Fiscal policy and the business cycle: the impact of government expenditures, public debt, and sovereign risk on macroeconomic fluctuations

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Chapter 4

Financial Stress, Government Policies, and the Consequences of Deficit Financing*

Abstract

We study the effects of deficit-financed government policies during a financial crisis based on a structural macroeconomic model with financial intermediation. Related studies that consider financial intermediation in a structural framework take for granted that the government does not rely upon intermediary financing. We set up a model where intermediaries not only channel funds from households to firms but also to the government. Accordingly, subject to balance sheet constraints, intermediaries use deposits to purchase government bonds and to provide loans to firms. Our framework thereby extends existing frameworks by allowing for different types of assets in intermediary portfolios. The latter has important consequences for the effectiveness of government policies. In particular, our results highlight a crowding out mechanism that has government borrowing tighten intermediary constraints such that a fiscal expansion can further raise credit spreads during a crisis, which can even further reduce economic activity.

4.1 Introduction

The fiscal response to the recent financial and economic crisis took the form of financial sector support measures and economic stimulus packages that were financed through budgetary deficits. What are the effects of such policies in a situation of financial

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stress such as the recent crisis? Standard macroeconomic models are not set up for policy analysis during crises, but new types of models have been developed that can be used to answer this question (see Gertler and Karadi, 2011; Gertler and Kiyotaki, 2010). However, these models take for granted that government policies are fully funded through markets that are not part of the relevant financial system. As we discuss below, this assumption seems unrealistic in view of the actual practice.

This chapter develops a structural macroeconomic model that integrates government deficit financing and financial intermediation with frictions in the intermediation process. These frictions imply a financial accelerator that is able to generate a deep financial crisis following a deterioration of intermediary balance sheets. We use this model to study the effects of deficit-financed policies during this type of crisis.

Our framework includes financial intermediaries that channel funds or deposits from households (the saving agents) to non-financial firms and the government (the borrowing agents). The intermediation process is subject to a similar agency problem between depositors and intermediaries as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). As those studies show, the latter leads to endogenous balance sheet constraints as key elements of a powerful financial accelerator mechanism. This accelerator mechanism generates dynamics which broadly reflect the relevant economic dynamics of a financial crisis. However, unlike the models in those studies, our framework allows for different classes of assets in intermediary portfolios instead of only one class.

The specific set-up is as follows. The intermediary asset portfolio consists of government bonds next to private claims from loans to non-financial firms. The portfolio size is tied to intermediary equity capital through endogenous leverage constraints, but the intermediaries can shift the composition of their portfolios towards assets with higher expected returns. Through this mechanism, the expected returns on bonds and private claims are jointly determined in equilibrium. Accordingly, when a new equilibrium arises in either the bond market or the market for private claims, everything else equal the expected return on bonds tends to deviate from the expected return on private claims. Individual intermediaries seek to exploit the differences in expected returns by altering the composition of their portfolios. In the general equilibrium, such arbitrage behavior by financial intermediaries leads to co-movements between different credit spreads relative to the rates at which intermediaries obtain funding.

We use this model to highlight the link between government policies and deficit financing in a situation of financial stress. In particular, we analyze the effects of demand (i.e. spending) stimulus and measures targeting the financial sector (i.e. transfers to intermediaries, zero interest loans, and loans at penalty rates). This set of policies is sufficient to explain the key implications of the model, but it also suitably captures the main fiscal policy measures that were applied during the recent crisis. The policies are financed by issuing bonds to intermediaries or by raising lump-sum taxes directly from households. The latter allows the government to circumvent the financial frictions and serves as a benchmark for our results.

Our findings suggest that intermediary financing has important consequences for the effectiveness of government policies. An early demand stimulus dampens the recession due to a financial crisis for some time (i.e. it reduces output losses). However, the stimulus tends to prolong the downturn later on. Moreover, the announcement of a stimulus has the potential to deepen the crisis until the stimulus is actually implemented. We also find that financial sector policies become less effective under intermediary financing. Some policies such as loans with relatively early repayment can also deepen the downturn. Temporary support can however bring initial stabilization gains if the cost to intermediaries is shifted towards later periods. Overall, these findings have implications beyond the predictions of previous studies that are apt to overturn conclusions on the effectiveness of deficit-financed government policies.

Key to understand our findings are the effects of government borrowing on intermediary balance sheet constraints and the associated adverse impacts on the cost of credit to non-financial firms. In our model, a fiscal expansion is associated with an economy-wide increase in credit spreads, as higher government deficits tighten intermediary balance sheet constraints. The rise in spreads lowers non-financial sector investment, which can offset the output gain of a demand stimulus. The same mechanism also reduces the effectiveness of financial sector policies. The fact that intermediary balance sheet constraints are forward-looking explains the links between the timing and the effects of government policies.

This chapter is closely related to the above-mentioned studies that emerged out of the experience of the recent crisis.[1] Gertler and Karadi (2011) evaluate the effects of government (central bank) credit intermediation, financed by issuing government debt to households, to offset a disruption of private financial intermediation. Gertler and Kiyotaki (2010) consider a generalization of the model in Gertler and Karadi (2011) with an interbank market and also analyze the effects of government equity injections, financed by raising lump-sum taxes from households. Thus, in these studies, government policies are financed directly by households. Our model allows for deficit financing of fiscal policy through financial intermediaries to do justice to the actual practice of fiscal financing in developed countries.

In fact, many financial institutions in developed countries are active in government funding markets. In the euro area, a significant fraction of monetary financial institutions' assets consists of government securities and direct loans to the government: on average about 9% of total assets and about 58% of the value of loans to non-financial corporations.[2] In addition, EU banks hold primarily domestic government securities (see ECB, 2010). Using a closed-economy approach, as we do, thus seems sufficient to capture the key elements of sovereign funding structures in Europe. Outside of Europe, Japanese bank holdings of government securities as a proportion of total assets have recently gone up to an all-time high, as banks have become the dominant buyers of government bonds. In the UK and the U.S., domestic depository institutions' claims on the government amount to approximately 6% and 8% of GDP, respectively (see IMF, 2010c). Hence, government securities holdings by domestic financial institutions play an important role in most high-income countries.

Overall, we therefore view this chapter as a further step towards a more realistic description of financial markets and as one of the first steps to reflect fiscal-financial linkages in macroeconomic models. Recurring post-crisis concerns on the sustainability of government debt in developed countries and the associated spillover effects across financial systems suggest that these are steps into a relevant direction.

The remainder of the chapter is structured as follows. Section 4.2 lays out the model.

[1] Other related studies include, for instance, Angeloni and Faia (2010), Bean, Paustian, Penalver, and Taylor (2010), Christiano and Ikeda (2011), and Gertler, Kiyotaki, and Queralto (2010).

[2] Source: European Central Bank; aggregated balance sheet of euro area monetary financial institutions, March 2011; `http://www.ecb.int/stats/money/aggregates/bsheets`.

Section 4.3 discusses the results of model-based simulations. It first compares the effects of deficit-financed and lump-sum-tax-financed changes in government purchases in comparison to a baseline model without financial intermediation to explain the main mechanisms at play. It then analyzes the effects of alternative fiscal policy responses to a simulated crisis to investigate the stabilization properties of different policies. Section 4.4 briefly reviews the related empirical literature to connect the key mechanisms and predictions of the model to the available evidence. Section 4.5 concludes.

4.2 Model description

We describe a monetary model with sticky prices and financial intermediation that builds on Christiano, Eichenbaum, and Evans (2005) and Gertler and Karadi (2011).

The model has a private sector and a public sector. The private sector consists of a non-financial sector that is formed by households and firms, and a financial sector that is formed by financial intermediaries.

The firm production chain is as follows. Capital producers combine used capital purchased from intermediate goods producers with investment goods to produce new productive capital which is again purchased by intermediate goods producers. The latter rent labor services from households and issue claims to financial intermediaries to finance their capital acquisition. They produce differentiated goods that are bought, re-packaged, and sold by retail firms in a monopolistically competitive market. Final goods producers buy those goods and combine them into a single output good.

The public sector is formed by a monetary authority that sets the risk-free nominal interest rate and a government that conducts purchases of the final good and financial sector policies. The government finances its operations by issuing debt to financial intermediaries or by raising lump-sum taxes from households. The intermediaries take funds from depositors which are remunerated at the risk-free nominal interest rate.

4.2.1 Households

There is a continuum of infinitely lived households with identical preferences and identical asset endowments. Following Gertler and Karadi (2011), within each household there is a fraction $1-\zeta$ of workers that supply labor to firms and a fraction ζ of bankers that operate financial intermediaries. There is perfect consumption insurance within the family. Households save by holding deposits at intermediaries which they do not own. Financial intermediaries have finite life times, to exclude the self-financing equilibrium. Thus, at the beginning of each period, with probability $1-\theta$ an individual intermediary exits and with probability θ the intermediary continues operating. If the intermediary exits, the respective bankers become workers and transfer any retained capital back to the household which owns that intermediary. Thus every period $(1-\theta)\zeta$ bankers become workers. To keep the relative proportions fixed, a similar number of workers become bankers. New bankers receive a start-up transfer from their household, as described below.

Household preferences depend on consumption and labor supply, with habit formation in consumption as in Christiano et al. (2005) in order to capture consumption dynamics. The objective of a representative household in period t is to maximize expected discounted utility

$$E_t \sum_{s=0}^{\infty} \beta^s [\log(c_{t+s} - \upsilon c_{t-1+s}) - (1+\varphi)^{-1} h_{t+s}^{1+\varphi}], \qquad \beta \in (0,1), \qquad \upsilon \in [0,1), \qquad \varphi \geq 0,$$

subject to the period-by-period budget constraint

$$c_t + d_t + \tau_t \leq w_t h_t + (1 + r_t^d) d_{t-1} + \Sigma_t,$$

where c_t denotes consumption of final goods, h_t denotes hours worked, w_t is the hourly wage rate, d_{t-1} are beginning-of-period deposits, d_t are end-of-period deposits, r_t^d is the net real interest rates on deposits, τ_t are lump-sum tax payments, and Σ_t collects payouts from ownership of both non-financial and financial firms, net of transfers given to household members that enter as bankers at time t.[3]

The household's decision problem is subject to a no-Ponzi game condition, and the household takes w_t, r_t^d, τ_t, Σ_t, prices, and its initial wealth endowment d_{-1} as given. The first-order conditions corresponding to the solution of the household's problem are

[3]Throughout, real (nominal) variables are denoted by lower (capital) letters, and variables without time subscript denote non-stochastic steady state values.

given by

$$
\begin{aligned}
c_t &: \lambda_t = (c_t - \upsilon c_{t-1})^{-1} - \beta \upsilon \left(E_t c_{t+1} - \upsilon c_t\right)^{-1}, & (4.1) \\
h_t &: h_t^{\varphi} = \lambda_t w_t, & (4.2) \\
d_t &: 1 = \beta E_t \Lambda_{t,t+1}(1 + r_{t+1}^d), & (4.3)
\end{aligned}
$$

where λ_t denotes the Lagrangian multiplier associated with the budget constraint and $\Lambda_{t,t+s} = \lambda_{t+s}/\lambda_t$ for $s \geq 0$. As $\lambda_t > 0$, the budget constraint holds with equality.

4.2.2 Financial intermediaries

Financial intermediaries are competitive and located on a continuum indexed by $j \in [0, 1]$. The intermediaries use the deposits obtained from households to purchase claims issued by intermediate goods firms and government bonds. Intermediaries thus act as specialists that assist in channeling funds from agents with a surplus of funds to agents with deficits of funds, where the latter include the government. The need for the government to resort to intermediaries is motivated by size arguments: bond issuance typically occurs in large tranches that cannot be handled by small investors.

To introduce different assets, we characterize the intermediary problem as a two-stage procedure that seems to have sufficient practical appeal. In particular, we assume that each intermediary is operated by a bank manager (or bank board) who makes size decisions and a portfolio manager (or portfolio department) who decides on the structure of assets. In the first stage, the bank manager chooses the total amount of assets relative to deposits to maximize the expected transfer to the household that owns the respective intermediary, similarly as in Gertler and Karadi (2011). Also following the latter, a moral hazard problem constrains the bank manager's ability to obtain funds. In the second stage of the intermediary problem, for a given portfolio size, the portfolio manager chooses portfolio weights to maximize the same objective as the bank manager.

Total assets of intermediary j at the end of period t are given by

$$p_{j,t} = q_t s_{j,t}^k + s_{j,t}^b,$$

where $s^k_{j,t}$ denote claims on intermediate goods firms by intermediary j that have the relative price q_t and that pay a net real return r^k_{t+1} at the beginning of period $t+1$, and $s^b_{j,t}$ are intermediary j's government bond holdings that pay a net real return r^b_{t+1} at the beginning of period $t+1$. The balance sheet of intermediary j thus looks as follows:

$$p_{j,t} = d_{j,t} + n_{j,t},$$

where $d_{j,t}$ denote deposits by households at intermediary j and $n_{j,t}$ denotes the intermediary's net worth. The latter evolves over time as the difference between earnings on assets and interest payments on liabilities minus payments or costs due to portfolio adjustments:

$$n_{j,t+1} = (1 + r^p_{t+1})p_{j,t} - (1 + r^d_{t+1})d_{j,t} - \Omega(\omega_{j,t})n_{j,t},$$

where r^p_{t+1} is the net real portfolio return. We further define portfolio weights $\omega_{j,t} = q_t s^k_{j,t}/p_{j,t}$ and $1 - \omega_{j,t} = s^b_{j,t}/p_{j,t}$, such that the ex-post gross portfolio return satisfies

$$1 + r^p_t = (1 + r^k_t)\omega_{j,t-1} + (1 + r^b_t)(1 - \omega_{j,t-1}). \tag{4.4}$$

The term $\Omega(\omega_{j,t})n_{j,t}$ above measures convex portfolio adjustment costs that are scaled by the level of net worth. We introduce these costs to achieve stationarity, to be able to use standard local approximation techniques. Such costs could come, for instance, from fees that are incurred when assets are bought and sold on the market.[4] In the context of our model, those fees are eventually paid out to households. The costs are scaled by the level of net worth to allow for aggregation, as conducted below, motivated by the idea that the total costs that an individual intermediary incurs on portfolio changes should depend on the total scale of that intermediary's operations. We apply the following functional form:

$$\Omega(x) = \frac{\varpi}{2}(x - \bar{\omega})^2, \qquad \Omega'(x) = \varpi(x - \bar{\omega}), \qquad \varpi > 0, \qquad \bar{\omega} \in (0,1).$$

The adjustment costs are thus increasing in deviations of the portfolio weight $\omega_{j,t}$ from

[4] The existence of costly portfolio adjustments is supported by aggregate estimates and micro evidence of infrequent portfolio changes by U.S. stockholders (see Luttmer, 1999; Bonaparte and Cooper, 2010).

a long-run target $\bar{\omega}$. The latter pins down the steady state portfolio weights and thus helps to match steady state supply of government bonds and the steady state level of private assets in the general equilibrium, as shown in Appendix 4.A.

