Online appendix for "Government Borrowing and Crowding Out"-Not intended for publication

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Abstract

This online appendix provides a detailed description of the quantitative model used in the manuscript. We rely heavily on Gertler and Karadi (2011) and Kirchner and van Wijnbergen (2016) and follow their notation. Some parts are by now standard and are reproduced here purely for convenience.

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A Appendix - Detailed description of the model

The model has two sectors: a private sector and a public sector. Households, firms, and the financial institution form the private sector, whereas a monetary authority determines the risk-free nominal interest rate according to a Taylor rule and a government that purchases the final goods from firms and conducts financial sector policies form the public sector.

There are four agents taking part in the production chain, all of which are owned by households. Perfectly competitive intermediate good producing firms rent labor services from households and borrow from banks by issuing claims to finance capital acquisition. At the end of the production of intermediate goods firms, capital producers purchase their capital, repair their depreciated capital, purchase investment goods, and transform them into new capital. This new capital is again purchased back by intermediate goods producers who sell their differentiated goods to monopolistically competitive retail firms which re-package these goods and sell them to the final goods producers whose job is to transform these varieties into a single good.

The public sector is, on the other hand, formed by two agents: a central bank that sets the risk-free nominal interest rate according to a Taylor-rule and a government that conducts purchases of the final good and borrows with one-period debt from banks that are subject to financial frictions. Banks collect deposits from households at the risk-free nominal interest rate. The problems of each agent in the economy are discussed below in detail.

A.1 Households

The economy is inhabited by a continuum of infinitely lived identical households who derive utility from consumption and leisure. They each save, consume and supply labor. Following Gertler and Karadi (2011), each household is composed of a worker and a banker who perfectly insure each other. Within the household, a constant ι fraction manages a bank and the remaining fraction supplies labor to firms. Wages of the workers and earnings of the bankers are returned to the household. Essentially, each household owns a bank that a banker operates but households keep their savings at a bank they do not own. Bankers have a finite life to rule out the possibility of complete self-financing. Thus, they survive to the next period with a constant probability $(0 < \theta < 1)$. An exiting banker becomes a worker and transfers all retained capital to the household who owns the bank. At the end of each period, the same number of workers become bankers to keep the worker/banker proportion fixed. New entrants are remitted with some start-up funds which are described under the bank's problem.

Preferences of households over consumption and leisure, with habit formation in consumption as in Christiano et al. (2005) are represented by the lifetime utility function. Let c_t be the consumption of final goods and h_t hours worked. The representative household in period t maximizes the following expected discounted utility

$$\mathcal{J}_t = E_t \sum_{i=0}^{\infty} \beta^i [\log(c_{t+i} - v c_{t-1+i}) - (1+\varphi)^{-1} h_{t+i}^{1+\varphi}]. \tag{A.1}$$

E_t is the expectation operator, $\beta \in (0,1)$ is the subjective discount factor, $v \in [0,1)$ governs the degree of habit formation and $\varphi > 0$ is inverse of the intertemporal elasticity of substitution. Households face the period-by-period budget constraint

$$c_t + d_t + \tau_t \leq w_t h_t + (1 + r_t^d) d_{t-1} + \Sigma_t. \tag{A.2}$$

On the right hand side are the wage income $w_t h_t$, deposits that are placed in a bank at the beginning-of-period grows with the net real interest rate $(1 + r_t^d) d_{t-1}$ and net profits remitted from firms owned by the households (non-financial and financial firms), net of start-up funds given to households that enter as bankers at time t, is denoted by Σ_t. Left hand side variables are end-of-period deposits d_t and lump sum taxes τ_t collected by the government.

