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Optimal Unconventional Monetary Policy in the Face of Shadow Banking

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Abstract

Using a DSGE framework, we discuss the optimal design of monetary policy for an economy where both retail banks and shadow banks serve as financial intermediaries. We get the following results. During crises times, a standard Taylor rule fails to reach sufficient stimulus. Direct asset purchases prove to be the most effective unconventional tool. When maximizing welfare, central banks should shy away from interventions in the funding process between retail and shadow banks. Liquidity facilities are the welfare-maximizing unconventional policy tool. The effectiveness of unconventional measures increases in the size of the shadow banking sector. However, the optimal response to shocks is sensitive to the resource costs of the implementation which may differ across central banks. Hence, optimal unconventional monetary policy is country-specific.

JEL-Classification: E 44, E52, E58

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1 Introduction

Over the past two decades and especially since the onset of the financial crisis starting in 2007-2009, the financial system has witnessed a remarkable change in some major advanced economies such as the US and the euro area. Retail banking services like deposit issuance and loan origination have progressively shifted into a market-based banking system called the shadow banking system. By appearing as an alternative provider of liquidity, shadow banking has certainly supplemented and partly even replaced the services offered by the traditional banking system and contributed to a more efficient allocation of financial assets (IMF 2014).

Empirical evidence clearly shows that these developments in financial markets have steadily increased in recent years. For 2014, calculations of the IMF (2014) indicate that lending by the shadow banking system compared to overall lending amounted to roughly 51% in the US and to roughly 28% in the euro area, for the former decreasing slightly and the latter showing an upward trend. Analyzing the distribution of assets held within the euro area financial sector, calculations by Doyle et al. (2016) indicate the same. In 2015, financial assets held by the euro area shadow banking system amounted to roughly € 28 trillion or 40.5% of total financial assets, showing an upward trend over the last decade.[1]

However, comparing the structure of both systems clearly reveals the differences and costs that follow for financial markets. While the traditional banking system provides credit, liquidity and maturity transformation under a single roof, backed by public deposit insurance and supported by central bank liquidity, the shadow banking system runs almost the same activities but without being able to resort to the last two mentioned points. Shadow activities are neither backed by deposit insurance nor can the central bank directly intervene in that system.

These changes and the ensuing disturbances of 2007-2009 forced central banks to expand their conventional interest rate tools by unconventional measures.

In order to consider these changes and challenges, we build a comprehensive DSGE-model featuring financial intermediation with shadow banking along the lines of Gertler, Kiyotaki and Prestipino (2016) and Meeks, Nelson and Alessandri (2017), henceforth GKP and MNA. This setup enables use to evaluate different unconventional policy measures, their relative effectiveness and the optimal policy intervention.

With this in mind, we endow the central bank with three different unconventional measures: direct purchases of assets (purchasing non-financial loans), an intervention policy in the funding process between retail and shadow banks (purchasing interbank

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[1]This "broad euro area shadow banking measure" of the ECB comprises financial vehicle corporations, non-money market investment funds and money market investment funds. Excluded are insurance companies and pension funds.

loans), and liquidity facilities (placing additional funds on the balance sheet of retail banks). We use these measures to analyze their effectiveness in stabilizing financial markets and the real economy. In a second step, we compute the optimal monetary policy responses to business cycle and financial sector shocks and calculate the maximum welfare gains from unconventional policies depending on different resource costs.

The unconventional measures we implement are based on the attempts of the Fed and ECB to tackle the recent financial crisis and to overcome the ineffectiveness of conventional monetary policy at the zero lower bound on nominal interest rates. However, effects, timing, and especially the point of intervention of these measures differed across central banks. Whereas the Fed reacted promptly after the markets collapsed in 2008/2009, the ECB chose a more moderate and smooth approach, not least because financial disturbances started much later in Europe.[2] To account for the majority of unconventional measures, we implement three different tools. The central bank can *(a)* directly intervene in the market for non-financial loans, *(b)* intervene in the funding process between retail and shadow banks, or *(c)* provide liquidity directly to retail banks. Direct intervention in the market for non-financial loans requires the central bank to directly purchase loans (assets) from non-financial firms (see e.g. Gertler and Karadi 2011). If the central bank intervenes in the funding process between retail and shadow banks, it essentially purchases loans that retail banks assigned to shadow banks. The third policy option follows Gertler and Kiyotaki (2011) and Dedola et al. (2013) and represents a form of liquidity facility where the central bank provides loans, i.e. liquidity injections directly to retail banks. All three non-standard tools differ in their point of intervention and, accordingly, have different effects.

The model we set up for studying these interactions is a hybrid of the setup of Gertler and Karadi (2011) combined with elements from GKP and MNA. In following the perception of GKP, we model shadow banks as intermediaries that can make non-financial loans to firms but are almost exclusively dependent on funds from their sponsors, retail banks, to finance their activities. A common funding market (virtually speaking an interbank market) is the direct link between retail and shadow banks and

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[2]To better stabilize financial markets and to extend the basic liquidity providing programs, the Fed launched different Credit Easing-programs (QE I, II, III) and intervened in markets for agency mortgage backed securities, agency debts and Treasury securities. The aim was to bring down long term interest rates through directly purchasing financial assets within these markets. In contrast, the ECB started with activities focussed on avoiding liquidity shortages in the interbank market and implemented unconventional measures in the sense of Quantitative Easing relatively late. The initial programs aimed at unrestricted lending to the banking sector (such as the FRFA-program) and were mainly liquidity providing measures. However, with the most recent "Corporate Sector Purchase Programme" introduced in June 2016, the ECB started to directly purchase corporate sector bonds in the primary and secondary market to "... further strengthen the pass-through of Eurosystem's asset purchases to the financing condition of the real economy" (Doyle et al. 2016).

merges their liquidity positions. The latter act solely as borrowers and the former appear solely as lenders. Management of financial capital comes at a cost, giving shadow banks an advantage over retail banks in making non-financial loans. Since we consider shadow banks to be highly leveraged and dependent on funding from retail banks, exogenous shocks to the business cycle lead to disturbances in the funding process and let shadow intermediation collapse.

We can draw three major results from the analyses: first, regardless of the shock, unconventional policy measures stabilize the standard targets output and inflation and improve welfare. Hereby, direct asset purchases outperform liquidity facilities in terms of business cycle stabilization, which in turn outperform interbank interventions. A higher shadow banking sector leads to a sharper recession but also makes unconventional monetary policy more effective. Second, the usefulness of interbank intervention is highly sensitive to the kind of shock and the size of the shadow banking sector. Third, our welfare analysis shows that liquidity facilities seem to be the most appropriate unconventional policy tool closely followed by direct asset purchases. However, that finding is conditional on several aspects, e.g. the financial structure of the economy, reasonable assumptions for the resource costs of interventions and a foreseeable exit. Hence, there is no one-size-fits-all solution for unconventional monetary policy.

We want to make the reader aware of what we do not do in this paper. The recent financial crisis has not only spawned changes in the framework of monetary policy, it has also changed thinking about regulation and macroprudential oversight with several new measures being put into place (see e.g. Levine and Lima (2015) or Palek and Schwanebeck (2015)). Although macroprudential tools could be easily implemented into our framework, within this paper we do not account for these changes in the regulatory framework and, in a first step, focus rather on the effects of unconventional monetary policy. Another point worth mentioning in the process of shadow credit intermediation is the importance of securitization and the decoupling into different steps that are carried out along a chain of different entities.[3] We do not explicitly account for that process, but nonetheless incorporate the direct effects of securitization, namely the higher collateral value of interbank debt ascribable to the reduction of idiosyncratic risk inherent in the process of securitization. While the recent unconventional measures are designed for extraordinary times of crisis, it remains an open debate of how and when monetary policy should actively exit. Although our analysis points to a tapering process that can be interpreted as an exit, we do not explicitly model an active exit from unconventional policies in the sense of Foerster (2015).

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[3]These entities comprise, among others, money market mutual funds, and special purpose vehicles. For a more detailed explanation of the entities involved in the shadow banking system and the process of securitization, we refer to Pozsar et al. (2013). A comprehensive literature review of shadow banking has been put in place by Adrian and Ashcraft (2012).

The remainder of the paper is structured as follows. In section 2, we give a short overview of related literature. Section 3 introduces our model economy. We explain the setup of the productive sector, the financial sector and the interaction between retail banks and shadow banks. The different unconventional policy measures are also introduced in section 3. In section 4, we start with the calibration of our model. To explain the dynamics of the model featuring shadow banking, we analyze the shocks without influence of unconventional policies and run several scenarios with different shadow banking magnitudes. Thereafter, we run several experiments and let the central bank react with unconventional measures. The optimal monetary policy reaction and the implications for welfare are studied as well in section 4. Section 5 concludes with final remarks.

2 Related Literature

The implementation of shadow banking into standard monetary DSGE models with financial frictions progressed only sluggishly in the last decade. Accordingly, there are few papers that mention a financial sector with two different intermediaries. While not referring directly to shadow banking, the model of Gertler and Kiyotaki (2011) is one of the first to account for a financial sector with two distinct intermediaries connected on an interbank market. The authors study how disruptions in financial intermediation lead to a financial crisis that later transmits into the real sector. They then introduce various policy measures and credit market interventions to tackle the crisis.

Verona et al. (2013) use a DSGE setup with shadow banks to study the effects of the zero lower bound on monetary policy decisions. Their introduction of shadow banking comes along with a separation of entrepreneurs into two risk classes. Dependant on their risk aversion, an entrepreneur either obtains credit from the commercial bank or from the shadow bank, with the latter only investing in less risky loans.

The two most recent and for our setup most important papers are GKP and MNA. Both augment the financial sector with aspects of shadow banking. Retail or commercial banks are no longer the only intermediaries to channel funds from savers to investors, but shadow banks, or alternatively wholesale banks, come into play and serve as a second provider of credit. They thereby alter the dynamics of the model. Up to now, these models mostly examine the impact of shadow banks on the availability of credit supply and the model dynamics in the face of financial and business cycle shocks. The result is that an active shadow banking sector increases the availability of credit but likewise causes a higher vulnerability of the financial system and the economy (MNA).

As in MNA, shadow banks can appear as off-balance sheet vehicles of commercial banks and carry out securitization activities. Commercial banks can off load parts of

their balance sheet to shadow banks, which then use these loans to manufacture high-quality ABS and sell them back to commercial banks. Since these ABS are of better quality than normal loans, commercial banks have an incentive to invest in ABS in order to relax their incentive constraint and extend credit supply. Their overall outcome is that shadow banking increases the availability of credit but likewise causes a higher vulnerability of the system to shocks.

Alternatively, wholesale banks (virtually speaking, shadow banks) appear alongside retail banks and serve as an alternative provider of credit (e.g. GKP). That setup is an holistic and comprehensive approach of how to implement financial intermediation with retail and wholesale banks into a macroeconomic setup. Their parametrization entails both retail and wholesale banks making loans to intermediate goods firms, but their source of funding for these loans differs. Whereas retail banks can take on deposits from households, wholesale banks do not have access to deposits and solely rely on funding from retail banks. When setting up our model, we use exactly these interlinkages to model the interaction between retail and shadow banks.

As regards unconventional monetary policy, there is already plenty of research that studies the effectiveness and transmission mechanisms of such tools. Gertler and Karadi (2011) set up a DSGE model with financial intermediation and a central bank that starts to intermediate in private credit, i.e. purchases assets, to manage an extraordinary financial crisis. They find that direct purchases of assets are effective even when the zero lower bound is not reached. As soon as this is the case, the benefits from intervention even increase. Ellison and Tischbirek (2014) use a DSGE model with financial intermediation and find that asset purchases by the central bank work well in stabilizing output and inflation, regardless of whether the economy runs through a deep recession or not. They call for implementing unconventional tools as an additional tool besides interest rate policies, even in normal times. In a comprehensive DSGE model with a financial sector, Foerster (2015) finds that asset purchases are indeed effective, but depend on the exit strategy and the expectations of agents. A recent publication by Nuguer (2016) develops a two-country DSGE model with cross-border banking where financial intermediaries in one country can lend to intermediaries in another country. She studies the international transmission of shocks and implements different unconventional policy measures. Her results indicate that unconventional measures are effective at stabilizing the economy. As regards empirical evidence, Joyce et al. (2012) find that unconventional tools like purchases of assets conducted during the crises were effective in bringing down longer term interest rates, thereby stimulating economic activity. The empirical results of Gambacorta et al. (2014) point in the same direction. Unconventional tools at the zero lower bound have positive effects on output and inflation.

To the best of our knowledge none of these papers analyzes the measures with respect to their implications on a financial sector featuring shadow banks.

3 The Basic Model

Our core framework is a standard monetary DSGE model with nominal rigidities and financial intermediation as in Gertler and Karadi (2011), extended by a shadow banking sector along the lines of GKP and MNA. The model consists of the following agents: households, intermediate goods firms, capital goods firms, retailers, and financial intermediaries, segmented into a retail bank and a wholesale (shadow) bank. Although both intermediaries can make non-financial loans to intermediate goods firms, their balance sheet structure differs. Only the retail bank is able to obtain deposits from households, shadow banks have to rely on funding from retail banks to finance their loans to firms. Moreover, both intermediaries face an agency problem; retail banks towards households, and shadow banks towards retail banks. This restricts the ability of intermediaries to obtain funds from their financiers due to their incentive of diverting a fraction of their balance sheet for personal use. In order to simplify the analysis and focus on the financial sector, we abstract from explicitly modelling agency frictions between financial intermediaries and non-financial firms. The focal point of our paper is the implementation and the effect of optimal unconventional monetary policy. Thus, we incorporate several measures into the model. They comprise central bank purchases of assets, i.e. credit policies, central bank intervention in the funding market between retail and shadow banks and liquidity facilities. In the following, we describe the model setup.

3.1 Households

There is a continuum of representative infinitely-lived households that consume, save and supply labor. Within each household exist three types of members, one worker and two bankers. Both bankers manage financial intermediaries, however, they are split up into a retail banker (i.e. managing a retail bank) and a shadow banker (i.e. managing an entity within the shadow banking sector). Through managing their financial intermediaries, both types of bankers accumulate net worth and transfer retained earnings back to their household once they have to shut down their intermediary and exit the banking sector. Following Gertler and Karadi (2011), this mechanism prevents bankers from accumulating enough net worth to independently fund all their investments. Simultaneously, workers supply labor to goods producers and return their earnings back to the household. After each period, the fraction of bankers who exit the industry become workers. In order to keep the family members constant over time, a corresponding fraction of workers become new bankers who are endowed with startup funds from their respective household. To guarantee the assumption of the representative agent framework, we assume perfect consumption insurance among household members.

