also affect the volatility of the variables of the model. To investigate this, we compute 5,000 short sample simulations of 20 years of

[18] All the other parameters are calibrated to the values reported in Table 3.

Figure 4: Impulse responses to a capital quality shock for $\theta \in \{0, 0.4, 1\}$



Note: Lending rate and spread are annualised. All responses are deviations from the steady state in percentage points.

data and we compute the implied empirical moments. In Table 5, we report for selected variables, the empirical standard deviation in the data and the simulated moments from the model with different calibrations of θ. The first important result is that increasing θ would result in a mitigation of the business cycle. The standard deviation of output would decline by 9% from the standard deviation simulated for the model where $\theta = 0$. This is mostly explained by a reduction of the variability of investments, which declines by almost 10%, while standard deviation of consumption increases. Interestingly, introducing risk weights for government bonds would not result in larger volatility of sovereign bond yields while it would stabilise the lending spread. Banks' assets, defined as $Assets_t = Q_t S_{b,t} + B_t$, would also be less volatile, essentially because of lower variability in loans. Because lending rates are more stable, banks' profitability proxied by return on assets (ROA) would also be more stable.

Table 5: Second moments of selected variables from the model for different values of θ

Variable	**Data**	**Benchmark** [1]	$\theta = 0.4$ [2]	$\theta = 1$ [3]
Y	1.18	1.21	1.13	1.10
C	0.78	1.01	1.07	1.10
K		3.39	3.19	3.11
I	3.82	3.81	3.51	3.42
Assets	15.52	12.09	10.63	9.99
R_D	0.78	1.19	1.17	1.17
R_G	1.33	1.19	1.17	1.17
$R_K - R_D$	0.41	1.73	1.67	1.64
Return on assets (ROA)	0.26	0.26	0.27	0.19

In Table 6, we report the effects from varying sovereign risk weights on the correlation of selected variables with GDP. The policy reduces somewhat the procyclicality of macroeconomic quantities like consumption and investments and certain financial variables such as banks' assets and profitability. By contrast, interest rates and spreads would be slightly more correlated (in absolute terms) with output. In Table 7, we present the effects on first-order autocorrelations for the same variables. Except for return on assets, increasing θ has negligible effects on autocorrelations.

Table 6: Correlations between output and selected variables from the model for different values of θ

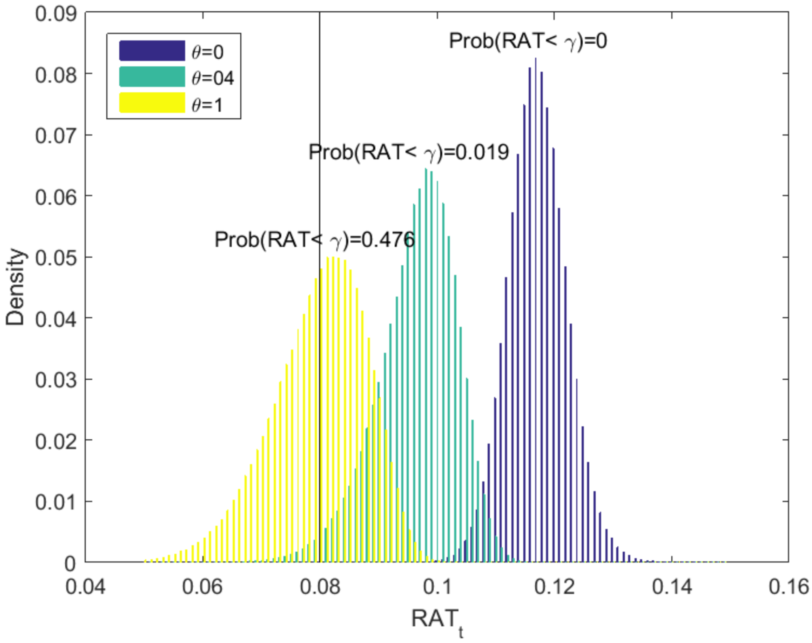
Variable	**Data**	**Benchmark** [1]	$\theta = 0.4$ [2]	$\theta = 1$ [3]
Y	1.00	1.00	1.00	1.00
C	0.67	0.67	0.64	0.63
K		0.57	0.53	0.50
I	0.89	0.88	0.84	0.81
Assets	-0.11	0.56	0.52	0.49
R_D	-0.47	-0.30	-0.33	-0.34
R_G	0.07	-0.30	-0.33	-0.35
$R_K - R_D$	-0.08	0.20	0.23	0.25
Return on assets (ROA)	0.26	0.18	0.13	0.13