The household chooses consumption c_t, hours worked h_t and how much deposit d_t to put in banks by taking prices, wages, interest rate on deposits, lump-sum taxes, net payouts to the household and initial endowment d_{-1} as given. The first order conditions of the utility maximization problem of the households are

$$\partial \mathcal{J}_t / \partial c_t \quad : \quad \lambda_t = (c_t - v c_{t-1})^{-1} - \beta v (E_t c_{t+1} - v c_t)^{-1}, \tag{A.3}$$

$$\partial \mathcal{J}_t / \partial h_t \quad : \quad w_t = \frac{h_t^{\varphi}}{\lambda_t}, \tag{A.4}$$

$$\partial \mathcal{J}_t / \partial d_t \quad : \quad 1 = \beta E_t \Lambda_{t,t+1} (1 + r_{t+1}^d). \tag{A.5}$$

Equation (A.3) defines the Lagrangian multiplier associated with the budget constraint, λ_t and equation (A.4) equates marginal disutility of labor to wages. Equation (A.5) represents the Euler equation for deposits and $\Lambda_{t,t+i}$ term in the equation equals λ_{t+i}/λ_t for $i \geq 0$. Since our analysis is restricted in a local neighborhood of the steady state, the budget constraint holds with equality.

A.1.1 Banks

There is only one type of bank in the economy: primary dealer banks, which are competitive and located on a continuum indexed by $j \in [0, 1]$. The role of banks is to collect deposits from households in order to provide resources to intermediate goods producers through purchasing claims issued by them and to lend to the government by purchasing one-period government bonds. The bank holds three types of assets to maximize the expected transfer to the household that owns the bank. Claims of firms and government bond holdings are a choice for the bank. However, extra government bond holdings are offloaded to primary dealer banks because of their primary dealer bank status are not a choice but an obligation.

The main financial friction in this economy arises from a moral hazard problem between bankers and depositors, leading to an endogenous leverage constraint. As in Gertler and Karadi (2011), the agency problem occurs because depositors believe that banks can divert a constant fraction of their assets in their own favor. Thus, if a bank wants to raise any external funding, banks' total assets must satisfy a leverage constraint so diverting should not be incentive compatible. When this leverage constraint binds, lenders adjust their position and limit their loans to bankers. Thus, bankers never divert funds.

Total assets of an intermediary j at the end of period t reads

$$a_{j,t} = q_t s_{j,t} + b^g_{j,t} + b^{prim}_{j,t}, \tag{A.6}$$

with $s_{j,t}$ denoting bank j's claims on intermediate good firms that have a relative price of q_t and a net real return of r^k_{t+1} at the beginning of next period. The bank holds two assets, $b^g_{j,t}$ and $b^{prim}_{j,t}$ where each asset pays a net real return of r^g_{t+1} and r^{prim}_{t+1} in the next period. Note that the bank cannot choose how much $b^{prim}_{j,t}$ to hold in its debt balances as $b^{prim}_{j,t}$ are government bond holdings that the bank is required to hold because of its primary dealer status. The balance sheet of bank j is then given by

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

where $d_{j,t}$ denotes household deposits made to the bank j and the last term $n_{j,t}$ denotes the bank j's net worth which can be dynamically written as the difference between asset earnings and liabilities that bear interest:

$$\begin{aligned} n_{j,t+1} &= (1 + r^k_{t+1}) q_t s_{j,t} + (1 + r^g_{t+1}) b^g_{j,t} + (1 + r^{prim}_{t+1}) b^{prim}_{j,t} - (1 + r^d_{t+1}) d_{j,t} \\ &= (r^a_{t+1} - r^d_{t+1})(a_{j,t} - b^{prim}_{j,t}) + (r^{prim}_{t+1} - r^d_{t+1}) b^{prim}_{j,t} + (1 + r^d_{t+1}) n_{j,t}, \end{aligned} \tag{A.7}$$

where r^a_{t+1} is the net ex-post real portfolio return excluding $b^{prim}_{j,t}$ debt holdings because of the intermediary's primary debt holding status. With portfolio weights $\omega_{j,t} = q_t s^k_{j,t}/(a_{j,t} - b^{prim}_{j,t})$ and $1 - \omega_{j,t} = b^g_{j,t}/(a_{j,t} - b^{prim}_{j,t})$, r^a_t satisfies:

$$1 + r^a_t = (1 + r^k_t)\omega_{j,t-1} + (1 + r^g_t)(1 - \omega_{j,t-1}). \tag{A.8}$$