The representative infinitely-lived household maximizes its utility function

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} U(C_\tau - hC_{\tau-1}, L_\tau) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[\log(C_\tau - hC_{\tau-1}) - \chi \frac{L_\tau^{1+\varphi}}{1+\varphi} \right], \quad (1)$$

consisting of consumption C_t with h as the parameter to allow for habit formation in consumption and labor L_τ. The households discount factor is β, φ is the inverse Frisch elasticity and χ a weight on labor utility. Households are the ultimate savers of the economy, thus they deposit funds D_t at banks other than the ones they own and may acquire government debt $B_{g,t}$. Both deposits and government debt are one-period riskless assets that pay the real riskless rate R_t and can be thought of as noncontingent short-term bonds. Besides, households obtain real wage income W_t from supplying labor L_t to goods producers and they receive net earnings Π_t arising out of bank returns and profits from providing management services plus the profits generated from the ownership of capital producers and retailers reduced by startup funds for new bankers. T_t represents lump sum taxes. Accordingly, the flow of funds of the household can be written as

$$C_t + D_t + B_{g,t} = W_t L_t + R_t D_{t-1} + R_t B_{g,t-1} + \Pi_t - T_t. \quad (2)$$

By maximizing the households utility function (1) subject to the flow of funds constraint we get the first-order conditions for labor supply and consumption/savings

$$U_{C_t} W_t = \chi L_t^\varphi \quad (3)$$
$$E_t \Lambda_{t,t+1} R_{t+1} = 1 \quad (4)$$

with the marginal utility of consumption defined as

$$U_{C_t} = (C_t - hC_{t-1})^{-1} - \beta h E_t (C_{t+1} - hC_t)^{-1}$$

and the households stochastic discount factor written as

$$\Lambda_{t,\tau} = \beta^{\tau-t} \frac{U_{C_\tau}}{U_{C_t}}.$$

3.2 Intermediate goods firms

Competitive intermediate goods firms employ the constant-returns-to-scale Cobb-Douglas production function given by

$$Y_{m,t} = (\psi_t K_t)^\alpha L_t^{1-\alpha} \quad (5)$$

using the input factors capital K_t and labor L_t to produce intermediate output $Y_{m,t}$, that is afterwards sold to retailers and then used to produce the final output. ψ_t reflects a shock to the quality of capital. Prior to use, capital for production in the subsequent period $t+1$ needs to be purchased from capital producers in period t. In order to obtain loans to finance the acquisition of capital, intermediate firms issue claims S_t to financial intermediaries. These claims equal the amount of acquired capital and are priced with Q_t, reflecting the real price of a unit of capital. It follows that

$$Q_t K_{t+1} = Q_t S_t \tag{6}$$

which states that the value of capital acquired equals the value of claims issued, with the evolution of the capital stock K_{t+1} following the law of motion given by

$$K_{t+1} = (1 - \delta)\psi_t K_t + I_t. \tag{7}$$

Capital for period $t + 1$ is the sum of current investment I_t and existing undepreciated capital subject to the shock to capital quality. The term $\psi_t K_t$ denotes the effective quantity of capital at t. It is best to think of this shock as a negative event triggering a sudden depreciation of the already installed capital, thereby causing a devaluation of the balance sheets of banks (e.g. describing the circumstances after the bursting of the US housing bubble in 07/08). As will be clear later, banks use capital as collateral in their balance sheet. Consequently, sudden changes in the value of capital affect the asset side of banks and thus their overall financing structure.

Profit maximization of the intermediate goods firms lead to the first-order conditions for labor input

$$W_t = P_{m,t}(1 - \alpha)\frac{Y_t}{L_t}, \tag{8}$$

where $P_{m,t}$ is the relative price of the intermediate good. The gross profits per unit of capital can be expressed as the marginal product of capital:

$$Z_t = P_{m,t}\alpha\frac{Y_{m,t}}{K_t}. \tag{9}$$

Following GKP, we assume that the funding process between intermediate firms and the corresponding financial intermediaries includes management costs which arise as costs for supervising contracting parties as well as complying with regulatory guidelines. Retail bankers make loans subject to management costs in form of $F_r = \iota(S_{r,t})^2/2$ while shadow banks do not face these costs ($\iota_w \to 0$), households on the other hand, are excluded from directly lending to firms ($\iota_h \to \infty$). However, households receive profits ($F_r' S_{r,t} - F_r$) from providing management services to retail banks by bearing the

management costs F_r while demanding the price $F_r' = \iota S_{r,t}$ per managed unit $S_{r,t}$.

As a result, shadow banks have a cost advantage over retail banks which results in different rates of return on non-financial loans:

$$R_{wk,t} = \frac{Z_t + (1-\delta)\psi_t Q_t}{Q_{t-1}}, \ R_{rk,t} = \frac{Z_t + (1-\delta)\psi_t Q_t}{Q_{t-1} + \iota S_{r,t-1}}. \tag{10}$$

3.3 Capital goods firms

Competitive capital goods firms produce new capital goods and sell the capital to intermediate goods producers at the price Q_t. Production of capital goods utilizes final output from retailers as input and is subject to investment adjustment costs following the functional form

$$f_i\left(\frac{I_t}{I_{t-1}}\right) = \frac{\eta_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \tag{11}$$

satisfying $f(1) = f'(1) = 0$ and $f''(1) > 0$. By choosing investment I_t, capital producers maximize their profits according to the objective function

$$\max E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau} \left\{ Q_\tau I_\tau - \left[1 + f_i\left(\frac{I_\tau}{I_{\tau-1}}\right)\right] I_\tau \right\}. \tag{12}$$

Profit maximization leads to the first-order condition for the marginal cost of investment

$$Q_t = 1 + f_i\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f_i'\left(\frac{I_t}{I_{t-1}}\right) - E_t \Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 f_i'\left(\frac{I_{t+1}}{I_t}\right) \tag{13}$$

which equals the price Q_t of a capital good. Since capital producers are owned by households, they return all profits back to their household.

3.4 Retailers

Monopolistically competitive retailers produce the final good by using the intermediate good as input and label it at no cost. Thus, final output Y_t as a CES aggregate of a continuum of retail output is given by

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{14}$$

where Y_{it} denotes the output of retailer i and ε is the elasticity of substitution between goods. Cost minimization leads to

$$Y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\varepsilon} Y_t, \ \ P_t = \left[\int_0^1 P_{it}^{1-\varepsilon} di\right]^{\frac{1}{1-\varepsilon}}. \tag{15}$$

To introduce nominal rigidities, we follow Christiano et al. (2005) and assume that only the fraction $1 - \zeta$ of retailers is able to adjust their prices each period, whereas the fraction ζ of retailers can only index their prices to lagged inflation according to $P_{it} = \pi_{t-1}^{\zeta_P} P_{it-1}$ with $\pi_t = P_t/P_{t-1}$ and ζ_P as a measure of price indexation. The retailers optimization problem boils down to choose the optimal price P_t^* in order to maximize profits following

$$\max E_t \sum_{\tau=t}^{\infty} \zeta^{\tau-t} \Lambda_{t,\tau} \left[\frac{P_t^*}{P_\tau} \prod_{j=1}^{\tau-t} \pi_{t+j-1}^{\zeta_P} - P_{m,\tau}\right] Y_{i\tau}. \tag{16}$$

The first-order condition is given by

$$E_t \sum_{\tau=t}^{\infty} \zeta^{\tau-t} \Lambda_{t,\tau} \left[\frac{P_t^*}{P_\tau} \prod_{j=1}^{\tau-t} \pi_{t+j-1}^{\zeta_P} - \frac{\varepsilon}{\varepsilon-1} P_{m,\tau}\right] Y_{i\tau} = 0 \tag{17}$$

and the aggregate price index evolves according to

$$P_t = \left[(1-\zeta)(P_t^*)^{1-\varepsilon} + \zeta(\pi_{t-1}^{\zeta_P} P_{t-1})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}. \tag{18}$$

3.5 Financial intermediaries

The financial system is responsible for channeling funds from savers (households) to investors (non-financial firms) and comprises two types of financial intermediaries, retail banks and shadow banks. Both intermediaries can make non-financial loans to intermediate goods firms and both have access to a common funding market. This funding market represents the direct link between retail and shadow banks, where shadow banks act solely as borrowers and retail banks appear solely as lenders. For the sake of simplicity, when we later mention the process of funding between retail and shadow banks we will refer to it as the interbank market. Furthermore, shadow banks have no direct access to retail financial markets (i.e. household deposits) and, besides accumulated net worth, have to rely on funding (loans) from retail banks to make non-financial loans. Hence, we consider shadow banks to be highly leveraged and dependent on funding

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from retail banks.

This structure of interaction between retail banks and shadow banks closely follows GKP. Here, in general both intermediaries would be able to obtain deposits from households and to borrow as well as lend in the interbank market. However, the authors focus their attention on the most realistic case where retail banks obtain deposits from households, lend funds to non-financial firms as well as shadow banks, and shadow banks exclusively rely on interbank borrowing from retail banks. Two pivotal assumptions guarantee this direction of the flow of funds: on the one hand, as outlined above, management of financial capital is subject to costs, and on the other hand, intermediaries differ in their ability to make use of the interbank market. The different ability to make use of the interbank market is captured by introducing two additional diversion parameters in the incentive constraints of the intermediaries. These parameters express the relative advantage of retail banks being able to lend funds to shadow banks instead of using them entirely for non-financial loans. We will elaborate on these parameters later on in the paper when we introduce the incentive constraints of retail and shadow banks.

3.5.1 Retail banks

At the beginning of the period t, an individual retail banker obtains deposits d_t from households and accumulates net worth $n_{r,t}$ from retained earnings, in order to allocate non-financial loans $s_{r,t}$ priced at Q_t to intermediate goods firms (including management services) and funds (loans) $b_{r,t}$ to shadow banks. The balance sheet identity during period t can be written as follows:

$$(Q_t + \iota s_{r,t}) s_{r,t} + b_{r,t} = d_t + n_{r,t} + m_t, \tag{19}$$

where m_t reflects one out of three possibilities of unconventional monetary policy by the central bank. Following Gertler and Kiyotaki (2011) and Dedola et al. (2013), the central bank conducts liquidity facilities in the sense of the ECB, i.e. allocating loans directly to retail banks at the noncontingent interest rate $R_{g,t}$.

Net worth $n_{r,t}$ at period t evolves as the difference between earnings on non-financial loans $s_{r,t-1}$ from $t-1$ to t and funds to shadow banks $b_{r,t-1}$ from $t-1$ to t at the interbank lending rate $R_{b,t}$ net of payments on deposits d_{t-1} at the non-contingent riskless rate R_t and payments on liquidity facilities at the penalty rate $R_{g,t}$. Accordingly, we can

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express the evolution of net worth as

$$
\begin{aligned}
n_{r,t} &= (Z_t + (1-\delta)\psi_t Q_t)\, s_{r,t-1} + R_{b,t} b_{r,t-1} - R_t d_{t-1} - R_{g,t} m_{t-1} \\
n_{r,t} &= (R_{rk,t} - R_t)\,(Q_{t-1} + \iota s_{r,t-1})\, s_{r,t-1} + (R_{b,t} - R_t) b_{r,t-1} \\
&\quad + R_t n_{r,t-1} - (R_{g,t} - R_t) m_{t-1}. \tag{20}
\end{aligned}
$$

Given a positive spread for retail bankers it is worth increasing their loan holdings indefinitely by raising new deposits until they have to exit the industry and become a worker. Accordingly, the objective of the retail banker is to maximize the expected terminal value of his net worth at the end of period t given by the value function

$$
V_{r,t} = E_t \left[\sum_{\tau=t+1}^{\infty} (1-\sigma)\sigma^{\tau-t-1} \Lambda_{t,\tau} n_{r,\tau} \right], \tag{21}
$$

with the surviving probability σ and the stochastic discount factor $\Lambda_{t,\tau}$, which equals that of households since retail bankers are members of the same.

Since retail bankers would try to expand their assets indefinitely by raising new deposits, we set up a moral hazard problem between them (Gertler and Karadi (2011)). Still in period t but after raising new funds from households, the banker can decide to behave corrupt instead of maximizing the terminal value of net worth. Being corrupt means to divert the fraction θ_t of the balance sheet that is funded by retained earnings and deposits and return them back to the respective household. Since the remaining households are only able to recover the fraction $1-\theta_t$, they force the retail banker into bankruptcy at the beginning of the next period. It follows that households are only willing to supply additional funds to retail banks, if the latter have an incentive to remain in business and supply further loans, i.e. if the present discounted value of future payouts exceeds or is at least equal to the gain from absconding with the divertable fraction θ_t. This relation can be expressed with the following incentive constraint

$$
V_{r,t} \geq \theta_t \left[(Q_t + \iota s_{r,t})\, s_{r,t} + \gamma_t b_{r,t} - \lambda m_t \right], \tag{22}
$$

where the weight of an asset is inversely related to its collateral value (see MNA).

Remaining in doing business implies that the franchise value $V_{r,t}$ of the bank must exceed, or is at least equal to, the gain from absconding with the divertable fraction θ_t of assets. However, the possibility to divert funds is not evenly distributed among assets. Whereas retail bankers can divert the fraction θ_t $(0 < \theta_t < 1)$ of non-financial loans, they are only able to divert the fraction $\theta_t \gamma_t$ of interbank loans, with $0 < \gamma_t < 1$, and the fraction $\theta_t \lambda$, with λ $(0 < \lambda < 1)$, of loans allocated by the central bank. Thus, non-financial loans are easier to divert compared to interbank loans and governmental

loans. This fact is motivated by the assumption that loans granted within the inter-bank market are easier to monitor and to evaluate for third parties (i.e. households) compared to loans from retail banks to non-financial firms. As argued by GKP, and MNA, mutual interbank lending largely destroys the idiosyncratic features inherent in such loans thereby making them a safer asset and more pledgeable. Accordingly, γ_t influences the composition of assets of retail banks and, particularly, the size of the shadow banking sector. Suppose a decrease in γ_t. The more the parameter shrinks, the less easy it is to divert interbank loans, and the higher is the incentive for retail banks to precipitate a relaxation of their incentive constraint by increasing interbank loans to shadow banks compared to non-financial loans. Subsequently, shadow banks are endowed with more funds leading to an increased intermediation activity of the very same, i.e. lending to non-financial firms.

There may be exogenous shocks ϵ_t^θ and ϵ_t^γ to the diversion parameters θ_t and γ_t that are assumed to follow AR(1) processes. One could think of these shocks as a sudden loss of confidence in the banking sector and a loss of pledgeability of interbank loans that are manifest in an increase in the attractiveness of diverting assets. This leads to a tightening of the incentive constraint and thereby triggers a credit crunch (see e.g. MNA and Dedola et al., 2013).

