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Macroprudential policy measures: macroeconomic impact and interaction with monetary policy

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This technical paper features research-based analysis on policy relevant topics conducted within the Research Task Force (RTF) on the interaction between monetary policy, macroprudential policy and financial stability. https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_research_task_force_rtf.en.html. Technical papers are written in a style that is more broadly accessible compared to standard Working Papers. Their distribution of technical papers is subject to the approval of the Director General of the Directorate General Research.

Abstract

This paper examines the interactions of macroprudential and monetary policies. We find, using a range of macroeconomic models used at the European Central Bank, that in the long run, a 1% bank capital requirement increase has a small impact on GDP. In the short run, GDP declines by 0.15-0.35%. Under a stronger monetary policy reaction, the impact falls to 0.05-0.25%.

The paper also examines how capital requirements and the conduct of macroprudential policy affect the monetary transmission mechanism. Higher bank leverage increases the economy's vulnerability to shocks but also monetary policy's ability to offset them. Macroprudential policy diminishes the frequency and severity of financial crises thus eliminating the need for extremely low interest rates. Countercyclical capital measures reduce the neutral real interest rate in normal times.

JEL codes: E4, E43, E5, E52, G20, G21

Keywords: Monetary Policy, Bank Stability, Credit

Non-technical summary

Macroprudential and monetary policy interact. Macroprudential measures affect credit supply and aggregate demand, impacting inflation in the medium term. Monetary policy affects the way macroprudential measures transmit to the real economy. This technical paper, which is divided into two main parts, lays out the implications of a number of important analytical tools at the European Central Bank (ECB) for the interactions discussed above.

In the first part of the paper we examine the implications of four medium scale dynamic stochastic general equilibrium (DSGE) models for the way the economy reacts to an increase in bank capital requirements. The purpose of the exercise is to benchmark the models' implications against one another as well as to examine the importance of different economic mechanisms for the way the policy is transmitted to the real economy.

The comparative model exercise reveals considerable similarities across the different analytical frameworks in the way the economy responds to an increase in bank capital requirements. All models incorporate a strong link between bank capital and credit supply (the bank capital channel) and imply a modest but significant fall in GDP (peak decline of 0.15-0.35 per cent). There are however several interesting differences in both the short and long run behaviour of the different models.

In the long run, models that ignore bank default imply that output falls permanently due to higher capital requirements while models that stress bank default imply no costs. In the short run, there are several channels which allow the economy to adjust to higher capital requirements without a large decline in lending. These are shown to be important in moderating the transitional costs of increasing bank capital. The ability of banks to reduce voluntary capital buffers or dividend payouts as well as the ability of corporate borrowers to substitute to non-bank funding sources are all important factors which allow the economy to adjust to higher capital requirements without large output costs.

The conduct of monetary policy also matters. The more strongly monetary policy leans against the negative effects of a capital requirements increase on aggregate demand, the smaller the impact on output and inflation over the transition. In a monetary union with a single 'one-size-fits-all' monetary policy, there is therefore a potential asymmetry in the way capital requirement changes affect small and large countries. Simulations with a two-country model show that larger countries (which have a larger weight in the overall output and inflation rate) experience a smaller decline in economic activity following a capital requirement increase. In the same vein, the argument for proactive macroprudential policies complementing monetary policy may even be stronger in a monetary union as they can be targeted to reflect the heterogeneous economic and financial developments across countries.

Finally, using a non-linear version of the Gertler and Karadi (2011) model, we examine the interaction between monetary policy and cyclical macroprudential policies. Here we stress the need for macroprudential measures to lean against excessive leverage during the boom and to support lending (by releasing buffers) following crises. Monetary policy is also used to lean against imbalances although only to a limited extent.

In the second part of the paper, we use a number of contributions which examine the way macroprudential policy affects the monetary transmission mechanism. The exercises use variants of the Gertler and Karadi (2011) model as well as of some of the medium scale DSGE models used in the first part of the paper. While all the models rely on the bank capital channel, the standard framework is modified in various ways to incorporate non-linearities and endogenous risk, the shadow banking sector as well as unconventional monetary policy.

A common lesson from all the contributions is that a high level of capital requirements and a safe and less leveraged financial system make the economy less responsive to conventional and unconventional monetary policy. This is intuitive because banks are exposed to economic shocks (including those coming from monetary policy) and their net worth becomes more sensitive to these shocks when leverage is high and assets are risky.

Finally, the paper argues that countercyclical macroprudential policy is likely to have important implications for the appropriate level of nominal interest rates over the economic and financial cycle. If macroprudential policy is effective at moderating credit booms and busts, this should eliminate the occasions when interest rates need to fall to very low levels. During boom times, however, macroprudential measures restrict lending and cool the economy down, implying lower policy interest rates compared to a world without macroprudential regulation.

Contents

1 Introduction

Macroprudential and monetary policy interact and affect each other's objectives. Macroprudential measures affect credit supply and aggregate demand, impacting inflation in the medium term. Macroprudential measures also change the behaviour of the banking system thus potentially modifying the way interest rates affect the economy.

The interaction operates in the other direction too. Monetary policy can affect the way macroprudential measures transmit to the real economy. By stimulating or discouraging bank risk taking, changes in interest rates could also change the desired stance of macroprudential policy.

This paper lays out the implications of a number of important analytical tools at the European Central Bank (ECB) for the interactions discussed above. The paper is divided into two main parts. The first analyses how capital requirements transmit to the macroeconomy and how this transmission is affected by the conduct of monetary policy. The second studies how macroprudential policy and the level of capital requirements change the monetary transmission mechanism. We argue that there are strong interactions that operate in both directions and that these interactions are important for policy makers to take into account when setting policy.

The impact of capital requirements on the macroeconomy: lessons from four macroeconomic models at the ECB

In the first part of the paper we draw on Darracq-Paries, Karadi, Kok and Nikolov (2019) to examine the implications of four medium scale dynamic stochastic general equilibrium (DSGE) models for the way the economy would react to an increase in bank capital requirements. Our focus on capital requirements as a financial stability policy tool is motivated by practical considerations. Basel III has focused on introducing a countercyclical capital buffer as the main tool for macroprudential policy and it is therefore vital that we understand what impact it has on the macroeconomy.

The models we employ in our comparative exercise are used frequently for policy analysis at the European Central Bank (ECB). These are the Darracq-Paries, Kok-Sorensen and Rodriguez-Palenzuela (2011) model (hereafter known as DKR), the Darracq-Paries, Jacquinot and Papadopoulou (2016) model (hereafter known as DJP), the Mendicino, Nikolov, Suarez and Supera (2018a) model (hereafter known as 3D because it models the defaults of banks, firms and households) and the Coennen, Karadi, Schmidt and Warne (2018) model hereafter known as NAWM II.[1]

The purpose of the exercise is two-fold. First, it allows the models to be benchmarked against one another and their quantitative and qualitative implications to be compared. We can also examine the importance of the different economic mechanisms for the way the policy is transmitted to the real economy. Second, it sets the stage for the quantification of the way the conduct of monetary policy affects the transmission of capital requirements.

The comparative model exercise reveals considerable similarities across the different analytical frameworks in the way the economy responds to an increase in bank capital requirements. All models incorporate a strong link between bank capital and credit supply (the bank capital channel) and all generate some decline in lending on impact as banks restrict credit supply. This reduces aggregate demand and leads to a modest but significant fall in GDP (peak decline of 0.15-0.35 per cent) despite the reaction of the monetary authority which lowers nominal interest rates.

There are however several interesting differences in both the short and long run behaviour of the different models. In the long run, the 3D model generates no decline in output while the other models do. We show that this is due to the presence of bank failure risk in the 3D which is reduced by the higher capital requirements with a positive effect on economic activity in the long run. In contrast, the other models either do not incorporate bank default or calibrate it to zero thus eliminating this potential impact of the increase in bank capital requirements.

In the short run, all models incorporate several channels which allow the economy to adjust to higher capital requirements without a large decline in lending. In the DJP and DKR, banks reduce their voluntary buffers over the transition thus smoothing bank loan supply. In the 3D, bank capital ratios are always binding but banks reduce dividend payouts (or issue new stock) thus speeding up the accumulation of equity through retained earnings. And in the NAWM II and the 3D, the corporate sector is able to replace some (though not all) of the lost bank funding with non-bank credit.

Sensitivity analysis shows that all of these inbuilt adjustment mechanisms are crucial in

[1]The abreviation stands for New Area-Wide Model with a financial sector. The version extends and re-estimates the original NAWM model (2008).

dampening the impact of higher capital requirements on the real economy. If banks are unwilling or unable to change capital buffers or dividend policy, this would result in a deeper contraction of lending and activity.

The conduct of monetary policy also matters. The more strongly monetary policy leans against the negative effects of a capital requirements increase on aggregate demand, the smaller the impact on output and inflation over the transition. In a monetary union with a single 'one-size-fits-all' monetary policy, this points to a potential asymmetry in the way capital requirement changes would work in small and large countries. Simulations with a two-country version of the DKR model show that indeed larger countries (which have a larger weight in the overall output and inflation rate) experience a smaller decline in economic activity following a capital requirement increase.

Finally, we examine how monetary and cyclical macroprudential policies should interact in a simplified version of the Gertler and Karadi model (2011). Here we stress the need for macroprudential measures to lean against excessive leverage during the boom and to support lending (by releasing buffers) following crises. Monetary policy is also used to lean against imbalances although only to a limited extent.

How does bank leverage and macroprudential policy affect the monetary transmission mechanism?

In the second part of the paper, we use a number of contributions which examine the way macroprudential policy affects the monetary transmission mechanism. The exercises use variants of the Gertler and Karadi model (2011) as well as of some of the medium scale DSGE models used in the first part of the paper. While all the models rely on the bank capital channel, the standard framework is modified in various ways to incorporate non-linearities and endogenous risk, the shadow banking sector as well as unconventional monetary policy.

A common lesson from all the contributions is that bank leverage and the default risk of the banking system matter a lot for the way monetary and other shocks are transmitted to the real economy.

Simulations with the Gertler and Karadi (2011) model as well as work by Darracq-Paries, Koerner and Papadopoulou (2019) show that a high level of capital requirements and a safe banking system make the economy less responsive to conventional and unconventional monetary policy actions. This is intuitive because banks are exposed to economic shocks (including those coming from monetary policy) and their net worth becomes more sensitive to these shocks when leverage is high and assets are risky. Positive (and negative) shocks are then amplified because they also raise (lower) bank net worth and expand (contract) credit supply. High capital requirements stabilize bank net worth, thus weakening the bank capital-related amplification mechanism. This makes the economy less responsive to short term interest rates or unconventional measures such as the asset purchase programme (APP).

The paper also shows that even though monetary policy is less powerful when bank leverage is low (capital requirements are high), the economy is not necessarily less responsive to non-monetary (e.g. demand) shocks. Even though the shocks themselves have a smaller impact, monetary policy is also weaker so the net effect is to leave the impact of non-monetary shocks broadly unchanged. However, if monetary policy becomes constrained by the zero lower bound (ZLB) on nominal interest rates, the impact of exogenous shocks will depend again on the leverage of the banking system, and a safer banking sector will reduce output volatility.

In a contribution based on the work in Mazelis (2016), the paper shows that financial system leverage coming from the so-called 'shadow banking system' also matters for the way the economy responds to shocks at the ZLB on nominal interest rates. The paper shows that measures to eliminate regulatory arbitrage and reduce aggregate financial system leverage makes the economy more resilient in times when monetary policy is unable to lean against negative shocks.

Finally, using the results in Van der Ghote (2018), the paper argues that, to the extent that macroprudential policy is effective at moderating credit booms and busts, this should have important implications for the level of the natural real interest rate over the financial cycle.[2]

If macroprudential policy makes crises less severe and less frequent, it will eliminate the states of the world in which the natural real interest rate falls significantly below zero. During boom times, macroprudential measures restrict lending and cool the economy

[2] The natural real interest rate is the real interest rate that is consistent with stable inflation in the medium term.

down, implying lower natural real interest rates compared to a world without macroprudential regulation.

In the end, the analysis in the second part of the paper carries one key lesson for policymakers: the health of banks and the nature of macroprudential policy matters a lot for monetary policy transmission. A weaker banking system amplifies the impact of monetary policy but also contributes to economic instability and to a fall in the neutral real interest rate. This is more likely to deprive monetary policy makers of potential firepower in tackling crises. Macroprudential measures which put banks on a sounder financial footing and tame the financial cycle bring an additional benefit by eliminating periods when the economy needs very negative real interest rates due to a financial panic.

The rest of the paper is organized as follows. Section 2 first examines how capital requirement changes affect the macroeconomy in four models used at the ECB for policy analysis. It then studies the way the conduct of monetary policy changes the transmission mechanism of capital requirement changes. Section 3 studies the interaction in the opposite direction. It examines how the level of capital requirements and the conduct of countercyclical macroprudential policy changes the transmission mechanism of monetary policy. Section 4 concludes.

2 How does monetary policy affect the transmission of macroprudential measures?

2.1 The impact of bank capital requirements: comparing the main ECB models [3]

The impact of bank capital requirements on the real economy remains highly uncertain, with much less empirical evidence compared to the impact of monetary policy changes. This is what makes structural macroeconomic models useful. They can be parameterized to fit various features of the aggregate banking, financial and macro data and then used to provide a quantitative evaluation of the impact of capital requirement changes on the macroeconomy.

[3] This section draws on analysis in Darracq-Paries, Karadi, Kok and Nikolov (2019)

However, as with all quantitative evaluations, gauging the real impact of policy using models is highly uncertain and contingent on the chosen model being a good approximation of reality. This is why most central banks rarely rely on a single model but on a 'suite' which provides a range of estimates based on different quantitative tools.

At the ECB, there are four medium scale models used for policy analysis: the DKR model, the DJP model, the NAWM II model and the 3D model. A full account of their structure is impossible within the confines of this paper and the reader is referred to the papers describing the models in detail.

Nevertheless, Table 1 shows several key characteristics of the models which will be important when discussing the model properties in response to a surprise increase in capital requirements. The first panel of the table focuses on the way banks are introduced in the different frameworks. Bank failures feature most prominently in the 3D model; they are also present in the DJP model but are calibrated to zero. The level of bank default will be a key factor in the way the economy responds to higher capital requirements in the medium to long term.

The second and third rows show the various ways banks can react to the policy change without cutting lending. Dividend cuts (3D model) and reductions in voluntary capital buffers (DJP and DKR) are two prominent mechanisms which allow the credit impact to be smoothed. Finally, the fourth row shows that in some of the models, non-bank funding sources can further help to shield bank borrowers from the tightening of loan supply. All these features will tend to dampen the short term impact of a capital requirements increase on the real economy.

The second panel focuses on the nominal rigidities present in the models. All feature sticky prices and most feature sticky wages, providing a role for monetary policy to affect output and to potentially help the economy in its adjustment to a capital requirement increase. All apart from the 3D model feature rigid nominal lending interest rates which should further slow down the effect of bank credit restrictions on real activity.

We subject each of the four models to the same capital requirement shock - a 1pp increase in the minimum capital ratio, implemented gradually over 1 year and then very gradually (with an autocorrelation coefficient of 0.99) unwound back to the starting value. So for all intents and purposes, this is a near permanent shock to the capital ratio (it has a half-life of 15 years).

Table 1: Model characteristics

	NAWM II	DKR	DJP	3D
The banking framework				
Bank failures	no	no	yes	yes
Issue new equity/vary dividends	no	no	no	yes
Change voluntary capital buffers	no	yes	yes	no
Non-bank funding sources for firms	yes	no	no	yes
Nominal rigidities				
Rigid prices	yes	yes	yes	yes
Rigid wages	yes	yes	yes	no
Rigid nominal lending interest rates	yes	yes	yes	no

Throughout the section, we will compare the implications for the real economy impact of the policy in the four models. We will focus on a set of 'executive summary' charts covering only the most important variables (output, inflation, total lending, consumption and investment). In the Appendix, there is a full set of IRFs covering all variables.

We start with Figure 1 which documents the impact of the capital requirement change on GDP and inflation. There are several noteworthy features of the results. The negative macroeconomic impact of the increase in capital requirements is significant but not overly large in all the models. It is somewhat smaller and far less persistent in the 3D than in the DJP, DKR and NAWM II models. The impact on annualized inflation is modest and disappears within 8-10 quarters in all models due to a flat Phillips curve.

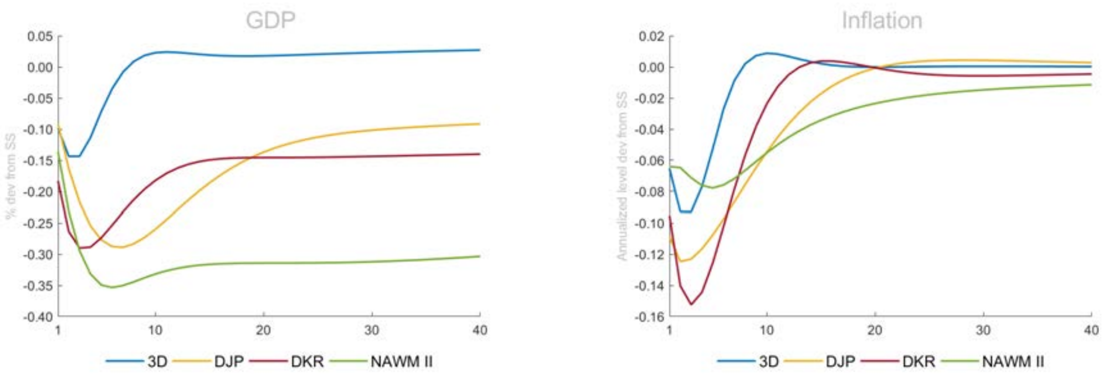

Figure 1: GDP and inflation.

In what follows, we sketch out the transmission mechanism that aggregates up to the dynamic responses in Figure 1. We do this by comparing the reaction of several other key variables in the models which help us identify the way higher capital requirements propagate through the economy. We start first with the way that higher capital requirements affect bank loan supply before outlining the models' implications for the way bank lending transmits to the demand components and real GDP in the four models.

2.1.1 The impact of the capital requirement change on bank credit supply

We start with the banking sector which is affected directly by the increase in minimum capital requirements. Figure 2 shows the way banks adjust their actual capital ratios and what impact this has on lending. The path of the minimum capital ratio is shown by the green line. It is labelled NAWM II because the capital ratios in the NAWM II and 3D models exactly follow the regulatory minimum.

In the DKR and DJP, there are endogenous voluntary buffers above the minimum capital requirement. At all times, banks in these two models face a trade-off between larger profits if they reduce their buffers and increase lending and a higher probability that their capitalization falls below the minimum with significant associated costs. The higher minimum capital requirements would lead to a large fall in lending and a big increase in lending spreads if banks maintained their previous buffers. The higher potential profits from a marginal unit of loans persuade banks to shrink their buffers while the financial system as a whole accumulates equity through retained earnings in reaction to the shock. This means that actual capital requirements increase gradually and reach the new minimum only in the "long run" (which, for the purposes of the current discussion we define to be 40 quarters after the policy change). [4]

In addition, the DKR and DJP models feature sticky lending interest rates which smooths the increase in lending spreads and hence the fall in bank lending in equilibrium.