Equation (A.7) illustrates that a banker j's net worth depends positively on the premiums of the returns earned on assets over the cost of deposits. It also shows that with a positive return difference between bankers' portfolio and deposits, net worth may explode and bankers may self-finance over time. As in the literature, particularly after Gertler and Karadi (2011), at any point in time a constant proportion of household members become bankers and the remaining ones become workers and an individual can switch between the two over time. The literature assumes a constant survival probability of a bank to rule out a possibility of complete self-financing. In particular, a bank operates with probability θ and exits with probability $1 - \theta$, during which retained capital is transferred to the household. The banker's objective is to maximize the expected value of the discounted terminal net worth of $V_{j,t}$ as follows

$$V_{j,t} = \max_{s^k_{j,t+1+i}, b^g_{j,t+1+i}} E_t \sum_{i=0}^{\infty} (1 - \theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} n_{j,t+1+i}, \tag{A.9}$$

which can be written recursively as,

$$V_{j,t} = \max_{s^k_{j,t+1}, b^g_{j,t+1}} \beta E_t \Big\{ \Lambda_{t,t+1} \left[(1 - \theta) n_{j,t+1} + \theta V_{j,t+1} \right] \Big\}. \tag{A.10}$$

With positive return rates, the solution to this maximization problem may generate indefinite expansion of assets. We rule out this by following Gertler and Karadi (2011) who introduce an agency problem between depositors and financial intermediaries. In particular, depositors believe that bankers can divert a constant fraction λ^* of total current assets, $a_{j,t}$. When depositors become aware of such a confiscation scheme, they would initiate a bank-run and liquidate the bank's net worth. Therefore, an incentive compatibility constraint $V_{j,t} \geq \lambda^* a_{j,t}$ must be satisfied to rule out a bank run in equilibrium. This inequality suggests that the cost to the banker of diverting assets should be greater or equal to the diverted portion of assets. So the maximization problem becomes:

$$\max_{s^k_{j,t}, b^g_{j,t}} V_{j,t} \quad \text{s.t.} \quad V_{j,t} \geq \lambda^* a_{j,t}.$$

We conjecture the solution can be linearly written as:

$$V_{j,t} = \nu_t a_{j,t} + \eta_t n_{j,t} = \nu^k_t q_t s_{j,t} + \nu^g_t b^g_{j,t} + \nu^{prim}_t b^{prim}_{j,t} + \eta_t n_{j,t}, \tag{A.11}$$

where

$$\begin{aligned}
\nu^k_t &= E_t \beta \Lambda_{t,t+1} \{ (1-\theta)(r^k_{t+1} - r^d_{t+1}) + \theta x^k_{t,t+1} \nu^k_{t+1} \}, & \text{(A.12)} \\
\nu^g_t &= E_t \beta \Lambda_{t,t+1} \{ (1-\theta)(r^g_{t+1} - r^d_{t+1}) + \theta x^g_{t,t+1} \nu^g_{t+1} \}, & \text{(A.13)} \\
\nu^{prim}_t &= E_t \beta \Lambda_{t,t+1} \{ (1-\theta)(r^{prim}_{t+1} - r^d_{t+1}) + \theta x^{prim}_{t,t+1} \nu^{prim}_{t+1} \}, & \text{(A.14)} \\
\eta_t &= E_t \beta \Lambda_{t,t+1} \{ (1-\theta)(1 + r^d_{t+1}) + \theta z_{t,t+1} \eta_{t+1} \}, & \text{(A.15)}
\end{aligned}$$

with $x^k_{t,t+1} = q_{t+1} s^k_{j,t+1} / (q_t s^k_{j,t})$, $x^g_{t,t+1} = b^g_{j,t+1} / b^g_{j,t}$, $x^{prim}_{t,t+1} = b^{prim}_{j,t+1} / b^{prim}_{j,t}$ and $z_{t,t+1} = n_{j,t+1} / n_{j,t}$. Among these recursive objects, ν^k_t represents the expected discounted marginal gain of an additional unit of claims on production firms, ν^g_t stands for the expected discounted marginal gain of holding an extra unit of government bonds, ν^{prim}_t is the expected discounted marginal gain of holding extra unit of government bonds because of the bank's primary dealer status, and lastly, η_t is the expected discounted marginal gain associated with an extra unit of net worth. We can now write Lagrangian as