Table 7: Autocorrelations for selected variables from the model for different values of θ

Variable	**Data**	**Benchmark** [1]	$\theta = 0.4$ [2]	$\theta = 1$ [3]
Y	0.85	0.92	0.91	0.91
C	0.81	0.96	0.96	0.97
K		0.97	0.97	0.97
I	0.84	0.90	0.89	0.89
Assets	0.97	0.96	0.96	0.96
R_D	0.81	0.40	0.40	0.40
R_G	0.89	0.40	0.40	0.40
$R_K - R_D$	0.84	-0.01	-0.01	-0.01
Return on assets (ROA)	0.67	0.84	0.79	0.75

When sovereign risk weight increases, ceteris paribus, the capital ratio declines, increasing the probability of banks failing to fulfil capital requirements. To better assess the likelihood of this event, we present in Figure 5 the histogram of simulated capital ratios for our benchmark model compared with the simulations from the models with positive values of θ. According to our calibrated benchmark model, banks have zero probability of failing to fulfil capital requirements. However, as θ increases to 0.4, the probability increases to almost 2%, while for $\theta = 1$ it reaches 48%. As reported in Table 8, despite the capital ratio being above 8% in most of the cases, the penalty is almost always negative. This is due to our calibration of $\bar{\mathcal{P}}$, guaranteeing that capital regulation does not generate additional resources. When the capital constraint is more binding, the penalty deteriorates banks' retained earnings. In Table 8, we show that banks' penalty as a share of banks' wealth rises from 0.32% to 0.71% as θ increases.

Figure 5: Histogram of simulated capital ratios for different levels of θ



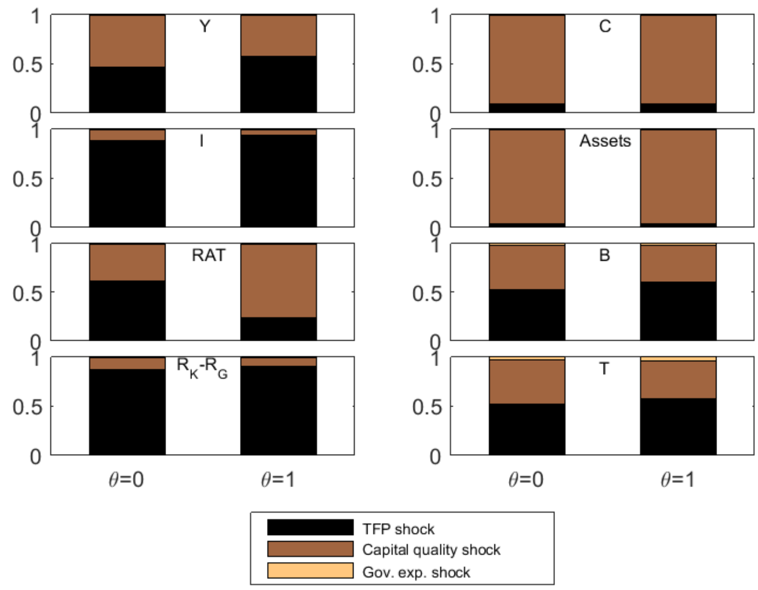
Note: Histograms are generated from simulated capital ratios from the model calibrated with different values of sovereign risk weight. We also report the empirical probability that the capital ratio falls below γ.

Table 8: Selected statistics for different levels of θ (%)

Variable	**Benchmark**	$\theta = 0.4$	$\theta = 1$
	[1]	**[2]**	**[3]**
$Prob(RAT_t < \gamma)$	0.00	1.85	47.65
$Prob(\mathcal{P}_t < 0)$	99.54	100.00	100.00
$\mathcal{P}_t/N_t$	-0.32	-0.52	-0.71

Given the previous results, we found evidence that removing the zero risk weighting on sovereigns would likely reduce the volatility of the business cycle and other financial variables. However, it would be interesting to understand if the policy change has significant effects on the resilience of these variables to the specific structural shocks that have been introduced. For this purpose, we perform a variance decomposition for a selection of variables when $\theta = 0$ and when $\theta = 1$. In figure 6, we present for each variable a bar plot that shows the relative contribution of each structural shock to the variable's overall volatility. A first striking result is that total factor productivity and capital quality shock are the only shocks that are quantitatively relevant. In Table 5, we have shown that the volatility of output and investment declines when we increase θ. According to the variance decomposition, this happens because the two variables are more resilient to capital quality shocks. More generally, the relative contribution of capital quality shocks to the system declines when we increase sovereign risk weights. This is because, when a capital quality shock hits the economy, banks are required to reduce loans by a lower amount when $\theta = 1$, which has positive effects on investment and overall economic activity.