In the 3D and the NAWM II, the capital requirement always binds and the actual capital requirement follows the minimum. This leads to a sharper decline in lending, other things equal. However, these two models feature other mechanisms which dampen the impact

[4] While the change in capital requirements is highly persistent, it is not permanent and in the very long run (i.e. 100 years out) the economy will be back to its starting point. However, the IRF is so persistent that we will from now on refer to the 'long run response' defined as the impact after 10 years.

of capital requirements on bank lending.

In the 3D, higher capital requirements make banks safer leading to lower uninsured debt funding costs which are passed on to borrowers by competitive banks. This means that lending is broadly unchanged in the long term whereas it falls in the other models which either do not model bank defaults (NAWM II and DKR) or calibrate bank default to zero (DJP). In the 3D, the risk of bank default is calibrated to approximately 0.8 per cent (the average for EA banks since 2001) and this implies considerable benefits from increasing capital requirements to make banks safer.

In the short term, banks in the 3D model reduce dividend payouts speeding up earnings retention. Dividend cuts are assumed to be costly for banks reflecting the observed smoothness of dividends in reality. However the value of additional retained funds increases after a capital requirement increase because lending spreads are very high while credit is restricted. Banks accumulate funds rapidly both on the back of stronger profitability as well as due to lower dividend payouts. Lending supply recovers quickly and is back to its starting value within a year.

In the NAWM II, debt is long term so capital requirements reduce the debt stock only very gradually. There too loan interest rates are sticky helping to avoid sharp movements in spreads.

Overall, the models produce relatively similar short term declines in lending. In the estimated NAWM II, DKR and DJP models, lending falls more gradually than in the calibrated 3D model but the differences in peak responses are not overly large. Where the models do differ very strongly is in the long term impact of capital requirements on the real economy.

In the DJP, DKR and NAWM II models, there is a permanent decline. In the 3D, lending and bank capital recover and are broadly unchanged in the long term due to benefits for the economy as bank default declines. This is a channel which has been strongly stressed in Clerc et al. (2015) and Mendicino et al. (2018a). We will be exploring further how the capital requirements impact is affected by this channel in subsequent sensitivity analysis.

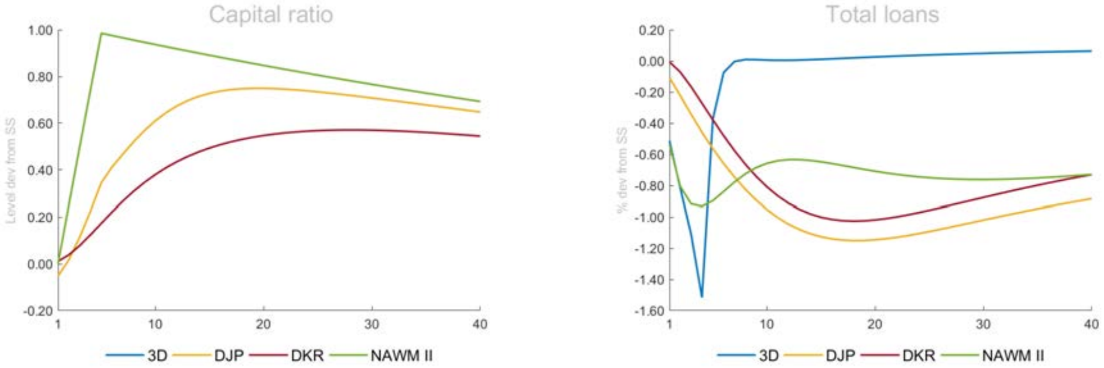

Figure 2: Bank capital requirement and total loans. Note that the minimum regulatory capital requirement is binding in the 3D and NAWM II.

2.1.2 The impact of bank loan supply on aggregate demand components

As Figure 3 shows, reduced lending affects investment demand by firms and consumption demand by households through very standard transmission channels.

The corporate sector relies on bank credit for most of its funding and the rise in the cost and reduction in the availability of bank lending cause a reduction in investment demand. However the 3D and the NAWM II also model non-bank funding which can be accessed but at an additional cost which grows with the size of non-bank funding. This cost is meant to reflect that, in practice, not all firms have access to the bond market on the same terms. For example smaller and more opaque firms will find it more difficult or more costly to access public debt markets directly. Nevertheless, in an environment of reduced bank credit, some of these non-bank sources of funding expand to some extent helping to moderate the fall in overall credit to the corporate sector.

Ultimately, business investment in the four models experiences a decline which reaches around 1.5% at its peak. Again, there is little difference between the models in the first few quarters. Further out, investment recovers most of its fall in the 3D and continues to be depressed for 4-5 years in the DKR, NAWM II and DJP models.

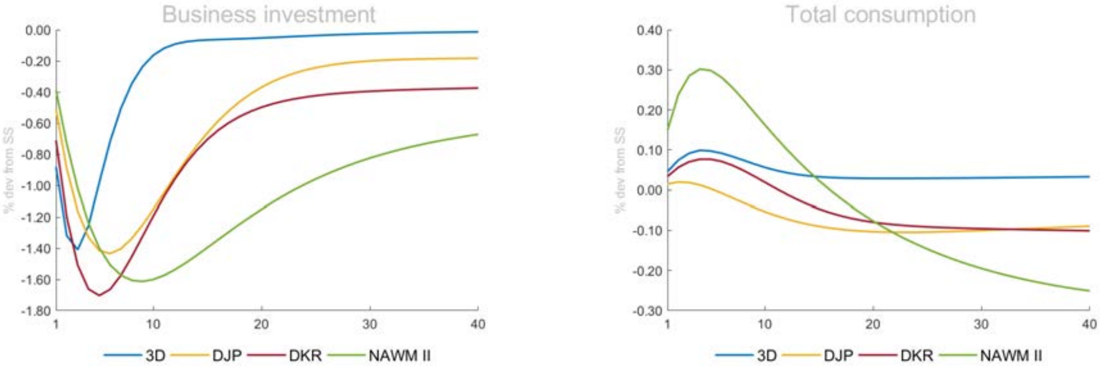

Figure 3: Business investment and total consumption.

The fall in bank credit hits some parts of the household sector as well. In all models apart from the DJP and NAWMII, there is an impatient household which is a borrower in equilibrium and whose demand for non-durables and housing depends on bank credit. The higher cost and lower availability of bank lending leads to a fall in the expenditure of this 'borrower' household.

However, as Figure 3 reveals, overall consumption increases over the adjustment path to the capital requirement policy change. This is due to the strong increase in the consumption and housing demands of saver (patient) households whose demand strengthens on the back of lower nominal and real interest rates.

Monetary policy is governed by the same Taylor rule in all the models and nominal interest rates are driven by inflation deviations from target and by deviations of output growth from trend. The weakness of output and inflation therefore lead to a relaxation of monetary conditions and savers who do not depend on bank lending, increase their expenditure helping to partially offset lower investment demand.

The endogenous response of monetary policy is an important determinant of the way lending restrictions affect final economic activity. We will return to this later in the paper when we examine how differences in the responses to inflation and real disequilibria affect the real impact of capital measures in the four models used in the paper.

By means of a summary of the results in the context of other studies, Table 2 reports the peak lending and GDP responses from the four ECB models alongside alternative estimates. Our impacts are in the ballpark of those found in the literature - somewhat smaller for lending but somewhat larger for GDP

Table 2: Macroeconomic impact of increasing the capital ratio by 1pp

Model/Study	**Lending reduction**	**GDP reduction**	**Country**	**Sample period**
DJP	1.15	0.29	Euro Area	2001-2016
DKR	1.03	0.29	Euro Area	2001-2016
NAWM II	1.26	0.36	Euro Area	1985-2014
3D	1.52	0.14	Euro Area	2001-2016
Angelini and Gerali (2012)		0.05 [0-0.36]	Euro Area	
Bridges et al. (2014)	3.5		UK	1990-2011
De-Ramon et al. (2012)	1.6	0.3	UK	1992-2010
Fraisse et al. (2015)	1-8		France	2008-2011
LEI (2010)		0.09	13 OECD countries	
MAG (2010)	1.4	0.1-0.15	17 OECD countries	
Miles et al. (2013)		0.25*	UK	
Noss and Toffano (2014)	1.4		UK	1986-2008
Roger and Vitek (2012)		0.11 [0.09-0.24]	15 advanced and emerging	
Slovik abd Cournède (2011)		0.2	3 OECD countries	
Suturova and Teply (2013)	1.4-3.5		Europe	2006-2011

Notes. Results are reported in % deviation from steady-state. (*) Effect of a 1% increase in the cost of capital.

2.1.3 Sensitivity analysis

The cost of reducing dividends in the 3D model

We now examine the sensitivity of the transmission mechanism to the dividend adjustment cost paid by the household in the 3D. As already discussed, this is a key mechanism which dampens the impact of the capital requirement increase on bank loan supply. Figure 4 compares the baseline simulation with the case where the cost of adjusting dividends is higher so that dividends are smoother and earnings retention has to rely only on profits rather than also on lower distributions.

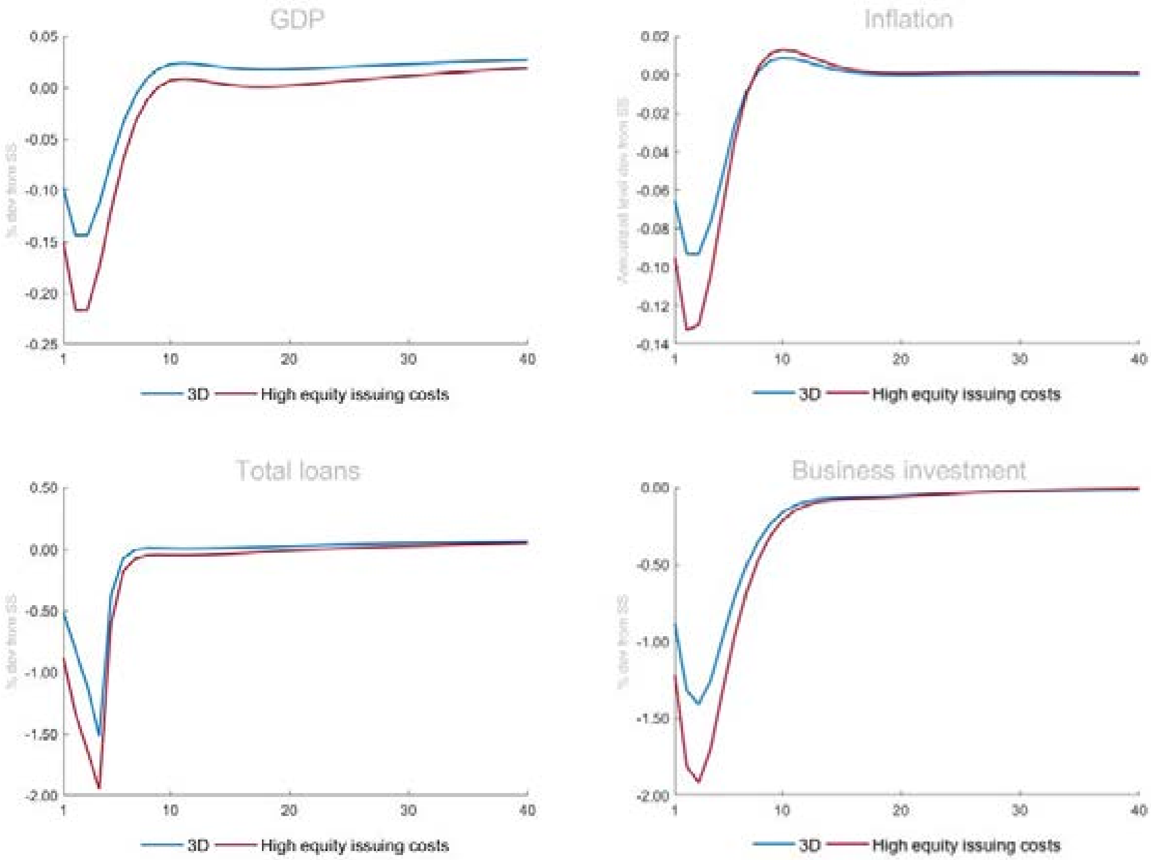

Figure 4: Sensitivity with respect to equity issuance costs in the 3D.

Increasing the cost of dividend variation boosts the short term output cost of the capital requirement increase. Lending and business investment decline by a greater amount, feeding into lower output and inflation. Looser monetary policy (not shown) helps to stimulate consumption but this is not sufficient to offset the negative impact of the lending reduction on aggregate demand and economic activity.

The fragility of the banking system

The riskiness of the banking system is another important factor which changes the real impact of capital requirements. In this section, we use the 3D and DJP models in order to understand how the baseline responses change when we increase the default risk of banks to a 2% annual probability. Figure 5 presents a summary of the results of this sensitivity exercise. In addition, Table 3 below shows a summary of the peak responses of key variables under the sensitivity analysis in this section. The Appendix contains a full set of impulse responses covering other variables in the models.

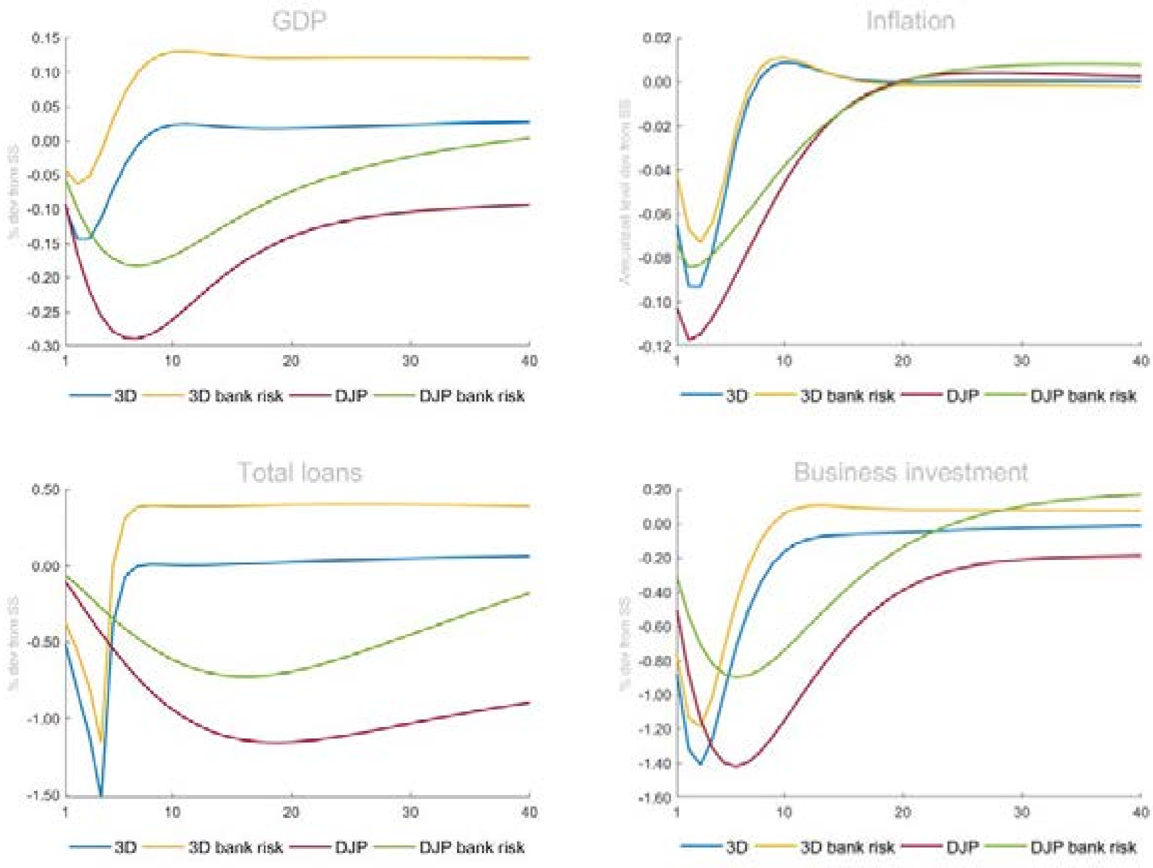

Figure 5: Sensitivity with respect to bank risk by increasing the std. of the idiosyncratic bank shock.

The main message of the sensitivity exercise is that both models deliver higher long term lending and economic activity as well as smaller transitional costs in the case when bank risk is high. This is consistent with the findings in Mendicino et al. (2018b) which shows that a capital requirements increase is less costly in the short term and more beneficial in the long term when the banking system faces higher default risk.

The intuition for this finding is that when bank capital requirements increase, banks become safer and the required interest rate on uninsured lending falls which stimulates lending and economic activity, other things equal. This effect is stronger in the long term when banks have accumulated more capital through retained earnings. The lower funding cost is passed on to borrowers, expanding economic activity.

Perhaps more surprisingly, output falls by much less in the short term in the case of high bank risk. As discussed in Mendicino et al. (2018b), this is due to the behaviour of forward looking firms and households who increase demand immediately in anticipation of the future benefits from less financial instability.

In the end, both models are consistent with the view that warranted capital requirement increases (i.e. when bank risk is high) are likely to be less costly than unwarranted ones (i.e. when bank risk is low). This underlines the importance of modelling the costs of financial instability in models used for macroprudential policy analysis.

Table 3: Sensitivity with respect to bank risk

	GDP	**Inflation**	**Total loans**	**Business investment**
3D	-0.144	-0.093	-1.517	-1.409
3D high bank risk	-0.063	-0.073	-1.158	-1.187
DJP	-0.290	-0.117	-1.158	-1.420
DJP high bank risk	-0.183	-0.084	-0.725	-0.898

Notes. Results are reported in % deviation from steady-state.