$$\begin{aligned}\mathcal{L} &= V_{j,t} + \mu_t(V_{j,t} - \lambda^* a_{j,t}) = [(1+\mu_t)\nu_t^k - \mu_t\lambda^*]q_t s_{j,t}^k + [(1+\mu_t)\nu_t^g - \mu_t\lambda^*]b_{j,t}^g \\ &\quad + [(1+\mu_t)\nu_t^{prim} - \mu_t\lambda^*]b_{j,t}^{prim} + (1+\mu_t)\eta_t n_{j,t}, \end{aligned} \tag{A.16}$$

where $\mu_t \geq 0$ is the associated Lagrangian multiplier with the incentive constraint. Note that the functional uses equations (A.6) and (A.11). Associated first-order conditions are given as

$$\begin{aligned}\partial\mathcal{L}/\partial s_{j,t}^k &: \quad (1+\mu_t)\nu_t^k q_t - \mu_t\lambda^* q_t = 0, \\ \partial\mathcal{L}/\partial b_{j,t}^g &: \quad (1+\mu_t)\nu_t^g - \mu_t\lambda^* = 0.\end{aligned}$$

The solution for v_t^k and v_t^g yields:

$$\nu_t^k = \frac{\mu_t\lambda^*}{1+\mu_t}, \qquad \nu_t^g = \frac{\mu_t\lambda^*}{1+\mu_t}.$$

We therefore obtain $\nu_t^k = \nu_t^g \equiv \nu_t$. Notice that we do not take the derivative of the Lagrangian with respect to $b_{j,t}^{prim}$ as it is not a choice for the bank but rather an obligation put forth by the government on primary dealer banks. Rewriting equation (A.11) as $\nu_t(a_{j,t} - b_{j,t}^{prim}) + \nu_t^{prim} b_{j,t}^{prim} + \eta_t n_{j,t}$ and combining it with equations (A.7) and (A.9) yields an expression for ν_t

$$\nu_t = E_t\beta\Lambda_{t,t+1}\left\{(1-\theta)(r_{t+1}^a - r_{t+1}^d) + \theta x_{t,t+1}\nu_{t+1}\right\}, \tag{A.17}$$

with $x_{t,t+1} = (a_{j,t+1} - b_{j,t+1}^{prim})/(a_{j,t} - b_{j,t}^{prim})$. With the complementary slackness condition

$$\mu_t(V_{j,t} - \lambda^* a_{j,t}) = \mu_t[(\nu_t - \lambda^*)(a_{j,t} - b_{j,t}^{prim}) + (\nu_t^{prim} - \lambda^*)b_{j,t}^{prim} + \eta_t n_{j,t}] = 0.$$

One can obtain that $\mu_t = \nu_t/(\lambda^* - v_t)$ and the multiplier μ_t is positive only if $\lambda^* > \nu_t > 0$.

As we approximate the stochastic equilibrium around the deterministic steady state, we are confined to cases where the incentive constraint of banks always binds (so $\mu_t > 0$). In steady state calculations, we verify that this holds. We can then proceed by using $\mu_t > 0$ and $\nu_t^k = \nu_t^g = \nu_t$ which ties the bank net worth through the leverage constraint as follows:

$$a_{j,t} - b_{j,t}^{prim}\left(\frac{\nu_t^{prim} - \nu_t}{\lambda^* - \nu_t}\right) = \phi_t n_{j,t}, \qquad \phi_t = \frac{\eta_t}{\lambda^* - \nu_t}. \tag{A.18}$$

A.2 Production

We now turn to the production and investment side of the economy. There are four types of firms in the economy, all of which are owned by the households: perfectly competitive intermediate goods firms that produce differentiated goods $y_{i,t}$, (ii) a monopolistically competitive retail firms whose function is to re-package one intermediate output $y_{i,t}$ into one retail output $y_{f,t}$, (iii) competitive capital goods producers whose function in the economy is to repair depreciated capital after intermediate goods production and build new productive capital by combining with an investment good, and (iv) perfectly competitive final goods producers that combine retails goods into a single good y_t.