Turning now to the optimization problem of the retail banker, we begin by writing the value function (21) recursively as the Bellman equation and get

$$V_{r,t-1} = E_{t-1} \Lambda_{t-1,t} \left[(1-\sigma) n_{r,t} + \sigma V_{r,t} \right]. \tag{23}$$

The retail banker maximizes (23) by choosing $\{s_{r,t}, b_{r,t}, m_t\}$ subject to (20) and (22). To solve the maximization problem, we guess and later verify that (23) can be stated by the following expression

$$V_{r,t} = \mu_{rs,t} \left(Q_t + \iota s_{r,t} \right) s_{r,t} + \mu_{rb,t} b_{r,t} + \nu_{r,t} n_{r,t} - \mu_{g,t} m_t, \tag{24}$$

where $\mu_{rs,t}$ is the excess return of non-financial loans over deposits, $\mu_{rb,t}$ is the excess return of interbank loans over deposits and $\nu_{r,t}$ is the marginal value of net worth while $\mu_{g,t}$ shows the excess cost of liquidity facilities. Now, the optimization problem of the retail banker can be solved by maximizing (24) subject to (22).

By rearranging the first-order conditions, we obtain

$$\mu_{rs,t} = \frac{1}{\gamma_t} \mu_{rb,t} \tag{25a}$$

$$\mu_{rs,t} = \frac{1}{\lambda} \mu_{g,t}. \tag{25b}$$

From (25a) we see that the excess return for the retail bank of assigning another unit of interbank loan is twofold. On the one hand, it is the excess return $\mu_{rb,t}$ resulting from that unit and, on the other hand, it is the relaxation of the incentive constraint governed by γ_t and the resulting increased willingness of households to supply further deposits. Accordingly, the retail banker accepts a lower excess return on interbank loans if the relaxation effect via γ_t is strong enough The same holds for governmental loans, i.e. liquidity facilities, as shown by (25b): the retail banker is willing to accept the excess cost $\mu_{g,t}$ due to the incentive-relaxing effect via λ.

By using (25a) and (25b), we can combine (24) and (22) to obtain an equation defining the leverage ratio $\phi_{r,t}$:

$$\phi_{r,t} = \frac{(Q_t + \iota s_{r,t})\, s_{r,t} + \gamma_t b_{r,t}}{n_{r,t}} = \frac{\nu_{r,t}}{\theta_t - \mu_{rs,t}} + \lambda \frac{m_t}{n_{r,t}}. \tag{26}$$

Now, by combining the guess (24), the Bellman equation (23), the incentive constraint (22), the leverage ratio (26), and the evolution of net worth (20), the value function of the retail banker can be rewritten as

$$V_{r,t} = E_t \Omega_{r,t+1} \left[\begin{array}{c} (R_{rk,t+1} - R_{t+1})(Q_t + \iota s_{r,t})\, s_{r,t} + (R_{b,t+1} - R_{t+1})b_{r,t} \\ + R_{t+1} n_{r,t} - (R_{g,t+1} - R_{t+1})m_t \end{array} \right], \tag{27}$$

where

$$\Omega_{r,t+1} = \Lambda_{t,t+1} \left[1 - \sigma + \sigma(\nu_{r,t+1} + \mu_{rs,t+1}\phi_{r,t+1}) \right].$$

Since retail banks face a binding financial friction, their stochastic discount factor Ω_{rt+1} differs from that of households.

In order to verify the initial guess of the Bellman equation, the coefficients of (24) have to satisfy

$$\mu_{rs,t} = E_t \Omega_{r,t+1}(R_{rk,t+1} - R_{t+1}) \tag{28a}$$

$$\mu_{rb,t} = E_t \Omega_{r,t+1}(R_{b,t+1} - R_{t+1}) \tag{28b}$$

$$\nu_{r,t} = E_t \Omega_{r,t+1} R_{t+1} \tag{28c}$$

$$\mu_{g,t} = E_t \Omega_{r,t+1}(R_{g,t+1} - R_{t+1}). \tag{28d}$$

Let us emphasize the important features inherent in the intermediation process of retail banks. The leverage ratio $\phi_{r,t}$ retail bankers must comply with in order for households to be willing to supply deposits limits the total amount of assets. Thus, under the assumption of a binding incentive constraint, the total amount of loans that a retail banker can allocate depends on his net worth. The more net worth a retail banker accumulates, the smaller (26) gets and the more loans can be provided. Furthermore,

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it is straightforward to see that $\phi_{r,t}$ is increasing in $\mu_{rs,t}$ and $\nu_{r,t}$, and decreasing in θ_t. The impact of $\mu_{r,st}$ and $\nu_{r,t}$ is as follows. Suppose an increase in the marginal gain from allocating another loan to non-financial firms. What follows is an increase in the franchise value of the retail bank and, due to a higher incentive to continue operating the bank, a relaxation of the retail bankers' incentive constraint. Now, the willingness of a household to supply deposits to retail banks is increasing. The same holds true for an increase in the marginal value of net worth. By contrast, an increase in θ_t makes diversion of assets simpler, and households more skeptical of bankers. This process tightens the incentive constraint of the retail bankers and translates into the need to deleverage, i.e. a reduction of loans (and thus deposits), to meet the leverage ratio. Finally, the unconventional monetary policy of allocating loans directly to retail banks improve their ability to provide loans.

3.5.2 Shadow banks

Unlike retail banks, shadow banks do not have direct access to financial retail markets and, consequently, are not able to raise deposits from households as a source of funding. In order to make non-financial loans $Q_t s_{w,t}$ to firms, an individual shadow bank has instead to rely on funding (interbank borrowing) $b_{w,t}$ from retail banks and accumulated net worth $n_{w,t}$. Thus, the balance sheet identity is given by

$$Q_t s_{w,t} = b_{w,t} + n_{w,t}. \tag{29}$$

Net worth $n_{w,t}$ at the beginning of period t is composed of earnings on non-financial loans $s_{w,t-1}$ less interest payments on interbank loans $b_{w,t-1}$ at $R_{b,t}$:

$$
\begin{aligned}
n_{w,t} &= \left(Z_t + (1-\delta)\psi_t Q_t\right) s_{w,t-1} - R_{b,t} b_{w,t-1} \\
n_{w,t} &= (R_{wk,t} - R_{bt})Q_{t-1}s_{w,t-1} + R_{b,t}n_{w,t-1}.
\end{aligned}
\tag{30}
$$

The evolution of net worth of shadow banks is dependent on the spread between the return on non-financial loans and the cost of borrowing. Given a positive spread, i.e. $R_{wk,t} - R_{b,t} > 0$, shadow bankers will want to increase lending indefinitely by borrowing additional funds from retail banks and retain all earnings until the time they exit. It follows that the objective of a shadow bank is to maximize the expected terminal value of net worth given by the value function

$$V_{w,t} = E_t \left[\sum_{\tau=t+1}^{\infty} (1-\sigma)\sigma^{\tau-t-1}\Lambda_{t,\tau}n_{w,\tau} \right]. \tag{31}$$

As with retail banks and households, a similar moral hazard problem limits the

ability of shadow banks to obtain funds from their creditor (retail) banks. What follows is that retail banks are only willing to supply funds (interbank loans) to shadow banks, if the latter have an incentive to continue doing business. This is only the case, if the following incentive constraint holds:

$$V_{w,t} \geq \theta_t[Q_t s_{w,t} - b_{w,t} + \omega b_{w,t}]. \tag{32}$$

The left side of the inequality represents the gain from remaining in business, namely the franchise value $V_{w,t}$. The right side reflects the gain from diverting assets, and, as a consequence, being forced into bankruptcy. It is straightforward to see that shadow bankers can divert the fraction θ_t of non-financial loans that are financed by net worth ($Q_t s_{w,t} - b_{w,t} = n_{w,t}$), but only the fraction $\theta_t \omega$ of non-financial loans financed by interbank borrowing $b_{w,t}$, with $0 < \omega < 1$. Following GKP and MNA, banks lending in the interbank market are better able to monitor as well as evaluate the quality of their counterparts. Hence, interbank loans that are used as funds for non-financial loans are harder to divert and thereby more pledgeable. Suppose a reduction in the ability to divert interbank loans $b_{w,t}$, what we express by reducing the value of ω. Now, interbank funding grows in attractiveness since the pledgeability of $b_{w,t}$ rises. As a consequence, shadow banks may want to increase interbank borrowing in order to relax their incentive constraint. The interbank market and thus the shadow banking sector grow in size.

Now, formulating (31) recursively yields the shadow banker's Bellman equation:

$$V_{w,t-1} = E_{t-1} \Lambda_{t-1,t} \left[(1-\sigma) n_{w,t} + \sigma V_{w,t} \right]. \tag{33}$$

The shadow banker maximizes (33) by choosing $s_{w,t}$ subject to (30) and (32). We start by guessing that (33) is linear in assets $Q_t s_{w,t}$ and net worth $n_{w,t}$ which yields

$$V_{w,t} = \mu_{ws,t} Q_t s_{w,t} + \nu_{w,t} n_{w,t}, \tag{34}$$

where $\mu_{w,st}$ is the excess return of loans over interbank loans, and $\nu_{w,t}$ is the marginal value of net worth.

Defining the ratio of assets $Q_t s_{w,t}$ to net worth $n_{w,t}$ as the leverage ratio of the shadow banker $\phi_{w,t}$, we can combine (34) and (32) to obtain:

$$\phi_{w,t} = \frac{Q_t s_{w,t}}{n_{w,t}} = \frac{\nu_{w,t} - \theta_t(1-\omega)}{\theta_t \omega - \mu_{w,st}}. \tag{35}$$

By combining the guess (34), the Bellman equation (33), the incentive constraint (32),

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the leverage ratio $\phi_{w,t}$ and the evolution of net worth (30) of the shadow banker, we get

$$V_{w,t} = E_t \Omega_{w,t+1} \left[(R_{wk,t+1} - R_{b,t+1})Q_t s_{w,t} + R_{b,t+1} n_{w,t} \right], \tag{36}$$

where stochastic discount factor Ω_{wt+1} is given by

$$\Omega_{w,t+1} = \Lambda_{t,t+1} \left[1 - \sigma + \sigma\theta_{t+1}[\omega\phi_{w,t+1} + (1 - \omega)] \right].$$

To verify the initial guess, the coefficients of (34) have to satisfy

$$\mu_{ws,t} = E_t \Omega_{w,t+1}(R_{wk,t+1} - R_{b,t+1}) \tag{37a}$$
$$\nu_{w,t} = E_t \Omega_{w,t+1} R_{b,t+1}. \tag{37b}$$

3.6   Resource constraint and central bank policies

The aggregate resource constraint is given by

$$Y_t = C_t + \left[1 + f_i \left(\frac{I_\tau}{I_{\tau-1}} \right) \right] I_t + \frac{\iota}{2}(S_{r,t})^2 + \Gamma_t, \tag{38}$$

where Γ_t shows the resource costs of central bank intermediation. Since the central bank can perfectly commit to repay its debt to its creditors, it is able to intermediate funds without being balance-sheet constrained like banks. However, unconventional policies come at costs Γ_t. Without these costs, it would be beneficial for the central bank to always engage in credit markets. Instead, resource costs impose a burden on central bank intermediation and restrict it solely to intervention during crises. We assume that these costs arise due to the high administrative effort when intervening in the markets caused by, among other things, the central bank's limited information about favorable investment projects and its less efficient monitoring technology (see e.g. Gertler and Karadi, 2011). Thus,during normal times, unconventional policy leads to an inefficient public engagement in private financial markets since the costs of engagement are higher compared to retail banks. We follow Gertler et al. (2012) and Dedola et al. (2013) by assuming an increasing resource cost function:[4]

$$\Gamma_t = \tau_1 \left(\Psi_{S,t} Q_t S_t + M_t + \Psi_{B,t} B_t \right) + \tau_2 \left(\Psi_{S,t} Q_t S_t \right)^2 + \tau_2 \left(M_t \right)^2 + \tau_2 \left(\Psi_{B,t} B_t \right)^2. \tag{39}$$

---

[4]An convex function seems plausible for us. We try to incorporate different aspects of a higher central bank intermediation such as e.g. higher management and exit costs and potential risks of default of these intermediated assets.

Conventional monetary policy is characterized by a standard Taylor rule

$$i_t = \rho i_{t-1} + (1 - \rho) \left[i + \kappa_\pi \pi_t + \kappa_y (\log Y_t - \log Y) \right], \tag{40}$$

where i_t denotes the nominal interest rate, i the steady-state nominal interest rate and Y the steady-state level of output. The Fisher equation interrelates the nominal interest rate i_t to the real rate according to

$$i_t = R_{t+1} E_t \pi_{t+1}. \tag{41}$$

However, when letting the shocks hit the economy it will become obvious that during times of stress conventional monetary policy alone appears to be an inappropriate tool for stabilization. Both output and inflation experience severe drops and show high volatility. Accordingly, we assume that the central bank is allowed to conduct unconventional monetary policies to stabilize the economy. Our understanding of unconventional measures closely follows Gertler and Karadi (2011), Gertler and Kiyotaki (2011), Gertler et al. (2012), Dedola et al. (2013), Gertler and Karadi (2013) and Nuguer (2016). There, the central bank conducts unconventional measures whenever the economy is hit by a shock that puts downward pressure on the price of capital Q_t, inducing an increase in the return of capital and a rise in credit spreads. As such, a crisis situation is an event when credit spreads rise sharply above their steady-state values. To alleviate such downturns the central bank intervenes in credit markets and begins to take over a fraction of financial assets (loans) based on simple feedback rules.

Since central banks like the ECB or the Fed have a range of different unconventional measures and intervene in different markets we implement a set of different feedback rules available to the monetary authority. Especially, we assume that the central bank can *(a)*, directly intervene in the market for non-financial loans *(b)*, intervene in the funding market between retail and shadow banks, or *(c)*, provide loans directly to retail banks.

Direct intervention in the market for non-financial loans requires the central bank to directly purchase loans from non-financial firms which is comparable to recent attempts of the ECB to intervene in the sector for corporate bonds. The feedback rule takes the form

$$\Psi_{S,t} = \kappa_S [E_t(R_{rk,t+1} - R_{t+1}) - (R_{rk} - R)] \tag{42}$$

The central bank intermediates the fraction ψ_t^S of overall non-financial loans in response to movements in the difference between the spread on the return on non-financial loans and the risk-free rate, $R_{rk,t+1} - R_{t+1}$, and its steady-state value $R_{rk} - R$. The feedback parameter κ_S governs the strength of intervention. Through conducting this policy, the central banks aims at stabilizing the asset price Q and lowering credit spreads. As a

result, output and inflation should return to their steady-state values at a faster pace.