2.2 How is the transmission mechanism of capital requirement changes affected by the conduct of monetary policy

The previous section examined the way capital requirement shocks are transmitted to the macroeconomy, conditioning on a Taylor type monetary policy rule which has been

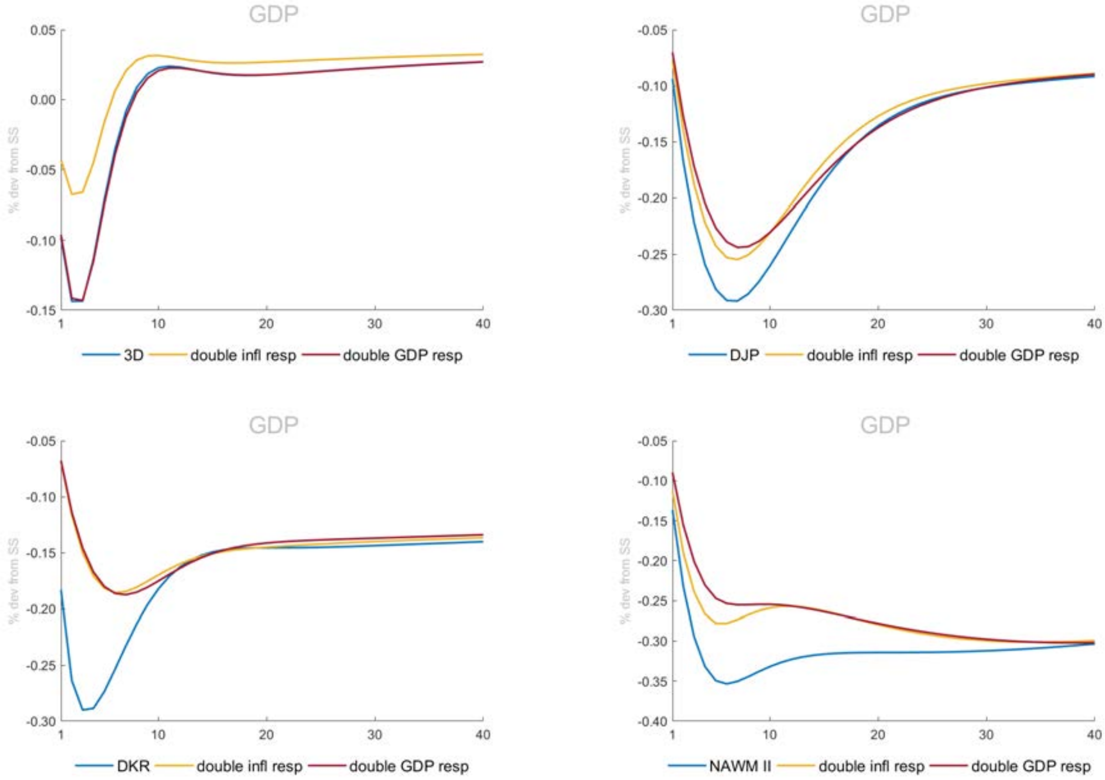

Figure 6: GDP in the four models.

estimated for the euro area. In this section, we examine the way changing the conduct of monetary policy alters the behaviour of the real economy in response to a capital requirement increase.

We consider two deviations from the baseline monetary policy rule. One deviation doubles the reaction coefficient to inflation deviations from target. The other deviation doubles the reaction coefficient to GDP growth. In what follows, we examine how the change in the policy rule affects behaviour both across models and variables in each model.

Figure 6 starts with GDP. Each panel of the graph focuses on a particular model. The blue line within each panel is the baseline IRF, the yellow line is the IRF in which the reaction coefficient to inflation has been doubled and the dark red line is the IRF in which the reaction coefficient to GDP growth has been doubled.

Several aspects of the figure are worth noting. First of all, the decline in GDP is lower in all models when the response to inflation deviations from target is stronger. However, in the DJP and DKR models, as well as in the NAWM II, the behaviour of GDP under both alternative rules is rather similar. Both responding to inflation and GDP growth deviations are equally effective in moderating the short term fall in output after a capital requirement increase. In contrast, in the 3D, responding to GDP growth has a minimal impact. The behaviour of inflation (shown in Figure 7) is consistent with the behaviour of GDP.

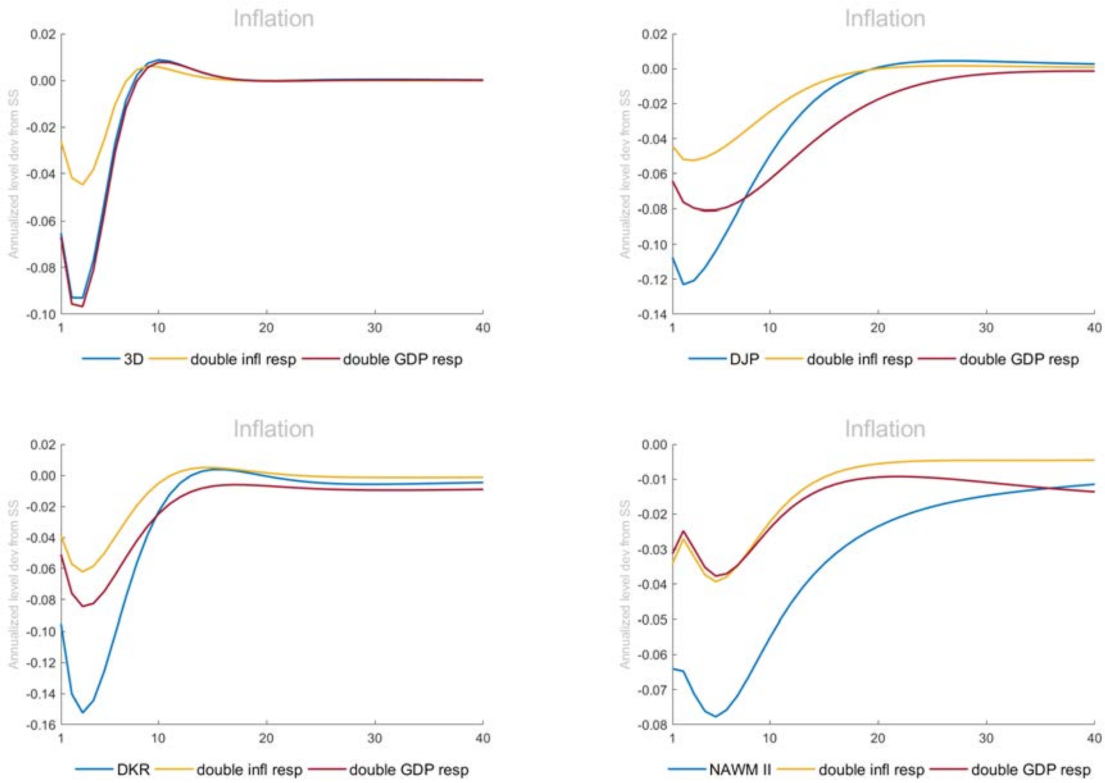

Figure 7: Inflation in the four models.

Figure 8 below shows that the stronger response to inflation (in all models) and GDP growth (in the DKR, DJP and NAWM II models) helps to boost consumption.

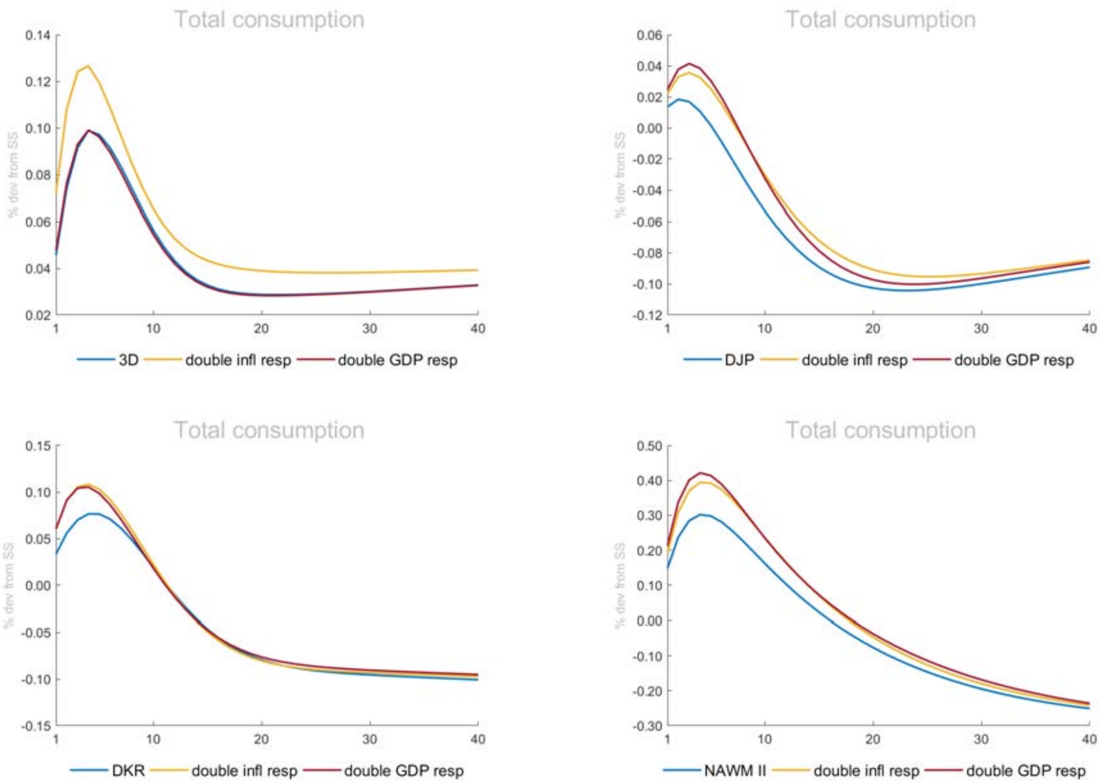

Figure 8: Total consumption in the four models.

Consumption is stronger for both borrowers and savers (shown in the Appendix) although the differences are considerably larger for borrowers in the two models where such a split exists (DKR and 3D). This shows that the main impact of the stronger interest rate reaction function is through the net worth of leveraged agents. Since net worth is better stabilized, there needs to be a smaller decline in borrowers' expenditure.

Business investment is also stronger when policy is more responsive (Figure 9). Here, yet again, the effectiveness of different policy rules in the various models is somewhat different. In the 3D, the main important factor is the response to inflation while in the DJP, DKR and NAWM II, the response to output growth is, if anything, slightly more effective at moderating the decline in investment.

In the 3D there exist levered (bank dependent) firms and un-levered (bank-independent) firms. The separate behaviour of these two sectors are not shown for the sake of brevity but the smaller fall in investment is mostly accounted for by a less significant fall in the investment of levered firms. Just as in the case of borrower households, the stronger response to inflation helps to support the net worth of bank dependent firms and allows them to maintain their operations rather than de-leverage.

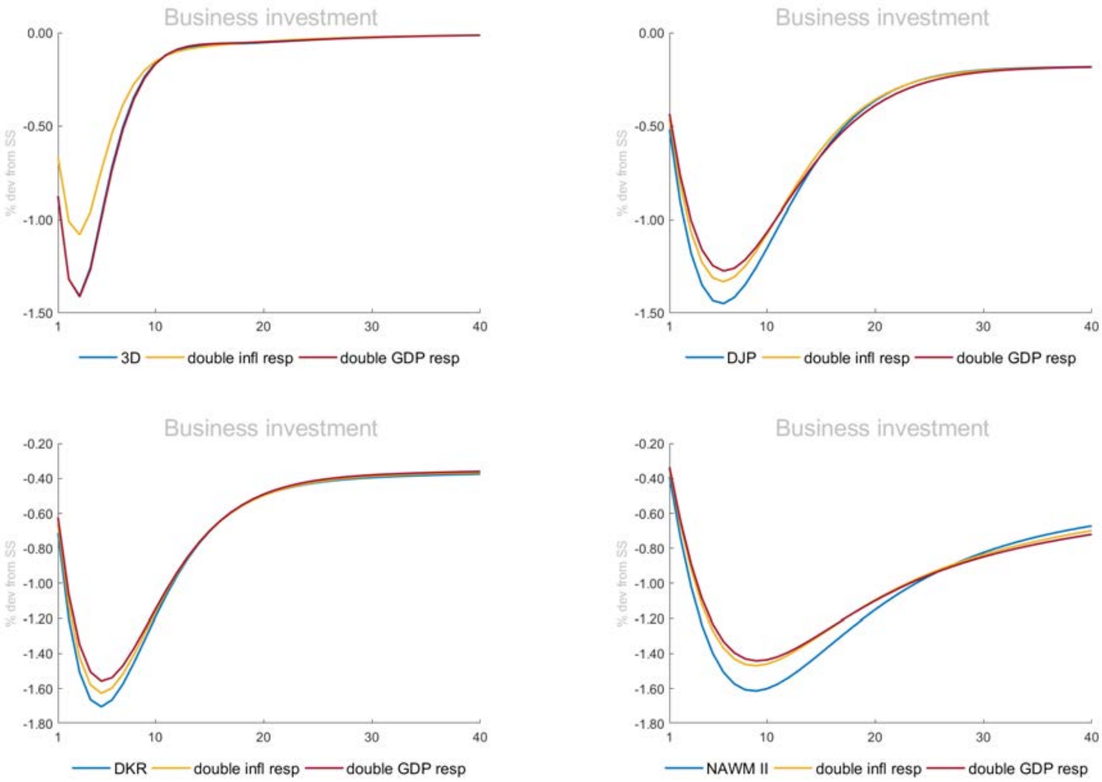

Figure 9: Business investment in the four models.

Table 7 below provides a summary of the peak responses of GDP, inflation, total loans and business investment under the four models and 3 alternative Taylor-type rules. The table clearly shows that the monetary response has a minor impact on lending but moderates the fall of GDP and inflation by boosting aggregate demand.

Table 4: Transmission mechanism in the three models

	GDP	Inflation	Total loans	Business investment
3D Baseline	-0.144	-0.093	-1.517	-1.409
3D 2*inflation response	-0.068	-0.045	-1.453	-1.080
3D 2*dGDP response	-0.143	-0.097	-1.519	-1.413
DJP Baseline	-0.292	-0.123	-1.153	-1.450
DJP 2*inflation response	-0.255	-0.052	-1.129	-1.332
DJP 2*dGDP response	-0.244	-0.081	-1.123	-1.275
DKR Baseline	-0.290	-0.152	-1.026	-1.703
DKR double infl resp	-0.186	-0.062	-0.987	-1.626
DKR 2*dGDP response	-0.188	-0.084	-0.966	-1.557
NAWM II Baseline	-0.353	-0.078	-0.933	-1.613
NAWM II 2*inflation response	-0.280	-0.039	-1.021	-1.468
NAWM II 2*dGDP response	-0.278	-0.038	-0.949	-1.441

Notes. Results are reported in % deviation from steady-state.

2.3 Macroprudential and monetary policy interactions in a monetary union [5]

The above analysis has focused on macroprudential policy transmission effects in a single country (euro area) context. While a useful exercise, it neglects the institutional arrangements currently prevailing in the Single Currency area; namely that macroprudential policy in the euro area is primarily conducted by designated national macroprudential authorities with a central coordinating and horizontal role for the ECB.[6]

[5]Prepared by Matthieu Darracq-Paries (ECB, DG Economics), Christoffer Kok and Elena Rancoita (both ECB, DG Macroprudential Policy and Financial Stability).

[6]This is especially the case since the establishment of the Single Supervisory Mechanism which granted the ECB some macroprudential powers. According to the SSM Regulation, the power to initiate and implement macroprudential measures will primarily remain with the national authorities, subject to a notification and coordination mechanism vis-à-vis the ECB; see Article 5 of Council Regulation (EU) No

The predominantly decentralized organization of macroprudential policymaking in the euro area inter alia reflects the still incomplete integration of national banking sectors and heterogeneous financial cycles across euro area countries. In addition, as the single monetary policy mandate is to deliver price stability over the medium term for the euro area as a whole, it may actually look through financial stability risks building up in specific market segments, jurisdictions or individual countries. Such risks could also have implications for financial stability at the area-wide level. Hence, in a monetary union setting such as the euro area, nationally-oriented macroprudential policies have a role to play in ensuring financial stability for all jurisdictions and supporting monetary policy conduct through the cycle.[7] Macroprudential policies are well suited to take into account national factors, such as the build-up of financial imbalances and the financial system's degree of resilience.

For the purpose of illustrating the role of national macroprudential policies in a monetary union, a DSGE model with various macro-financial linkages and consisting of two countries subject to a single monetary policy is employed (see Darracq-Paries, Kok and Rancoita, 2019). The model is a two-country DSGE model, where the home country represents one country of the euro area and the foreign country represents the aggregation of the other euro area member states.[8] The model was calibrated five times so that, each time the home country was calibrated on one of the four largest euro area economies (Germany, France, Italy and Spain).

In the model, the two countries are interconnected via trade and banking sector linkages. On the trade side, residential goods are treated as durable goods and are non-tradable, while non-residential goods can be traded across countries. For what concerns cross-border credit linkages it is assumed that households and firms can borrow abroad (as well as at home).

To explore the potential benefits of tailoring macroprudential policies to national circumstances while taking account of the single monetary policy stance, the two-country model is successively calibrated to capture the banking system characteristics and macroeconomic features of each of the five largest euro area countries, against the rest of the euro area. The cross-country heterogeneity is reflected first through the degree of demand-side

1024/2013.

[7]See e.g. Constâncio, V., "Financial stability risks, monetary policy and the need for macroprudential policy", speech at the Warwick Economics Summit, February 2015.

[8]The individual economies are modelled following the DKR model of Darracq-Paries et al. (2011).

and supply-side credit frictions related to i) leverage and credit risk profile of households and firms, ii) the lending rate pass-through and iii) bank capital channel. Then, countries differ through their size, trade openness and financial interconnectedness.

We illustrate the transmission of macroprudential policies in a monetary union context as usual using a 1pp increase of capital requirements.

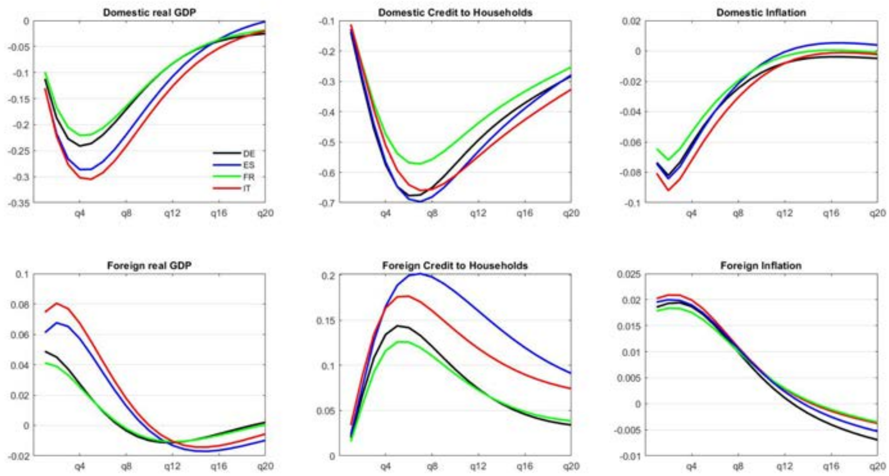

Figure 10: Transition in the 2 country model: 1pp increase in capital requirements.

The domestic transmission is qualitatively similar to the results for the DKR model shown before. Worth noting, however, is that the amplitude and pattern of the transmission differs across countries depending on their financial structures and trade openness.

In terms of cross-border spillovers, macroprudential measures in the targeted jurisdiction are transmitted to the rest of the euro area through various channels. Trade linkages propagate the expenditure slowdown for the domestic economy into weaker foreign demand for the other country. Banks' cross-border loan exposures create direct financial spillovers: the deleveraging pressures of domestic banks lead to funding pressures on foreign banks which ultimately tighten the credit conditions to their local customers.[9]

Finally, in a monetary union, domestic shocks are transmitted abroad through the monetary policy reaction. In particular, the monetary policy response may provide a shield for

[9]This assumes full reciprocity of the macroprudential measures to be imposed also on foreign branches operating in the "home" country and ignores any leakages of targeted activities to non-regulated entities (such as shadow banks); see also the ESRB Handbook chapter 11.

macroeconomic allocations in the domestic economy, provided that the country is large enough and monetary policy has scope to accompany the bank balance sheet adjustment at times of increasing capital buffers.