Bank manager

At the beginning of period $t+1$, after financial payouts have been made, an individual financial intermediary continues operating with probability θ and exits with probability $1-\theta$, in which case it transfers its retained capital to its household. The bank manager's objective in period t is therefore to maximize expected terminal wealth, given by

$$V_{j,t} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} n_{j,t+1+i}.$$

However, following Gertler and Karadi (2011), a costly enforcement problem constrains the ability of financial intermediaries to obtain funds from depositors. In particular, at the beginning of period t, before financial payouts are made, the bank manager can divert a fraction λ of total assets. The depositors can then force the intermediary into bankruptcy and recover the remaining assets, but it is too costly for the depositors to recover the funds that the banker diverted. Accordingly, for the depositors to be willing to supply funds, the incentive constraint $V_{j,t} \geq \lambda p_{j,t}$ must be satisfied. That is, the opportunity cost to the banker of diverting assets cannot be smaller than the gain from diverting assets. It can be shown that $V_{j,t}$ can be expressed as follows:

$$\begin{aligned}
V_{j,t} &= v_t p_{j,t} - \eta_t d_{j,t} - \varrho_t n_{j,t}, \\
v_t &= \beta E_t \Lambda_{t,t+1}\{(1-\theta)(1+r^p_{t+1}) + \theta x_{t,t+1} v_{t+1}\}, \quad x_{t,t+1} = p_{j,t+1}/p_{j,t}, && (4.5) \\
\eta_t &= \beta E_t \Lambda_{t,t+1}\{(1-\theta)(1+r^d_{t+1}) + \theta z_{t,t+1} \eta_{t+1}\}, \quad z_{t,t+1} = d_{j,t+1}/d_{j,t}, && (4.6) \\
\varrho_t &= \beta E_t \Lambda_{t,t+1}\{(1-\theta)\Omega(\omega_{j,t}) + \theta f_{t,t+1} \varrho_{t+1}\}, \quad f_{t,t+1} = n_{j,t+1}/n_{j,t}. && (4.7)
\end{aligned}$$

Holding the other variables constant, the variable v_t is the expected discounted marginal gain of an additional unit of assets. The variable η_t is expected discounted marginal gain cost of another unit of deposits. The variable ϱ_t is the expected discounted marginal cost of another unit of net worth conditional on portfolio changes.

We assume that the bank manager takes the expected returns and the portfolio weights as given when deciding on the total size of assets. The Lagrangian of the bank manager's optimization problem is given by $L = V_{j,t} + \mu_t(V_{j,t} - \lambda p_{j,t})$, where $\mu_t \geq 0$ is the Lagrangian multiplier associated with the incentive constraint. The first-order conditions are

$$\begin{aligned} p_{j,t} &: \quad (1+\mu_t)(v_t - \eta_t) - \mu_t \lambda = 0, \\ \mu_t &: \quad (v_t - \eta_t - \lambda)\, p_{j,t} + (\eta_t - \varrho_t)\, n_{j,t} \geq 0. \end{aligned}$$

The last condition holds with equality if $\mu_t > 0$, otherwise it holds with strict inequality. The condition for $p_{j,t}$ yields $\mu_t = [\lambda/(v_t - \eta_t) - 1]^{-1}$. The multiplier is therefore strictly positive if $\lambda > v_t - \eta_t$. That is, the incentive constraint holds with equality if the banker has an incentive to divert funds obtained from depositors and go bankrupt instead of continuing to operate with the additional funds. We assume that the incentive constraint binds within a local region of the non-stochastic steady state and verify that it does bind in the steady state in the calculations in Appendix 4.A.

In the optimum, the total amount of intermediary assets is then tied to intermediary net worth through the leverage constraint $p_{j,t} = \phi_t n_{j,t}$, where

$$\phi_t = \frac{\eta_t - \varrho_t}{\lambda - (v_t - \eta_t)} \tag{4.8}$$

denotes the intermediary's leverage ratio of assets over net worth. As indicated by (4.8), a higher marginal gain from increasing assets v_t supports a higher leverage ratio in the optimum. A higher marginal cost of deposits η_t lowers the leverage ratio. Higher marginal adjustment costs ϱ_t and a larger fraction of divertable funds λ also lower the leverage ratio.

Portfolio manager

The portfolio manager determines the asset structure of intermediary j's balance sheet by choosing portfolio weights to maximize the same objective as the bank manager, taking as given the total size of assets $p_{j,t}$ and the interest rates r^i_{t+1}, $i = k, b, d$.

Using the portfolio weights, the holdings of individual assets by intermediary j satisfy $q_t s^k_{j,t} = \omega_{j,t} p_{j,t}$ and $s^b_{j,t} = (1-\omega_{j,t})p_{j,t}$. Net worth of intermediary j can therefore be re-written as follows:

$$\begin{aligned} n_{j,t+1} &= (1+r^k_{t+1})q_t s^k_{j,t} + (1+r^b_{t+1})s^b_{j,t} - (1+r^d_{t+1})d_{j,t} - \Omega(\omega_{j,t})n_{j,t}, \\ &= (r^k_{t+1} - r^d_{t+1})\omega_{j,t}p_{j,t} + (r^b_{t+1} - r^d_{t+1})(1-\omega_{j,t})p_{j,t} + [1 + r^d_{t+1} - \Omega(\omega_{j,t})]n_{j,t}. \end{aligned}$$

The optimization problem of the portfolio manager is then given by

$$\max_{\omega_{j,t}} \; E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} n_{j,t+1+i}.$$

The first-order condition looks as follows:

$$E_t(r^k_{t+1} - r^d_{t+1})p_{j,t} = E_t(r^b_{t+1} - r^d_{t+1})p_{j,t} + \varpi(\omega_{j,t} - \bar{\omega})n_{j,t}.$$

Dividing through by $n_{j,t}$ and re-writing yields:

$$E_t(r^k_{t+1} - r^b_{t+1})\phi_t = \varpi(\omega_{j,t} - \bar{\omega}). \tag{4.9}$$

Accordingly, given the leverage ratio ϕ_t, in the optimum the differential of the expected returns on the individual assets, i.e. $E_t(r^k_{t+1} - r^b_{t+1})$, is driven to zero with a speed that is inversely related to the marginal portfolio adjustment costs.

4.2.3 Goods-producing firms

The production side of the economy is characterized by four types of firms that are owned by the households: (i) a continuum of perfectly competitive intermediate goods firms indexed by $i \in [0,1]$ that produce differentiated goods $y_{i,t}$, (ii) a continuum of monopolistically competitive retail firms indexed by $f \in [0,1]$ that re-package intermediate goods $y_{i,t}$ into retail goods $y_{f,t}$, (iii) a continuum of perfectly competitive final goods producers that combine the intermediate goods into a single good y_t, and (iv) a continuum of competitive capital goods producers that repair depreciated capital and build new productive capital.

Final goods producers

A representative final goods firm combines intermediate goods bought from retailers using the technology $y_t^{(\epsilon-1)/\epsilon} = \int_0^1 y_{f,t}^{(\epsilon-1)/\epsilon} df$, where ϵ is the elasticity of substitution among intermediate goods. The final goods firm operates in a perfectly competitive market, maximizing profits $P_t y_t - \int_0^1 P_{f,t} y_{f,t} df$ over input demands $y_{f,t}$, taking the retail prices $P_{f,t}$ and the final goods price P_t as given.

The first-order conditions corresponding to the solution of this problem yield input demand functions, $y_{f,t} = (P_{f,t}/P_t)^{-\epsilon} y_t$, for all f, and an expression for the aggregate price level, $P_t^{1-\epsilon} = \int_0^1 P_{f,t}^{1-\epsilon} df$.

Retail firms

Retail firms buy intermediate goods $y_{i,t}$ at the market price P_t^m and re-package those goods into retail goods $y_{f,t}$ which are sold in a monopolistically competitive market. It takes one unit of intermediate output to make a unit of retail output, i.e. $y_{f,t} = y_{i,t}$. The nominal profit of retailer f in period t is thus given by $(P_{f,t} - P_t^m)\, y_{f,t}$.

Following Calvo (1983) and Yun (1996), in each period a fraction $1-\psi$ of firms can optimally reset their prices, where ψ is exogenously given. A firm that can optimally reset its price maximizes the expected sum of discounted profits. The stochastic discount factor for nominal payouts to households is given by $\beta^s \Lambda_{t,t+s}(P_t/P_{t+s})$, for $s \geq 0$. The relevant part of firm f's optimization problem is then as follows:

$$\max_{P_{f,t}} E_t \sum_{s=0}^{\infty} (\beta\psi)^s \Lambda_{t,t+s}(P_t/P_{t+s})[P_{f,t} - P_{t+s}^m] y_{f,t+s},$$

subject to the demand function $y_{f,t} = (P_{f,t}/P_t)^{-\epsilon} y_t$. By symmetry, all optimizing firms will set the same price P_t^*.

Defining the relative price $m_t = P_t^m/P_t$, the first-order condition is given by

$$\frac{P_t^*}{P_t} = \frac{\epsilon}{\epsilon-1} \frac{E_t \sum_{s=0}^{\infty} (\beta\psi)^s \lambda_{t+s} P_{t+s}^{\epsilon} P_t^{-\epsilon} m_{t+s} y_{t+s}}{E_t \sum_{s=0}^{\infty} (\beta\psi)^s \lambda_{t+s} P_{t+s}^{\epsilon-1} P_t^{1-\epsilon} y_{t+s}}.$$

Defining further the relative price $\pi_t^* = P_t^*/P_t$ and the gross inflation rate $\pi_t = P_t/P_{t-1}$, the first-order condition can be re-written in recursive form as follows:

$$\pi_t^* = \frac{\epsilon}{\epsilon-1}\frac{\Xi_{1,t}}{\Xi_{2,t}}, \quad \Xi_{1,t} = \lambda_t m_t y_t + \beta\psi E_t \pi_{t+1}^{\epsilon}\Xi_{1,t+1}, \quad \Xi_{2,t} = \lambda_t y_t + \beta\psi E_t \pi_{t+1}^{\epsilon-1}\Xi_{2,t+1}. \tag{4.10}$$

Finally, by Calvo pricing, the aggregate price level evolves as follows (see Yun, 1996):

$$1 = (1-\psi)\left(\pi_t^*\right)^{1-\epsilon} + \psi\pi_t^{\epsilon-1}. \tag{4.11}$$

Intermediate goods producers

Intermediate goods firms produce differentiated goods that are sold in a perfectly competitive market. Each firm i has access to the following production technology:

$$y_{i,t} = a_t(\xi_t k_{i,t-1})^{\alpha} h_{i,t}^{1-\alpha}, \qquad \log x_t = \rho_x \log x_{t-1} + \varepsilon_{x,t}, \qquad \rho_x \in [0,1),$$

for $x = a, \xi$ and with $\varepsilon_{x,t} \sim N(0,\sigma_x^2)$. Here, a_t denotes total factor productivity and ξ_t denotes the quality of capital. Thus, $\xi_t k_{i,t-1}$ measures the effective quantity of capital usable for production in period t. The shock ξ_t is meant to capture economic depreciation or obsolescence of capital and provides a simple source of variation in the quality of capital and thus the value of intermediary assets in the general equilibrium (see Gertler and Karadi, 2011).

Each period, firm i rents labor services $h_{i,t}$ at the wage rate w_t from households and finances its capital acquisition by obtaining funds from financial intermediaries. The timing is as follows. At the end of period t, the firm acquires capital $k_{i,t}$ for use in production in period $t+1$. To finance the capital acquisition, the firm issues claims $s_{i,t}^k$ to intermediaries equal to the units of capital acquired, which pay a state-contingent net real return r_{t+1}^k at the beginning of period $t+1$. The price of each claim is the relative price of a unit of capital q_t. After production in period $t+1$, the firm sells the effective capital that has depreciated during that period, $(1-\delta)\xi_{t+1}k_{i,t}$, at the price q_{t+1}. Thus, firm i's real profits in period t are given by $\Pi_{i,t} = m_t a_t(\xi_t k_{i,t-1})^{\alpha} h_{i,t}^{1-\alpha} + q_t(1-\delta)\xi_t k_{i,t-1} - (1+r_t^k)q_{t-1}k_{i,t-1} - w_t h_{i,t}$. Taking the relative output price m_t and the input prices q_t, r_t^k, and w_t as given, intermediate goods firms maximize $E_t\sum_{s=0}^{\infty}\beta^s\Lambda_{t,t+s}\Pi_{i,t}$.