A.2.1 Final goods producers

Final goods producers combine different varieties $y_{f,t}$, that are sold at the monopolistically determined price $P_{f,t}$ by retailers, into a final good that sells at the competitive price P_t, according to the constant returns-to-scale technology,

$$y_t = \left[\int_0^1 y_{f,t}^{1-\frac{1}{\epsilon}} df\right]^{1-\frac{1}{\epsilon}}, \tag{A.19}$$

where ϵ is the elasticity of substitution among intermediate goods. The profit maximization problem of final goods producers is given by

$$\max_{y_{f,t}} P_t \left[\int_0^1 y_{f,t}^{1-\frac{1}{\epsilon}} df \right]^{1-\frac{1}{\epsilon}} - \int_0^1 P_{f,t} y_{f,t} df, \tag{A.20}$$

along with the zero profit condition implies that the optimal variety demand is

$$y_{f,t} = \left(\frac{P_{f,t}}{P_t} \right)^{-\epsilon} y_t, \tag{A.21}$$

with retail prices $P_{f,t}$ and the aggregate price level P_t satisfying

$$P_t = \left[\int_0^1 P_{f,t}^{1-\epsilon} df \right]^{\frac{1}{1-\epsilon}}. \tag{A.22}$$

A.2.2 Retail firms

Retailers' function in the economy is to re-package intermediate goods $y_{i,t}$ at the market price P_t^m and turn them into retail goods $y_{f,t}$ to be sold at the monopolistically determined price $P_{f,t}$. Retailers use one unit of intermediate output to produce one unit of retail output, that is, $y_{f,t} = y_{i,t}$. Thus, multiplying this value with the difference in sale and purchase price would give the retailer f's nominal profit, that is, $(P_{f,t} - P_t^m) y_{f,t}$.

After describing the instantaneous nominal profit of retailers in period t, we turn to the firm's price decision following Calvo (1983). In each period, a fraction of (1 - ψ) firms, where $0 \leq \psi < 1$, gets to charge a new price $\widetilde{P}_t$ and the other fraction, ψ, must charge the previous period's prices times average inflation π_a regardless of the time elapsed since the last price change. Hence, Calvo type implies that, with the new price commitment in period t is denoted by P_t, the price index follows the recursive form given by

$$P_t = \left((1-\psi) \widetilde{P}_t^{1-\epsilon} + \psi \pi_a^{1-\epsilon} P_{t-1}^{1-\epsilon} \right)^{1-\epsilon}. \tag{A.23}$$

Expected value of future profits for retailers are then obtained as the sum of two parts: future states in which price is still $\widetilde{P}_t$ and future states where the price is not $\widetilde{P}_t$, thus $\widetilde{P}_t$ becomes irrelevant. We can then write

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

$$\overbrace{E_t \sum_{s=0}^{\infty} (\beta\psi)^s \Lambda_{t,t+s} (P_t/P_{t+s}) \left[\widetilde{P}_t - P^m_{t+s}\right] y_{f,t+s}}^{\text{future profits over all future states with firm price } \widetilde{P}_t} + X_t,$$

where X_t is the present value of all other future states with price different than $\widetilde{P}_t$, thus $\frac{dX_t}{\widetilde{P}_t} = 0$. By substituting out the demand curve, $y_{f,t} = (P_{f,t}/P_t)^{-\epsilon} y_t$, expected value of future profits becomes

$$E_t \sum_{s=0}^{\infty} (\beta\psi)^s \Lambda_{t,t+s} \frac{P_t}{P_{t+s}} P^{\epsilon}_{t+s} y_{t+s} \left[\widetilde{P}_t^{1-\epsilon} - P^m_{t+s} \widetilde{P}_t^{-\epsilon}\right]. \tag{A.24}$$

Now, let's differentiate equation A.24 with respect to $\widetilde{P}_t$

$$E_t \sum_{s=0}^{\infty} (\beta\psi)^s \Lambda_{t,t+s} \frac{P_t}{P_{t+s}} P^{\epsilon}_{t+s} y_{t+s} \left[(1-\epsilon)\widetilde{P}_t^{-\epsilon} + \epsilon P^m_{t+s} \widetilde{P}_t^{-\epsilon-1}\right] = 0,$$

$$E_t \sum_{s=0}^{\infty} (\beta\psi)^s \Lambda_{t,t+s} \frac{P_t}{P_{t+s}} P^{\epsilon}_{t+s} y_{t+s} \left[\widetilde{P}_t - \frac{\epsilon}{\epsilon - 1} P^m_{t+s}\right] = 0. \tag{A.25}$$

Notice that with $\psi = 0$, price becomes fixed markup over marginal cost.