2.4 How do cyclical macroprudential policy and monetary policy interact?

The previous subsections all focused on models which are relatively rich in terms of their characterization of the banking sector as well as other parts of the economy. This had the advantage of allowing a thorough characterization of the transmission mechanism of capital requirement changes onto the macroeconomy. However, these models entirely ignored endogenous risk considerations (Brunnemeier and Sannikov (2015)) due to the fact that a non-linear solution is not technically feasible.

In order to capture the benefits of countercyclical macroprudential policy and its interactions with monetary policy, it is essential to capture endogenous risk. This is what is done in the work of Van der Ghote (2018) and this section summarizes its main findings.

The paper uses a continuous time version of the Gertler and Karadi (2011) model. A key feature of the environment used is that it may lead to "excessive" risk-taking by banks through elevated leverage. The reason is that the severity of crises increases with the leverage of the banking system. When banks make losses on their investments, their borrowing limits bind and they need to liquidate assets. This liquidation reduces the price of all assets in the economy, further reducing the net worth of banks and thereby leading to further asset liquidations. The more leveraged banks are, the stronger this "fire sale extrnality" is. However, because each bank is relatively small, it ignores the contribution of its own leverage decisions to the overall severity of financial crises. As a result, leverage may be excessive and leaning against imbalances with regulatory measures is potentially beneficial.

The paper asks three key questions. First, under what circumstances should macroprudential authorities activate countercyclical capital requirements and when should these be released? Second, should monetary policy help macroprudential policy by "leaning against the wind" over the financial cycle? Third, are there any gains to co-ordinating monetary and macroprudential instruments?

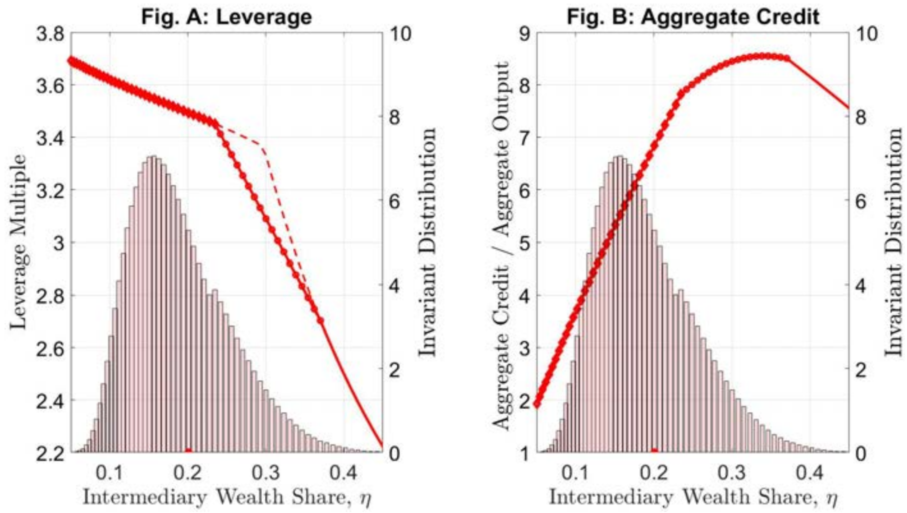

Figure 11: Socially Optimal Macroprudential Policy.

Notes. Fig. A: Left y-axis: Leverage multiple, denoted using lines. In solid-square and solid-circle segments, credit allocation is inefficient. In the former segment, market-based leverage constraints bind; in the latter, macroprudential leverage requirements do so. In solid line, credit allocation is efficient. The dash line omits the macroprudential leverage requirement. Right y-axis: Invariant distribution over aggregate state, denoted using bars. X-axis: dot denotes stochastic steady state. Fig. B: Same notation as in Fig. A.

A summary of the optimal macroprudential policy in Van der Ghote (2018) be seen in Figure 11. The dashed line shows the privately optimal leverage while the solid circles show the bank leverage chosen by the macroprudential authority. The paper finds that countercyclical macroprudential measures should be activated when the banking system has sufficient capital to satisfy the majority of the economy's lending needs but leverage remains relatively high. This can be seen clearly in the figure: only at intermediate values of the size of the banking system is the leverage chosen by the regulator below that chosen by the market.

Macroprudential measure are activated at intermediate capitalization levels because, at such a point in the financial cycle, potential "fire sale externalities" are large due to elevated asset prices and elevated bank leverage. This combination makes banks vulnerable to a sufficiently adverse set of economic shocks. Hence, it is optimal to strengthen the system's resilience to negative shocks by requiring banks to hold more capital than they would voluntarily choose.

Figure 11 also shows that privately and socially optimal leverage coincide when the banking system has either very low or very high levels of capital. When capital is low (i.e. following a crisis), countercyclical capital buffers should be released in order to support lending to the real economy. When capital is very high, no further tightening of bank leverage is needed because the banking system is sufficiently well capitalized to withstand losses without reducing lending.

Van der Ghote (2018) also analyses the interactions of macroprudential and monetary policies (the second and third questions posed above) by evaluating and contrasting two different policy scenarios. In the first scenario, monetary policy targets only inflation stability, while macroprudential policy targets only financial stability, and both policies disregard any potential effect they could have on the other's objective.

In the second scenario, monetary and macroprudential policies jointly aim to achieve both inflation stability and financial stability. To keep the analysis simple, monetary policy is limited to the setting of short-term, nominal interest rates, while macroprudential policy is limited to the determination of capital requirements for banks. Monetary and macroprudential policy rules, however, are allowed to be nonlinear, and contingent, in particular, on aggregate financial conditions. In the model, a proxy indicator of those conditions is the net worth of banks.

Table 5: Benefits from monetary and macroprudential policies

	First policy scenario (non-coordinated policies)	Second policy scenario (coordinated policies)
Benefits from inflation stability (1)	0.00%	-0.04%
Benefits from financial stability (2)	0.61%	0.72%
Total benefits, (1)+(2)	0.61%	0.68%

Note: Benefits are measured relative to a real laissez-faire version of the model and are expressed in permanent changes in aggregate per annum consumption levels.

Table 5 reports benefits from conducting monetary and macroprudential policy optimally in accordance with their respective objectives under each policy scenario. Benefits from inflation stability are reported in the first row, those from financial stability in the second row, and the third row reports totals. For convenience, benefits are measured relative to levels attained in a real, laissez faire version of the model in which monetary policy has no effect on the real side of the economy and there is no macroprudential policy. They are expressed in terms of permanent changes in the annual consumption of the representative household in the model.

A first important takeaway from Table 5 is that the benefits from prudential capital requirements for banks are large. The main reason is that, by lowering systemic risks while banks are relatively well capitalised, these policies significantly reduce the frequency and intensity of periods of deep financial distress.

But what about the role of monetary policy? In the first policy scenario, monetary policy adjusts nominal interest rates to keep the economy stable around what economists usually refer to as the neutral growth path. This essentially means that monetary policy is concerned solely with keeping inflation and unemployment rates low and stable at their structural levels. In the second scenario, monetary policy instead contributes to financial stability by (i) stimulating aggregate demand relative to that neutral benchmark during periods of financial distress, and (ii) slowing down aggregate demand relative to that same benchmark during tranquil periods. This temporarily stimulates banks' excess returns during distress periods, speeding up their recapitalisation and thus the economic recovery at precisely those times when banks are severely undercapitalised and capital requirements are not useful for stabilising the economy.

As Table 5 shows, however, the financial stability gains from this additional contribution of monetary policy are quantitatively modest. The reason is that monetary policy does not stray too far from its natural benchmark, both because it still aims to maintain inflation and unemployment rates close to their structural levels and because – given the presence of optimal macroprudential policies – the additional benefits from further enhancing financial stability remain moderate. In fact, the use of monetary policy to enhance financial stability generates costs in terms of increased inflation variability

3 How does macroprudential policy affect the monetary transmission mechanism?

The previous section analysed the way the conduct of monetary policy change the real impact of capital requirements on the macro-economy. In this section we examine the interaction between monetary policy and macroprudential measures in the other direction. We ask how bank leverage and the countercyclical macroprudential policy conduct changes the monetary transmission mechanism.

Sections 3.1 and 3.2 examine the role of bank leverage in the transmission of shocks. Section 3.1 uses the Gertler and Karadi model while section 3.2 uses a version of the DJP model that has been extended to analyse unconventional monetary policy such as the asset purchases programme (APP). Both papers find that high bank leverage enhances the real impact of monetary policy (both conventional and unconventional).

Section 3.3 also looks at the issue of how overall financial system leverage affects shock transmission at the ZLB of nominal interest rates. Using a version of the Gertler and Karadi model extended to include market finance and shadow banking he finds that a more heavily leveraged shadow banking system amplifies the response of the economy to negative shocks at the ZLB.

Finally, section 3.4 uses a non-linear version of the Gertler and Karadi model but solves it using a global approximation in order to analyze the impact of countercyclical macroprudential policy on the natural real interest rate over the financial cycle.

3.1 Capital adequacy regulation and monetary policy effectiveness at the effective lower bound [10]

This study analyses the implications of capital adequacy regulation for the transmission of monetary policy using a standard macroeconomic model with balance sheet constrained financial intermediaries.

The analysis uses the quantitative macroeconomic model described in Gertler and Karadi

[10]Prepared by P. Karadi (ECB, DG Research). This study has benefited from comments from Fiorella de Fiore, Alejandro Van der Ghote and Kalin Nikolov (all ECB, DG Research).

(2013). In the model, nominal rigidities generate a role for interest rate policy to stabilise economic activity. Furthermore, costly adjustment of capital – the key asset in the model – implies endogenous asset price variation. The model also features banks which transfer funds between households and productive firms, but their ability to obtain funds is constrained by an agency problem. It ultimately makes the balance sheet of the banking sector a critical determinant of the availability and the cost of credit the firms face. By exchanging the market-imposed constraints with (tighter) regulatory constraints, the model can be used to assess the interaction between capital adequacy regulation and monetary policy. We have recalibrated the model to the Euro Area to reflect a somewhat higher nominal rigidity, a more important role of leveraged banks in financial intermediation, and their marginally higher aggregate leverage.[11]

In the model banks face leverage[12] constraints and can raise equity only gradually through retained earnings. These funding frictions make the balance sheet position of banks relevant for economic activity. In the framework lower aggregate leverage obtained through tighter capital requirement regulation mitigates the effectiveness of monetary policy transmission by weakening the credit channel.

The particular mechanism in the framework is the following. In the presence of nominal rigidities, a monetary policy tightening causes an economic downturn that reduces the marked-to-market value of bank assets and the value of its loans (potentially increasing the required loan loss provisioning). If bank leverage were high, loan losses would cause greater equity losses and ceteris paribus an increase in leverage. As leverage constraints become binding, this would limit the ability of banks to extend credit to the macroeconomy. The ensuing tighter credit conditions would amplify the negative effects on economic activity. Lower aggregate leverage, in contrast, mitigates the amplification effect of this credit channel.

In our quantitative exercises, we use the Euro Area Accounts (EAA) to obtain estimates of the average leverage of a broad range of financial intermediaries, which is the relevant measure to assess the strength of the credit channel. The regulation is primarily influencing this measure through its impact on banks. During the period covering these

[11] See Andrade et al. (2016)

[12] We use the term leverage as the ratio of bank assets to bank capital, in line with how the term 'deleveraging' is generally used while banks rebuild their capital buffers. It should be noted, however, that the term is applied differently in the Basel III regulation, which defines leverage ratio as the inverse of bank assets to bank capital ratio.

new capital requirements, the weighted[13] average leverage of Euro Area Monetary and Other Financial Institutions decreased from around 8 at the onset of the financial crisis (2008Q4) to around 6.5 by 2013Q3. Assuming that deleveraging is still an on-going process, we might expect further reductions.[14] These observations provide the motivation for our thought experiments, where we compare the impact of monetary policy across three different environments with aggregate bank leverage constrained at 8, 6.5 and 5, respectively.

Figure 12 presents the quantitative impact of a monetary policy shock in our calibrated model under three levels of bank leverage (8, 6.5 and 5). In the experiments, we assume that banks have already been given sufficient time to adjust their equity fully to the various leverage restrictions when the shock hits. The figure shows that a reduction of leverage from 8 to 6.5 reduces the impact of a monetary policy shock on output by around 10%; and a leverage of 5 would imply a further reduction by around 10%.[15]

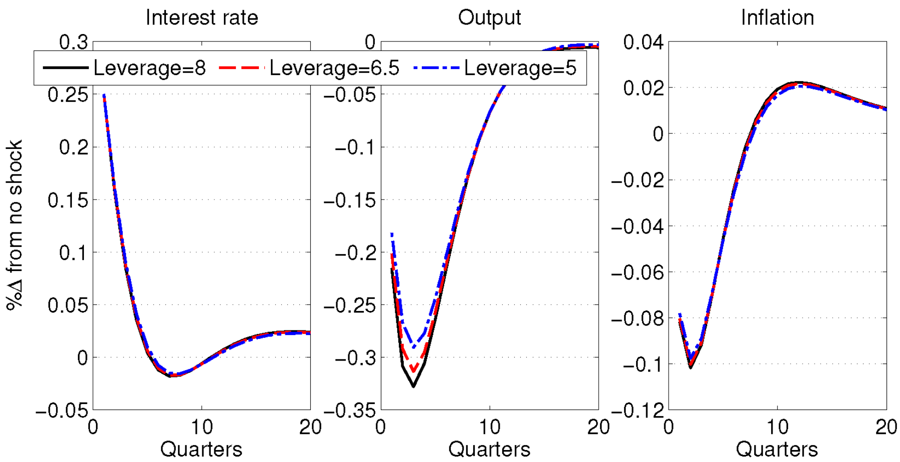

Figure 12: Response to a monetary policy shock.

At the same time, lower leverage also mitigates the destabilising effect of shocks hitting the

[13]We use the ratio of outstanding gross assets of MFIs and OFIs for weighting.

[14]In the Financial Stability Report (November 2013), the ECB supports the overall conclusion that are drawn from the EAA data. In particular, it finds that the median risk-weighted capital ratio of significant banking groups have increased from around 7% in 2008 to 11% at the end of 2013. A similar pattern has been observed for large and complex banking groups. These numbers would imply a leverage of 14 in 2008 and 9 in 2013. These measures confirm significant deleveraging, but cannot be directly compared to the leverage measures obtained from the EAA. First, we also include non-bank financial intermediaries (OFI)-s in our leverage calculations. Second, the equity measure in EAA includes Tier 2 capital as well as Tier 1 used in the Financial Stability Report. Third, the EAA disregards risk weighting.

[15]High calibrated nominal rigidities limit the shock's impact on the inflation rate.

economy. As an example, consider a 'demand' shock, modelled here as a temporary, but persistent reduction in government expenditures. Absent monetary policy stabilisation and in the presence of nominal rigidities, the shock would cause an economic downturn. The downturn would reduce the value of bank assets, but lower bank leverage would mitigate the impact on banks' equity and funding position. This would mitigate the shock's impact on credit conditions. For the same reason that monetary policy is less effective under lower leverage, the economic impact of fluctuations is also mitigated. And indeed, the same systematic monetary policy (modelled here as a Taylor-type interest rate rule responding to inflation and the output gap) is able to achieve a very similar level of stabilisation after a demand shock under different levels of leverage (see Figure 13) in our calibrated model.

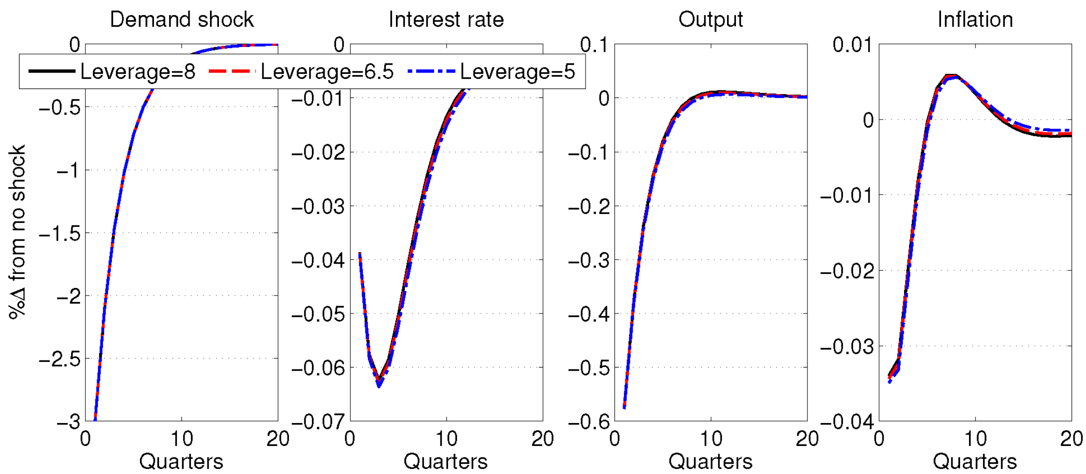

Figure 13: Response to a demand shock.

The importance of leverage for economic fluctuations reappears, however, if monetary policy stabilisation is constrained as a result of the ELB. With monetary policy limited by the ELB, the credit channel amplifies the effect of demand shocks.

Figure 14 shows a scenario with the demand shock as before, but assuming that the interest rate cannot be lowered any further. This means, in this example, that nominal interest rates cannot respond to the shock for more than 2 years. As a result, the impact of the shock becomes substantially more powerful, causing an economic downturn more than 4-7 times as large as when the monetary policy was unconstrained. The shock is also causing a sizeable reduction in the inflation rate.

Bank leverage here has significant impact: a leverage of 6.5 generates real output and inflation effects that are 25% lower than those with a leverage of 8. We can conclude that tighter capital adequacy regulation can substantially improve economic stability if monetary policy is constrained at the ELB.

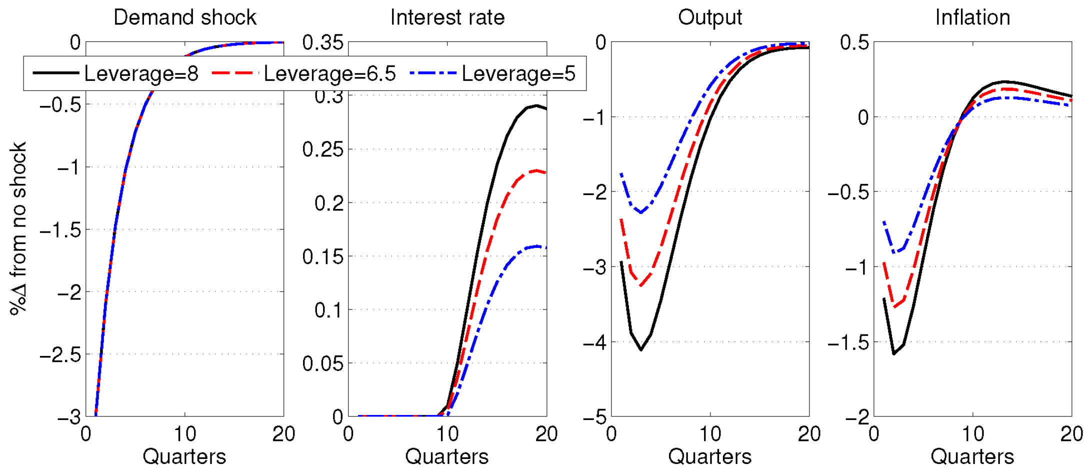

Figure 14: Response to a demand shock at the zero lower bound.