The first-order conditions are as follows:

$$\begin{aligned} h_{i,t} &: \ w_t = (1-\alpha)\, m_t y_{i,t}/h_{i,t}, \\ k_{i,t} &: \ E_t \beta \Lambda_{t,t+1} q_t (1+r^k_{t+1}) = E_t \beta \Lambda_{t,t+1} [\alpha m_{t+1} y_{i,t+1}/k_{i,t} + q_{t+1}(1-\delta)\xi_{t+1}]. \end{aligned}$$

Perfect competition implies that each intermediate goods firm earns zero profits period by period. Accordingly, the firms pay out the ex-post return on capital to financial intermediaries, which is seen by substituting out w_t in the zero profit condition, i.e. $\Pi_{i,t} = 0$:

$$r^k_t = q^{-1}_{t-1}[\alpha m_t y_{i,t}/k_{i,t-1} + q_t(1-\delta)\xi_t] - 1.$$

Solving the last expression and the first-order condition for $h_{i,t}$ for the factor demands yields

$$\begin{aligned} h_{i,t} &= (1-\alpha) m_t w_t^{-1} y_{i,t}, \\ k_{i,t-1} &= \alpha m_t [q_{t-1}(1+r^k_t) - q_t(1-\delta)\xi_t]^{-1} y_{i,t}. \end{aligned}$$

Inserting the factor demands into the technology constraint then yields the following expression for the relative intermediate output price:

$$m_t = \alpha^{-\alpha}(1-\alpha)^{\alpha-1} a_t^{-1}\{w_t^{1-\alpha}[q_{t-1}(1+r^k_t)\xi_t^{-1} - q_t(1-\delta)]^{\alpha}\}. \tag{4.12}$$

4.2.4 Capital-producing firms

After production in period t, competitive capital producers purchase the stock of depreciated capital, given by $(1-\delta)\xi_t k_{t-1}$, from intermediate goods firms at the relative price q_t. The capital producers combine the depreciated capital with investment goods to produce new productive capital, using an identical capital accumulation technology. The newly produced capital is then sold back to intermediate goods firms and any profits are transferred to households. A representative capital producer's accumulation technology is given by

$$k_t = (1-\delta)\xi_t k_{t-1} + [1-\Psi(\iota_t)]\, i_t, \quad \Psi(\iota_t) = \frac{\gamma}{2}(\iota_t - 1)^2, \quad \gamma \geq 0, \quad \delta \in [0,1], \tag{4.13}$$

where i_t denotes investment expenditures in terms of the final good as a materials input, with relative price unity, and $\Psi(\cdot)$ are convex investment adjustment costs in $\iota_t = i_t/i_{t-1}$. Thus, the capital producer's real profits in period t are given by $q_t k_t - q_t(1-\delta)\xi_t k_{t-1} - i_t$. The problem of the capital producer is then to solve

$$\max_{i_t} \; E_t \sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \left\{ q_{t+s}[1 - \Psi(\iota_{t+s})] - 1 \right\} i_{t+s},$$

taking q_t as given. The first-order condition is as follows:

$$q_t \left[1 - \Psi\left(\iota_t\right)\right] - 1 - q_t \iota_t \Psi'\left(\iota_t\right) + \beta E_t \Lambda_{t,t+1} q_{t+1} \iota_{t+1} \Psi'\left(\iota_{t+1}\right) = 0,$$

where $\Psi'(\iota_{t+s})$ denotes the partial derivative of $\Psi(\cdot)$ with respect to ι_{t+s} for $s \geq 0$. Substituting out the functional terms, the price of capital is seen to satisfy

$$\frac{1}{q_t} = 1 - \frac{\gamma}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \frac{\gamma i_t}{i_{t-1}}\left(\frac{i_t}{i_{t-1}} - 1\right) + \beta E_t \Lambda_{t,t+1} \frac{q_{t+1}}{q_t}\left(\frac{i_{t+1}}{i_t}\right)^2 \gamma \left(\frac{i_{t+1}}{i_t} - 1\right). \tag{4.14}$$

4.2.5 Fiscal policy

The government conducts purchases of the final good and financial sector policies. Government purchases g_t consist of a stochastic part $\tilde{g}_t$ plus a possible response to shocks ξ_t:

$$g_t = \tilde{g}_t + \varsigma(\xi_{t-l} - \xi), \qquad \varsigma \leq 0, \qquad l \geq 0,$$

where $\tilde{g}_t$ follows an autoregressive process in logs, $\log(\tilde{g}_t/\bar{g}) = \rho_g \log(\tilde{g}_{t-1}/\bar{g}) + \varepsilon^u_{g,t} + \varepsilon^a_{g,t-4}$, with $\varepsilon^x_{g,t} \sim N(0, \sigma^2_{g,x})$ for $x = u, a$, $\rho_g \in [0,1)$, and $\bar{g} > 0$. Below, we study the effects of surprise changes in spending due to the unanticipated shock $\varepsilon^u_{g,t}$ and spending changes that are pre-announced one year in advance due to the news shock $\varepsilon^a_{g,t}$. The parameter ς determines the spending response to shocks to the quality of capital. Below, this shock serves as the initiating disturbance leading to a financial crisis. If $\varsigma < 0$, spending increases during the crisis above its steady state value. If $\varsigma = 0$, there is no government intervention. Through the parameter l, the response occurs contemporaneously ($l = 0$) or with some lag ($l > 0$). Although it may seem less appealing from a practical point of view than e.g. an endogenous output feedback, an exogenous feedback of this type makes the policy experiments conducted below comparable by excluding second-round effects onto government interventions.

We also allow for different kinds of government interventions in the financial sector. In particular, we assume that the government is willing to provide funds $n_{g,t}$ to financial intermediaries according to a rule that is symmetric to the spending rule:

$$n_{g,t} = \varkappa(\xi_{t-l} - \xi), \qquad \varkappa \leq 0, \qquad l \geq 0.$$

According to this rule, if $\varkappa < 0$, the government provides funds in the face of shocks to the quality of capital, which can again occur contemporaneously or with some lag as determined by l. If $\varkappa = 0$, there are no government interventions in the financial sector. In addition, we allow for the possibility that the funds provided in this way are repaid by the intermediaries, where the period-t repayment $\tilde{n}_{g,t}$ is specified as follows:

$$\tilde{n}_{g,t} = \vartheta n_{g,t-e}, \qquad \vartheta \geq 0, \qquad e \geq 1.$$

Hence, the size of intermediary repayments relative to the funds provided by the government is determined by the penalty factor ϑ: if $\vartheta = 0$, the government makes a transfer or "gift" to intermediaries, $\vartheta = 1$ nests the case of a zero-interest loan, and if $\vartheta > 1$, the funds need to be repaid at some positive (penalty) interest rate. Furthermore, any repayments occur with some delay as determined by the parameter e.[5]

Let b_{t-1} (b_t) denote the stock of government debt at the beginning (at the end) of period t. We assume that, perhaps hypothetically, the government can raise lump-sum taxes from households according to the rule

$$\tau_t = \bar{\tau} + \kappa_b(b_{t-1} - b) + \kappa_g(g_t - g) + \kappa_n n_{g,t}, \qquad \kappa_b > 0, \qquad \kappa_g, \kappa_n \in [0, 1], \qquad \bar{\tau} > 0.$$

As $\kappa_b > 0$, following Bohn (1998), a tax rule of this type ensures fiscal solvency for any finite initial level of debt. In addition, we would like to have a benchmark against

[5]Similar types of policies have been implemented during the recent crisis e.g. in the Netherlands, where penalty interest rates up to 50 percent were charged on government loans to financial institutions that were to be repaid after about three years.

which we can judge the effects of intermediary deficit financing. We therefore introduce the parameters κ_g and κ_n and the respective components. For $\kappa_g = 0$ ($\kappa_n = 0$), goods purchases (financial sector policies) are fully financed by deficits. For $\kappa_g = 1$ and $\kappa_n = 1$, fiscal policy is entirely financed by lump-sum taxes on households. It should be noted that the introduction of small distortionary taxes for debt repayment are unlikely to change our main qualitative conclusions.

The period-by-period government budget constraint is then given by

$$b_t + \tau_t + \tilde{n}_{g,t} = g_t + n_{g,t} + (1 + r_t^b)b_{t-1}. \tag{4.15}$$

4.2.6 Monetary policy

To close the model, we assume that the monetary authority sets the risk-free nominal interest rate on deposits r_t^n to stabilize inflation and output according to a Taylor rule of the form

$$r_t^n = (1 - \rho_r)[r^n + \kappa_\pi(\pi_t - \bar{\pi}) + \kappa_y \log(y_t/y_{t-1})] + \rho_r r_{t-1}^n + \varepsilon_{r,t}, \quad \kappa_y \geq 0, \quad \kappa_\pi > 1,$$

with $\rho_r \in [0, 1)$ and $\varepsilon_{r,t} \sim N(0, \sigma_r^2)$. The parameter $\bar{\pi} \geq 1$ stands for the inflation target. The strength of the monetary authority's reaction to fluctuations of inflation and output is determined by the parameters κ_π and κ_y, where we have imposed Taylor's (1993) principle as $\kappa_\pi > 1$. We also allow for an interest rate smoothing component in the Taylor rule, where the strength of interest rate smoothing is controlled by the parameter ρ_r.[6] The following Fisher relation then defines the ex-post gross real interest rate on deposits:

$$1 + r_t^d = (1 + r_{t-1}^n)\pi_t^{-1}. \tag{4.16}$$

Notice that the model emphasizes the direct links of e.g. central bank lending rates to intermediary funding rates by the choice of the deposit rate as the instrument for monetary policy. The interest rate on government bonds is however endogenously determined in the general equilibrium.

[6] The specification of the Taylor rule uses the log deviation of current output from last period's output, to approximate the output gap that appears in Taylor's (1993) original version, following common specifications in empirical macroeconomic models (e.g. Christoffel, Coenen, and Warne, 2008).

4.2.7 Aggregation and market clearing

Financial variables

Given the overall asset size, $p_{j,t} = \phi_t n_{j,t}$, and the asset structure of the balance sheets of individual financial intermediaries, $q_t s^k_{j,t} = \omega_{j,t}\phi_t n_{j,t}$ and $s^b_{j,t} = (1 - \omega_{j,t})\phi_t n_{j,t}$, the evolution of intermediary j's net worth can be re-written as follows:

$$n_{j,t+1} = [(r^p_{t+1} - r^d_{t+1})\phi_t + 1 + r^d_{t+1} - \Omega(\omega_{j,t})]n_{j,t}.$$

We therefore also have the terms

$$\begin{aligned} x_{t,t+1} &= n_{j,t+1}/n_{j,t} = (r^p_{t+1} - r^d_{t+1})\phi_t + 1 + r^d_{t+1} - \Omega\left(\omega_{j,t}\right), \\ z_{t,t+1} &= p_{j,t+1}/p_{j,t} = \left(\phi_{t+1}/\phi_t\right)\left(n_{j,t+1}/n_{j,t}\right) = \left(\phi_{t+1}/\phi_t\right) x_{t,t+1}, \\ f_{t,t+1} &= d_{j,t+1}/d_{j,t} = \left(\phi_{t+1} - 1\right)/\left(\phi_t - 1\right)\left(n_{j,t+1}/n_{j,t}\right) = \left(\phi_{t+1} - 1\right)/\left(\phi_t - 1\right) x_{t,t+1}, \end{aligned}$$

The portfolio problem of intermediary j further implies that the individual portfolio weights are given by $\omega_{j,t} = \varpi^{-1}E_t(r^k_{t+1} - r^b_{t+1})\phi_t + \bar{\omega}$. Substituting out the latter as well as υ_t, η_t, and ϱ_t in the above terms, it follows that none of the components of ϕ_t depend on individual factors. Thus, we also have that $\omega_{j,t} = \omega_t$ for all j.

The aggregate asset demands $s^k_t = \int_0^1 s^k_{j,t}dj$ and $s^b_t = \int_0^1 s^b_{j,t}dj$ then follow as

$$q_t s^k_t = \omega_t \phi_t n_t, \qquad s^b_t = \left(1 - \omega_t\right)\phi_t n_t, \tag{4.17}$$

where $n_t = \int_0^1 n_{j,t}$ denotes aggregate net worth. Aggregate net worth n_t is the sum of total net worth of financial intermediaries that continue operating $n_{c,t}$, total net worth of newly entering intermediaries $n_{e,t}$, and net transfers by the government, $n_{g,t} - \tilde{n}_{g,t}$. Total net worth of continuing intermediaries is given by $n_{c,t} = \theta[(r^p_t - r^d_t)\phi_{t-1} + 1 + r^d_t - \Omega(\omega_{t-1})]n_{t-1}$. To obtain an expression for $n_{e,t}$, it is assumed that new bankers receive a start-up transfer from households equal to a fraction $\chi/(1-\theta)$ of aggregate net worth at the end of period $t-1$, which is equal to $(1-\theta)n_{t-1}$. Thus, $n_{e,t} = \chi n_{t-1}$.

Accordingly, we have

$$n_t = \{\theta[(r_t^p - r_t^d)\phi_{t-1} + 1 + r_t^d - (\varpi/2)(\omega_{t-1} - \bar{\omega})^2] + \chi\}n_{t-1} + n_{g,t} - \tilde{n}_{g,t}, \qquad (4.18)$$

Further, aggregate securities issued by intermediate goods firms to financial intermediaries satisfy $q_t \int_0^1 s_{i,t}^k di = q_t \int_0^1 s_{j,t}^k dj = q_t \int_0^1 k_{i,t} di$, or, using the market clearing conditions $s_t^k = \int_0^1 s_{i,t}^k di = \int_0^1 s_{j,t}^k dj$ and $k_t = \int_0^1 k_{i,t} di$:

$$s_t^k = k_t. \qquad (4.19)$$

Similarly, aggregate bonds issued by the government to financial intermediaries satisfy

$$s_t^b = b_t. \qquad (4.20)$$

The aggregate asset portfolio follows by integrating over individual portfolios:

$$p_t = \int_0^1 p_{j,t} dj = q_t \int_0^1 s_{j,t}^k dj + \int_0^1 s_{j,t}^b dj = q_t s_t^k + s_t^b. \qquad (4.21)$$

Aggregate deposits follow by integrating over individual balance sheets:

$$d_t = \int_0^1 d_{j,t} dj = \int_0^1 p_{j,t} dj - \int_0^1 n_{j,t} dj = p_t - n_t. \qquad (4.22)$$

Factor demands

Demand by final goods producers for each retail good is $y_{f,t} = y_{i,t} = y_t(P_{f,t}/P_t)^{-\epsilon}$, for all f and all i. With $y_{i,t} = y_{f,t}$, the factor demands by firm i are given by

$$h_{i,t} = (1-\alpha)m_t w_t^{-1} y_{f,t}, \qquad k_{i,t-1} = \alpha m_t [q_{t-1}(1 + r_t^k) - q_t(1-\delta)\xi_t]^{-1} y_{f,t}.$$