Defining the relative price $P_{m,t} = P^m_t / P_t$, the first-order condition is given by

$$\frac{\widetilde{P}_t}{P_t} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{s=0}^{\infty} (\beta\psi)^s \lambda_{t+s} P^{\epsilon}_{t+s} P_t^{-\epsilon} P_{m,t+s} y_{t+s}}{E_t \sum_{s=0}^{\infty} (\beta\psi)^s \lambda_{t+s} P^{\epsilon-1}_{t+s} P_t^{1-\epsilon} y_{t+s}}. \tag{A.26}$$

Let's $\widetilde{\pi} = \widetilde{P}_t / P_t$ and the gross inflation rate $\pi_t = P_t / P_{t-1}$ so that we can write equations (A.23) and (A.26) more conveniently as

$$1 = (1-\psi)(\widetilde{\pi})^{1-\epsilon} + \psi \pi_a^{\epsilon-1} \pi_t^{\epsilon-1}, \tag{A.27}$$

$$\pi_t^* = \frac{\epsilon}{\epsilon - 1} \frac{\zeta_t}{Z_t}, \tag{A.28}$$

where $\zeta_t = \lambda_t P_{m,t} y_t + \beta \psi E_t \pi_{t+1}^{\epsilon} \zeta_{t+1}$, $Z_t = \lambda_t y_t + \beta \psi E_t \pi_{t+1}^{\epsilon-1} Z_{t+1}$ and π_a is taken to be 1 for simplicity.

A.2.3 Intermediate goods producers

Intermediate goods producers, indexed by i, produce variety $y_{i,t}$ using the constant returns-to-scale production technology. Let z_t and ξ_t denote total factor productivity and the quality of capital shock (Gertler and Karadi (2011) define $\xi_t k_{i,t-1}$ as the effective quantity of capital). We can then write the production as

$$y_{i,t} = z_t (\xi_t k_{i,t-1})^{\alpha} h_{i,t}^{1-\alpha}.$$

Firms choose the level of capital and labor used in the production. Total factor productivity z_t and the quality of capital shock ξ_t follows

$$z_t = \rho_z \log z_{t-1} + \varepsilon_{z,t},$$
$$u_t = \rho_u \log u_{t-1} + \varepsilon_{\xi,t},$$

with $\rho_z, \rho_u \in [0, 1)$ and $\varepsilon_{z,t} \sim N(0, \sigma_z^2)$, $\varepsilon_{u,t} \sim N(0, \sigma_u^2)$.

Producer i rents labor services $h_{i,t}$ at the wage rate w_t from households and borrows from banks for its finances with the following timing. At the end of period t, the firm acquires capital $k_{i,t}$ to be used in the next period's production in period $t+1$. To finance, the producer borrows $s_{i,t}^k$ units of claims at a price q_t from banks and promises a state-contingent net real return of r_{t+1}^k at the beginning of the next period. After each production, the firm sells the depreciated effective capital $(1-\delta)\xi_t k_{i,t-1}$ at a price q_t to capital producing firms.

Let $P_{m,t}$ be the price of intermediate goods output. Then producer i's real profits in period t are given by

$$\Pi_{i,t} = P_{m,t} z_t (\xi_t k_{i,t-1})^{\alpha} h_{i,t}^{1-\alpha} + q_t(1-\delta)\xi_t k_{i,t-1} - (1+r_t^k) q_{t-1} k_{i,t-1} - w_t h_{i,t}. \tag{A.29}$$

Intermediate goods firms then maximize

$$\mathcal{W}_t = E_t \sum_{s=0}^{\infty} \beta^s \Lambda_{t,t+s} \Pi_{i,t+s}. \tag{A.30}$$