3.2 How does macroprudential policy affect the transmission of central bank asset purchases? [16]

The focus of this section is on the interactions between non-standard monetary policy and financial policies within a DSGE framework with a rich banking sector, based on Darracq et al (2019). The model is closed economy version of DJP, estimated on euro area data and extended to account for long-term government bond holding by banks and households.

Within this framework, we show that in a weakly-capitalised banking system, risk-taking motives caused by limited liability together with a deposit insurance scheme reinforces the credit easing effects of central bank asset purchases, thereby compounding the associated financial stability risks. Central bank asset purchases compress government bonds yields and, through portfolio re-balancing, reduce banks credit intermediation margins. With low initial bank capital position, risk-shifting motives increase the strength of banks' portfolio re-balancing from government bonds towards loans. Excessive credit origination

[16]Prepared by J. Koerner (ECB, DG Monetary Policy).

spurs sizable and protracted macroeconomic support to the real economy. However, this comes at the cost of higher bank default probability which can endanger financial stability. In this case, higher capital requirements effectively can deter banks risk-shifting and restore a more efficient transmission mechanism of central bank asset purchases. Through the regulatory constraint, banks internalize the pecuniary externality associated with excessive bank leverage: starting from a weakly-capitalised banking system, the economic stimulus of asset purchases is largely preserved with higher bank capital requirements while the financial stability risks of the non-standard monetary policy measure are drastically reduced.

In order to illustrate this mechanism, we focus on the purchase of government bonds by the central bank. Our non-standard monetary policy experiment mimics the January 2015 ECB's PSPP announcement of euro area long-term government bonds purchases by 60 billion per month from March 2015 until September 2016. The stock of central bank asset holdings was expected to peak at approximately 9.6% of annual GDP. The announced monthly flow of purchases is introduced through news shocks in the model. After the purchases, the portfolio holdings start decaying following an AR(1) process consistent with the assumption that the bonds are 10-year equivalent and would be held to maturity.

In the model, two key frictions are providing leeway for central bank asset purchases to affect government bond yields, credit conditions and ultimately the economy at large. First, we introduce adjustment costs on the holdings of sovereign bonds for household and banks: together with a frictionless intermediation sector, this friction still enables asset purchases to compress sovereign bond yields, but without impact on the real and nominal allocation.

The second key set of frictions relates to the bankers decision problem. As in DJP, the financial authority imposes a penalty on banks in case its capital breaches a regulatory threshold. This friction opens up a bank capital channel in the model. In addition, banks may default when their return on assets is not sufficient to cover the repayment of deposits. Then the deposit insurance agency serves the depositors and takes over the loan portfolio of the failed banker subject to resolution costs. Introducing limited liability together with deposit insurance, provides an implicit subsidy for bankers, since their financing instrument, e.g. deposits, is not priced according to the default risk it bears. This generates misaligned perceptions on expected loan return and excess risk-taking.

In this context, central bank asset purchases do have an impact on government bond yields and compress the excess return on this asset class. Banks therefore benefit from holding gains on their securities portfolio. The lower expected return on government bond portfolios urges banks to shed sovereign bonds and increase loan exposures. This re-balancing mechanism leads in equilibrium to strong loan origination and a protracted decline in lending rates. Further down the intermediation chain, credit quality improves alongside with economic activity and asset prices. The model-based propagation of asset purchases might become harmful on bankers capital position, to the extent that compressed net interest income is not compensated by valuation gains on securities held and the general equilibrium effects of improving credit quality.

Figure 15 shows the impact of asset purchases for three different model specifications: In the first specification, banks do not benefit from limited liability, bearing the full impact of asset return realizations on their profit and loss (see red dashed-dotted line). In the second one, banks are subject to limited liability under a deposit insurance scheme (see blue dotted line). In the third specification, banks are well-capitalized, whereby the capital buffer prevents the banks form mis-pricing the risks of loans (see black dashed line).

Let us consider first the propagation of central bank asset purchases in a weakly-capitalised banking system, comparing the transmission with and without limited liability. As the central bank acquires government bonds from financial intermediaries and the yield on this asset class diminishes, banks with limited liability have an incentive to issue more loans and charge a lower risk premium to compensate for weaker profitability. Loan origination expansion is twice stronger with limited liability, relative to the case of fully liable bankers, and significantly more protracted. The moral hazard problem strengthens the portfolio re-balancing channel of asset purchases as banks are more eager to substitute government bonds for risky private debt in order to exploit the implicit subsidy of limited liability. Turning to the bond market, the higher willingness to sell government bonds under limited liability dampens the drop in yields and leads to weaker capital gains from bond holdings. Altogether, banks' net worth deteriorates much more over the medium-term and bankers probability of default increases sharply. Excessive leverage and bank fragility reveal that bankers with limited liability are less reluctant to breach any low level of capital ratio.

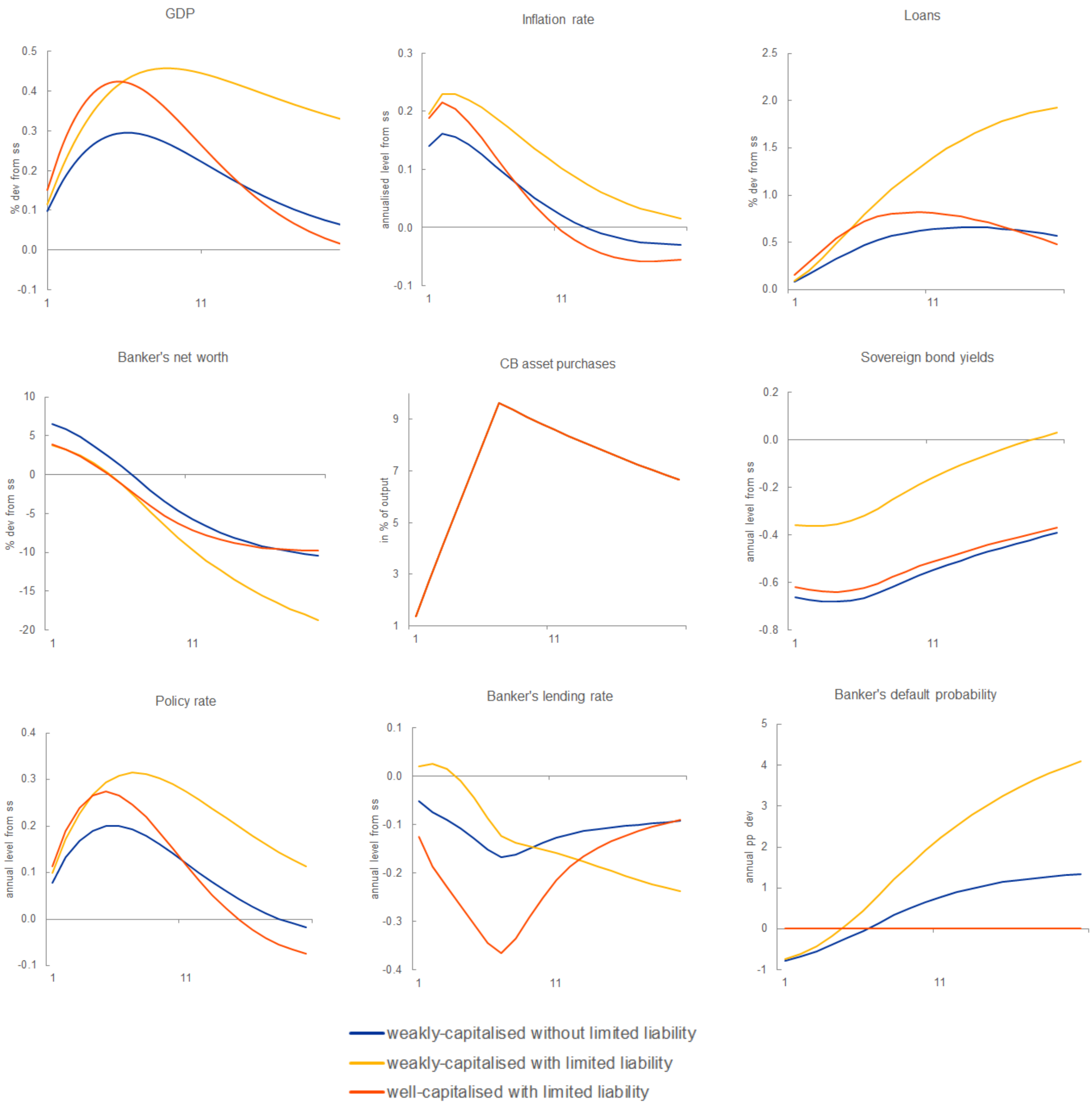

Figure 15: Non-standard monetary policy in a weakly capitalized banking sector with and without limited liability contrasted with a well-capitalized banking sector.

Regarding the macroeconomic impact of central bank asset purchases, the increase in activity and investment is almost twice bigger under limited liability, with delayed peak effects. The transmission is also more persistent: output remains significantly above the steady state after 20 quarters whereas in the absence of limited liability it already converges back to steady state. Similarly, the inflationary pressure from the non-standard measure is higher by 0.1 p.p. all through the simulation horizon under limited liability, which leads to a tighter stance of the rule-based standard monetary policy.

Two striking implications result from this simulation exercise which emphasises the need to impose bank capital regulation. First, under limited liability, the credit easing channel of central bank asset purchases could entail strong inefficiencies which can be addressed by capital regulation. Second, the limited liability distortion reinforces a much more protracted impact of the non-standard policy intervention. Such a policy persistence, however, may complicate the use of the non-standard instrument for macroeconomic stabilisation purposes or require very active central bank portfolio management to deliver the intended temporary stimulus: capital regulation might also tame the persistence of the macroeconomic impact, alongside with the financial stability risks.

Against this background, Figure 15 also shows that well-capitalised banks due to stricter regulation, originate less loans in response to central bank asset purchases. Higher regulatory capital mutes banks' risk-taking incentive as stronger capital base improves bankers solvency risk. Lower bank default probabilities mitigate the implicit subsidy stemming from limited liability. Consequently, the credit easing effect of central bank asset purchases becomes significantly less persistent. Tighter capital requirements induce bankers to internalize its pecuniary externality associated with high leverage. Another remarkable observation is that higher capital requirements mitigate banks' willingness to sell government bonds. Consequently, the response of long-term yields resembles the one obtained for weakly-capitalised banks without limited liability.

Turning to macroeconomic outcomes, the real effects of outright government bond purchases with tight regulation are qualitatively similar to the ones with weakly-capitalised banks over the first year. But the expansion of key macroeconomic variables is more short-lived, reverting back to baseline as fast as in the simulation without limited liability. One aspect worth mentioning is that regulatory pressures not only deter risk-shifting behaviour but also pull back the peak transmission of non-standard monetary policy. Capital requirements by correcting the limited liability distortion eliminate bank defaults and thereby reduce excess credit. This is achieved without curtailing the magnitude of the output multiplier at a policy relevant horizon.

Darracq et al (2019) go beyond this analysis and explore other interactions of financial policy with non-standard monetary policy measures. During times of central bank asset purchases, countercyclical macroprudential rules can contain excessive risk-taking by banks but at a cost in terms of macroeconomic stabilization. We consider the macroprudential rule proposed by the ESRB by which capital demands react to the credit-to-annual GDP gap. The rule brings about tighter bank capital regulation and mutes the economic stimulus of central bank asset purchases. This is not accompanied by tangible improvement in financial stability when the banking system is well-capitalised to start with. Macroprudential policy should in this case look through the effects of the central bank asset purchases on bank balance sheets and adopt a general equilibrium perspective. Conversely, with fragile bank balance sheets, the combination of central bank asset purchases with macroprudential feedback provides strong safeguards against the potential financial stability risks of the non-standard measures. The macroprudential intervention actually substitutes for too lax minimum capital requirements and leans against excessive loan origination.

3.3 Implications of Shadow Bank Regulation for Monetary Policy at the Zero Lower Bound [17]

The previous section showed that a more levered financial system amplifies demand shocks at the zero lower bound (ZLB) for nominal interest rates. One important reason for the high level of leverage in the financial system was the existence of so-called 'shadow banks' - levered financial institutions which perform bank-like functions but without bank capital regulation of supervisory oversight. Post-crisis reforms have aimed to bring credit intermediation out of the 'shadows', either by differently regulating or abolishing shadow banks. This section uses the results of Mazelis (2017) to explore the consequences of these regulatory reforms for shock transmission in normal times and at the ZLB.[18]

The starting point of our analysis is the closure of the shadow banks and the fundamental uncertainty regarding the kinds of financial intermediaries which will expand to take their place. In this section, we do not take a stand on this important issue and, instead, explore the implications of two extreme cases for shock transmission. In one case, credit demand that was previously met by shadow banking entities is now fulfilled by debt-financed traditional banks. In another case, credit is provided by equity financed investment funds.

[17]Prepared by F. Mazelis (ECB, DG Monetary Policy).

[18]Further details on the model structure and dynamics can be found in Mazelis (2017).

We modify the now standard framework of Gertler and Kyiotaki (2010) and Gertler and Karadi (2011) to include investment funds and study the impact of a conventional shock to aggregate demand under these different financial structures.

Debt and equity financing are modeled using two different types of frictions. Debt financing via the incentive constraint as in Gertler and Kyiotaki (2010) and Gertler and Karadi (2011) guarantees that as long as the intermediary does not exceed a maximum amount of leverage per intermediary value, default does not occur and households only demand the risk free interest rate on bank deposits.

Equity financing, in contrast, is risky and subject to search frictions. An investment fund must search for investors by paying advertising costs. The costly advertising succeeds in generating demand for fund shares but only gradually and at a rate which depends positively on advertising expenditure. The search and matching approach can be thought of as a shortcut for capturing limited attention in the equity market or heterogeneity in risk attitudes. Advertising expenditure helps to attract household attention to the investment opportunities in investment fund equities but it does not do so instantaneously.

The search and matching friction has two important implications for shock transmission. First of all, the search frictions introduce a time varying equity premium which depends on the value of having a fund-investor match.[19] In good times, the value of such a match is high and expected returns on fund shares are high. In a recession, this equity premium is low because credit demand is low and funds are not looking to issue new shares actively. Secondly, the search friction ensures that only some households invest in investment fund shares. The rest save their wealth in bank deposits. The different evolution of the risk free rate and the rate of return on fund shares then drives a wedge between the consumption demands of 'stockholder' and 'non-stockholder' households. This wedge will be crucial in understanding how the economies with and without investment funds react to economic shocks.

Having described the key features of our economy, we are now ready to investigate how the 'bank-based' (high leverage) and 'fund-based' (low leverage) economies respond to a shock which increases the patience of consumers and makes them increase their savings and reduce their consumption. Under nominal rigidities, this shock causes a fall in aggregate demand and output.

[19]This is very similar to the search and matching labour literature where the value of a job fluctuates over time depending on the demand and supply for labour.

Figure 16 shows the impact of the shock on the real economy. The green, dotted line is the 'bank-based' economy while the red, dashed line is the 'fund-based' economy. The top panel plots the case when the ZLB on nominal interest rates is not binding. It shows that in this case monetary policy can offset this demand shock regardless of financial structure. This result echoes the findings in the previous section based on a simple version of the Gertler and Karadi (2011) model with only traditional banks.

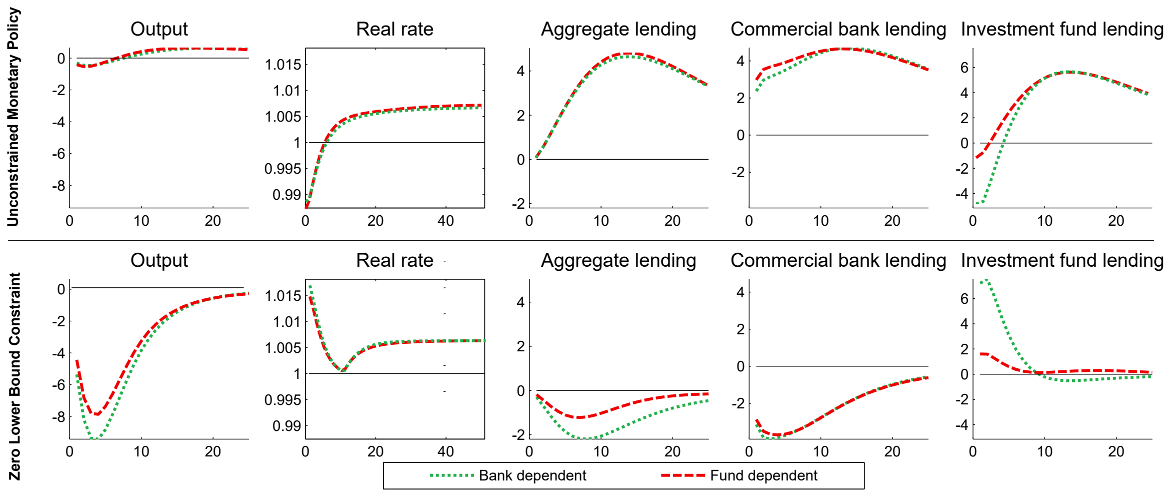

Figure 16: Responses of intermediaries to a demand shock. Note: Horizontal axes show periods in quarters, vertical axes are percentage deviations from steady state.

More interesting is the case in which the economy is constrained by the ZLB and the policy rate cannot counter the negative demand shock. This is shown in the bottom panel of Figure 16. We can immediately see that the recession is considerably deeper in the 'bank-based' high-leverage economy. This happens due to the negative feedback effects of the ZLB on the consumption of deposit holders. In the absence of a policy loosening, current period consumption drops, generating a recession and a fall in inflation. The real interest rate then increases further due to deflation, magnifying the effect of the shock. A much more pronounced recession is the result.

The key difference between the two economies is the presence of stock holders in the fund-based economy. The fall in output due to the shock reduces credit demand and lowers the value of fund-investor matches. This, in turn, leads to lower expected future returns on investment fund shares, incentivizing stock holders to bring consumption forward, boosting aggregate demand. In other words, the recession reduces the equity premium, acting as an interest rate reduction for stock holders. This helps to stabilize aggregate demand in the fund-based economy compared to the bank-based economy.

The results in Mazelis (2017) show that disintermediation due to the growth of bond mutual funds and 'plain-vanilla' securitisations may have some important positive side effects. For example, such a financial structure would make the economy more stable and resilient during ZLB episodes in the future.

3.4 Implications of Macroprudential Policy for the Frequency, Duration and Intensity of Negative Nominal Interest Rate Episodes [20]

Implications for the natural real interest rate The natural real interest rate is a key concept for the theory and practice of monetary policy conduct. It is the real interest rate which is consistent with stable prices and, optimal monetary policy in simple models involves closely tracking the natural real interest in response to most economic shocks.