The aggregate factor demands follow by the market clearing conditions $\int_0^1 h_{i,t} di = h_t$ and $\int_0^1 k_{i,t-1} di = k_{t-1}$:

$$\begin{aligned} h_t &= (1-\alpha)m_t w_t^{-1} y_t \Delta_t, \\ k_{t-1} &= \alpha m_t [q_{t-1}(1 + r_t^k) - q_t(1-\delta)\xi_t]^{-1} y_t \Delta_t, \end{aligned}$$

where $\Delta_t = \int_0^1 (P_{f,t}/P_t)^{-\epsilon} df$ is a price dispersion term with the recursive form

$$\Delta_t = (1-\psi)\left(\pi_t^*\right)^{-\epsilon} + \psi \pi_t^{\epsilon} \Delta_{t-1}, \tag{4.23}$$

see Yun (1996). Hence, the aggregate capital-labor ratio follows as

$$k_{t-1}/h_t = \alpha(1-\alpha)^{-1} w_t [q_{t-1}(1+r_t^k) - q_t(1-\delta)\xi_t]^{-1} = k_{i,t-1}/h_{i,t}. \tag{4.24}$$

Aggregate supply

Integrating $y_{i,t} = a_t(\xi_t k_{i,t-1})^{\alpha} h_{i,t}^{1-\alpha}$ over i, it follows that

$$\int_0^1 a_t(\xi_t k_{i,t-1})^{\alpha} h_{i,t}^{1-\alpha} di = a_t \xi_t^{\alpha} \left(\frac{k_{t-1}}{h_t}\right)^{\alpha} \int_0^1 h_{i,t} di = a_t(\xi_t k_{t-1})^{\alpha} h_t^{1-\alpha}.$$

Integrating $y_{f,t} = y_t(P_{f,t}/P_t)^{-\epsilon}$ over f then yields output of the final good:

$$y_t \Delta_t = a_t(\xi_t k_{t-1})^{\alpha} h_t^{1-\alpha}. \tag{4.25}$$

Goods market clearing

Goods market clearing further requires that aggregate demand equals aggregate supply:

$$c_t + i_t + g_t = y_t. \tag{4.26}$$

4.2.8 Equilibrium

The *rational expectations equilibrium* of this model is then the set of sequences $\{c_t, h_t, w_t, i_t, k_t, q_t, y_t, m_t, \pi_t, \pi_t^*, \Xi_{1,t}, \Xi_{2,t}, \Delta_t, r_t^d, r_t^p, r_t^k, r_t^b, \omega_t, v_t, \eta_t, \varrho_t, \phi_t, n_t, s_t^k, s_t^b, p_t, d_t, b_t\}_{t=0}^{\infty}$ and shadow prices $\{\lambda_t\}_{t=0}^{\infty}$, such that for given initial prices and initial values, a fiscal policy $\{g_t, n_{g,t}, \tilde{n}_{g,t}, \tau_t\}_{t=0}^{\infty}$, a monetary policy $\{r_t^n\}_{t=0}^{\infty}$, and sequences of shocks $\{a_t, \xi_t\}_{t=0}^{\infty}$, conditions (4.1)-(4.26), dropping the j subscripts for individual intermediaries where appropriate, and the transversality conditions are satisfied.

This closes the description of the model. The model is solved by a first-order perturbation around the non-stochastic steady state which is derived in Appendix 4.A.

4.3 Model analysis

4.3.1 Calibration

Table 4.1 lists the choice of parameters for the baseline version of the model. The calibration mostly follows Gertler and Karadi (2011). This concerns the subjective discount factor β, the degree of habit formation ν, the Frisch elasticity of labor supply φ^{-1}, the elasticity of substitution among intermediate goods ϵ, the Calvo probability of keeping prices fixed ψ, the effective capital share in production α, and the investment adjustment cost parameter γ. The respective parameter values are estimates by Primiceri, Schaumburg, and Tambalotti (2006). The parameters in the monetary policy rule are set to conventional values. In addition, we take a conservative stance on the parameters that are specific to our model. In particular, we use a small value for the portfolio adjustment cost parameter ϖ to limit the impact of the adjustment costs on the dynamics to a minimum (cf. Footnote 8). The value of the debt feedback on taxes κ_b is chosen to have stability conditions satisfied in both the version of the model with intermediaries and the version without intermediaries (see Appendix 4.B).

Following again Gertler and Karadi (2011), the steady state leverage ratio ϕ is set to four to roughly match aggregate U.S. financial data. The steady state credit spread Γ is set to one hundred basis points to match the pre-2007 spreads of bank lending rates to risk-free bonds. The average survival rate of bankers $\Theta = 1/(1-\theta)$ is set to sixteen quarters (thus smaller than in Gertler and Karadi, 2011) by calibrating the survival probability θ, to make sure that the proportional transfer to entering bankers χ is positive (see Appendix 4.A). To roughly match U.S. macroeconomic data, the steady state ratios of investment and government spending over GDP i/y and g/y are set to 20 percent, the latter by calibrating δ, and the ratio b/y is set to 2.4 which implies an annual debt-to-GDP ratio of 60 percent.

4.3.2 Surprise spending shock

We begin our discussion of results by an examination of the dynamics due to a surprise spending shock. Figure 4.1 shows the responses of selected variables to an unanticipated

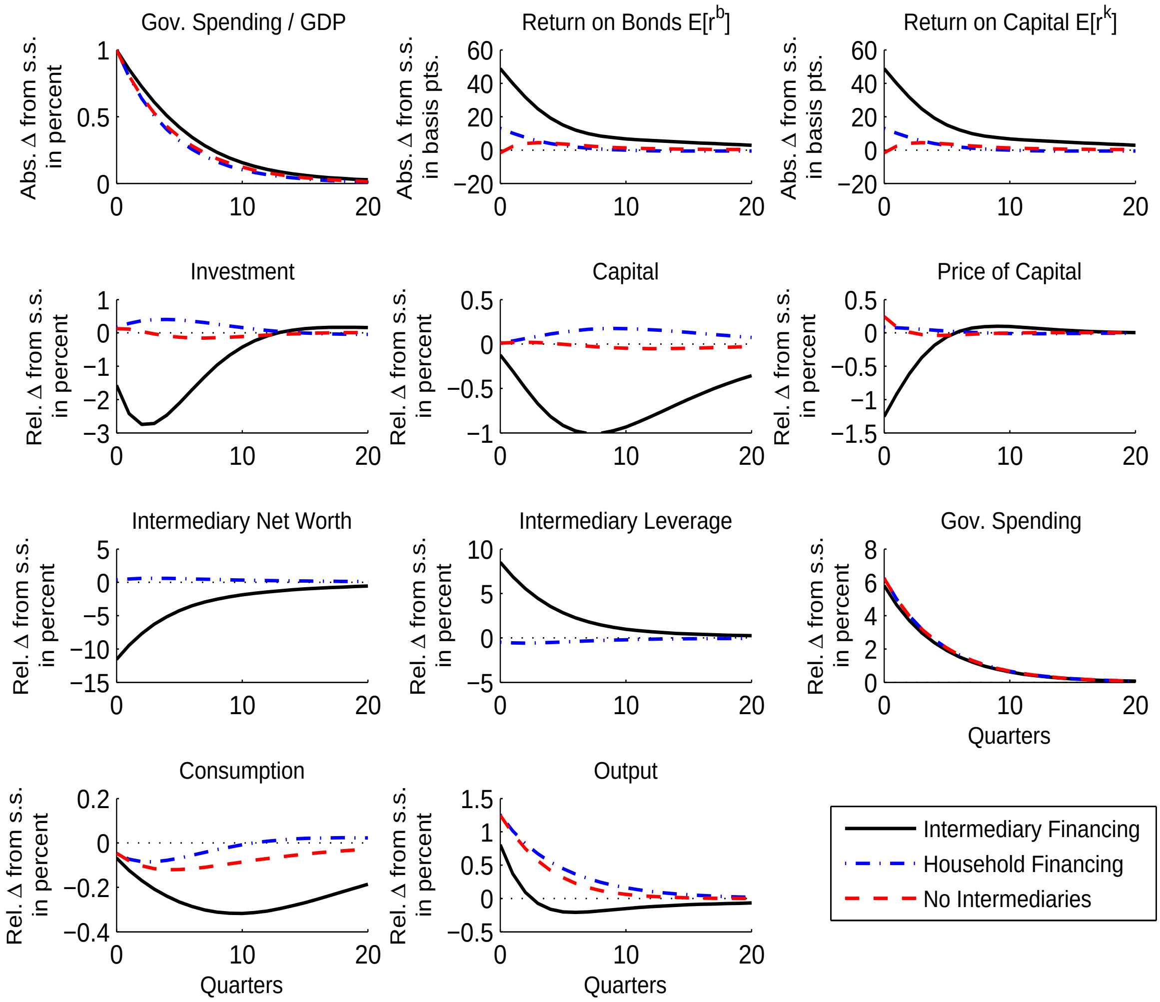
Table 4.1: Model parameters

Parameter	Value	Definition
Households		
β	0.990	Subjective discount factor
ν	0.815	Degree of habit formation
φ	0.276	Inverse Frisch elasticity of labor supply
Financial intermediaries		
λ	0.226	Fraction of assets that can be diverted
θ	0.938	Survival probability of bankers
χ	0.016	Proportional transfer to entering bankers
ϖ	0.001	Portfolio adjustment cost parameter
Goods-producing firms		
ϵ	4.176	Elasticity of substitution
ψ	0.779	Calvo probability of keeping prices fixed
α	0.330	Share of effective capital in production
Capital-producing firms		
δ	0.079	Depreciation rate of effective capital
γ	1.728	Investment adjustment cost parameter
Policy[a]		
κ_b	0.020	Government debt feedback on taxes
ρ_r	0.800	Interest rate smoothing parameter
κ_π	1.500	Inflation feedback on nominal interest rate
κ_y	0.125	Output feedback on nominal interest rate

increase in government spending (goods purchases) that is normalized to 1% of GDP on impact and that is persistent with autocorrelation coefficient $\rho_g = 0.8$. We consider the case of full intermediary financing and, as a benchmark, the case of full household financing through lump-sum taxes. The figure also shows the impulse responses from the version of the model without financial intermediaries, as a reference case. This version of the model is described in Appendix 4.B.

According to the model without intermediaries, the spending expansion raises output by more than one percent on impact, since investment increases initially while the fall in consumption that is caused by consumption smoothing in the face of higher future taxes is subdued initially through the presence of habit formation. However, in the model with intermediaries and with intermediary financing of the spending expansion, the output response is smaller than one percent on impact and it is also significantly

Figure 4.1: Impulse responses to a surprise spending shock



Note. Unexpected increase in government spending in quarter 0 (innovation $\varepsilon^u_{g,t}$) by 1% of GDP relative to its steady state value.

less persistent as output decreases over the medium term.

Underlying those effects are the funding pressures that are put on financial intermediaries by a deficit-financed fiscal expansion. The fiscal expansion raises both expected interest rates through the associated tightening of intermediary balance sheet constraints and intermediary balance sheet adjustments. The precise mechanism through which this occurs is explained in Section 4.3.3 below. As a consequence of the rise in borrowing costs, the demand for capital by intermediate goods firms and thus investment by capital producers is crowded out. The fall in investment is amplified by the financial accelerator mechanism described in Gertler and Karadi (2011) that is due to procyclical variation in intermediary balance sheets: falling investment leads to a falling price of capital, which lowers intermediary net worth and thus further tightens intermediary constraints, which further raises borrowing costs such that investment falls by more, further decreasing asset prices, and so forth. These effects feed through the whole economy as falling wages distract household labor supply and as the associated worsening of budgetary conditions depresses consumption.

It is interesting to see that the spending expansion would be more effective in our model when it would be financed by households compared to the model without intermediaries, where households hold all government bonds and claims issued by intermediate goods firms.[7] Under household financing, the intermediary balance sheet mechanism makes the spending expansion comparably more effective as the build-up of investment (which occurs under household financing just like in the model without intermediaries) raises the price of capital over time and thus eases intermediary balance sheet constraints. As a consequence, an analysis of stimulus policies in a similar model as in Gertler and Karadi (2011), without considering intermediary financing of government deficits, is likely to lead to the conclusion that the benefits of such policies are *enhanced* by the relevant financial frictions.

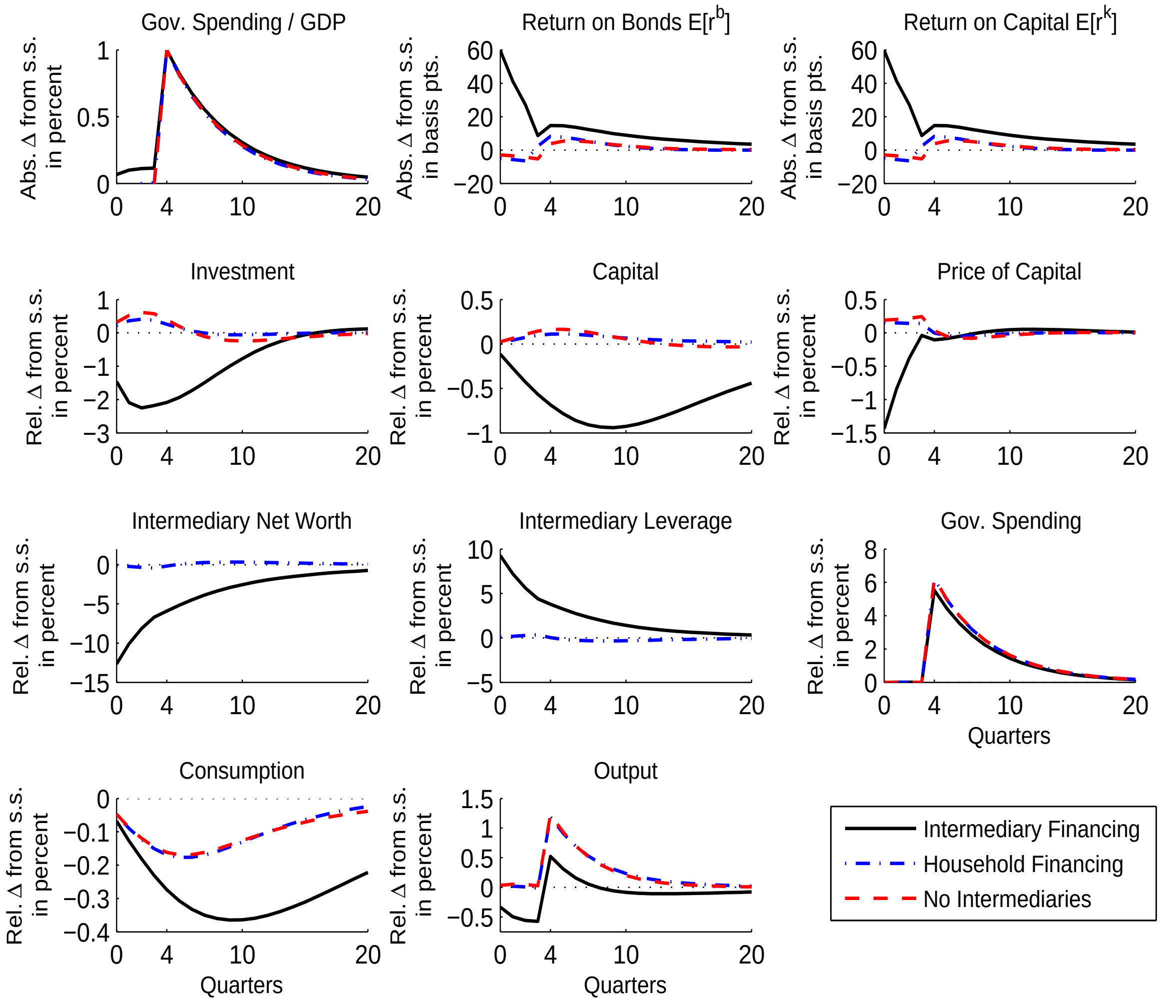
4.3.3 Pre-announced spending shock

The intermediary balance sheet adjustments in interaction with balance sheet constraints that are at the heart of our model become clear when we look at the effects of a spending increase that is pre-announced one year in advance. This experiment allows to distinguish the relevant expectational effects from other effects.