The corresponding derivatives to solve this profit maximization problem are as follows:

$$\begin{aligned}
\partial \mathcal{W}_t / \partial h_{i,t}: &\quad w_t = (1-\alpha) P_{m,t} y_{i,t} / h_{i,t}, \\
\partial \mathcal{W}_t / \partial k_{i,t}: &\quad E_t \beta \Lambda_{t,t+1} q_t (1+r_{t+1}^k) = E_t \beta \Lambda_{t,t+1} [\alpha P_{m,t+1} y_{i,t+1} / k_{i,t} + q_{t+1}(1-\delta)\xi_{t+1}].
\end{aligned}$$

The first order conditions to this problem with perfect competition in intermediate goods market assumption determine the return on capital, optimal factor demands and the relative intermediate output price:

$$1 + r_t^k = \frac{\alpha P_{m,t} \frac{y_{i,t}}{k_{i,t-1}} + q_t(1-\delta)\xi_t}{q_{t-1}}, \tag{A.31}$$

$$h_{i,t} = (1-\alpha) P_{m,t} w_t^{-1} y_{i,t}, \tag{A.32}$$

$$k_{i,t-1} = \alpha P_{m,t} y_{i,t} \frac{1}{q_{t-1}(1+r_t^k) - q_t(1-\delta)}, \tag{A.33}$$

$$P_{m,t} = \alpha^{-\alpha}(1-\alpha)^{\alpha-1} z_t^{-1} \{ w_t^{1-\alpha} [q_{t-1}(1+r_t^k) - q_t(1-\delta)]^{\alpha} \}. \tag{A.34}$$

A.3 Capital producing firms

After intermediate goods production in period t, $(1-\delta)\xi_t k_{t-1}$ unit of depreciated capital is purchased at a per-unit price of q_t by competitive capital producers owned by households. These firms repair the depreciated capital by combining it with an investment good to produce new capital goods to sell it back to the intermediate goods producers and profits are rebated to the household. Capital producers incur adjustment costs while producing new capital. The investment adjustment cost function is a quadratic function of the investment growth and is given as follows

$$\Psi\left(\frac{i_t}{i_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2. \tag{A.35}$$

Capital producing firms require i_t units of investment good at a price of unity and incur $\Psi\left(\frac{i_t}{i_{t-1}}\right)$ unit of adjustment cost per unit of investment to be able to produce new capital goods i_t, which are sold at a price q_t. Thus, a capital producer makes an investment decision each period. The maximization problem of the capital producer is then

$$\max_{i_t+s} \sum_{s=0}^{\infty} E_0 \beta^s \Lambda_{t,t+s} \left\{ q_{t+s} i_{t+s} - \Psi\left(\frac{i_{t+s}}{i_{t+s-1}}\right) q_{t+s} i_{t+s} - i_{t+s} \right\}. \tag{A.36}$$

The optimality condition for investment to solve a capital producer's discounted profits gives the following "Q"-investment relation for capital goods:

$$q_t\left[1 - \Psi\left(\frac{i_t}{i_{t-1}}\right)\right] = 1 + q_t \frac{i_t}{i_{t-1}} \Psi'\left(\frac{i_t}{i_{t-1}}\right) - \beta E_t \Lambda_{t,t+1} q_{t+1} \frac{i_{t+1}}{i_t} \Psi'\left(\frac{i_{t+1}}{i_t}\right). \tag{A.37}$$

Finally, the aggregate physical capital stock of the economy evolves according to

$$k_{t+1} = (1-\delta)\xi_{t+1} k_t + \left[1 - \Psi\left(\frac{i_t}{i_{t-1}}\right)\right] i_t, \tag{A.38}$$

with $\gamma \geq 0$ and $\delta \in [0,1]$.

A.4 Government policy

The government purchases final goods and undertakes borrowing with one-period bonds to finance its operations.

A.4.1 Government purchases

Government purchases g_t consist of a stochastic process $\widetilde{g}_t$ which follows an autoregressive process. That is,

$$g_t = \widetilde{g}_t, \tag{A.39}$$

with $log\left(\frac{\widetilde{g}_t}{\overline{g}}\right) = \rho^g log\frac{\widetilde{g_{t-1}}}{\overline{g}} + \varepsilon_t^g$, where $\varepsilon_t^g \sim N(0, \sigma_g^2)$ and $\rho^g \in [0,1)$, $\overline{g} > 0$.