In modern macroeconomic models, the natural real interest rate is determined by two key factors - expected future economic growth and expected future consumption volatility. The first determines real interest rates through consumers' desire to ensure a flat consumption profile over time, the second, through their desire to smooth consumption over states of nature by accumulating precautionary savings. Macroprudential policy can therefore have an important impact on the natural real interest rate to the extent that it is able to reduce the macroeconomic risk which comes from "systemic" (or endogenous) factors rather than exogenous shocks.

We saw earlier in the paper that the model of Van der Ghote (2018) involves an optimal policy which activates capital buffers when the economy is at intermediate levels of bank capital. This is when systemic risk is at its highest and should be counteracted by measures to reduce bank leverage and reduce the likelihood and severity of a financial crisis. In this section, we outline the implications of the model for the way macroprudential policy affects the evolution of the natural real interest rates over the financial cycle. This is shown in Figure 17.

[20] Prepared by A. Van der Ghote (ECB, DG Research). This study has benefited from comments from Peter Karadi and Kalin Nikolov (all ECB, DG Research).

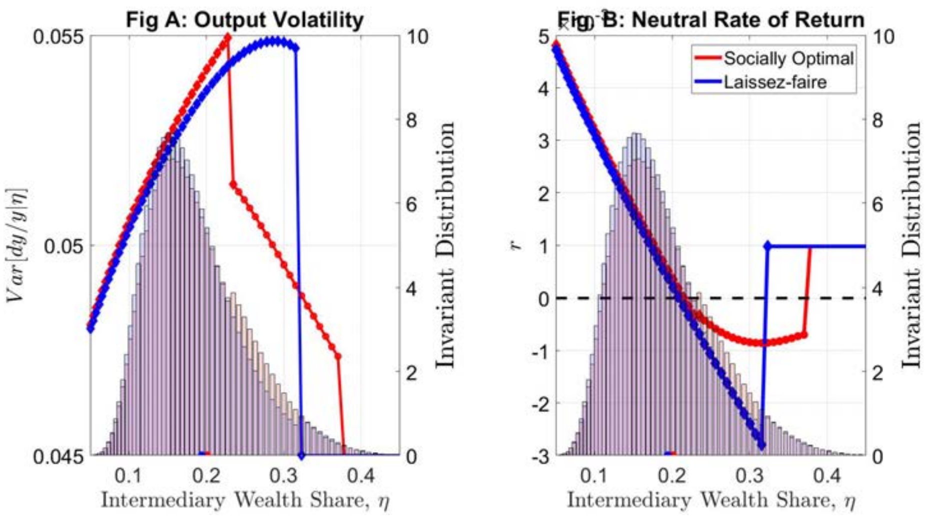

Figure 17: Neutral Rate under Socially Optimal and Laissez-faire Macroprudential Policy. Notes. Left y-axis: Neutral rate, denoted using lines. In solid-square and solid-circle segments, credit allocation is inefficient. In the former segment, market-based leverage constraints bind; in the latter, macroprudential leverage requirements do so. In solid line, credit allocation is efficient. Right y-axis: Invariant distribution over aggregate state, denoted using bars. X-axis: dots denote stochastic steady state.

The figure shows that the key effect of the macroprudential measures is to reduce macroeconomic volatility very substantially during crisis episodes. This is intuitive. By building banks' resilience to losses, the policy makes crises less likely and less severe, and consumption and output volatility is moderated as a result. Effective macroprudential policy therefore reduces the need for households to build up precautionary savings and the natural real interest rate does not fall as much in the rare event that a crisis does actually occur.

Figure 17 shows, however, that the socially optimal macroprudential policy also prolongs the periods in which neutral real interest rates remain low. This is because the countercyclical macroprudential measures keep banks constrained by their regulatory capital requirements for longer during the financial cycle. This increases output volatility somewhat during the recovery and helps to maintain the natural real rate at low levels.

Implications for the likelihood of negative nominal interest rates The model solution is fully non-linear and therefore complex even in a stylized model such as the one considered by Van der Ghote (2018). As a result, taking into account also an occasionally

Table 6: Implications of macroprudential policy for the frequency and intensity of negative nominal interest rate episodes

	Av. intensity	Frequency
Laissez-faire	-0.025%	23%
Socially optimal Policy	-0.017%	28%

binding zero lower bound (ZLB) constraint on nominal interest rates is infeasible. Nevertheless, the model can say something about the likelihood of negative nominal interest rates over the financial cycle even if its misses all of the potential consequences of the ZLB for macroeconomic performance and financial stability.

Socially optimal macroprudential policy has two main implications for the occurrence of episodes with negative nominal interest rates. First, it reduces the maximal intensity of periods of negative nominal rates. In other words, conditional on experiencing negative nominal interest rates, the extent to which rates fall below zero is reduced once macoprudential policy is active. This is because the natural real interest rates does not fall to very low levels and this supports nominal interest too. In the baseline simulation, macro-prudential measures change an average negative nominal rate episode from -0.025% (2.5bps below zero) to -0.017% (1.7 bps), as shown in Table 6.

However, because macroprudential measures reduce the natural real interest rates in the recovery and boom phase of the financial cycle, they prolong the average duration of negative interest rate episodes and increase their frequency. In the baseline simulation, the unconditional frequency of negative nominal interest rate episodes increases from 23% to 28% of all time periods in a long simulation.

In conclusion, countercyclical macroprudential measures eliminate the need for periods of extremely loose monetary policy during crises but prolong the need for low interest rates during economic recoveries in which macroprudential measures are activated. This implies that, in the new world of activist macroprudential policies, we should not expect nominal or real interest rates to reach levels that used to be normal in past economic cycles. Equally, the enhanced resilience of the banking system will ensure that interest rates do not have to fall to very negative levels during recessions or financial crises.

4 Conclusions

Monetary and macroprudential policies interact and the way each is conducted affects the way the other is transmitted to the macroeconomy. In this paper, we first examine the transmission mechanism of macroprudential measures to the real economy. This is done through a cross-model exercise comparing the implications of three medium scale macro-financial models for the economy's reaction to a standardized capital requirement shock.

We then study the interactions between monetary and macroprudential policies. First we examine the way the monetary policy rule changes the transmission of capital requirement changes to the real economy. Second we analyse the way bank leverage or the conduct of countercyclical macroprudential policy change the monetary policy transmission mechanism (of both conventional and unconventional measures). The exercises in the paper teach us a number of important lessons.

From the comparative model exercise we learn that the precise impact of a change of bank capital requirements (or of a loss of bank capital) depends crucially on how banks, monetary policy authorities and the wider economy react to it. In practice, there are many adjustment mechanisms and those may function well in certain circumstances but not in others. For example, in normal times, banks may be able to raise equity or reduce their buffers without problems. Corporate bond markets may be open to smaller and riskier firms and not just the safest and largest ones. Monetary policy may react aggressively, keeping aggregate demand and inflation stable. Then bank losses or changes to banks' capital ratios should not have a large real impact.

In contrast, in crisis times all these adjustment mechanisms may break down. Equity issuance may be prohibitively expensive. Banks may be unwilling to reduce their dividend payouts or their capital buffers for fear of sending a bad signal to nervous financial markets. Monetary policy may be constrained by the ZLB of nominal interest rates. Then a negative aggregate demand shock or an attempt to strengthen banks' capital ratios could lead to significant short term declines in lending, economic activity and inflation.

In practical use of models for macroprudential policy it would be important to incorporate these adjustment mechanisms but to exercise judgement (or perform sensitivity checks) on the extent to which the banking system and the economy at large would be able to adjust to capital requirements without a reduction in credit supply. This is especially important at the ZLB of nominal interest rates when monetary policy cannot be relied on to offset a large fall in lending.

Our work also highlights the importance of analysing the impact of macroprudential measures in a framework that can capture the benefits of these measures whether those might relate to reducing bank default or dampening the financial cycle. Both the short and long term costs from imposing capital requirements were shown to be much smaller when bank default risk is greater and higher bank capital is actually called for. Putting weak banks on a sound financial footing carries significant benefits in terms of cheaper debt funding, helping to maintain or even increase lending and output in the long run. Modelling bank default is crucial in capturing this transmission mechanism of higher bank capital to the real economy.

In addition, we saw that the incorporation of non-linearities and fire-sale externalities was important in analysing the benefits of counter-cyclical macroprudential policy in terms of lower output and lending volatility. The reduction in bank leverage and the risk of financial crises was shown to have important implications for the natural real interest as well as the way interest rated changes transmit to the real economy.

Successful macroprudential policy reduces the extent to which nominal interest rates need to go below zero in order to ensure stable inflation in the medium term. However, the tighter bank capital requirements keep nominal interest rates lower (and even below zero) during the recovery phase from financial crisis episodes. This is a feature of the nonlinear version of the Gertler-Karadi (2011) model which seems remarkably relevant in explaining the recent experiences of a number of countries around the world.

Using non-linear models for policy simulations is inevitably complex and requires the toleration of simplifications needed to ensure tractability. Nevertheless, these models do provide key additional insights which are difficult to obtain from traditional DSGE models solved with linearization techniques. This makes them a useful addition to the policy analysis toolbox of central banks.

In the euro area where macroprudential policy is conducted at the country level while monetary policy is at the union level, the international dimension is important. One of the key reasons is the interaction between monetary and macroprudential policy at the individual member state level. Larger and smaller countries may face different costs from implementing capital measures due to the different endogenous reaction of nominal interest rates. Since monetary policy is conducted at EMU level in a 'one-size-fits-all' manner, smaller countries would face higher costs due to their small weight in determining EMU-wide output and inflation.

In addition, countries with large and internationally interconnected banking systems may generate significant spillovers to the economies of other EMU members. The analysis in the paper showed that increasing capital requirements in a large country increased output and lending in neighbouring economies by virtue of the response of the common monetary policy. In contrast, countries with banks that have large lending activities abroad create negative lending spillovers as their banks contract credit supply following an increase in domestic capital requirements.

The different cross-country spillovers as well as different short term transitional costs of macroprudential measures are all factors that a full cost-benefit analysis of capital requirements at the level of each EMU member state ought to take into account.

Finally, despite the large number of models and issues we review in our paper, there remains a long list of model features and policy tools which would be important subjects for future work. We do not yet have a good understanding of borrower-based macroprudential measures such as Loan-to-value (LTV) or Loan-to-income (LTI) limits. We also lack models capable of analyzing the benefits of liquidity policies, at least in part due to the fact that characterizing bank runs in DSGE models remains computationally challenging. In addition, while some progress has been made in including unconventional monetary policy measures in our toolkit, more work is needed in order to fully understand their implications for financial stability and hence their interaction with macro-prudential policies.

References

Andrade, P., J. Breckenfelder, F. De Fiore, P. Karadi and O. Tristani, 2016. “The ECB’s asset purchase programme: an early assessment”, *ECB Working Paper*, 1956.

Brunnermeier M. and Y. Sannikov, 2014. “A macroeconomic model with a financial sector”, *American Economic Review*, 104(2): 379–421.

Christoffel, K., G. Coenen and A. Warne, 2008. “The New Area-Wide Model of the euro area: A micro-founded open-economy model for forecasting and policy analysis, *ECB Working Paper*, No. 944.

Clerc, L., A. Derviz, C. Mendicino, S. Moyen, K. Nikolov, L. Stracca, J. Suarez and A. P. Vardoulakis, 2015. “Capital Regulation in a Macroeconomic Model with Three Layers of Default”, *International Journal of Central Banking*, 11(3): 9–63.

Coenen, G., P. Karadi, S. Schmidt and A. Warne, 2018. “The New Area-Wide Model II: an extended version of the ECB’s micro-founded model for forecasting and policy analysis with a financial sector”, *ECB Working Paper*, No. 2200.

Darracq Paries, M., Karadi, P., Kok, C. and Nikolov, K. (2019), ’The impact of capital requirements on the macroeconomy: lessons from four macroeconomic models’, mimeo

Darracq Pariès, M., P. Jacquinot and N. Papadopoulou, (2016). ”Parsing financial fragmentation in the euro area: a multi-country DSGE perspective”, *ECB Working Paper* No 1891.

Darracq Pariès, M., J. Koerner and N. Papadopoulou, (2019). “Empowering Central Bank Asset Purchases: The Role of Financial Policies”, *ECB Working Paper* No 2237.

Darracq Pariès, M., C. Kok and E. Rancoita, (2019). “Macroprudential Policy in a Monetary Union with cross border Banking”, *ECB Working Paper* No 2260.

Darracq Pariès, M., C. Kok-Sorensen and D. Rodriguez-Palenzuela, 2011. “Macroeconomic Propagation under Different Regulatory Regimes: Evidence from an Estimated DSGE Model for the Euro Area”, *International Journal of Central Banking*, 7(4): 49–113.

Darracq Pariès, M., D. Moccero, E. Krylova and C. Marchini, 2014. "The retail bank interest rate pass-through: The case of the euro area during the financial and sovereign debt crises", *ECB Occasional Paper.*

den Haan, W. and V. Sterk, 2011. "The Myth of Financial Innovation and the Great Moderation", *Economic Journal*, 121(553): 707–739.

ECB, 2013. "Financial Stability Report", nr 8, November.

Financial Stability Board, 2016. "Implementation and Effects of the G20 Financial Regulatory Reforms", 2nd Annual Report.

Gertler M. and P. Karadi, 2011. "A Model of Unconventional Monetary Policy", *Journal of Monetary Economics*, 58(1): 17–34.

Gertler, M. and P. Karadi, 2013. "QE1 vs. 2 vs. 3...: A Framework for Analysing Large-Scale Asset Purchases as a Monetary Policy Tool", *International Journal of Central Banking*, 9(S1): 5–53.

Gertler M. and N. Kiyotaki, 2010. "Financial intermediation and credit policy in business cycle analysis", in Benjamin M. Friedman, and Michael Woodford, eds., *Handbook of Monetary Economics, volume 3 of Handbook of Monetary Economics*, chapter 11, 547–599 (Elsevier).

Igan, D., A. Kabundi, F. Nadal-De Simone and N. Tamirisa, 2013. "Monetary Policy and Balance Sheets", *IMF Working Papers*, 13(158).

Mazelis, F., 2017. "Implications of Shadow Bank Regulation for Monetary Policy at the Zero Lower Bound", Working Paper.

Mendicino, C., K. Nikolov, J. Suarez and D. Supera, 2018a. "Optimal Dynamic Capital Requirements", *Journal of Money, Credit and Banking*, 50(6): 1271–1297.

Mendicino, C., K. Nikolov, J. Suarez and D. Supera, 2018b. "Bank Capital in the Short and in the Long Run", *Working Papers wp2018_1807*, CEMFI.

Nelson, B., G. Pinter and K. Theodorodis, 2015. "Do contractionary monetary policy shocks expand shadow banking?", *Bank of England working papers*, 521.

Pescatori, A. and J. Sole, 2016. "Credit, Securitization and Monetary Policy: Watch Out for Unintended Consequences", *IMF Working Papers*, 16(76).

Petrongolo, B. and C. Pissarides, 2001. “Looking into the Black Box: A Survey of the Matching Function”, *Journal of Economic Literature*, 29(2): 390–431.

Van der Ghote, A., 2018. “Coordinating Monetary and Financial Regulatory Policies”, *ECB Working Paper*, 2155.

Appendix

A Model comparison

Below is a full set of IRFs for the main model comparison exercise in section 2.1.

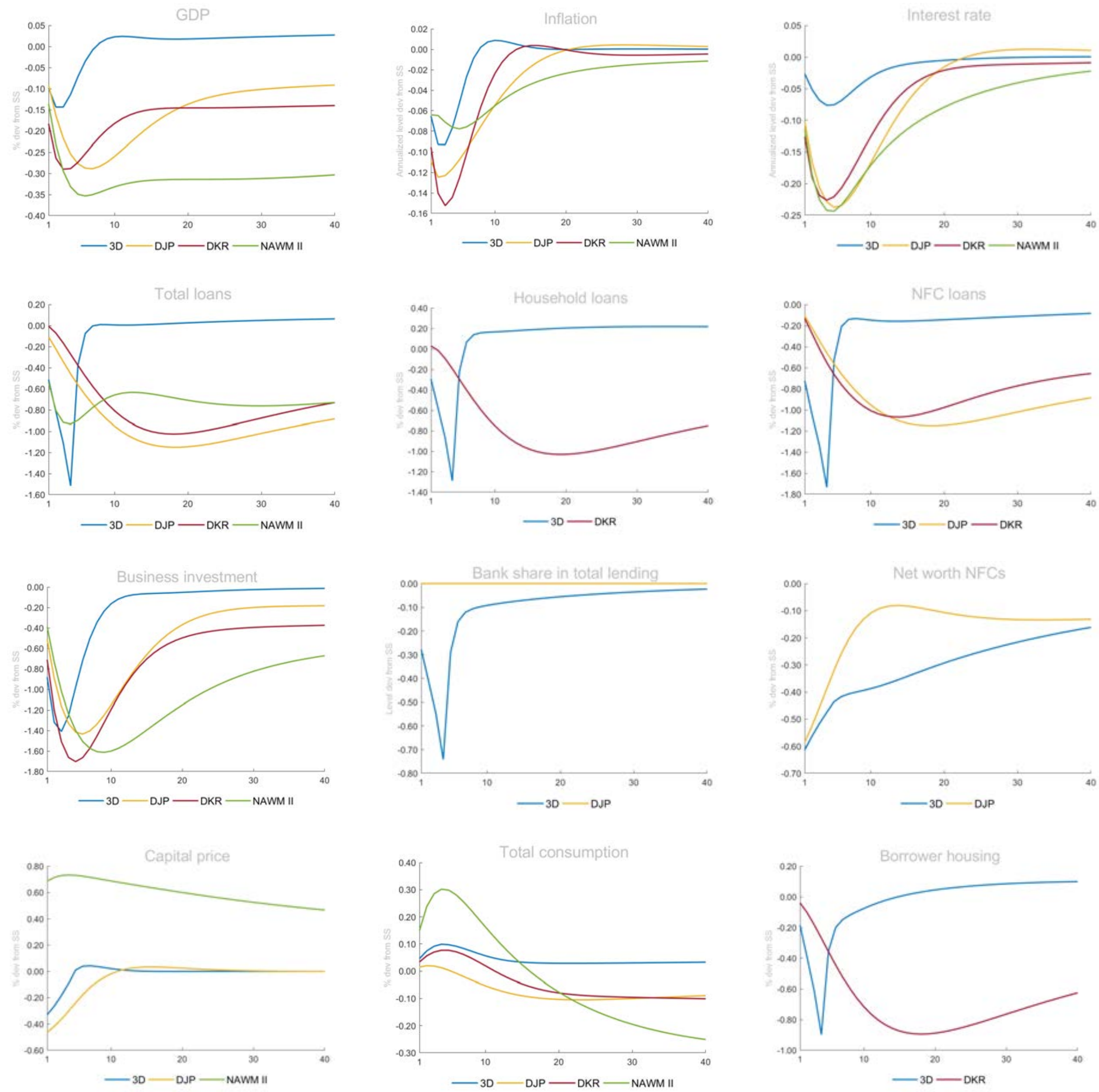

Figure 18: Comparison of the four main models.