If the central bank engages in the funding market between retail and shadow banks, i.e. the market for interbank debt, it purchases interbank loans from retail banks. The feedback rule now responds to changes in the spread between the return on interbank loans and the risk-free rate, $R_{b,t+1} - R_{t+1}$, and its steady-state value $R_b - R$ and gets

$$\Psi_{B,t} = \kappa_B[E_t(R_{b,t+1} - R_{t+1}) - (R_b - R)], \tag{43}$$

where ψ_t^B is now the fraction of overall interbank debt B_t that is funded by the central bank. κ_B is the feedback parameter for this kind of intervention. The aim of this policy is to stabilize the drop in credit between intermediaries through acquiring a share of these credits.

As a third policy option and in line with Dedola et al. (2013), we implement a form of liquidity facility where the central bank provides loans directly to retail banks, following the feedback rule

$$\Psi_{M,t} = \kappa_M[E_t(R_{rk,t+1} - R_{t+1}) - (R_{rk} - R)], \tag{44}$$

where

$$\Psi_{M,t} = \frac{M_t}{Q_t S_t}$$

is the ratio of aggregate liquidity facilities to non-financial loans. Conducting this kind of policy implies that the central bank places loans directly on the balance sheet of retail banks and thereby mitigates potential losses that result from devaluations of the asset side. The main difference between the last two mentioned policies is their transmission mechanism. Whereas liquidity facilities are an additional source of funding and strengthen the balance sheet of retail banks and, accordingly, their overall lending activities, interventions in the funding market between intermediaries rather incentivize the retail bank to off-load interbank loans in order to protect the balance sheet from devaluations.

Resource costs and expenditures due to intervention policies are financed by lump sum taxes T_t and one-period riskless government bonds $(B_{g,t} = \Psi_{S,t}Q_tS_t + M_t + \Psi_{B,t}B_t)$ that are issued to households. The government pays the risk-free rate R_t for these bonds. We get the following budget constraint

$$\Gamma_t = T_t + (R_{g,t} - R_t)M_{t-1} + (R_{b,t} - R_t)\Psi_{B,t-1}B_{t-1} + (R_{rk,t} - R_t)\Psi_{S,t-1}Q_{t-1}S_{t-1}. \tag{45}$$

We implement three sources of disturbances into the model, among them a shock to the quality of capital ψ_t, and shocks to the diversion parameters θ_t and γ_t. The latter two shocks are specific to the financial sector and are supposed to replicate a change of

financial constraints. GKP use variations in these parameters to model changes in the size of the shadow banking sector. Thereby, they highlight the emergence of financial innovation that led to an increased availability of credit. In addition, MNA model such shocks to illustrate a breakdown of securitization activity, i.e. a collapse of the shadow banking sector.

3.7 Aggregation and equilibrium

Aggregate net worth is given by the sum of the net worth of existing (surviving) bankers who retain net worth according to (20) and net worth of the fraction of new, entering bankers. The latter receive startup funds $\xi_r[R_{rk,t}(Q_{t-1} + \iota S_{r,t-1}) S_{r,t-1} + R_{b,t}B_{r,t-1}]/(1 - \sigma)$ from their respective household. Accordingly, we express aggregate net worth as

$$
\begin{aligned}
N_{r,t} &= \left[\sigma \left(R_{rk,t} - R_t - (R_{rk,t} - R_{b,t}) b_{r,t-1}^*\right) + \xi_r \left(R_{rk,t} - (R_{rk,t} - R_{b,t}) b_{r,t-1}^*\right)\right] A_{t-1} \\
&\quad + \sigma R_t N_{r,t-1} - \sigma \left(R_{g,t} - R_t\right) M_{t-1},
\end{aligned} \tag{46}
$$

where the ratio of interbank loans to total assets $A_t = (Q_t + \iota S_{r,t}) S_{r,t} + B_{r,t}$ is given by $b_{r,t}^* = B_{r,t}/A_t$. Aggregate net worth of the shadow banking sector evolves according to

$$
N_{w,t} = \left[\sigma \left(R_{wk,t} - R_{b,t}\right) + \xi_w R_{wk,t}\right] Q_{t-1} S_{w,t-1} + \sigma R_{b,t} N_{w,t-1}, \tag{47}
$$

where new bankers receive startup funds $\xi_w R_{wk,t} Q_{t-1} S_{w,t-1}/(1 - \sigma)$.

The model is closed with the market clearing conditions for non-financial loans and for interbank debt. The non-financial loan markets clear when total loan demand from non-financial firms equals total supply of loans from retail banks and shadow banks, following the equation

$$
(1 - \Psi_{S,t})S_t = S_{r,t} + S_{w,t}, \tag{48}
$$

where $\Psi_{S,t}S_t$ is the fraction of non-financial loans intermediated by the central bank in case of intervention by the same. The market for interbank debt clears when total demand from shadow banks equals total supply from retail banks

$$
(1 - \Psi_{B,t})B_{w,t} = B_{r,t}, \tag{49}
$$

where $\Psi_{B,t}B_{w,t}$ describes the intervention by the central bank in the interbank market.

4   Model Analysis

4.1   Calibration and welfare measure

Table 1 lists the values for our parameters that we use when simulating the model. The time interval of the model is a quarter. The conventional parameter choices for households (e.g. discount factor of $\beta = 0.99$ which implies a steady-state risk-free rate of roughly 4.1% per annum, habit parameter of $h = 0.815$, utility weight of labor of $\chi = 2.585$ to ensure $L = 1/3$, inverse Frisch elasticity of labor supply $\varphi = 0.276$), intermediate goods firms, capital producers and retailers are standard values and in accordance with, e.g., Gertler and Karadi (2011).

The remaining parameters describe the setup of the financial sector and the central bank. Here, we chose parameter values similar to MNA in order to reproduce the following values for the steady-state. The surviving rates of retail and shadow bankers σ generate a dividend payout rate of 10%. The annual spread between non-financial loans and deposits, $R_{rk} - R$, as well as the relevant spread for shadow bankers, $R_{wk} - R_b$, are set to 100 basis points. Regarding the annual spread between the interbank loan rate and the deposit rate, MNA point out that comparable ABS spreads lie within a relevant range of 0-70 basis point. Thus, $R_b - R$ is chosen to equal 50 basis points. Following MNA, the leverage ratios are set to $(S_r + B)/N_r = 5.2$ and $\phi_w = 8$ in order to replicate the extraordinary high degree of leverage within the shadow banking sector. However, a ratio of 8 is a rather conservative value for entities in the shadow banking system (see MNA and GKP). Furthermore, in our benchmark scenario, we target a size of the shadow banking sector to 25%, i.e. $S_w/K = 0.25$. This entails a ratio of interbank loans to non-financial loans (B/S_r) of 0.3 and the ratio of retail bank non-financial loans to net worth (S_r/N_r) of 4, which is roughly identical to the median ratio of commercial banks' loans to the sum of Tier 1 and 2 capital as fixed in the Basel regulation (MNA).

In our benchmark calibration, we follow Dedola et al. (2013) and set the resource costs of government intermediation to $\tau_1 = 0.00001$ and $\tau_2 = 0.0001$. In accordance with, for instance, Gertler and Karadi (2011), Gertler et al. (2012) and Nuguer (2016), the credit policy rule parameter κ_S is set to 100, describing an "aggressive" credit policy. To guarantee comparability among policies, the parameters for interbank policies and liquidity facilities, κ_B, and κ_M respectively, are set such that the amount of government purchases relative to output, $B_{g,t}/Y_t$ is the same on impact. For the liquidity provision, we choose $\lambda = \gamma$ which leads to $R_g - R = R_b - R$ and allows for comparability between interbank loans and liquidity facilities.

The three shocks $(\psi_t, \theta_t, \gamma_t)$ follow AR(1) processes with autoregressive factors of $(0.66, 0.8, 0.8)$ and the disturbances are a 1% decline in ψ_t, a 10 percent increase in

Households			
β	0.99	Discount factor	
h	0.815	Habit parameter	
χ	2.585	Relative utility weight of labor	
φ	0.276	Inverse Frisch elasticity of labor supply	
Intermediate goods producers			
α	0.33	Capital share in production	
δ	0.025	Depreciation rate	
Capital producers			
η_i	1.728	Elasticity of investment	
Retailers			
ε	4.167	Elasticity of substitution between goods	
ζ	0.779	Calvo parameter	
ζ_P	0.241	Measure of price indexation	
Financial intermediaries			
σ	0.90	Survival probability	
ι	0.0003	Management cost	
θ	0.2443	Divertable fraction of assets	
γ	0.50	Relative divertibility of retail banks' interbank loans	
ω	0.5935	Relative divertibility of shadow banks' interbank loans	
ξ_r	0.0153	Proportional startup transfer to new retail bankers	
ξ_w	0.0089	Proportional startup transfer to new shadow bankers	
Conventional monetary policy			
ρ	0	Smoothing parameter	
κ_π	1.5	Weight of inflation in Taylor rule	
κ_y	0.5/4	Weight of output gap in Taylor rule	

Table 1: Parametrization

θ_t and a 20 percent increase in γ_t.[5] These magnitudes guarantee roughly comparable welfare losses.

To account for the effect of variations in the size of the shadow banking sector, we run all three shocks in different versions of our model. We capture alterations in the size of shadow banking through the interbank agency friction parameter ω (see (32)). A lower (higher) ω increases (decreases) the attractiveness of interbank borrowing which leads to more (less) credit intermediation by shadow banks. The no S-banks scenario ($\omega = 0.6932$) is a reduced setup similar to Gertler and Karadi (2011), where only

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[5]The first two autoregressive factors are in line with Dedola et al. (2013) while the third is chosen for the sake of comparability.

Scenario	Y	C	L	K	S_r	N_r	B	S_w	N_w
no S-banks	0.820	0.688	0.332	5.125	5.125	1.050	0	0	0
25% S-banks	0.835	0.698	0.333	5.392	4.044	1.006	1.180	1.348	0.169
45% S-banks	0.854	0.709	0.335	5.708	3.145	0.982	2.266	2.563	0.298

Table 2: Steady states of selected variables in the three scenarios

one single financial intermediary, the retail bank, is active. The 25% S-banks scenario (benchmark case) matches the size of euro area shadow intermediation while the 45% S-banks scenario ($\omega = 0.5$) leads to an allocation that is rather comparable to findings for the US financial sector.

Table 2 summarizes the results for selected variables. Relaxing the shadow banks' incentive constraint let them operate with higher leverage ratios while retail banks also relax their incentive constraint by increasing interbank lending (see (22)). Since shadow banks have a cost advantage over retail banks (see (10)), a higher shadow banking sector leads to a more efficient financial intermediation and thus a more efficient steady state.

Welfare evaluations are conducted by using the second-order approximation approach of Schmitt-Grohé and Uribe (2004, 2007). To be more precise, we calculate the unconditional expected value of lifetime utility $E(\Phi_t)$ of the representative household, where the welfare criterion (see Faia and Monacelli, 2007) is measured by

$$\Phi_t = U(C_t - hC_{t-1}, L_t) + \beta E_t \Phi_{t+1}, \tag{50}$$

by taking a second-order approximation of the model and (50) about the steady state for each shock.[6]

Welfare gains from unconventional policy interventions are determined as consumption equivalents υ that make the representative household indifferent between the conventional policy (simple Taylor rule) case and the unconventional policy cases. Let $E(\Phi_t^*)$ be the welfare level that follows from an intervention policy. Then, υ satisfy

$$E\sum_{\tau=t}^{\infty}\beta^{\tau-t}U((1+\upsilon)\left(C_\tau - hC_{\tau-1}\right), L_\tau) = E(\Phi_t^*), \tag{51}$$

meaning that the no policy intervention $(E(\Phi_t))$, i.e. only conventional policy is in place,

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[6]Leaving the steady-state distortions uncorrected seems more plausible to us, although this could lead to situations where shocks improve welfare (see also Galí and Monacelli, 2016). However, this is not the case in our analysis. Furthermore, we calculate welfare gains from policy interventions compared to a simple Taylor rule instead of using steady-state welfare as a benchmark. Using conditional welfare as the criterion leads to virtually unchanged results (available upon request).

with consumption equivalents must be equal to $E(\Phi_t^*)$. Given the utility function (1), υ can be obtained from

$$\upsilon = \exp\left\{(1-\beta)\left(E(\Phi_t^*) - E(\Phi_t)\right)\right\} - 1. \tag{52}$$

4.2 Crises experiments

We now run crises experiments and analyze our model in the face of the three disturbances, a shock to the quality of capital ψ_t and two shocks specific to the financial sector that affect the financial constraints of intermediaries, namely θ_t and γ_t. To obtain the pure dynamics of the model, we turn off any unconventional policy measures. In section 4.3, we work out the transmission mechanisms and effects of different unconventional monetary policy measures.

Let us begin by analyzing the dynamics of a shock to the quality of capital. Figure 1 shows the impulse responses.[7]

The order of events in the no S-banks scenario is analogous to the crisis experiment of Gertler and Karadi (2011): the sudden and unexpected decline in the quality of already installed capital drives down asset values which deteriorates retail banks' net worth. Since banks are leverage-constrained, they start a fire sale of assets which depresses the price of capital Q_t. This induces an increase in credit spreads and a sharp cut in investment and output. As inflation drops, the central bank reacts with a reduction of the policy rate in order to stabilize inflation and output.

Increasing the size of shadow intermediation to 25% yields a more severe and persistent recession. While both intermediaries face a deterioration in net worth, the reduction in shadow banks' net worth is more severe since shadow banks' leverage multiple is higher than that of retail banks. The negative impact on the balance sheet of shadow banks is amplified by the fact that retail banks are now able to transfer losses into the shadow banking sector. The fire sale in the shadow banking sector induces retail banks to cut down interbank lending, $b_{r,t}^*$ decreases. Simultaneously, retail bankers are able to increase lending to non-financial firms since a higher $S_{r,t}$ increases their franchise value and relaxes their incentive constraint. As a result, their net worth recovers faster. However, they are less efficient in providing loans to non-financial firms and the increase in $S_{r,t}$ cannot compensate the reduction of $S_{w,t}$. The drop in overall intermediated credit is stronger and Q_t contracts more which leads to higher credit spreads as well as stronger and more protracted declines in investment and output. The effect on inflation is ambiguous: the initial drop is larger while π_t is more stable in the aftermath. An even higher credit intermediation via shadow banks (45% S-banks) puts

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[7]The impulse responses are computed as absolute deviations from the different steady states (see also Table 2). This approach guarantees better traceability of the results for the different scenarios.

more pronounced downward pressure on financial activity and amplifies the described effects.

Let our focus now turn to the shocks θ_t and γ_t within the financial sector that affect the agency problems of the intermediaries. While the former is a general loss of confidence in the banking system, the latter is an interbank shock and can be interpreted as a securitization crisis. Although our model does not directly account for the process of securitization, it replicates the core mechanisms of shadow banking. Accordingly, a γ_t-shock changes the collateral value of shadow bank loans held by retail banks. The impulse responses of the shocks are shown in the Figures 2 and 3.