Thus, Figure 4.2 shows the response of the economy to news in quarter 0 that spending is going to increase by 1% of GDP in quarter 4. The results show that the spending expansion would have almost no effect on output under household financing after the news and before the implementation, similarly as in the model without intermediaries. With intermediary financing, however, output falls in the first year due to

[7]In that model, borrowing rates co-move through arbitrage behavior by households and the central bank sets the interest rate on bonds. The model is observationally equivalent to one where financial intermediaries would take deposits from households but face no leverage constraints.

Figure 4.2: Impulse responses to a pre-announced spending shock I

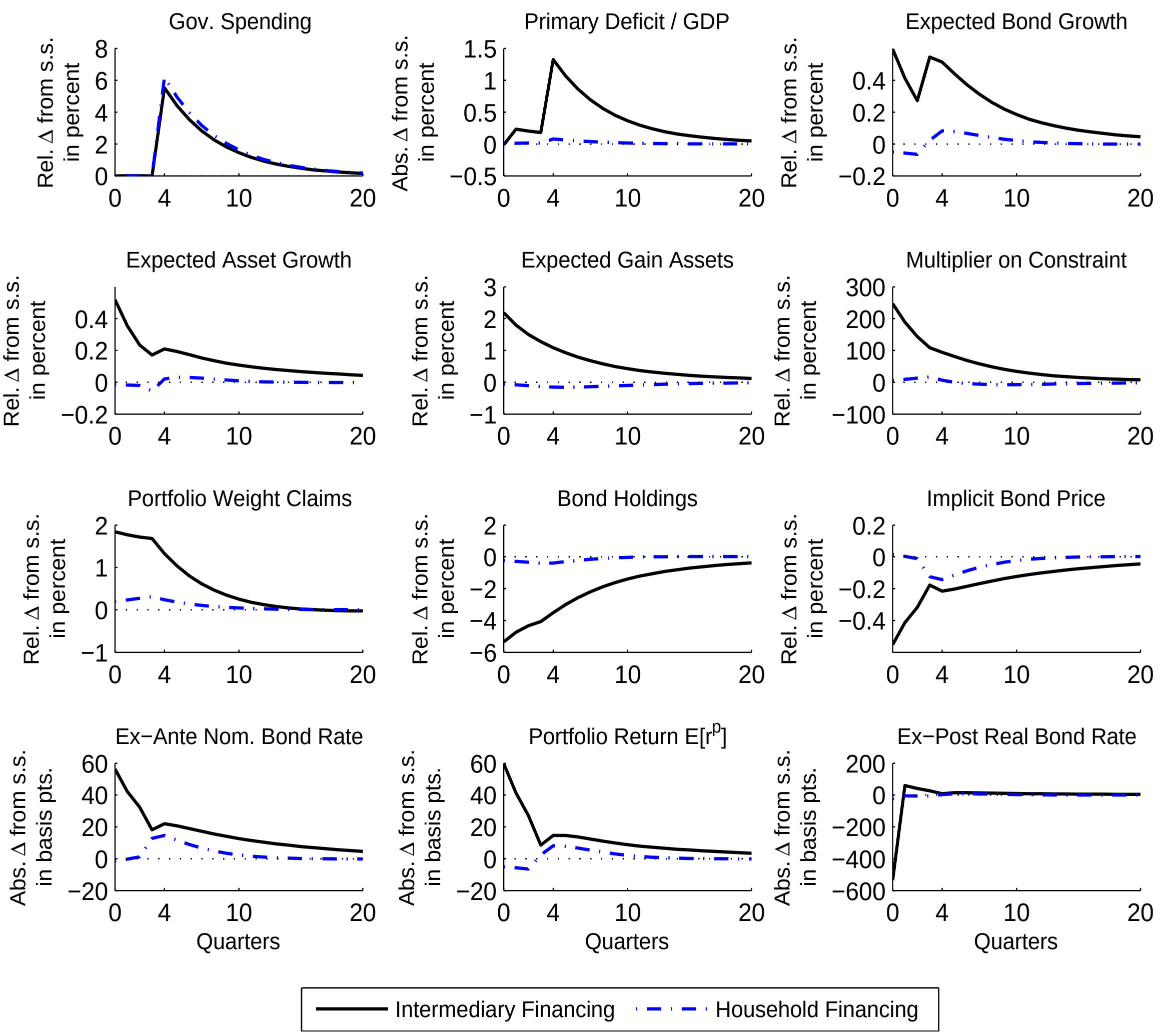


Note. Announcement in quarter 0 (innovation $\varepsilon^a_{g,t}$) that government spending is going to increase by 1% of GDP relative to its steady state value in quarter 4.

an immediate fall in investment after the announcement of the spending expansion.

The underlying mechanism is revealed by a closer look at the impulse responses of a second set of variables to the same shock which are shown in Figure 4.3. A first effect works through a tightening of intermediary balance sheet constraints. The expected future increase in government primary deficits due to the upcoming spending expansion implies higher expected growth rates of bonds and total assets. The intermediaries have an incentive to accumulate assets due to a rise in the expected discounted marginal gain of assets. This incentive, however, tightens leverage constraints as indicated by a

Figure 4.3: Impulse responses to a pre-announced spending shock II



Note. See Figure 4.2.

strong rise in the associated Lagrangian multiplier. The latter restricts intermediary asset demand and raises the costs of credit to both the government and intermediate goods firms during the announcement period (i.e. it raises credit spreads).

A second effect works through intermediary portfolio adjustments. Rising spreads distract investment, which lowers the price of capital. Everything else equal, the fall in the price of capital enhances the rise in the expected return on capital. Intermediaries thus shift their portfolios into assets with higher expected returns, i.e. claims on intermediate goods firms. The associated fall in the demand for bonds reduces the implicit bond price and raises the ex-ante nominal interest rate on bonds. The expected real rate on bonds increases, which adds to the rise in the expected overall portfolio return. The increase in the expected portfolio return further enhances incentives to accumulate assets and thus reinforces the first effect discussed above.[8]

Notice that the fall in the demand for bonds is only consistent with an equilibrium if the ex-post real interest rate on bonds falls given a fixed initial supply of bonds by the government. Hence, a planned fiscal expansion in this environment might give an impression of further fiscal space due to low interest rates when, in fact, there is none. Once the expansion takes place output shoots up to give the arguably erroneous impression that it is actually effective, albeit only for a short time.

4.3.4 Financial crisis and policy responses

We now analyze the effects of alternative government policy interventions during a simulated financial crisis. The type of crisis is the same as in Gertler and Karadi (2011), the initiating disturbance being an unexpected decline in the quality of capital ξ_t by five percent on impact with autocorrelation coefficient $\rho_\xi = 0.66$.

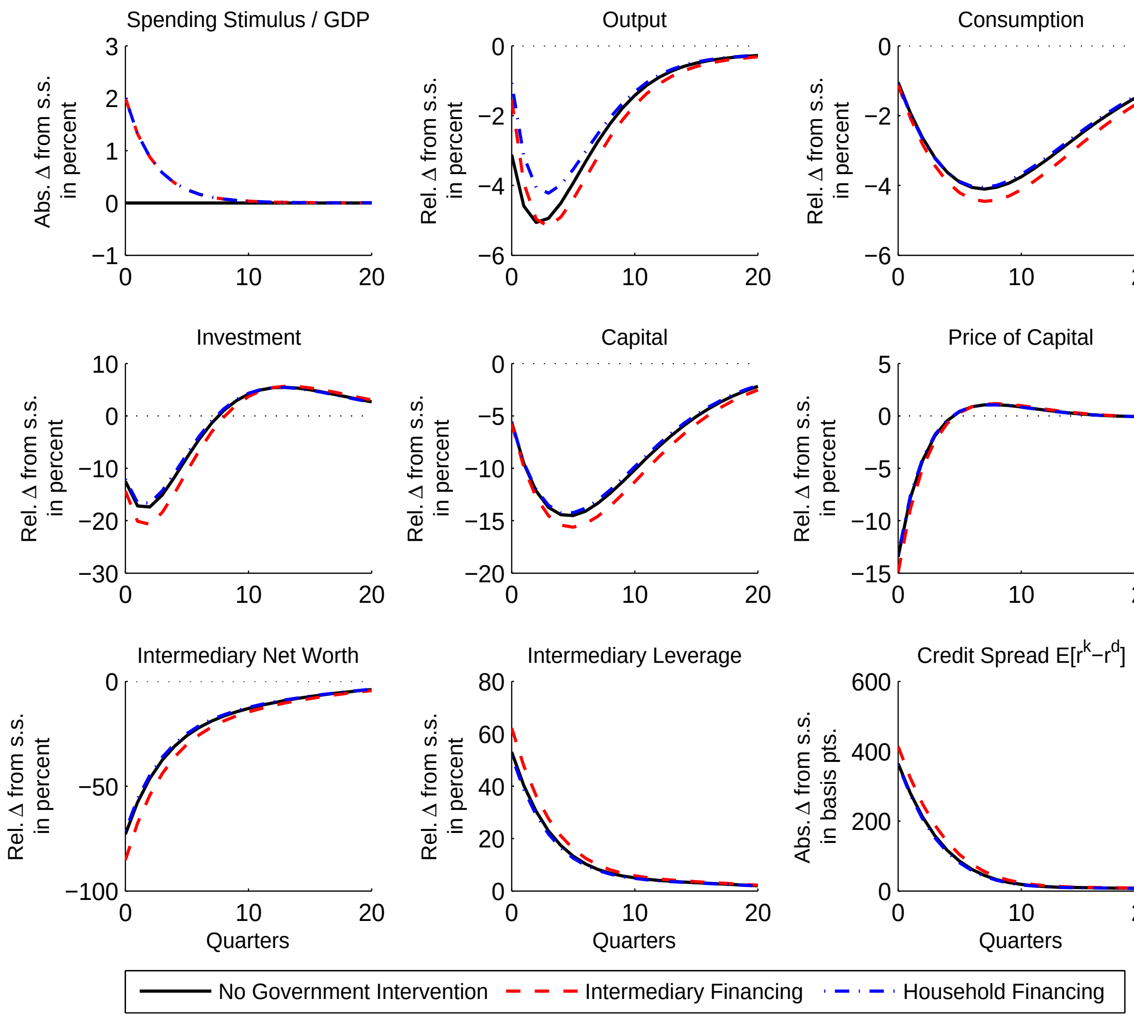
This experiment creates a similar crisis of the type, the magnitude, and the duration of the recent crisis. Other initiating shocks are conceivable, but the specific type of shock is irrelevant for the qualitative implications. Following Gertler and Karadi (2011), we assume that the monetary authority reduces its tendency to smooth interest rates in the face of the shock, to capture the notion that monetary policy tends to act more aggressively during a financial crisis.[9] As seen in the following figures, absent any government intervention, the deterioration in intermediary asset quality produces a sharp recession with a peak output decline of more than five percent, as intermediary net worth drops and credit tightens, leading to a sharp rise of the credit spread. As investment eventually picks up when financial conditions have calmed down to rebuild the destroyed capital stock, it takes more than four years for output to recover.

We consider the following government policies: (i) immediate deficit-financed spend-

[8] The portfolio shift into claims tends to dampen the rise in the expected return on capital. With higher portfolio adjustment costs, this dampening effect becomes weaker and the crowding-out effect stronger. By allowing for low adjustment costs, our results thus rather fall on the conservative side.

[9] The smoothing parameter ρ_r in the Taylor rule is reduced by half but not more so that non-negativity constraints on nominal interest rates are satisfied.

Figure 4.4: Crisis policy I – immediate spending stimulus



Note. Initiating shock is unexpected decline in the quality of capital by five percent relative to its steady state value in quarter 0; autocorrelation coefficient $\rho_\xi = 0.66$.

ing stimulus; (ii) delayed stimulus; (iii) immediate transfers to intermediaries; (iv) delayed transfers; (v) zero-interest loans with delayed repayment; (vi) loans at penalty interest rates; (vii) partly and fully tax-financed spending stimulus.[10] This set of policies is sufficient to explain the relevant implications of the model, but it also suitably captures the main fiscal measures applied during the recent crisis. The policies are either financed by issuing bonds to intermediaries or by raising lump-sum taxes directly from households without resorting to the intermediaries, as a benchmark.

[10]To make the results comparable, the different policy measures are scaled to have the same size relative to GDP on impact by adjusting the feedback parameters ς and $\varkappa$ accordingly.