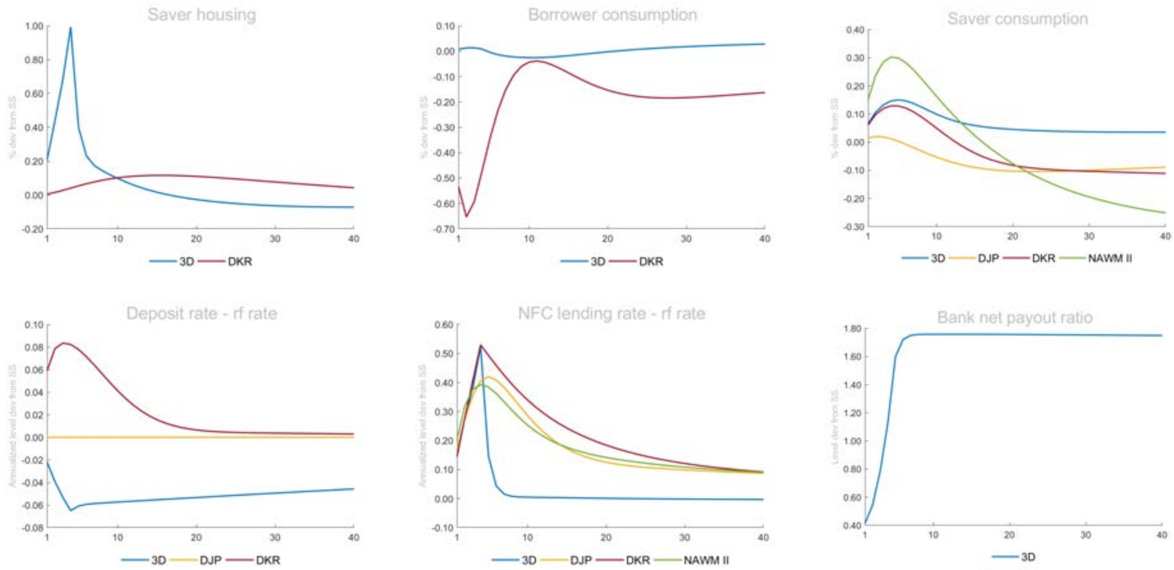

Figure 18: Comparison of the four main models (Continued).

B Sensitivity: Equity issuance

Below is a full set of IRFs for the equity issuance sensitivity exercise in Subsection 2.1.3.

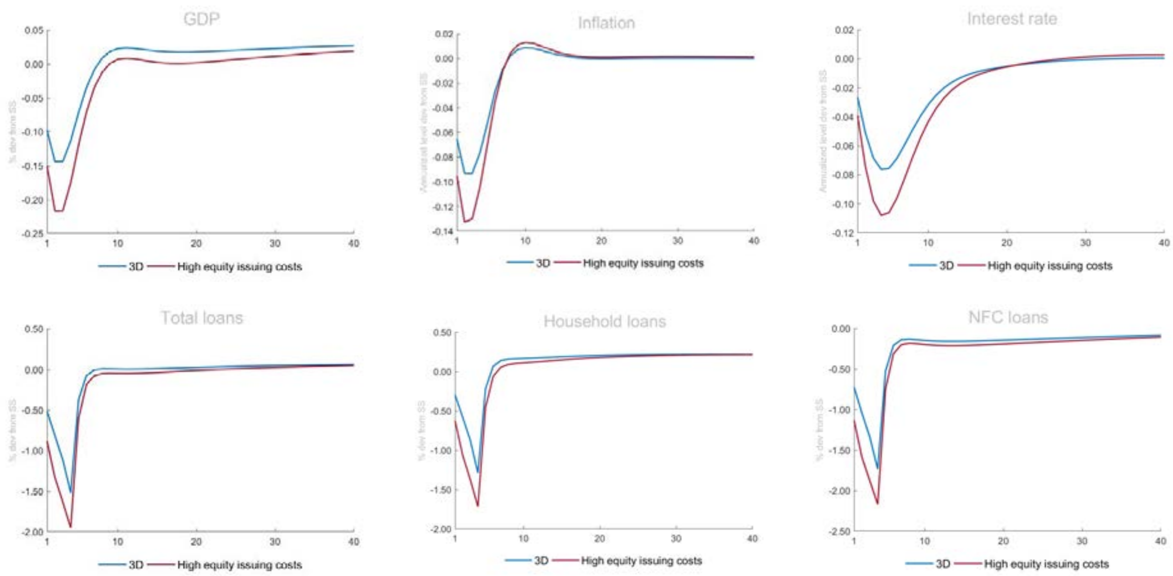

Figure 19: Sensitivity with respect to equity issuance costs in the 3D.

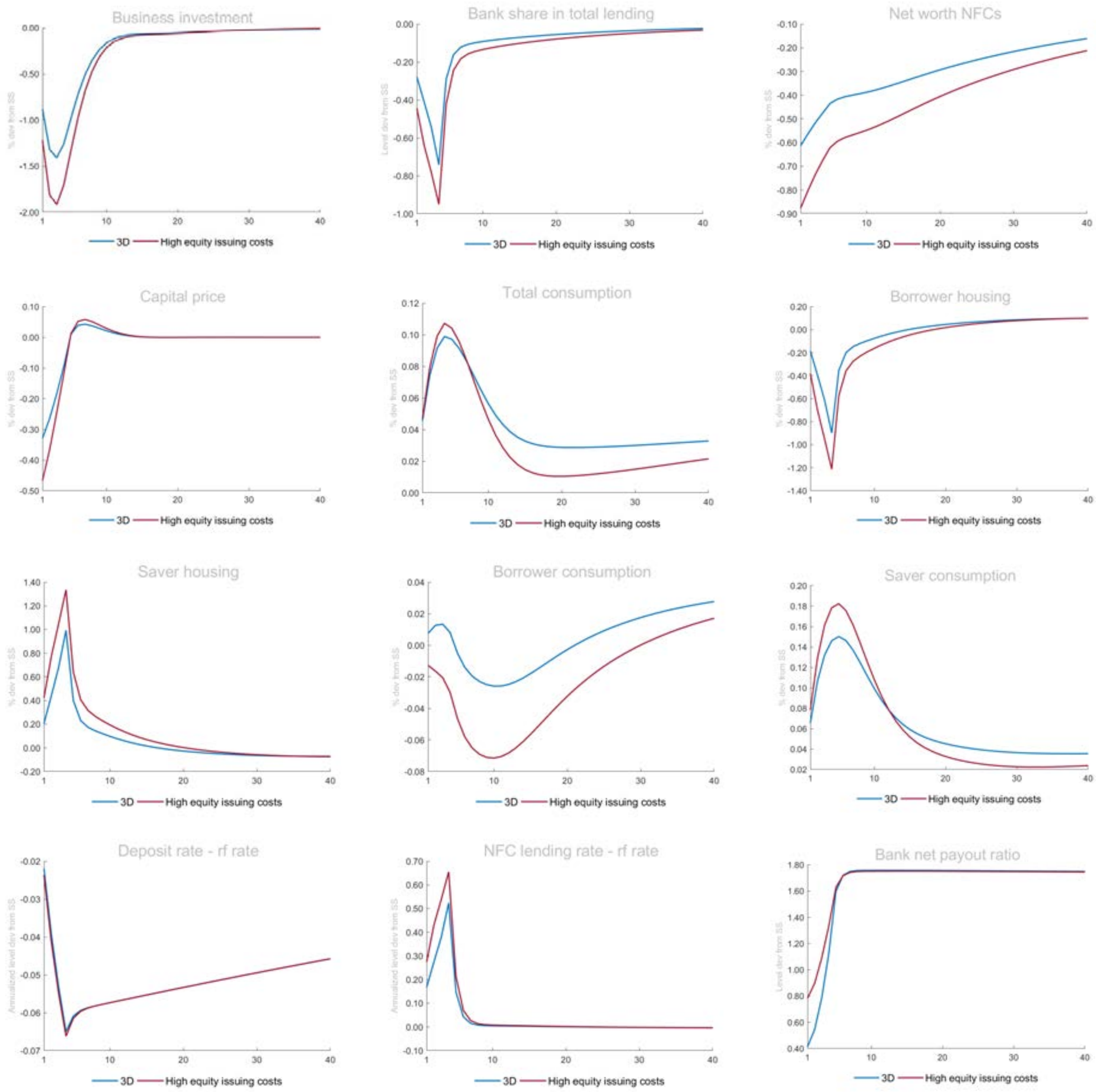

Figure 19: Sensitivity with respect to equity issuance costs in the 3D (Continued).

C Sensitivity: Bank risk

Below is a full set of IRFs for the bank risk sensitivity exercise in Subsection 2.1.3. We analyse high bank risk in both the 3D and the DJP.

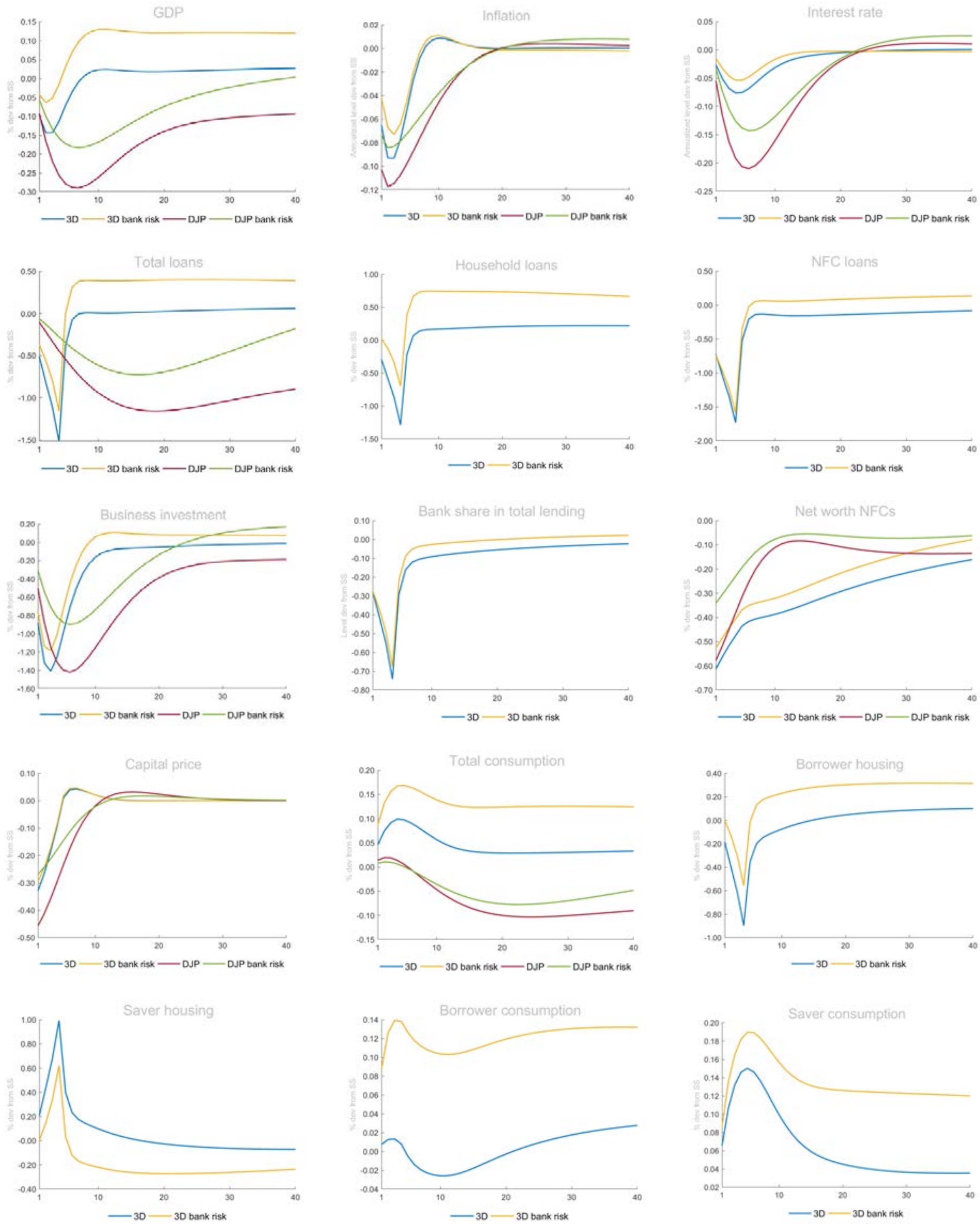

Figure 20: Sensitivity with respect to bank riskiness.

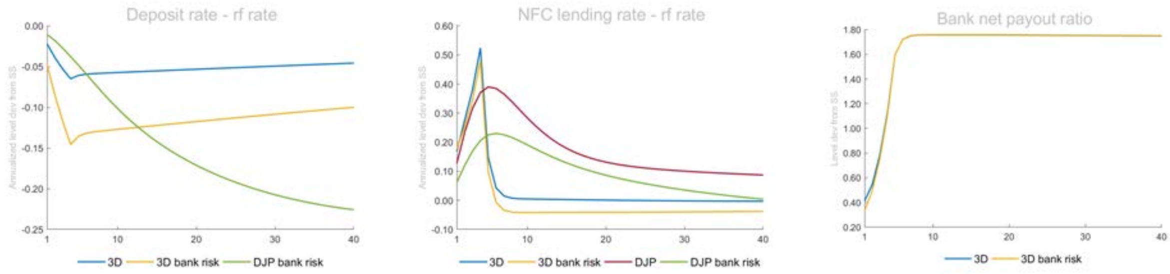

Figure 20: Sensitivity with respect to bank riskiness (Continued).

D Sensitivity: NFC risk

Below is a full set of IRFs for the NFC risk sensitivity exercise in the 3D and the DJP. We examine the sensitivity of our results with respect to NFC leverage. In this exercise we reduce the deadweight default cost for firms until the NFC default rate reaches 2%.

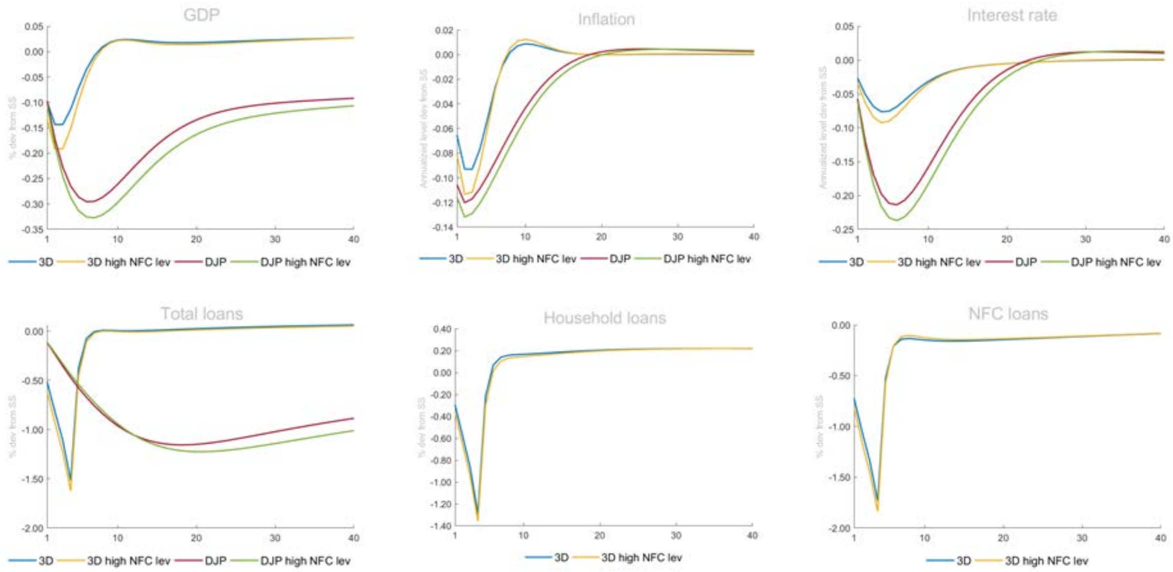

Figure 21: Sensitivity with respect to NFC riskiness.

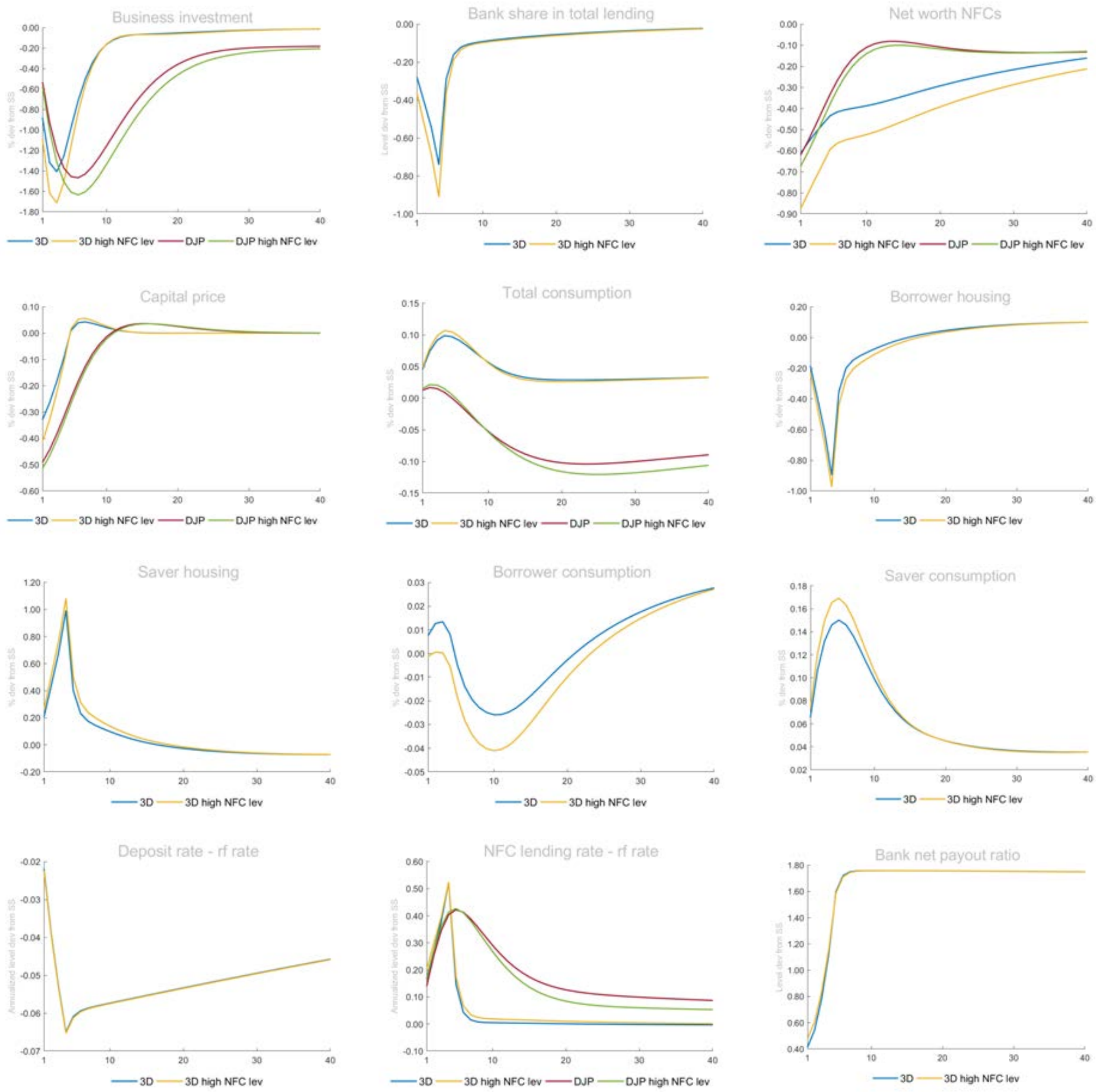

Figure 21: Sensitivity with respect to NFC riskiness (Continued).