Starting with the no S-banks scenario, the loss of confidence (θ_t-shock) affects the incentive constraint of retail bankers, the collateral value of assets shrinks. They start a deleveraging process by reducing loans and deposits to meet the leverage constraint. This drives down the asset price Q_t, credit spreads rise, investment and thus output decline. As output and inflation drop, the central bank lowers the policy rate in order to stabilize both targets.

In the economy with 25% shadow intermediation, both intermediaries face a reduction of the collateral value of their assets. Both start a deleveraging process which drives down the price of capital. However, since retail banks are aware of the incentive of shadow banks to divert assets, they reduce interbank lending which depresses the reduction in $S_{w,t}$ still further. Simultaneously, they expand their amount of non-financial loans which rises their franchise value and relaxes their incentive constraint. Again, the existence of shadow banks allows retail banks to transfer a share of the losses off their balance sheet into the shadow banking sector. However, the drop in overall credit is stronger, credit spreads are higher and output losses are larger and more persistent. Similar to the capital quality shock, we obtain an ambiguous effect on inflation. As in the experiment before, increasing the size of shadow banking to 45% of intermediated credit yields comparable dynamics of the core variables though showing larger and more prolonged swings.

Suppose now a decline in the collateral value of shadow bank loans held by retail banks in the 25% S-banks scenario. The effects of this rise in γ_t are similar to the θ_t-shock. Retail banks are forced to restructure their balance sheet by reducing lending to shadow banks while increasing the amount of non-financial loans. Since shadow banks are dependent on funds from retail banks, they have to deleverage and scale down their lending activity to the non-financial sector, $S_{w,t}$ shrinks and so does $N_{w,t}$. In the aggregate, overall intermediated credit and Q_t drop, credit spreads rise whereas investment, output and inflation fall. In the 45% S-banks scenario, retail banks hold a greater amount of interbank loans. As the agency friction worsens, retail banks reduce lending to shadow banks more strongly, $b_{r,t}^*$ drops more. This amplifies the described effects which leads to larger and more protracted swings in the core variables.

The main results are summarized in

Proposition 1 *Turn off any unconventional policy. a) Suppose a negative shock to the quality of capital. The higher the credit intermediation via shadow banks, the stronger the decline in the price of capital, the higher the rise in credit spreads and the more severe and prolonged the drop in overall credit and output. The effect on inflation is ambiguous. b) The same holds true in the case of a loss of confidence in the banking system. c) Suppose a negative interbank shock. The higher the credit intermediation via shadow banks, the stronger the decline in the price of capital, the higher the rise in credit spreads and the more severe and prolonged the drop in overall credit, output and inflation.*

4.3   Implications of unconventional monetary policy

As the former section showed, following the described shocks, a simple Taylor rule is not able to stabilize the business cycle. This raises the question of whether an optimal conventional policy would be more effective in stabilizing the economy or is there a need for unconventional policy interventions. To answer this, we run the model with an optimized Taylor rule and compare the welfare gains measured by (52) with the gains by following the simple unconventional feedback rules (42), (43) and (44) outlined in section 3.6. We allow for interest rate smoothing and solve for the welfare-maximizing parameters by applying grid search as in Bergin et al. (2007).[8] Table 3 shows the welfare gains of the policies compared to the simple Taylor rule case. A simple and shock-invariant policy of direct intervention in the market for non-financial loans (S-Policy) outweighs a Taylor rule that is optimized for every single shock. In the case of an interbank shock, the optimal conventional policy fails compared to the simple unconventional policies. For shocks in ψ_t and θ_t, the optimal Taylor rule outperforms simple liquidity facilities (M-Policy) and partially simple interbank credit policy (B-Policy). However, these benefits diminish or are completely offset as the shadow banking sector grows. To sum up, unconventional policies can lead to significant welfare improvements.

Again, we begin by analyzing the dynamics of a shock to the quality of capital. Figure 4 shows the impulse responses. The most striking result is that direct asset purchases (S-Policy) are the superior policy option given the chosen parameter values for the resource costs (τ_1, τ_2) and feedback parameters $(\kappa_S, \kappa_B, \kappa_M)$ of central bank intervention. The superiority of direct asset purchases stems from the point of intervention of that policy. By starting to purchase non-financial loans (financial assets), i.e. acquire

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[8]We arranged the following grid: the interest rate smoothing parameter ranged from 0 to 1 with a step size of 0.05 while the parameters for inflation and output vary between 0 and 5 with a step size of 0.125.

| | 25% S-banks | | | 45% S-banks | | |
Policy	ψ_t	θ_t	γ_t	ψ_t	θ_t	γ_t
Optimal Taylor rule	0.905	0.437	0.121	1.144	0.592	0.255
Simple S-Policy	1.150	1.737	1.536	1.783	2.495	2.712
Simple B-Policy	0.644	0.559	0.845	1.077	1.116	1.466
Simple M-Policy	0.448	0.248	0.770	0.856	0.788	1.335

Table 3: Welfare gains of different policies compared to a simple Taylor rule in percentage terms

a share of overall intermediated credit, the central bank is able to directly impact on the asset price Q_t. Since the considered capital quality shock induces a drop in Q_t, direct purchases intervene at the very source of economic disturbances. In contrast, interbank interventions (B-Policy) and liquidity facilities (M-Policy) mainly operate through the impact on the balance sheet of retail banks and change their financing conditions. We will elaborate on their stabilization effects and transmission mechanism later on.

The S-Policy lowers the drop in Q_t what in turn stabilizes credit spreads and moderates the downturn in the shadow banking sector, intermediation by shadow banks decreases but less compared to the other scenarios. The resulting effect on investment and output is cushioned, both drop less. Note that direct purchases of assets lead to a side effect. Since non-financial credit intermediated by the central bank amounts to roughly 5% on impact and tapers off very slowly over time, retail banks experience a crowding out of their lending activity to non-financial firms, $S_{r,t}$ drops. The lower intermediation by retail banks is amplified by the effect of lower credit spreads on their evolution of net worth $N_{r,t}$. Since the rebuilding of net worth takes longer, the incentive constraint of retail banker tightens for several periods and forces them to intermediate lower amounts of $S_{r,t}$.

Liquidity facilities (M-Policy) and interbank interventions (B-Policy) show less efficiency in stabilizing the economy compared to the S-Policy scenario. The initial drop in Q_t is only halved while credit spreads widen more. Accordingly, the decline in output is less moderated. Regarding the balance sheet items (except for $b_{r,t}^*$), both policies deliver comparable initial effects. This results from the assumption of $\lambda = \gamma$. By combining (25a) and (25b), we find that $R_g - R = R_b - R$, making both options equally effective for relaxations of retail bankers' incentive constraint. Initially, the banker is indifferent between holding another unit of liquidity facility m_t and paying the excess cost $R_{g,t} - R_t$ or, alternatively, reducing interbank funding $b_{r,t}$ by one unit and giving up the excess return $R_{b,t} - R_t$. The first-round effect is the same: retail bankers increase $S_{r,t}$ in order to raise the franchise value. However, the slightly different transmission channels lead to diverging output effects.

Due to their binding incentive constraint, shadow banks cannot use the interbank lending policy to expand their balance sheet. They primarily benefit from a more stable Q_t. Since retail banks can only use these additional funds to drive down $b^*_{r,t}$ which is now intermediated by the central bank, $\Psi_{B,t}$ massively increases. Although $S_{r,t}$ initially increases, it drops in the aftermath. The decline in overall credit is longer lasting which explains the output response. The drop is initially moderated, and the maximum decline hits the economy at a later date. Thus, the recession is postponed. Concerning the welfare gains of this policy (see Table 3), they are mainly driven by lower labor supply (not shown).

In contrast, liquidity facilities are an additional source of funding for retail banks, they stabilize the balance sheet and mitigate the cut-off from interbank loans. Retail banks increase $S_{r,t,}$ and due to the higher credit spreads their net worth recovers faster. Shadow banks benefit from the more stable Q_t and $b^*_{r,t}$. Compared to the conventional policy case, the drop in overall intermediated credit as well as output are lower.

In the first instance, it seems that the M-Policy delivers the lowest stabilization effects. However, since the findings for liquidity facilities are sensitive to the parametrization of λ, we now run two alternative scenarios which are shown in Figure 5. By increasing λ to $\lambda = 0.8$, every additional unit of liquidity provision induces a stronger relaxation of the incentive constraint. Initially, the retail banker increases $S_{r,t}$ and reduces his position of $b^*_{r,t}$ in order to increase $V_{r,t}$. However, the effect of λ on the incentive constraint makes this restructuring now less urgent and the retail banker simultaneously starts to drive down the holdings of $S_{r,t}$ and begins to rebuild $b^*_{r,t}$ faster. This effect moderates the fire sale of assets in the shadow banking sector, benefiting shadow banks by rebuilding $S_{w,t}$ at a faster pace. Overall credit is higher, Q_t is more protected and the recovery of output is faster while showing less volatility.

If we lower λ, e.g. $\lambda = 0.2$, the formerly explained relaxation of the incentive constraint diminishes and so does the stabilizing impact of liquidity provision on the balance sheet of retail bankers. The effect on output is straightforward: the drop is stronger and more protracted.

Let us now turn our focus on the shocks θ_t and γ_t. Since both shocks affect the incentive constraint of retail banks in a very similar vein, the ensuing reactions of intermediaries as well as the effects of unconventional policy measures are equivalent. The impulse responses are shown in Figure 6 and Figure 7.

Similar to the capital quality shock, direct asset purchases (S-Policy) are the superior policy option as they deliver the highest degree of stabilization. However, retail bankers, normally substituting $b_{r,t}$ with $S_{r,t}$ to relax the incentive constraint, are again faced with the aforementioned crowding out effect which implies a long-lasting credit intermediation by the central bank.

Again, the interbank lending policy drives down $b^*_{r,t}$ while $\Psi_{B,t}$ massively increases.

The initial drop in overall credit is moderated, whereas the decline is prolonged which results in a postponed output response. While inflation is benign, the welfare gain comes from lower labor supply.

In contrast, the different transmission channel of liquidity facilities is obvious. As an additional source of funding, they stabilize the balance sheet of retail banks, the reduction in $b_{r,t}^*$ is less severe. Shadow banks benefit from the more stable Q_t and $b_{r,t}^*$. The drop in output is lower, but still stronger than in the S-Policy case. As before, we find that variations in λ induce changes to the efficiency of liquidity facilities. The higher the value for λ, the higher the stabilizing effect for the balance sheet of retail banks. They rebuild $b_{r,t}^*$ faster, helping shadow banks to rebuild $S_{w,t}$ faster. Both output and inflation decrease less and show more stable recoveries.

We can summarize

Proposition 2 *Suppose negative shocks to the quality of capital, the confidence in the banking system or the collateral value of interbank assets. a) All three unconventional policy measures outperform the standard Taylor rule. b) In terms of output and inflation stabilization, direct asset purchases outperform liquidity facilities, while liquidity facilities outperform interbank interventions. The effectiveness of direct asset purchases stems from the fact that the decline in the price of capital can be almost offset, credit spreads are the lowest, the drop in output is less severe and inflation is substantially stabilized. c) Purchases of interbank loans have an on-impact stabilizing effect. However, they lead to postponed declines in overall credit and output. d) The effectiveness of liquidity facilities is sensitive to λ. The higher λ, the stronger the stabilization effect on the price of capital, credit spreads, output and inflation.*

Next, we consider variations in the size of the shadow banking sector. Table 4 shows standard deviations of core variables under all three unconventional policies relative to the standard deviations in the conventional policy case. For instance, a value of 0.886 means that the S-Policy leads to a standard deviation of output that is 11% lower than under the conventional monetary policy.

The most striking result is that the output-stabilization effect of all unconventional policies is increasing in the share of credit intermediation by shadow banks. As shown in the previous sections, a higher shadow banking sector leads to more efficient but also more vulnerable financial intermediation due to the stronger financial accelerator effect of the binding leverage constraints. Hence, policies aimed at and able to stabilize this intermediation process are more effective the higher the credit intermediation via shadow banks.

In terms of output and inflation stabilization, direct asset purchases are the most effective measure while liquidity facilities outperform interbank interventions. Again,

	5% S-banks			25% S-banks			45% S-banks		
	S-Pol	B-Pol	M-Pol	S-Pol	B-Pol	M-Pol	S-Pol	B-Pol	M-Pol
ψ_t-shock									
Y	0.886	1.093	0.981	0.831	1.008	0.934	0.785	0.953	0.901
π	0.728	0.976	0.954	0.740	1.022	0.975	0.688	1.041	0.966
K	0.944	1.049	0.992	0.894	0.995	0.957	0.857	0.958	0.931
Q	0.299	0.637	0.667	0.317	0.649	0.673	0.322	0.657	0.673
θ_t-shock									
Y	0.558	1.012	0.801	0.483	0.861	0.730	0.412	0.770	0.686
π	0.467	1.223	0.925	0.521	1.308	0.974	0.471	1.186	0.911
K	0.756	1.001	0.756	0.484	0.721	0.658	0.405	0.656	0.630
Q	0.061	0.534	0.559	0.067	0.541	0.559	0.072	0.548	0.559
γ_t-shock									
Y	0.724	0.940	0.845	0.455	0.832	0.715	0.308	0.734	0.641
π	0.526	1.131	0.933	0.504	1.255	0.958	0.415	1.187	0.905
K	0.799	0.930	0.858	0.454	0.702	0.643	0.278	0.577	0.550
Q	0.063	0.524	0.558	0.062	0.536	0.556	0.058	0.541	0.553

Table 4: Standard deviation of selected variables relative to the standard deviation in the conventional policy case

it can be seen that the S-Policy primarily works through stabilizing Q_t. However, for shocks in ψ_t and θ_t, it seems that the B-Policy is only useful when we pass a certain threshold of shadow banking sector size. Below that threshold, interbank interventions lead to more output volatility. Furthermore, it seems that the B-Policy leads to generally higher inflation volatility independent of the size of the shadow banking sector.

Proposition 3 *Suppose negative shocks to the quality of capital, the confidence in the banking system or the collateral value of interbank assets. a) The higher the credit intermediation via shadow banks, the more effective are the three unconventional policy measures in terms of output stabilization. The effect on inflation is ambiguous. b) The usefulness of interbank interventions is sensitive to the kind of shock and the size of the shadow banking sector.*

4.4   Optimal policy and welfare implications

In this subsection, we compute the optimal policy responses and calculate the maximum welfare gains from unconventional policies depending on different resource costs

parametrizations. Since we cannot rely on actual data for the efficiency costs parametrization (τ_1, τ_2), we follow Dedola et al. (2013) and Gertler et al. (2012) and choose reasonable values of purchasing high grade securities (e.g. mortgage backed securities). Thus, we conduct our analysis of the welfare effects for a range of values for τ_2 from 0 to 0.0012 while $\tau_1 = 0.1\tau_2$.