Figure 6: Variance decomposition for $\theta \in \{0, 1\}$



6 Robustness

In this section, we perform a battery of robustness checks with respect to the choice of several key parameter values, especially the ones in the penalty function. This is important, since most of the parameters of the model are calibrated on a small sample (i.e. starting in 2000), consisting of macroeconomic and financial variables. In line with our previous analysis (see Table 5), we concentrate on the effect of different parameter choices on the second moments of the main macro aggregates.

In Table 9, we report the ratio of the standard deviation of a selected variable for the case in which $\theta = 1$ to the one in which $\theta = 0$. The benchmark calibration is denoted by specification [1]. For the other specifications, we report this ratio for alternative calibrations in which we change only one parameter compared to the benchmark, i.e. the respective parameters shown in the table. For specification [2] and [3], we change the inverse elasticity of the labour supply. This parameter affects the intertemporal choice of labour supply and more generally consumption and savings decisions. The results turn out to be robust to alternative calibrations of this parameter, as the ratios of standard deviations do not change significantly compared to the benchmark (specification [1]). The choice of the discount factor, β, which is chosen to match a real deposit rate, R_D, of 2% in the benchmark case affects our results to a larger extent. When the discount factor increases such that the real deposit rate equals 1.5%, the variability of output and investments would be reduced by 10% and 13%, respectively, under equally risk-weighted sovereign bonds. Therefore, as the average real deposit rate in the euro area fell below 1% after 2003, the potentially positive effects of a change in those risk weights are likely to be underestimated in our benchmark economy that targets a real deposit rate of 2%. Finally, we consider changes in parameter ϕ that strongly affects the shape of the penalty function. We set the alternative value for ϕ so that the lending spread in the steady state equals 0.75%, which is larger than the 0.65% in the benchmark economy.[19] Similar to increases in the discount factor, a higher sensitivity of the penalty to changes in the bank capital ratio leads to larger stabilization effects by removing the zero risk weight on government bonds. In column [7], we investigate differences in model results when using first instead of second order approximation around the steady state for solving the model. In this case, increasing risk weights on sovereigns is slightly less effective than in the benchmark case. This suggests that nonlinearities in the model play a role but are not essential in shaping our results.

Finally, we report the ratio of standard deviations in a model with a different functional form of the penalty function compared to the benchmark, denoted by specification [8]. More specifically, we adopt a slightly modified penalty function which reads

$$\mathcal{P}_t = \bar{\mathcal{P}} + \phi \log \left(1 + \frac{N_t - \gamma RWA_t}{RWA_t} \right).$$

Similar to Fève et al. (2019), the penalty is defined in terms of excess capital with respect to capital requirements, but as a fraction of risk-weighted assets. The penalty can be rewritten as

$$\mathcal{P}_t = \bar{\mathcal{P}} + \phi \log \left(1 + RAT_t - \gamma \right).$$

As in our benchmark case, the shape of the penalty function strongly depends on the parameter ϕ. Moreover, the derivatives of this penalty function are given by

$$\frac{\partial \mathcal{P}_t}{\partial Q_t S_t^b} = -\phi \frac{RAT_t}{(1 + RAT_t - \gamma) RWA_t}, \qquad \frac{\partial \mathcal{P}_t}{\partial B_t} = -\phi \theta \frac{RAT_t}{(1 + RAT_t - \gamma) RWA_t}. \tag{43}$$

As in the benchmark specification of the penalty function, the first derivatives with respect to loans and sovereign bonds are decreasing in the risk-weighted assets. This implies that there is still substitutability between government bonds and loans. Moreover, the capital ratio constraint γ negatively affects the derivative of the penalty function and, consequently, positively affects the spread. The parameter ϕ is calibrated to match the observed lending spread, while the remaining parameters have been left at the values from the benchmark calibration. Using this alternative penalty function, the effects from introducing positive sovereign risk weights on second moments is larger than for our benchmark calibration. In particular, output volatility and investment volatility decline by 13% and 16% respectively, while among financial variables, the volatility of assets and ROA decline by 25% and 10%.