We can see in Figure 25 that this change amplifies greatly the impact of higher capital requirements on investment, output and inflation in both models used in the simulation (3D and DJP). Interest rates have to fall further in order to maintain aggregate demand. Consumption increases by more driven by looser monetary policy.

Table 7: Sensitivity with respect to NFC risk

	GDP	**Inflation**	**Total loans**	**Business investment**
3D	-0.144	-0.093	-1.517	-1.409
3D high NFC lev	-0.192	-0.113	-1.622	-1.714
DJP	-0.295	-0.120	-1.155	-1.468
DJP high NFC lev	-0.327	-0.132	-1.224	-1.635

Notes. Results are reported in % deviation from steady-state.

E Monetary policy rules

Below is a full set of IRFs for each model under different monetary policy rules as in Subsection 2.2. We show the baseline taylor rule, a high inflation response taylor rule and a high GDP growth response taylor rule in the 3D, DJP, DKR, and the NAWM II.

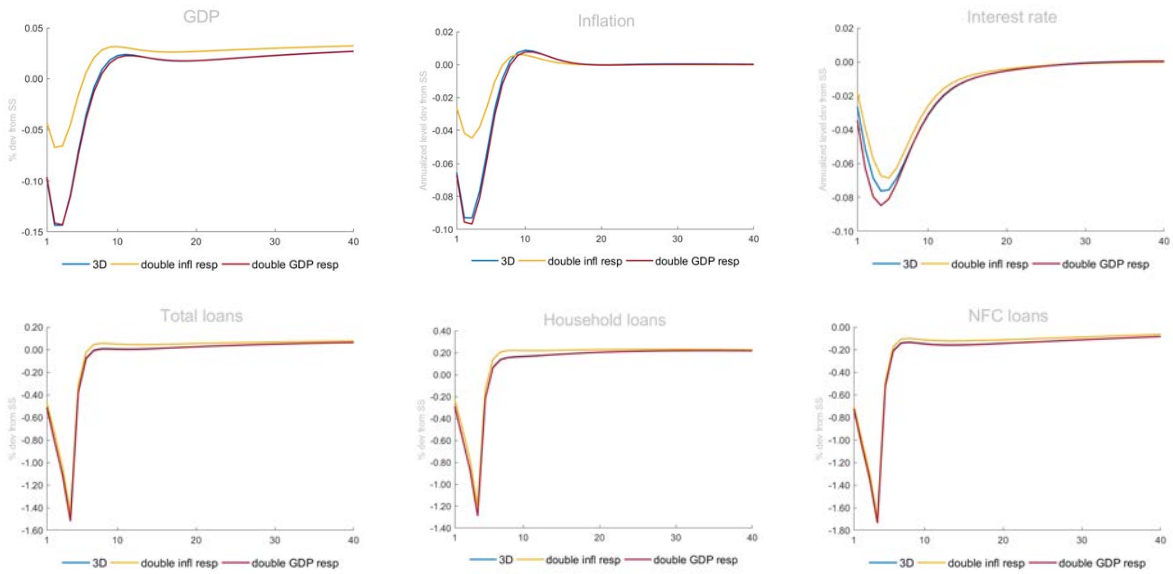

Figure 22: Monetary policy rule variations in the 3D.

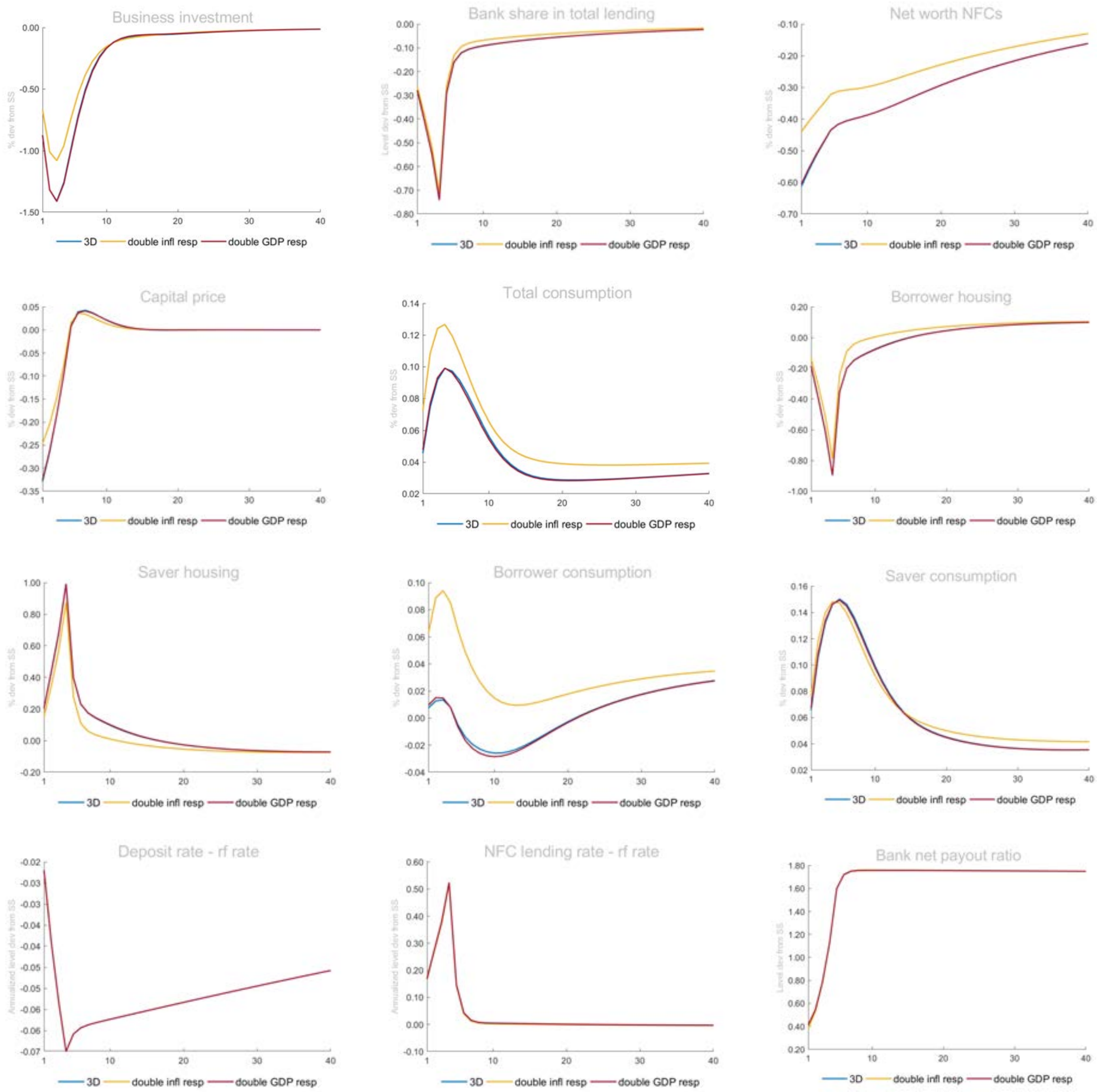

Figure 22: Monetary policy rule variations in the 3D (Continued).

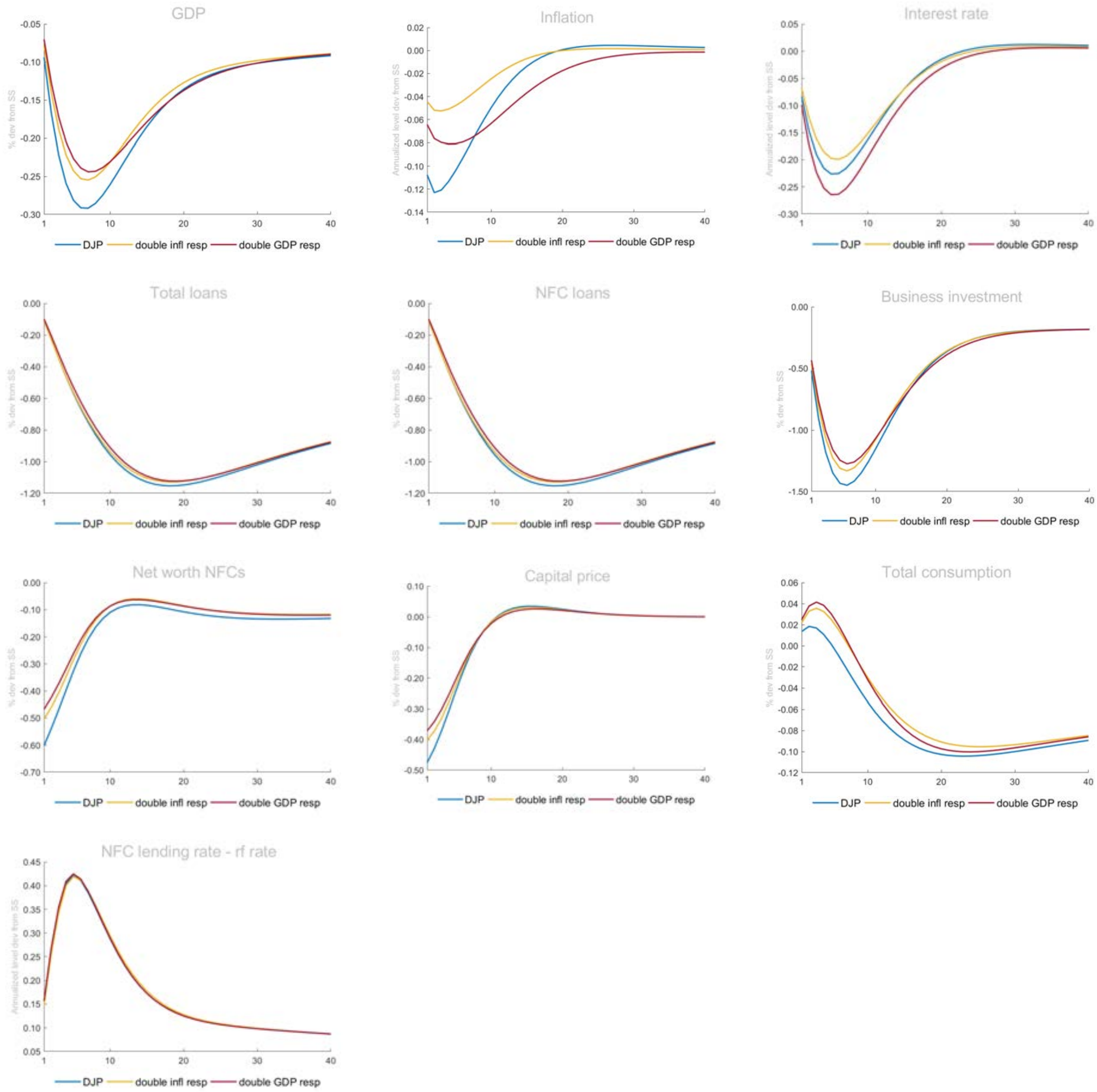

Figure 23: Monetary policy rule variations in the DJP.

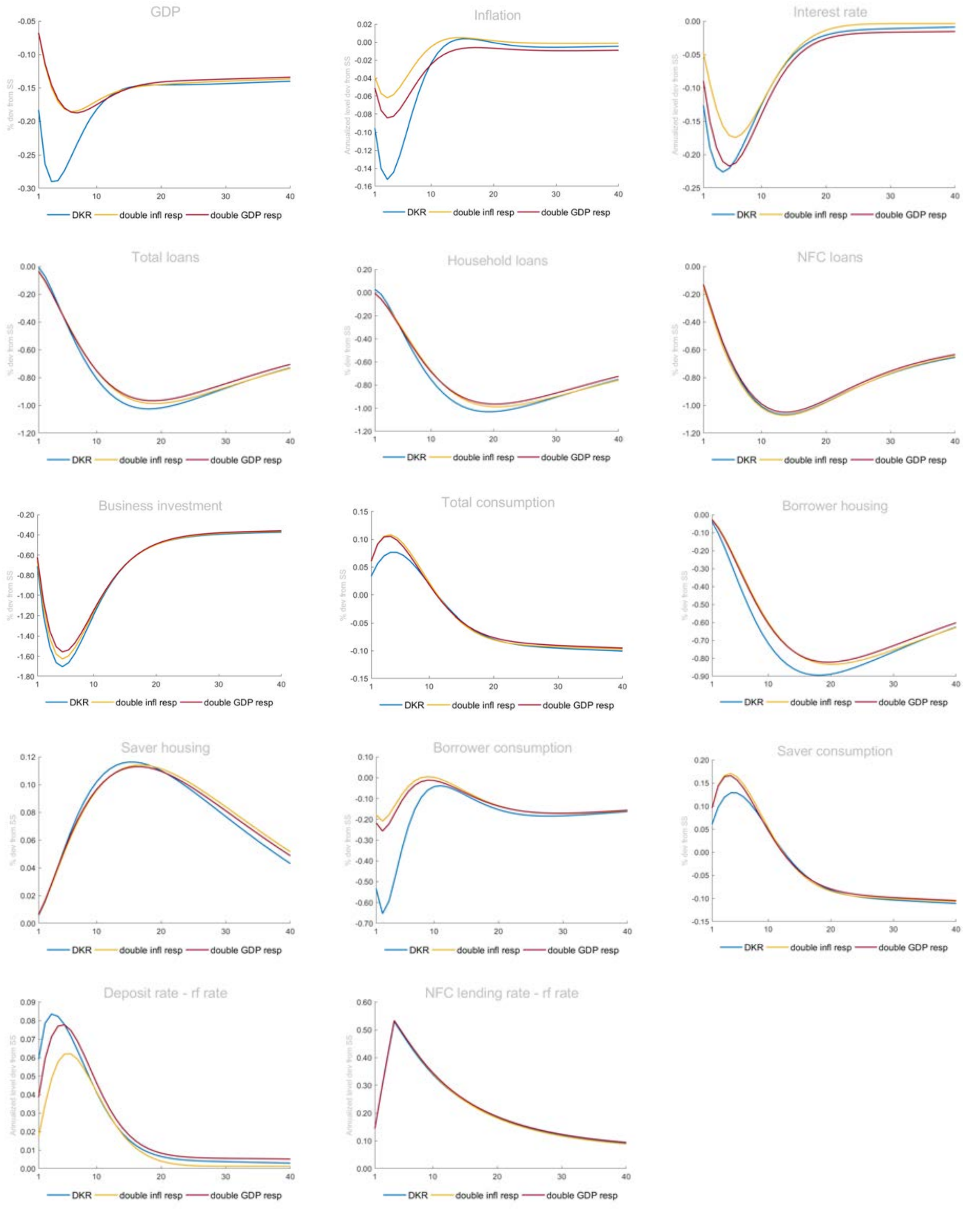

Figure 24: Monetary policy rule variations in the DKR.

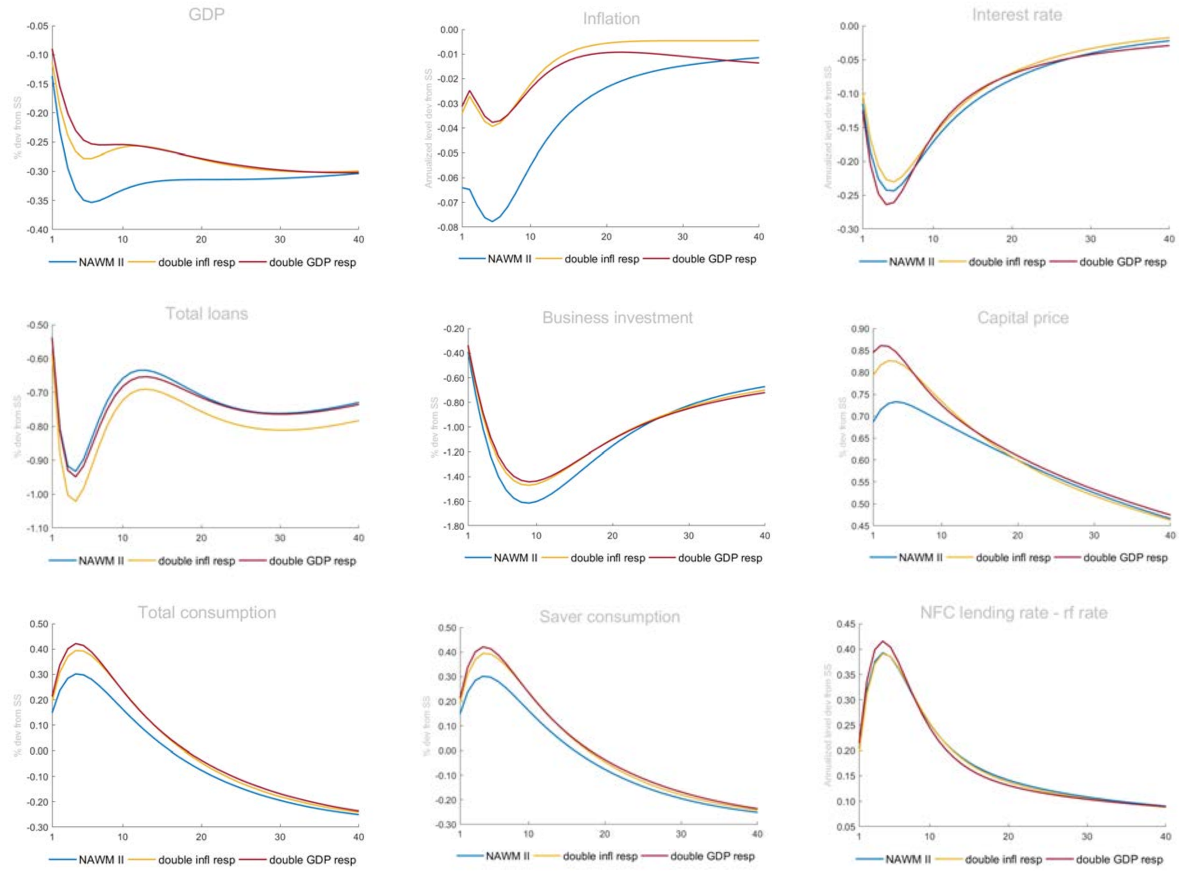

Figure 25: Monetary policy rule variations in the NAWM II.

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