Fiscal stimulus

Figure 4.4 illustrates the effects of a countercyclical, persistent spending stimulus of two percent of GDP that occurs immediately when the shock hits. The results show that the deficit-financed demand stimulus is able to dampen the initial decline in output by more than one percentage point relative to the no intervention case. After about one year, the fall in output turns however slightly stronger than without government intervention and it remains more negative afterwards. This effect is due to an enhanced fall in investment associated with an additional rise in the credit spread that is caused by a further tightening of leverage constraints due to the increase in government borrowing. The fall in investment and an enhanced decline in consumption due to a higher tax load offset the output gain from the additional government spending.

What happens if the spending stimulus occurs relatively late during the recession? In Figure 4.5 the policy is implemented with a delay of one year after the initial shock. The deficit-financed stimulus seems counterproductive in this case as the fall in output is amplified. The peak decline in output now reaches almost six percent. The reason is that credit tightens immediately in the face of the upcoming spending expansion, as discussed in Section 4.3.3. A similar fall in investment as under an early fiscal expansion thus takes place, but the actual stimulus arrives later, such that the initial decline in output is further amplified compared to the no intervention case.

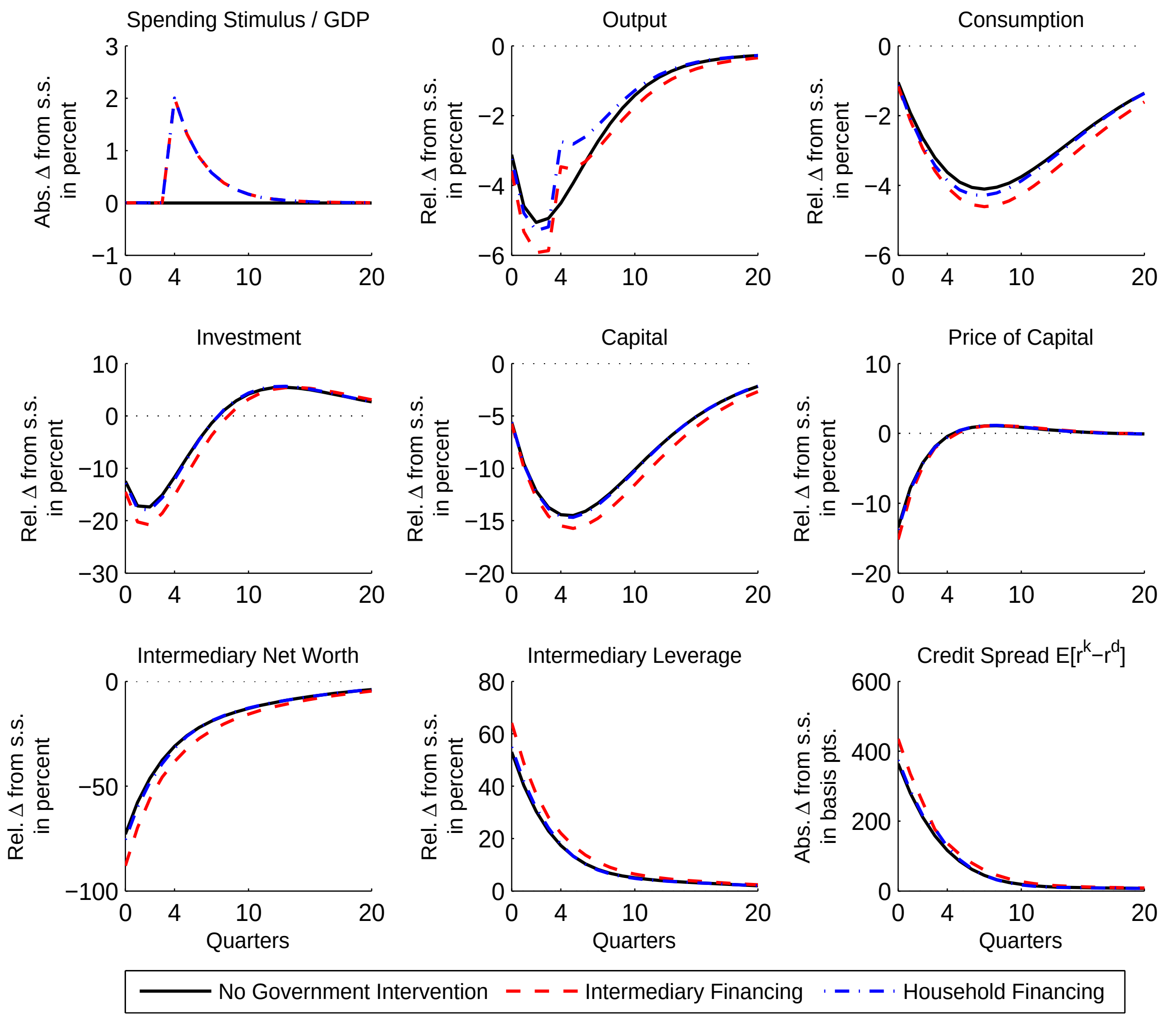
Notice that in both of the above cases the stimuli would be more effective under the benchmark of household financing than under deficit financing. The reasoning goes in line with the discussion in Sections 4.3.2 and 4.3.3, the latter because the upcoming stimulus is anticipated by the agents as soon as the capital quality shock hits.[11]

Financial sector support

We analyze next the effects of financial sector support measures, in the form of transfers to intermediaries with possible repayment. The responses of the credit spread $E_t[r^k_{t+1} - r^d_{t+1}]$ and output under pure transfers, immediate or delayed by one year, and zero-

[11] A household-financed stimulus would also lead to a small decrease in output during the initial quarters, as seen in Figure 4.4. This result can be adhered to the lower interest smoothing parameter in the crisis experiment and the associated valuation effects on intermediary liabilities.

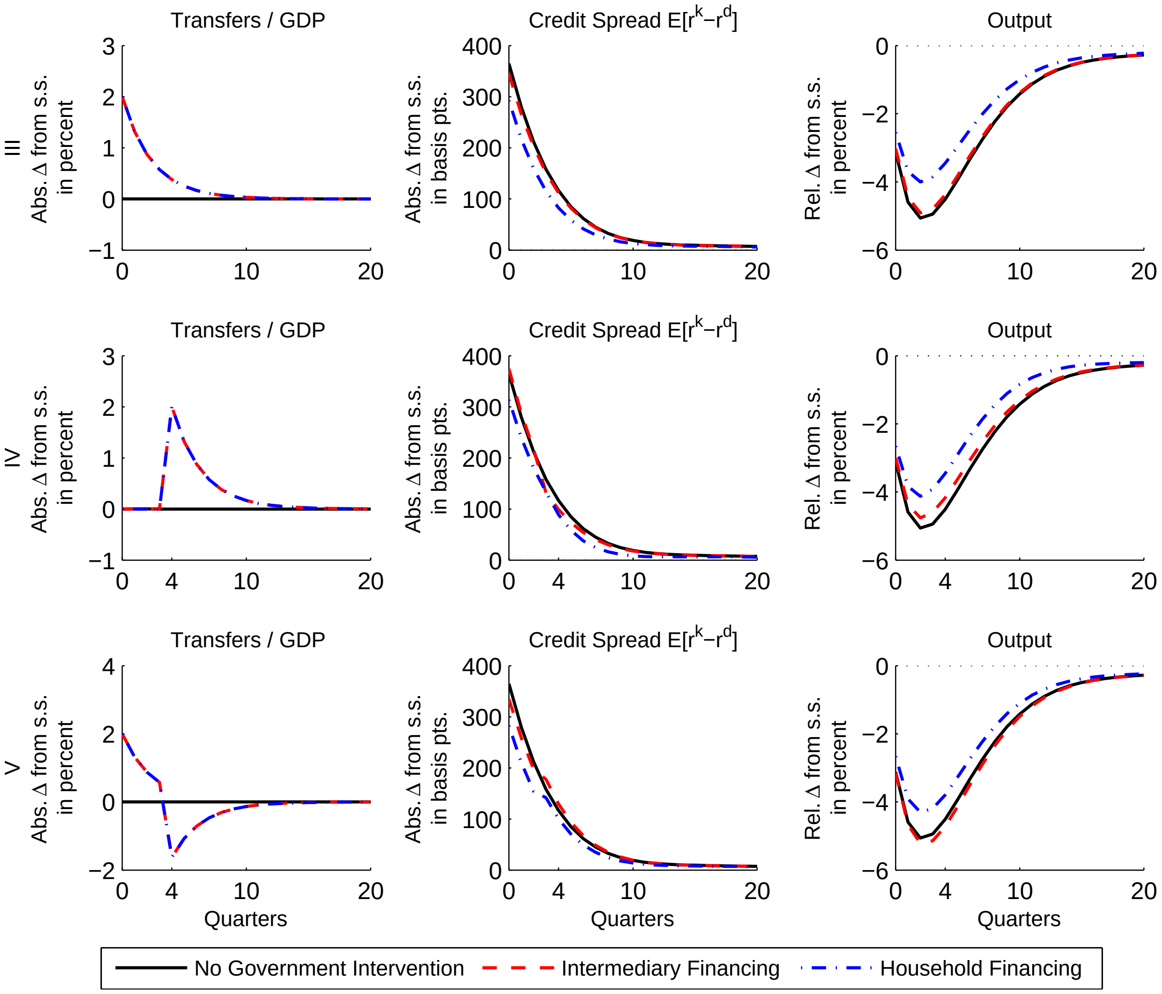
Figure 4.5: Crisis policy II – delayed spending stimulus



Note. See Figure 4.4.

interest loans with delayed repayment after one year are shown in Figure 4.6. The charts in the first two rows show that both immediate pure transfers but also delayed pure transfers, due to the forward-looking character of the intermediary constraints, are able to moderate the recession. The positive effect on output is stronger under household financing, but also under deficit financing the policy tends to be beneficial. In both cases, the transfers dampen the rise in the spread by raising intermediary net worth. The third row considers the case of zero-interest loans that are repaid after four quarters. According to the results, such loans are not effective in dampening the crisis under deficit financing. In the benchmark case of household financing, however, the

Figure 4.6: Crisis policies III to V – immediate transfers to intermediaries, delayed transfers, and zero interest loans with delayed repayment



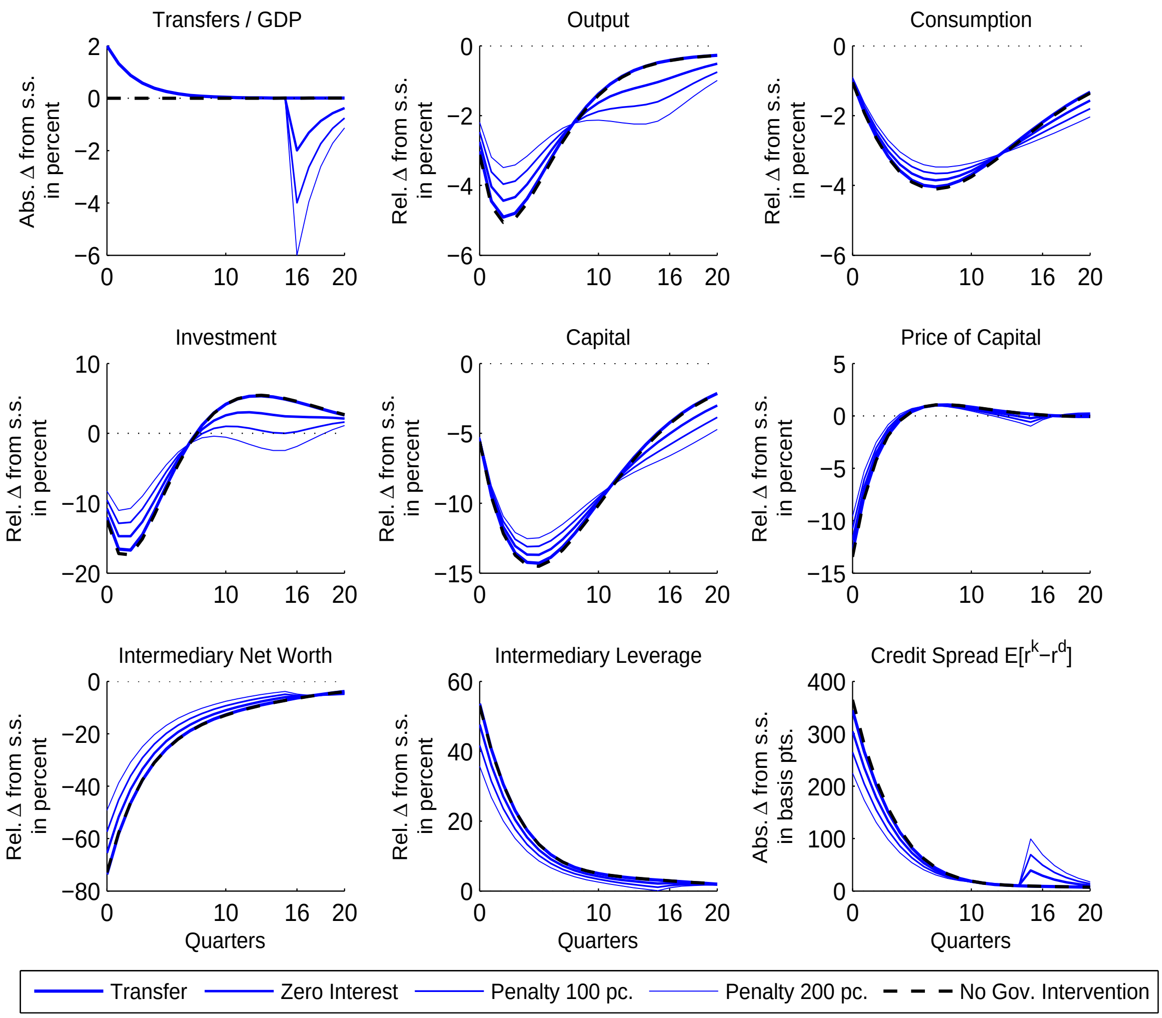
Notes. III: immediate transfers; IV: delayed transfers; V: zero interest loans; see Figure 4.4.

loans would be effective in reducing the output loss.