These exercises show that the estimated effects of removing differences in risk weights across assets are robust with respect to the choice of several key parameters and alternative

[19]In the same sample, the average lending spread calculated as the difference between the interest rate on loans to non-financial corporations and the deposit rate from ECB data is 1.32%. However, these two rates might have different durations and credit ratings.

penalty function specifications.

Table 9: Ratio between the standard deviations of a target variable in the economy where $\theta = 1$ and the economy where $\theta = 0$

	Benchmark [1]	$\varphi = 1.5$ [2]	$\varphi = 2.5$ [3]	$R_D = 3\%$ [4]	$R_D = 1.5\%$ [5]	$\phi = 0.08$ [6]	First-order approx. [7]	Modified penalty [8]
Y	0.911	0.903	0.919	0.935	0.894	0.887	0.924	0.865
C	1.089	1.076	1.100	1.062	1.112	1.114	1.081	1.123
K	0.918	0.914	0.921	0.934	0.906	0.896	0.929	0.876
I	0.896	0.900	0.895	0.935	0.865	0.859	0.918	0.841
Assets	0.826	0.825	0.829	0.865	0.799	0.788	0.867	0.750
R_D	0.983	0.984	0.983	0.988	0.980	0.979	0.989	0.967
R_G	0.982	0.983	0.982	0.987	0.979	0.978	0.988	0.963
$R_K - R_G$	0.946	0.944	0.952	0.961	0.939	0.935	0.959	0.919
Return on assets (ROA)	0.737	0.701	0.719	0.546	1.056	0.845	1.697	0.904

7 Concluding remarks

This paper analyses the macroeconomic effects of increasing risk weights on government bonds in the regulatory capital ratio of banks. For this purpose, we make use of a standard RBC model incorporating a banking sector, where bank capital regulation is specified as a penalty for negative deviations from the target capital ratio, and as a reward for positive deviations. This framework is extended by a government sector issuing bonds that are held by domestic banks. Increasing the risk weight on government bonds in the capital adequacy ratio is found to have positive long-run (steady state) effects. The relatively lower weight on loans, used by firms for capital acquisition, leads to a decline in the lending spread, therefore stimulating investment and output. Moreover, the volatility of the business cycle decreases through lower investment volatility, as lending rates are stabilised. Our results are robust with respect to different calibrations of the parameters in the penalty function of banks. Of course, our analysis does not capture all possible benefits and costs of increasing risk weights on government bonds, making it difficult to judge at this stage whether this policy should ultimately be implemented or not. For instance, we do not account for the transitional costs of switching between the regulatory regimes and we ignore the possibility of government default, which may be important where increasing risk weights on government bonds drive up the interest rate on these assets. Given the connection of our results to the capital taxation literature, as differential risk weighting has detrimental effects on private lending and hence on the capital stock and output, it would be also straightforward to perform our analysis within a richer fiscal set-up. In general, our results should be treated with caution as we assume there to be a riskless economy. It will be crucial to perform this analysis within a set-up in which there is a risk of both firms and countries defaulting. Those aspects are left for future research.

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Appendix

Data source

Table 10: Data description

Variable	Series	Source	Starting year
R_D	Deposit rate to households in the euro area (quarterly averages)	ECB	2003
$R_K - R_D$	AAA rated corporate bond - German government bond spread	Thomson Reuters	2000
$Loans$	Private lending from banks to non-financial sector for Germany, France, Spain, Italy, Greece	BIS	1995
SOV	Domestic sovereign bond holdings of banks for Germany, France, Spain, Italy, Greece	Breughel	1999
Y	GDP euro area	Eurostat	1995
I/Y	Investments over GDP euro area	Eurostat	1995
G/Y	Government expenditures over GDP euro area	Eurostat	1995
T/Y	Taxes over GDP	Eurostat	2002
B/Y	Public debt over GDP euro area	Eurostat	2000
ROA	Return on assets banks euro area (annual averages)	Fed, World Bank	1996