In order to calculate welfare, we take a second-order approximation of the model and (50) about the steady state for each shock given the feedback parameter of each unconventional policy rule. Then, we search for the optimal values of $\kappa_S, \kappa_B, \kappa_M$ that maximize $E(\Phi_t)$. Finally, we determine the welfare benefits of unconventional policy in the form of consumption equivalents υ (see (52)). Figure 8 shows the welfare gains under each policy for different scenarios and different values of τ_2.

Let us start with some general results.[9] Independently of the kind of shock, the relative efficiency of direct asset purchases compared to the other policies is increasing in the resource costs of implementing unconventional policies. Comparing the panels of the top three rows, we can conclude that the higher λ, the higher are the welfare gains of liquidity facilities. The panels in the top and bottom rows show that the advantage of the S-Policy and M-Policy compared to the interbank intervention increases as the size of the shadow banking sector grows.

Focusing on the ψ_t-shock, we see that, except for small values of τ_2 and a high value of λ, direct purchases of non-financial loans are the superior unconventional policy. For low resource costs, it seems that interbank-loan purchases have an advantage over the other policies. However, this advantage vanishes as λ or credit intermediation via shadow banks increases. Here, liquidity facilities almost completely outperform interbank interventions.

As regards a shock in θ_t, irrespective of shadow banking sector size and resource costs parametrization, the S-Policy outperforms the M-Policy while liquidity facilities outperform the B-Policy. In the case of a higher λ, liquidity facilities could be more welfare-improving than direct purchases of non-financial loans.

In the case of a γ_t-shock, interbank interventions outperform liquidity facilities except for higher τ_2, while the M-Policy outperforms the S-Policy. However, the advantage of the B-Policy over liquidity facilities diminishes as λ increases while it is completely offset when the size of the shadow banking sector is larger. Here, the M-Policy is superior, whereas direct non-financial asset purchases are the second-best option.

To sum up, there is no one-size-fits-all solution. Furthermore, all unconventional policies are implemented under equal resource costs. As this is a completely unsolved empirical issue, we could relax this assumption and suggest that the S-Policy might lead to the highest resource costs due to the difficulty of managing non-financial loans

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[9]Note that the advantage of a policy in the case of zero resource cost is pointless and can be ignored.

	Determ.	Conv. Policy		S-Policy		B-Policy		M-Policy	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
				ψ_t-shock					
C	0.698	0.684	0.048	0.693	0.042	0.694	0.051	0.695	0.038
L	0.333	0.331	0.019	0.332	0.013	0.333	0.005	0.334	0.021
				θ_t-shock					
C	0.698	0.683	0.014	0.700	0.004	0.697	0.018	0.699	0.002
L	0.333	0.332	0.020	0.334	0.004	0.334	0.016	0.334	0.001
				γ_t-shock					
C	0.698	0.684	0.003	0.697	0.001	0.698	0.007	0.697	< 0.001
L	0.333	0.332	0.004	0.333	0.001	0.333	0.004	0.333	< 0.001

Table 5: Deterministic and stochastic steady states under different policies in the benchmark calibration

by the central bank. As described above, mutual interbank lending largely destroys idiosyncratic risks of non-financial loans, thereby being a safer asset and more pledgeable. Thus, the resource costs of managing these assets should be at least lower than in the S-Policy case. However, the financial crisis has shown that this may not always be the case. Regarding the M-Policy, Gertler and Kiyotaki (2011) stress that there might be capacity constraints on the ability of the central bank to monitor the retail banks' activities. However, we can suggest that the resource cost would be relatively low due to the possibility to use the penalty rate $R_{g,t}$ (via λ) as "control tool". Under these suggestions, it seems that liquidity provisions might be the superior solution as a higher penalty rate combined with low resource costs make it the most effective policy option.[10]

If we consider the circumstances for the Fed and ECB, we could assume that the resource costs of unconventional policies are higher for the ECB since the currency union is more heterogenous than the US. Thus, for the Fed which means 45% S-banks and low τ_2, liquidity facilities are superior at least for shocks in ψ_t and γ_t, but also in the case of a loss of confidence in the banking system by increasing $R_{g,t}$ (via λ).[11] Direct asset purchases seem to be also highly appropriate. For the ECB which means 25% S-banks and higher values of τ_2, we get the same result: liquidity facilities with a high penalty rate are the first-best solution.

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[10]See the second and bottom rows in Figure 8.

[11]For the Fed case, see the bottom row in Figure 8. By increasing λ, the M-Policy line would shift upward making it the superior policy. For the ECB case, see the panels in the second row. In the case of a γ_t-shock, a further increase in λ would make the M-Policy outperforming the B-Policy even for midsize values of τ_2.

Nevertheless at first glance, it seems that, at least in the benchmark case, the B-Policy leads to the highest welfare gains in the case of a γ_t-shock and also for low resource costs in the ψ_t-shock scenario. How can this outcome, which is contradictory to our previous findings, be explained? Table 5 gives a first clue. It shows the means and standard deviations of consumption and labor for all policy scenarios in the benchmark calibration. The welfare gain of the interbank lending policy mainly stems from the first-order effect of a shift in the means due to uncertainty. Concerning the second-order welfare component, the B-Policy leads to an even higher consumption variance. However, given our utility function (1) which is logarithmic in consumption, the higher variance does not affect welfare in a second-order approximation. Adapting the utility function, i.e. the intertemporal elasticity of substitution differs from unity, would lead to an overwhelming advantage of the S-Policy as well as M-Policy. In addition, the alleged large welfare improvements of the B-Policy are also driven by the calculation of welfare gains as an indefinite flow. For this policy, the main part is received decades after the crisis. This computation is also criticized by Gertler and Karadi (2011). As every shock leads to a crisis that should be treated as a single event, they propose to only cumulate the benefits of the moderation of the crisis and not the benefits for years after the crisis. On the contrary, calculating welfare in this manner is not consistent with the model as there is no microfoundation for using only a short-time period to calculate welfare gains. However, this measure would also favor direct asset purchases and liquidity facilities.

Figure 9 illustrates this argument and points to another issue: the exit from unconventional monetary policy. The figure shows the ratio of central bank's expenditures due to unconventional policy relative to output for $\tau_2 = 0.0001$ and $\tau_2 = 0.001$ in the 25% and 45% S-banks scenarios. It can be seen that the B-Policy, which might be preferable for low values of τ_2 in the case of shocks in ψ_t and γ_t, leads to extreme prolonged positions. After ten years, the central bank is still engaged in the interbank loan market with expenditures in the amount of 40% and 10% of output. This is not a plausible crisis management. For a ψ_t-shock, the S-Policy leads to the lowest share of expenditures per GDP which tapers off more quickly compared to the other policies. However, for the financial sector shocks, this policy also results in permanent central bank intermediation. Here, liquidity facilities seem to be more appropriate. Although the central bank massively increases the amount of liquidity facilities in the crisis period, this intervention tapers off very quickly. Thus, for these shocks, not only being the most appropriate unconventional policy tool, liquidity provisions also imply an early exit, leading to the capability to fight the next crisis.

5 Conclusions

In this paper, we build a comprehensive DSGE-model featuring financial intermediation with shadow banking that enables use to evaluate different unconventional policy measures, their relative effectiveness and the optimal policy intervention. We endow the central bank with three different unconventional measures: direct purchases of assets, an intervention policy in the funding process between retail and shadow banks and liquidity facilities. We use these measures to analyze their effectiveness in stabilizing financial markets and the real economy. In a second step, we compute the optimal monetary policy responses to business cycle and financial sector shocks and calculate the maximum welfare gains from unconventional policies depending on different resource costs.

We can draw three major results from our analyses: first, regardless of the shock, unconventional policy measures stabilize the standard targets output and inflation and improve welfare. Hereby, direct asset purchases outperform liquidity provision, which outperform interbank interventions. Given the different points of intervention, this result is straightforward. If the central bank purchases assets and intervenes in the markets for these assets, it directly affects its price. As a consequence, credit spreads only deviate slightly, investment and output as well as inflation recover much faster. A higher shadow banking sector and the accompanied higher leverage induce a sharper recession but also makes unconventional monetary policy more effective. Second, the usefulness of interbank interventions is highly sensitive to the kind of shock and the size of the shadow banking sector. However, the central bank should be aware of the fact that this measure is only useful given certain circumstances and when the identification of the source of the shock is unproblematic. Third, our welfare analysis shows that liquidity provisions seem to be the most appropriate unconventional policy tool closely followed by direct asset purchases. However, that finding is conditional on several aspects, e.g. the financial structure of the economy, reasonable assumptions for the resource costs of interventions and a foreseeable exit. Resource costs may reflect the massive expansion of the balance sheet of the central bank and the accompanying problem of exiting from these positions, or the administrative efforts of intervention. However, comparing the structure of the markets the Fed and the ECB have to manage, it is obvious that these costs may differ between central banks and that there is no one-size-fits-all solution for optimal unconventional measures.

Although our analysis points to a tapering process that can be interpreted as an exit, we do not explicitly model an active exit from unconventional policies. Nevertheless, some questions are worth considering: what are the macroeconomic impacts of driving down large scale asset purchases, is there a mixture of conventional and unconventional policies to best deal with an exit, how could the Fed or the ECB downscale their balance

sheet positions? To answer these questions, our analysis could be extended by explicitly modelling exit strategies in the sense of Foerster (2015).

The recent financial crisis has not only spawned changes in the framework of monetary policy, it has also changed thinking about regulation and macroprudential oversight with several new measures being put into place. Macroprudential tools could be easily implemented into our framework along the lines of GKP. These are interesting issues for future research.