We can also go a step further and look at loans that need to be repaid at penalty interest rates. Figure 4.7 shows the dynamics due to the capital quality shock when the loans need to be repaid after sixteen quarters, at zero interest or at one hundred and two hundred percent penalty rates.[12] The figure also shows the dynamics without government intervention (dashed line) and with transfers to intermediaries (thickest solid line). The figure shows that the downturn is dampened during the initial quarters,

[12]The delay of sixteen quarters is chosen because at that point the crisis is arguably over, thus motivating repayment of temporary support measures.

Figure 4.7: Crisis policy VI – loans at penalty interest rates

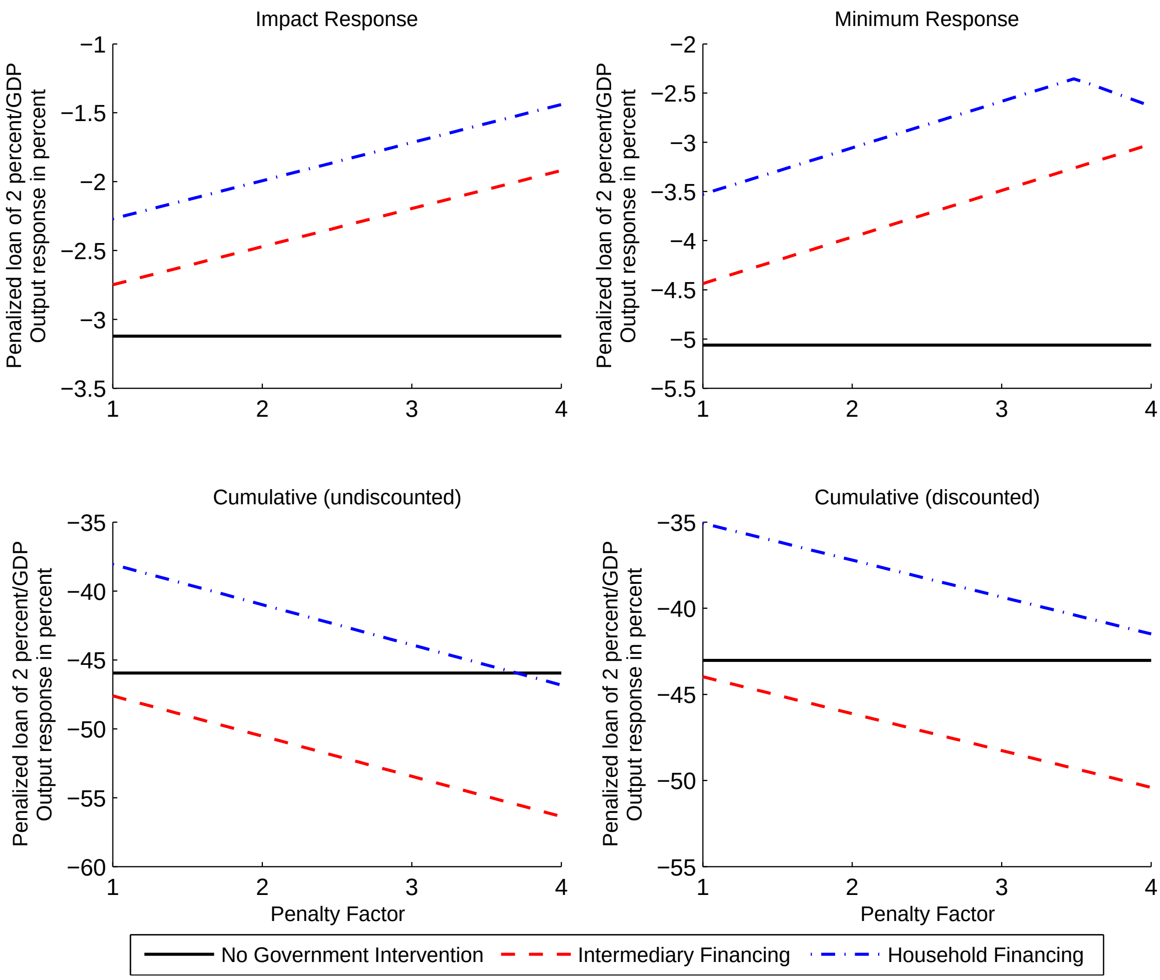


Note. See Figure 4.4.

the more the higher the repayment, but towards the time of the repayment the recession is prolonged in a double-dip fashion, the second (first) dip being larger (smaller) the larger the repayment requirements. In fact, the credit spread shows spikes around the time when the repayments are due in the four different cases.

It seems interesting that the initial recession is dampened more strongly the higher the repayment factors. This effect is due to an initial easing of credit conditions. The main underlying reason is that capital producing firms anticipate the future tightening of credit conditions and the associated future fall in the price of capital. The capital producers therefore increase their initial investment, given relatively higher resale

Figure 4.8: Output gains from penalty-rate loans



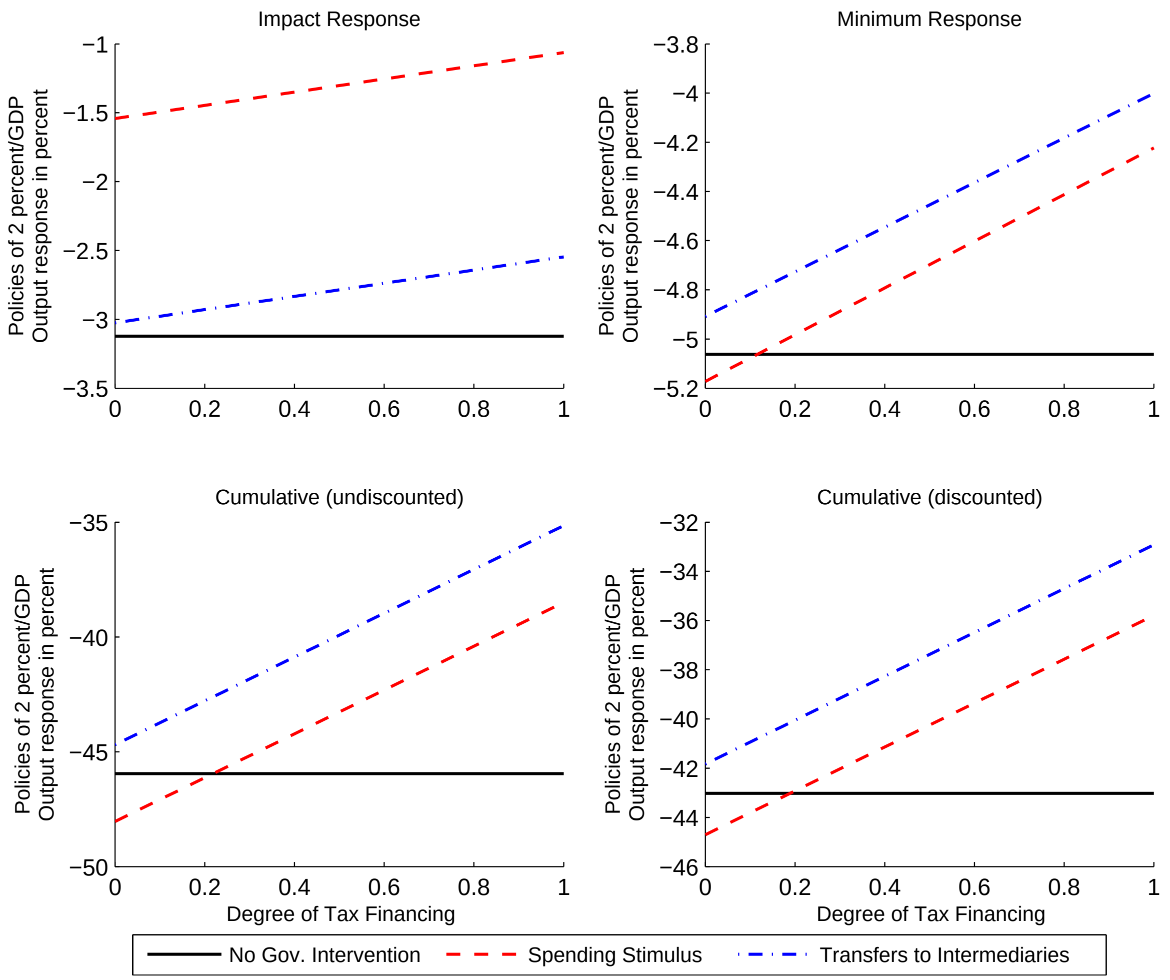
Notes. Crisis experiment as in Figure 4.4; 2% of GDP initial loans with delayed repayment at penalty rates; penalty factor x: $100 \times (x - 1)$ percent penalty interest rate.

prices, which leads to an accelerated rise in the price of capital that eases balance sheet constraints on financial intermediaries and thus tends to dampen the initial crisis.

Output gains

Can the stabilizing effects during the crisis potentially suffice to generate overall output stabilization gains from penalty loans? Figure 4.8 plots measures of output gains against the penalty factor in loan repayment, which occurs after sixteen quarters. The four charts show the impact responses, the minimum responses, and the undiscounted and discounted cumulative responses of GDP under both deficit-financed loans (dashed

Figure 4.9: Output gains from stimuli and transfers under mixed financing



Notes. Crisis experiment as in Figure 4.4; 2% of GDP initial spending stimuli; degree of tax financing x: $100 \times x$ percent household financing, $100 \times (1 - x)$ percent intermediary financing.

lines) and household-financed loans (dashed-dotted lines) relative to the case of no intervention (solid lines).[13] The loans are again scaled to two percent of GDP.

According to the impact and minimum responses, under both deficit financing and household financing, loan provision is found to be an effective means to dampen the crisis recession for all values of the penalty factor considered. The reason is that some of the output loss is instead shifted towards later periods due to (the anticipation of) rising

[13] Denote as $\breve{y}_k$ the percentage deviation of output from its steady state value at horizon $k = 0, 1, 2, \ldots, T$ with the government intervention. The measures are calculated as follows: impact responses $\breve{y}_0$; minimum responses $\min_k \breve{y}_k$; undiscounted cumulative responses $\sum_{k=0}^{T} \breve{y}_k$; discounted cumulative responses $\sum_{k=0}^{T} \beta^k \breve{y}_k$, where β is the household subjective discount factor. We set $T = 1000$.

credit spreads and thus falling investment at the time of the repayment, as indicated by the decreasing undiscounted cumulative gains (see Section 4.3.4).[14] However, most remarkably, under household financing the prediction would be that even very large penalty factors can still bring overall cumulative stabilization gains. Under deficit financing, on the other hand, there are no overall stabilization gains according to both cumulative measures considered.

Hence, a straightforward analysis of financial sector policies in a similar model as in Gertler and Karadi (2011), without intermediary financing of government deficits, could lead to a rather odd conclusion: overall output stabilization gains are possible when temporary support measures are repaid after some time at *huge* penalty rates. When considering deficit financing by intermediaries, however, the relatively small overall gains from deficit-financed policies should lead to more cautious predictions.

As a final step, we examine stabilization gains from demand stimulus as well as transfers to intermediaries depending on the degree of deficit financing as determined by κ_g and κ_n. This final experiment serves to compare whether there is some critical point at which the benefits from these policies surpass the costs due to the tightening of intermediary constraints, in view of the core question of this chapter. According to the results in Figure 4.9, both measures are least effective under full deficit financing. Transfers, hypothetically perhaps, can bring stabilization gains even under full deficit financing. However, already for moderate degrees of household financing above 20 percent, the stimulus is also able to dampen the recession (cf. the minimum responses) and moderate the overall output loss (cf. the cumulative responses). This result again emphasizes the importance of taking the precise financing mode of fiscal policy into account when deciding on policy measures in a situation of financial stress.

4.4 Related empirical evidence

This section provides a brief review of the empirical evidence that is linked to our study. The related evidence can be grouped into results from fiscal VAR studies on the

[14]The kink in the upper right chart is due to the fact that at some point, for relatively high penalty factors, the output drop at the time of the repayment turns larger than the minimum response during the crisis.

effects of government spending or goods purchases, in particular on private investment, findings of cross-sectional studies that investigate the impact of financial sector policies and fiscal stimulus during financial crises, and results from empirical studies looking at the effects of fiscal finances on interest rates.

Among the first group of studies, both structural VAR (SVAR) methods and event-study approaches point towards negative effects of government spending on private investment. On the SVAR side, Blanchard and Perotti (2002) find that investment is consistently crowded out by government spending shocks in the U.S. over the period 1960Q1-1997Q4, with a peak decline of up to one percent due to a 1% of GDP spending increase. Using a yearly panel VAR on 18 OECD countries over the period 1960-1996, Alesina, Ardagna, Perotti, and Schiantarelli (2002) also find a sizable negative effect of public spending (particularly public wages) on investment, a one percentage point increase in the primary spending-to-GDP ratio leading to a fall in the investment-to-GDP ratio of 0.15 percentage points on impact and to a cumulative fall of 0.74 percentage points after five years. On the side of event-studies, identifying spending shocks based on war dates and professional forecasts, Ramey (2011b) finds that after a positive defense news shock in the U.S. both non-residential and residential investment fall significantly, with peak effects of up to -1 percent (non-residential investment) and -1.5 percent (residential investment). Shocks identified based on professional forecast errors over the period 1969-2008 indicate even stronger falls of -1.5 percent and -3.5 percent, respectively, as well as a medium-term decline in output.

Our model predicts stronger crowding-out effects of spending-based fiscal expansions on investment than most of the above VAR studies (see Figures 4.1 and 4.2).[15] The qualitative predictions are however similar. The quantitative differences also do not come as a big surprise as the model mainly describes business cycles in times of financial stress, whereas the above studies look instead at sample averages. Related to this fact, Baldacci, Gupta, and Mulas-Granados (2008) estimate the effects of fiscal policy interventions during 118 episodes of banking crises in a cross-section of developed and emerging countries. In line with the results of Section 4.3.4, they find that

[15] The fall in investment in Figure 4.1 implies a 0.48 percentage points decline in the investment-to-GDP ratio on impact and a cumulative fall of more than three percentage points after five years.

financial sector policies can shorten such crises whereas fiscal stimulus going along with such policies can have stabilizing effects, but the latter does not hold for countries where fiscal policy is subject to funding constraints.[16]

Finally, a recent study on the effects of fiscal finances on interest rates has been conducted by Laubach (2009), who estimates the effects of U.S. government debt and deficits on Treasury yields, isolating those effects from other factors affecting interest rates (e.g. due to countercyclical monetary policy and automatic fiscal stabilizers) by focusing on the relation between long-horizon expectations of both interest rates and fiscal variables. According to Laubach, the idea is that measures of expectations hold out the prospect of uncovering causal effects from fiscal variables to interest rates. Laubach concludes that the effects of fiscal variables on interest rates are statistically significant and economically relevant; in particular, for the period 1976-2006 an increase in the projected deficit-to-GDP ratio by one percentage point raises forward rates five and more years into the future by about 25 basis points. This result corroborates the findings shown in Figures 4.1 and 4.2 from a qualitative perspective.[17]

4.5 Conclusion

After a wave of calls for fiscal stimulus to lift distressed economies out of recession in the context of the recent crisis, when economic growth finally picked up after the implementation of large fiscal packages, the policy efforts where deemed effective at first.[18] However, despite reduced credit spreads and diminishing job losses, the recovery turned out to be less robust than originally hoped, particularly in the U.S. where the largest package was adopted in absolute size (see Mankiw, 2009). Dissatisfaction with the impact of the implemented policies spread and many observers asked why the stimulus was not more effective (see e.g. Adams and Gangnes, 2011).

[16]A similar conclusion is reached by Ilzetzki, Mendoza, and Végh (2010); based on a quarterly dataset for 20 developed and 24 developing countries over the period 1960-2007, they find that during episodes where government debt was higher than 60% of GDP, spending multipliers are not statistically different from zero on impact and negative (and statistically significant) in the long run.

[17]See also Canzoneri, Cumby, and Diba (2002), Cohen and Garnier (1991), Elmendorf (1993), Wachtel and Young (1987), as reviewed in Laubach (2009). Most of these studies also find statistically and economically significant effects of deficits on interest rates.

[18]See, for instance, Romer (2009), Romer and Bernstein (2009); see also CBO (2009), IMF (2009a), and OECD (2009).

Our model is able to provide an answer to this question. Key to the answer is the fact that it takes time to implement announced measures: in the case of the U.S., it took more than one year between the first plans for fiscal stimulus (cf. Summers, 2008) and the enactment of the American Recovery and Reinvestment Act of 2009. Our results suggest that an announced but delayed stimulus of this type can appear to be effective once it occurs, through lower credit spreads and higher output growth. However, the announcement of the stimulus can *deepen* the crisis before the implementation of any measures. Moreover, after its direct demand effects are realized, the stimulus tends to be followed by lower medium-term growth than without any government interventions.

Our findings thereby support the notion that it is important that fiscal stimulus is timely but with the warning that even a timely stimulus can have undesirable crowding-out effects that can potentially offset its desired impact. This warning, which hinges on the degree of intermediary financing, should be taken into account together with warnings on potential long-run crowding-out effects of fiscal stimulus e.g. due to distortionary taxation (see e.g. Coenen et al, 2010; Drautzburg and Uhlig, 2011).

If not fiscal stimulus, what can governments do to stabilize the economy in times of financial stress? Our results tend to confirm the conclusion from previous studies that financial sector policies can be effective tools. However, once realistic aspects of deficit financing are taken into account, such policies seem less effective. According to our findings, if transfers to intermediaries are not the favored means, an important condition for alternative means such as loans to intermediaries to be effective is that repayments are agreed to occur with a significant delay. If they need to be repaid relatively early, the funding pressures that are put on financial intermediaries by an increase in government borrowing can again offset the desired recapitalization effects. Remarkably, however, short-run stabilization gains are still possible even if loans are to be paid back at penalty rates. The benefits to intermediaries from such policies are then realized at the peak of the crisis and repayment effects tend to be discounted in a way that the initial stabilization gains are enhanced. Quite oddly, however, a similar model as ours that does not consider deficit financing of government policies predicts that very large penalty factors of more than two hundred percent can bring overall stabilization gains. The latter underlines the relevance of taking the consequences of intermediary financing of government policies into account.

To conclude, we would like to emphasize that the model discussed in this chapter highlights specific mechanisms that seem relevant for an analysis of government policies in times of financial stress, while neglecting other well-known aspects that are relevant to characterize the macroeconomic effects of fiscal policy. We could look at additional policies such as tax cuts, transfers to liquidity-constrained consumers, public investment, labor market policies etc. in the context of our model. The effects of such policies are however well-studied by now, and extensions of our model into that direction are unlikely to change our main conclusions or to add much understanding to the key mechanisms highlighted in this chapter.

4.A Steady state solution

This appendix derives the solution for the non-stochastic steady state of the model and shows that the incentive constraint is binding in the steady state. For simplicity, the solution is derived for a zero inflation steady state. This is achieved by setting the target inflation rate in the monetary policy rule accordingly, i.e. $\bar{\pi} = 1$; the Taylor rule then implies that $\pi = 1$. The steady state real interest rate on deposits and the steady state risk-free nominal interest rate then follow from the household's consumption Euler equation and the corresponding Fisher relation:

$$r^d = \beta^{-1} - 1, \qquad r^n = r^d.$$

Further, by the capital producer's first-order condition, the relative price of capital equals one in the steady state: $q = 1$.

To solve for the variables that are determined by the financial intermediaries' problem, we guess and verify that there is an equilibrium with $r^k - r^d = r^b - r^d = \Gamma > 0$. We also take as given the total leverage ratio ϕ by calibrating χ, the average survival time of bankers $\Theta = 1/(1-\theta)$ by setting $\theta = (\Theta - 1)/\Theta$ and the interest rate spread Γ by calibrating λ. As $r^k = r^b$, we then obtain from the portfolio manager's first-order condition that $\omega = \bar{\omega}$. Given r^d, we also obtain $r^k = r^d + \Gamma$ and $r^b = r^k$. From the equation for r^p, it follows that $r^p = r^k$. We further obtain

$$\varrho = 0, \qquad \upsilon = \frac{\beta(1-\theta)(1+r^p)}{1-\beta\theta}, \qquad \eta = \frac{\beta(1-\theta)(1+r^d)}{1-\beta\theta}, \qquad \lambda = \upsilon + \frac{(1-\phi)\eta}{\phi}.$$

We also have

$$\chi = 1 - \theta(\Gamma\phi + 1 + r^d).$$

Next, we see that the incentive constraint indeed binds in the steady state, because

$$\lambda - \upsilon + \eta = \eta/\phi = (1-\theta)\beta(1+r^d)\phi^{-1}(1-\theta\beta)^{-1} > 0.$$

We now solve for the production allocation. From the price setting equations, for a zero inflation steady state, we have

$$\pi^* = \Delta = 1, \qquad \Xi_1 = m\lambda y(1-\beta\psi)^{-1}, \qquad \Xi_2 = \lambda y(1-\beta\psi)^{-1},$$

such that $\Xi_1/\Xi_2 = m$. The first-order condition of the intermediate goods firms' price-setting problem therefore implies that $m = (\epsilon-1)/\epsilon$. As $\Delta = 1$ and $a = \xi = 1$, we will use that steady state final output is $y = k^\alpha h^{1-\alpha}$. Further, the steady state real wage can be derived from the marginal cost equation, given r^k and m:

$$w = [\alpha^\alpha(1-\alpha)^{1-\alpha} m (r^k+\delta)^{-\alpha}]^{\frac{1}{1-\alpha}}.$$

The capital-labor ratio is then

$$k/h = \alpha(1-\alpha)^{-1} w (r^k+\delta)^{-1}.$$

By the resource constraint, the steady state ratio of consumption over output is

$$c/y = 1 - i/y - g/y,$$

where i/y and g/y are taken as given. The household's remaining first-order conditions for consumption and hours worked then imply that

$$\lambda = (1-\beta\upsilon)[(1-\upsilon)(c/y)y]^{-1}, \qquad h = \{(1-\beta\upsilon)w[(1-\upsilon)(c/y)y]^{-1}\}^{\frac{1}{\varphi}}. \qquad (4.27)$$

Steady state final output then follows from $y = (k/h)^{\alpha}h$, or

$$y = (k/h)^{\frac{\alpha\varphi}{1+\varphi}}\{(1-\beta\upsilon)w[(1-\upsilon)(c/y)]^{-1}\}^{\frac{1}{1+\varphi}}.$$

such that λ and h can be computed from (4.27). Steady state consumption, investment, and government spending are thus

$$c = (c/y)y, \qquad i = (i/y)y, \qquad g = (g/y)y.$$

The government spending process can then be specified such that g/y can be taken as given, as it was assumed above, by setting $\bar{g} = g$. The capital accumulation equation furthermore implies that $i/k = \delta$. Steady state investment therefore satisfies $i = \delta(k/h)h$. The steady state ratio of investment over GDP is thus

$$i/y = \delta(k/h)(h/y) = \delta(k/h)^{1-\alpha} = \delta[\alpha(1-\alpha)^{-1}w(r^k+\delta)^{-1}]^{1-\alpha} = \delta\alpha m(r^k+\delta)^{-1}.$$

Solving the last equation for δ yields

$$\delta = r^k\,(i/y)\,(\alpha m - i/y)^{-1}.$$

Hence, δ can be calibrated such that i/y can be taken as given, as it was assumed above. The steady state capital stock then follows from the capital accumulation equation: $k = i/\delta$. Given k, we obtain the steady state level of claims on non-financial firms by financial intermediaries from the market clearing condition: $s^k = k$. On the fiscal side, we take the steady state ratio of government debt over GDP b/y as given by calibrating the steady state level of taxes $\bar{\tau}$, such that

$$b = (b/y)y, \qquad \bar{\tau} = g + r^b b.$$

To equalize the demand for government bonds by financial intermediaries s^b and bond supply by the government b, given s^k, we calibrate $\bar{\omega}$ accordingly, as $\omega = \bar{\omega}$ and $s^b/(1-\omega) = \phi n = s^k/\omega$, or

$$\omega = (s^k/s^b)(1 + s^k/s^b)^{-1}.$$

Given b, we thus obtain the steady state level of the intermediaries' government bond holdings from the market clearing condition: $s^b = b$. The remaining financial variables then follow as

$$n = s^k(\omega\phi)^{-1}, \qquad p = \phi n, \qquad d = p - n.$$

4.B The model without financial intermediaries

This appendix describes the version of the model without financial intermediaries. In this model, there are no bankers and households are thus formed entirely by infinitely lived workers with mass unity. Households save by investing in government bonds and by purchasing claims issued by intermediate goods firms. Accordingly, the budget constraint of a representative household becomes

$$c_t + s_t^b + q_t s_t^k + \tau_t \leq w_t h_t + (1 + r_t^b)s_{t-1}^b + \left(1 - \bar{\tau}^k\right)(1 + r_t^k)q_{t-1}s_{t-1}^k + \Sigma_t.$$

We have introduced a flat-rate tax on capital income $\bar{\tau}^k$ whose function is discussed below. With $\Lambda_{t,t+1}$ as in the main text, the first-order conditions for the household's choices of s_t^b and s_t^k are

$$s_t^b \; : \; 1 = \beta E_t \Lambda_{t,t+1}(1 + r_{t+1}^b), \tag{4.28}$$

$$s_t^k \; : \; 1 = \beta E_t \Lambda_{t,t+1}(1 - \bar{\tau}^k)(1 + r_{t+1}^k). \tag{4.29}$$

As in the main text, the monetary authority sets the risk-free nominal interest rate r_t^n. A Fisher relation defines the ex-post gross real interest rate on government bonds:

$$1 + r_t^b = (1 + r_{t-1}^n)\pi_t^{-1}. \tag{4.30}$$

On the fiscal side, the government budget constraint becomes

$$b_t + \tau_t + \bar{\tau}^k(1 + r_t^k)q_{t-1}s_{t-1}^k = g_t + (1 + r_t^b)b_{t-1}. \tag{4.31}$$

The *rational expectations equilibrium* of this model is then the set of sequences $\{c_t, h_t, w_t, i_t, k_t, q_t, \ \ y_t, m_t, \pi_t, \pi_t^*, \Xi_{1,t}, \Xi_{2,t}, \Delta_t, r_t^k, r_t^b, s_t^k, s_t^b, b_t\}_{t=0}^{\infty}$ and shadow prices $\{\lambda_t\}_{t=0}^{\infty}$, such that for given initial prices and initial values, a fiscal policy $\{g_t, \tau_t\}_{t=0}^{\infty}$, a monetary policy $\{r_t^n\}_{t=0}^{\infty}$, and sequences of shocks $\{a_t, \xi_t\}_{t=0}^{\infty}$, conditions (4.1)-(4.2), (4.10)-(4.14), (4.19)-(4.20), (4.23)-(4.26), (4.28)-(4.31), and the transversality conditions are satisfied. The tax $\bar{\tau}^k$ is calibrated such that this model implies the same steady state values for the relevant variables as the model with financial intermediaries, to make the impulse responses shown in the main text comparable. In particular, as r_t^b replaces the deposit rate r_t^d in this model, without any adjustment there would be no steady spread between r_t^k and r_t^b. This means that steady state capital, investment, output, etc. would be higher than in the model with financial intermediation. To address this issue, we take a steady state that satisfies $r^k = r^b + \Gamma$, with $\Gamma > 0$ as in the main text and $r^b = r^n = \beta^{-1} - 1$, and we calibrate $\bar{\tau}^k$ to generate this spread. In particular, (4.28)-(4.29) imply that

$$1 + r^b = (1 - \bar{\tau}^k)(1 + r^k) = (1 - \bar{\tau}^k)(1 + r^b + \Gamma),$$

or

$$\bar{\tau}^k = \Gamma(1 + r^b + \Gamma)^{-1} > 0.$$

For a small spread, $\bar{\tau}^k$ will be small enough not to have a significant impact on the dynamics. In addition, we need to change the calibration of $\bar{\tau}$ to have identical values for the fiscal variables:

$$\bar{\tau} = g + r^b b - \bar{\tau}^k(1 + r^k)s^k.$$

The steady state calculations for the remaining relevant variables and parameters are identical to those described in Appendix 4.A.