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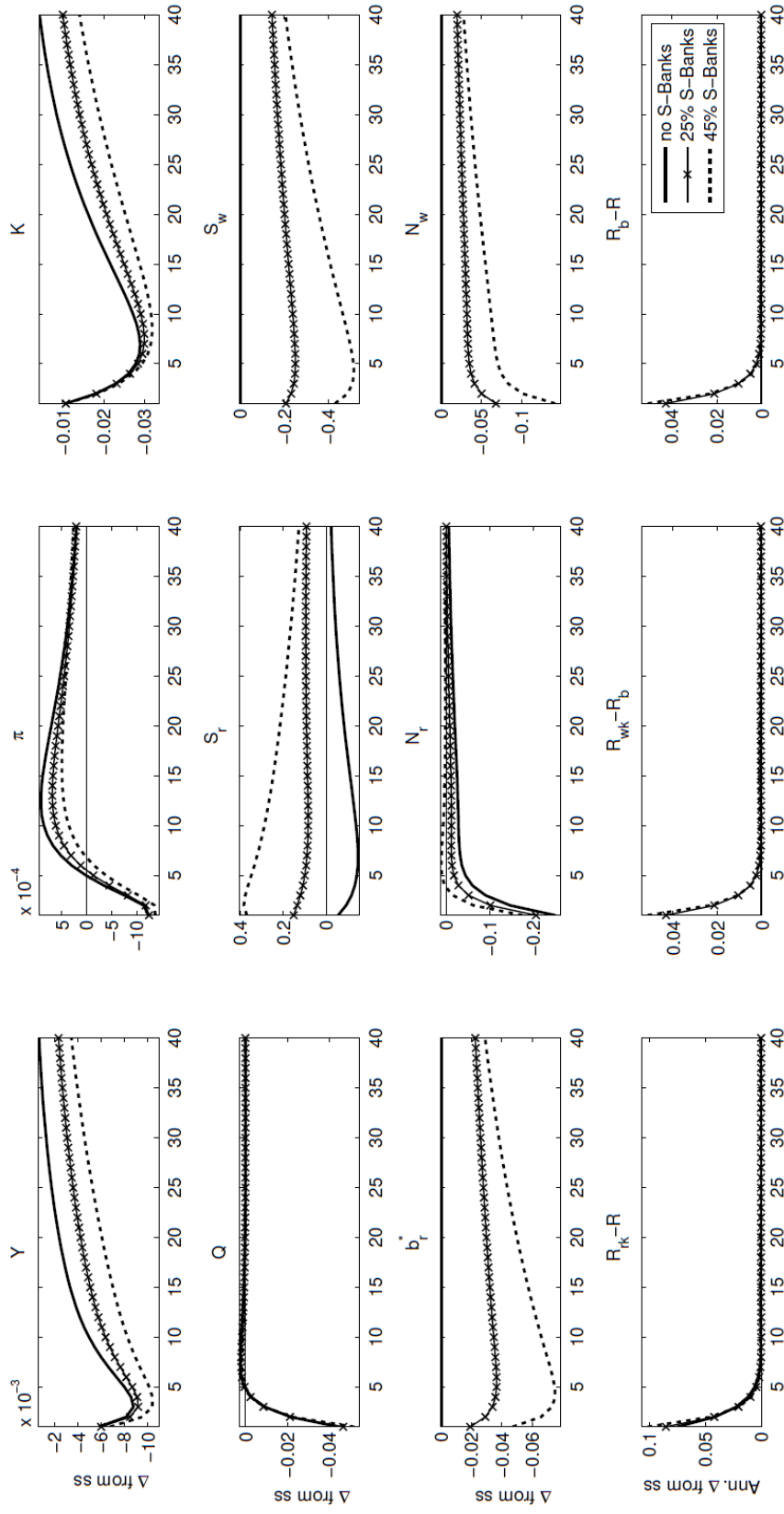
Figure 1: Impulse responses to a capital quality shock
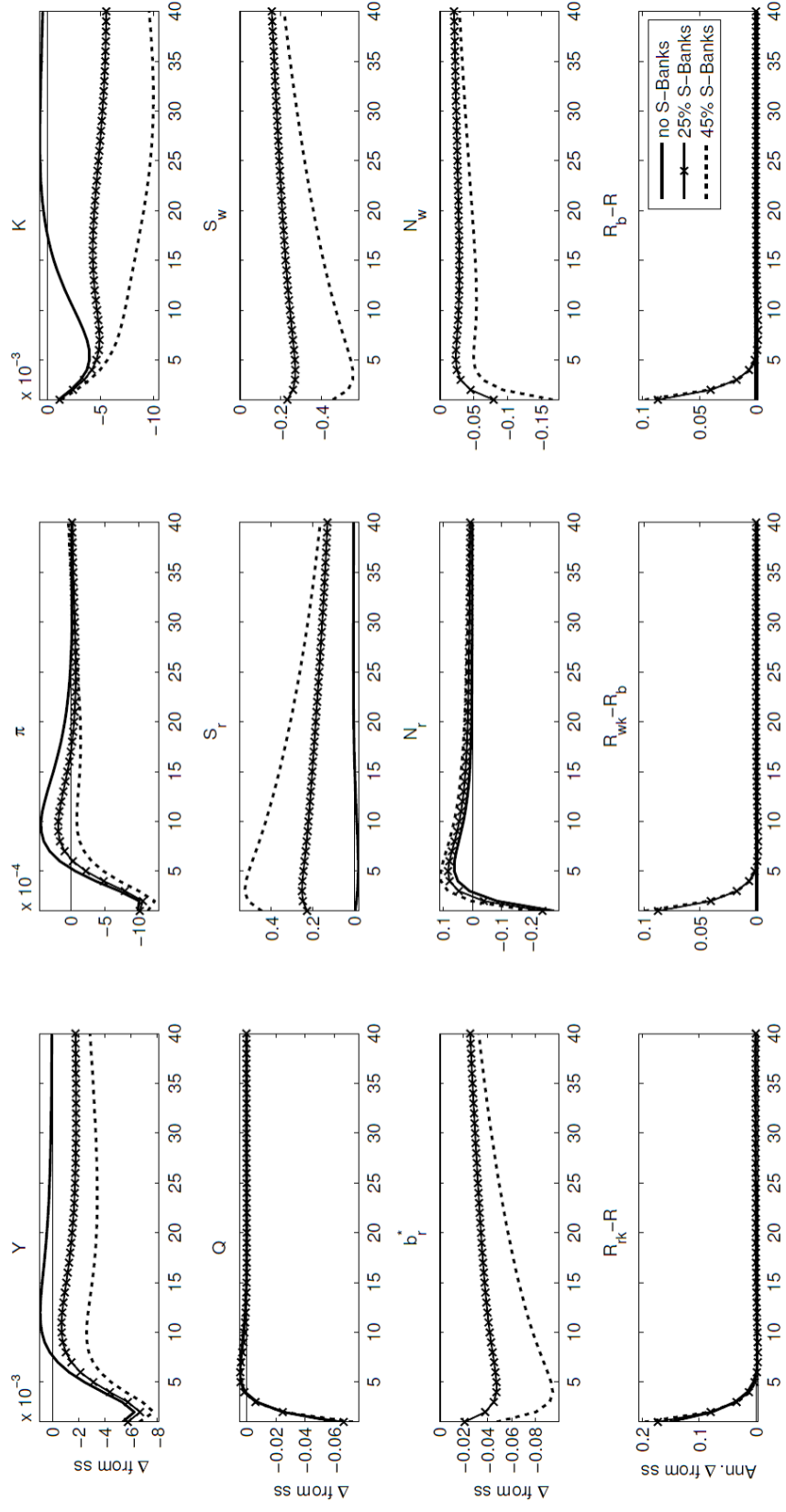
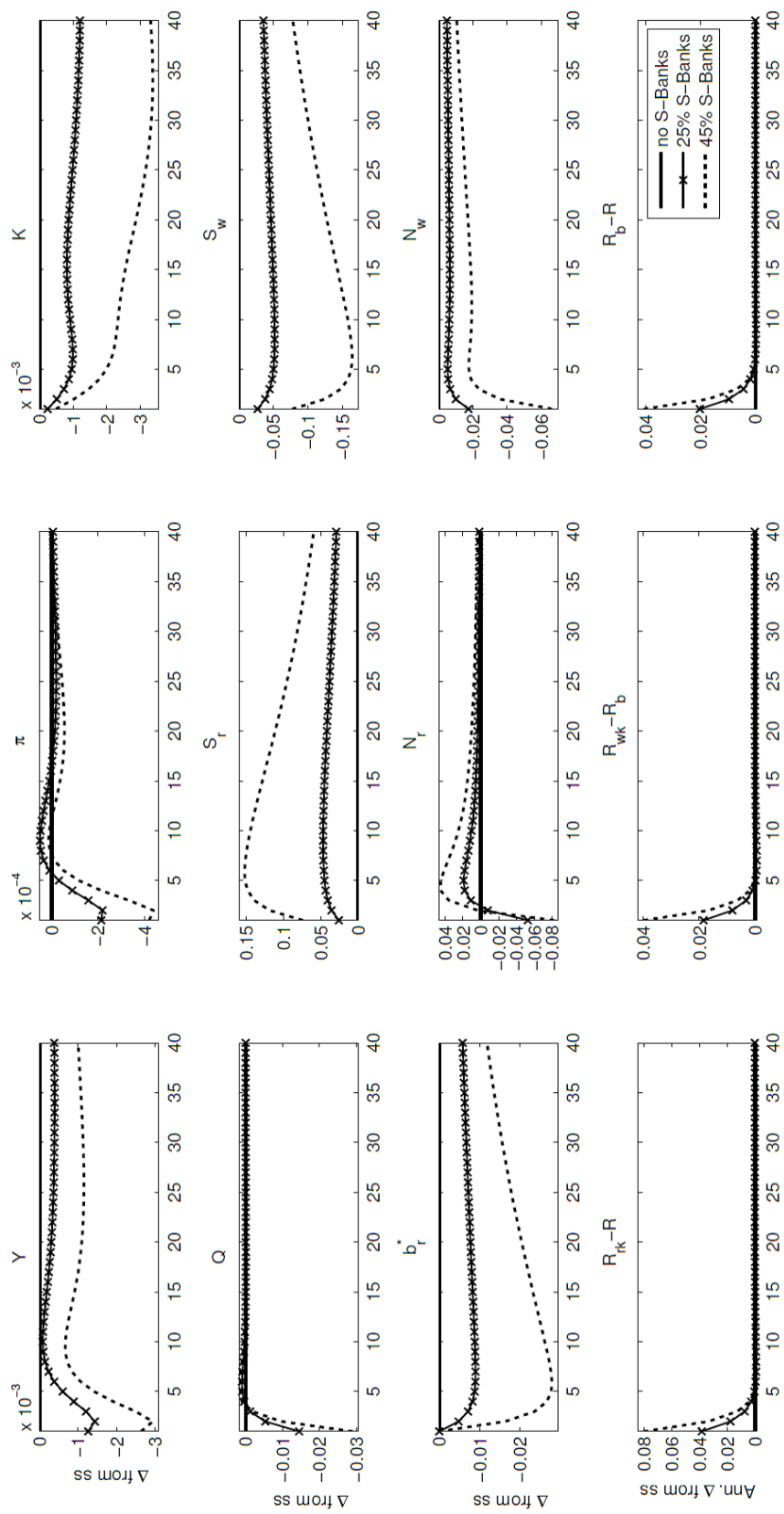Figure 2: Impulse responses to an overall financial shock

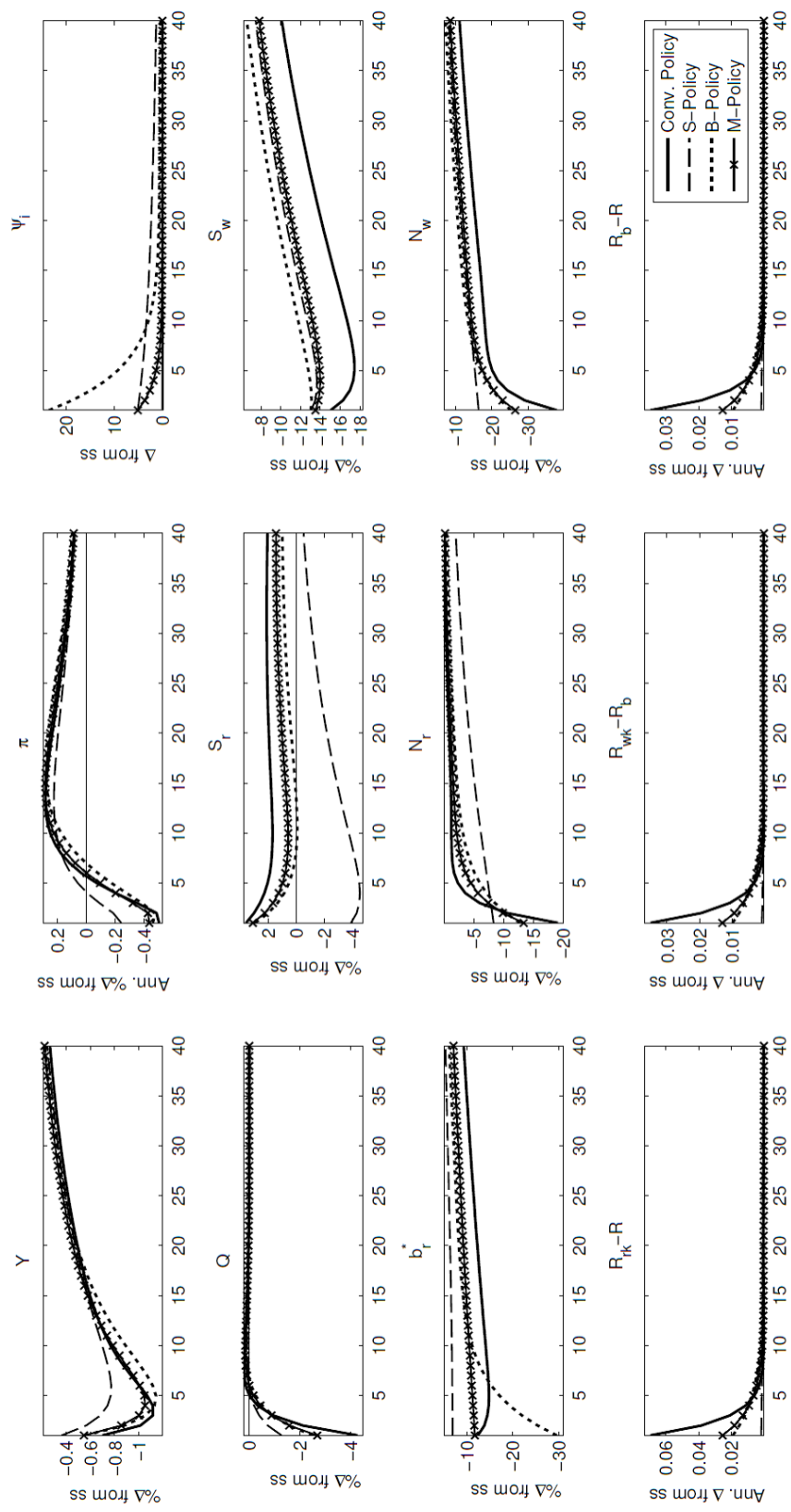Figure 3: Impulse responses to an interbank shock

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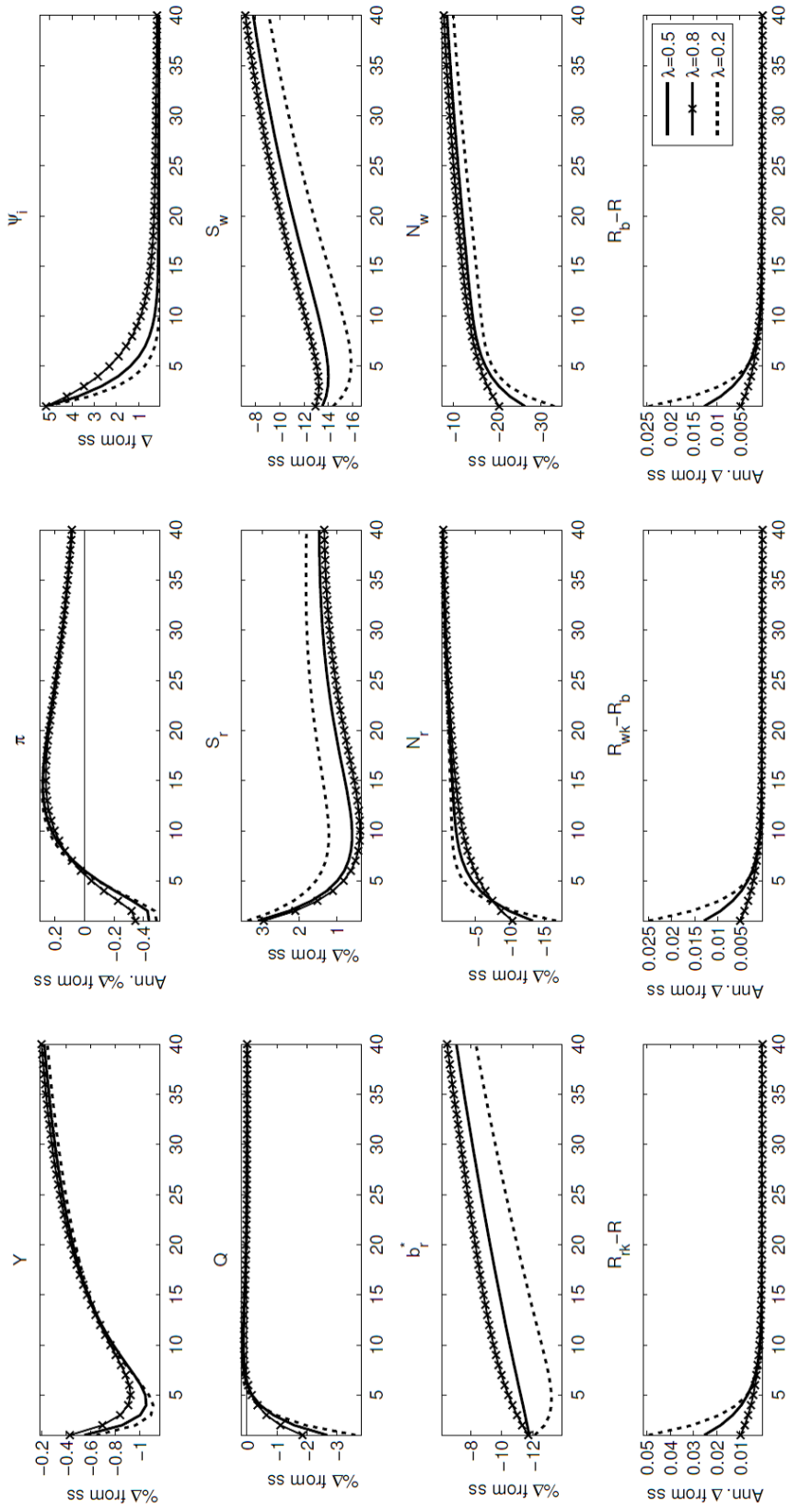Figure 4: Impulse responses to a shock to a capital quality shock with policy responses
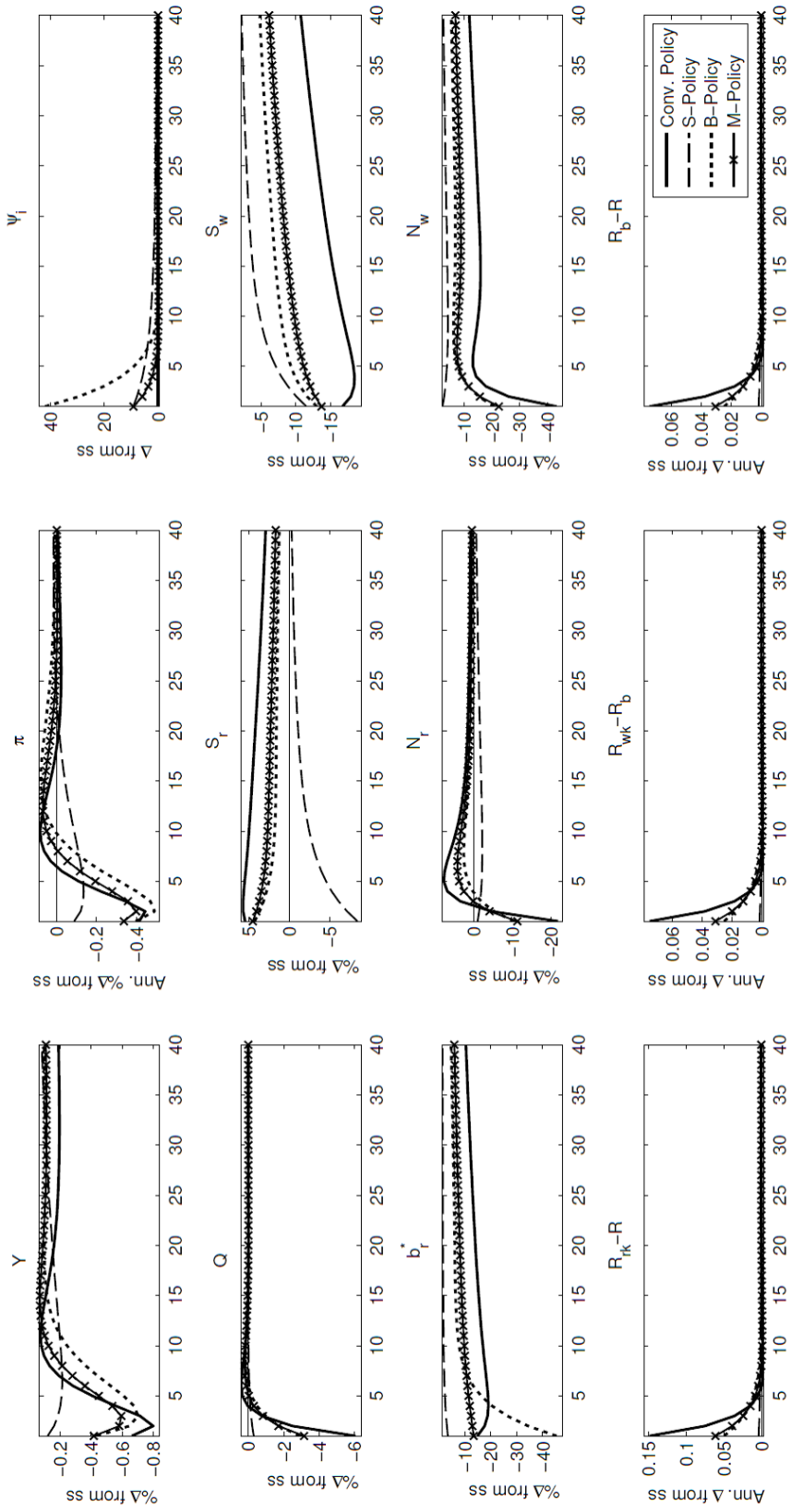
Figure 5: Impulse responses to variations in lambda

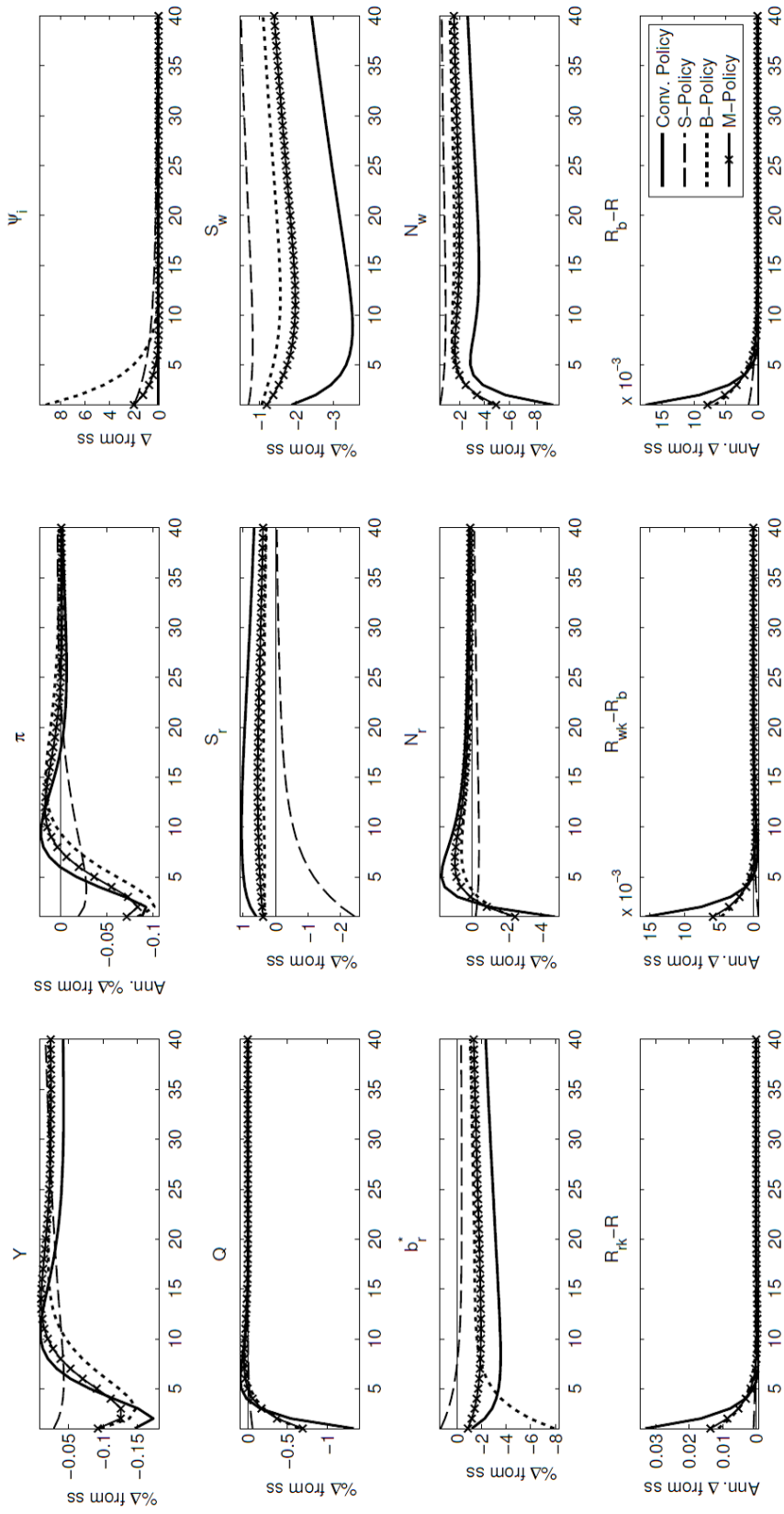Figure 6: Impulse responses to an overall financial shock with policy responses

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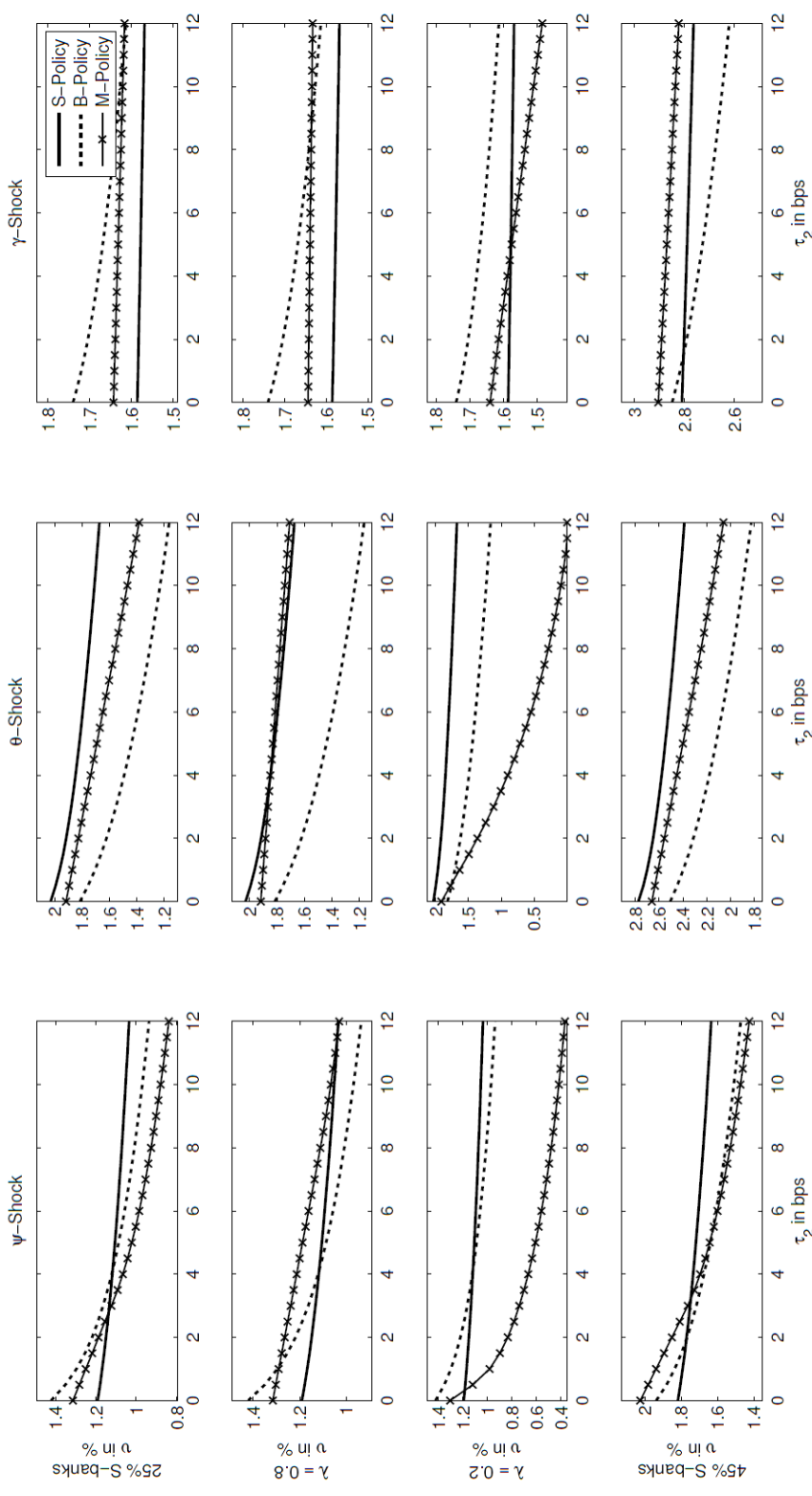Figure 7: Impulse responses to an interbank shock with policy responses

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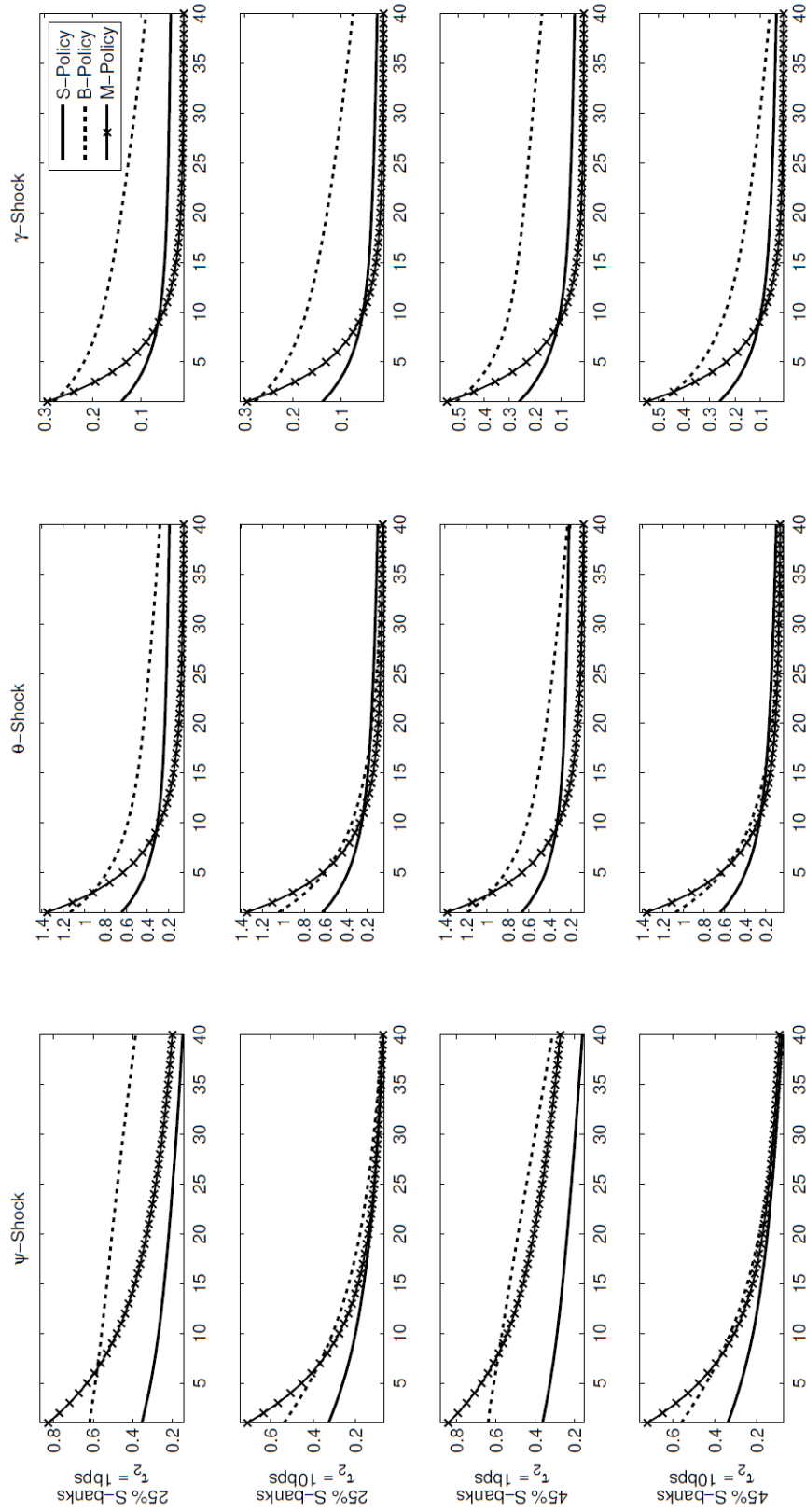Figure 8: Welfare gains from optimal unconventional policies

Figure 9: Expenditures for optimal unconventional policies in relation to output