A.4.2 Borrowing through financial sector

Following Kirchner and van Wijnbergen (2016), let b_{t-1} denote the government's outstanding debt holdings at the beginning of a period. Taxes follow the following rule

$$\tau_t = \overline{\tau} + \kappa_b(b_{t-1} - b), \tag{A.40}$$

with $\kappa_b \geq 0$ and $\overline{\tau} > 0$. This tax rule ensures fiscal solvency for any finite initial level of debt Bohn (1998). As noted before, the government's borrowing decision has two ingredients, b^g and b^{prim}, of which banks can anticipate the first part but b^{prim} comes as a surprise.

The stock of anticipated government debt that are held by banks therefore satisfies the following law of motion:

$$b_t^g = g_t - \tau_t + (1 + r_t^g)b_{t-1}^g + (1 + r_t^{prim})b_{t-1}^{prim} - b_t^{prim}. \tag{A.41}$$

Government purchases of b^{prim} follows an autoregressive process such that $b_{t+1}^{prim} = \widetilde{b_{t+1}^{prim}}$ where

$$log\left(\frac{b_{t+1}^{prim}}{\overline{b^{prim}}}\right) = \rho^{prim} log\left(\frac{b_{t}^{prim}}{\overline{b^{prim}}}\right) + \varepsilon_{t+1}^{prim}, \tag{A.42}$$

where $\varepsilon_{t+1}^{prim} \sim N(0, \sigma_{prim}^2)$ and $\rho^{prim} \in [0,1)$, $\overline{b^{prim}} > 0$.

A.5 Monetary policy

The last bit of the model concerns the arrangement of risk-free nominal interest rate on deposits i_t^n. It is assumed that monetary policy is characterized by a simple Taylor-rule to stabilize inflation. Let i^n be the steady state nominal rate, then

$$i_t^n = (1-\rho_r)\left[i^n + \kappa_\pi(\pi_t - \bar{\pi}) + \kappa_y\left(\log(y_t) - log(y_{t-1})\right)\right] + \rho_i i_{t-1}^n + \varepsilon_{i,t}, \tag{A.43}$$

with output gap coefficient of the Taylor rule $\kappa_y \geq 0$ and inflation coefficient of the Taylor rule $\kappa_\pi > 1$, both jointly determine the strength of the monetary authority's reaction to fluctuations in inflation and output. Taylor rule also allows for interest rate smoothing with parameter $\rho_i \in [0,1)$. The model also allows for an exogenous shock to monetary policy $\varepsilon_{i,t} \sim N(0, \sigma_i^2)$. The parameter $\bar{\pi} \geq 1$ stands for the inflation target.

The link between nominal and real interest rates is given by the following Fisher relation which defines the ex-post real interest rate on deposits:

$$1 + r_t^d = \frac{(1 + i_{t-1}^n)}{\pi_t}. \tag{A.44}$$

Notice that the interest rate on deposits is determined by the central bank. However, the interest rate on government bonds is endogenously determined. As noted before, the interest rate of primary dealer banks follows

$$r_t^{prim} = r_t^d. \tag{A.45}$$

A.6 Aggregation and market clearing

A.6.1 Financial variables

The evolution of bank j's net worth in equation (A.7) can be re-written as follows

$$n_{j,t+1} = \left[(r^a_{t+1} - r^d_{t+1}) \frac{\nu^{prim}_t - \lambda^*}{\lambda^* - \nu_t} + r^{prim}_{t+1} - r^d_{t+1} \right] b^{prim}_{j,t} + [(r^a_{t+1} - r^d_{t+1})\phi_t + 1 + r^d_{t+1}] n_{j,t}, \tag{A.46}$$

by using the following equality:

$$a_{j,t} - b^{prim}_{j,t} = \frac{\nu^{prim}_t - \lambda^*}{\lambda^* - \nu_t} b^{prim}_{j,t} + \phi_t n_{j,t}.$$

As we focus on symmetric equilibrium, all banks have the same asset prices and thus have identical portfolio weights, that is, $\omega_{j,t} = \omega_t \; \forall \; j$. With symmetric equilibrium assumption, we can also aggregate variables. The aggregate asset demands becomes $s^k_t = \int_0^1 s^k_{j,t} dj$, $b^g_t = \int_0^1 b^g_{j,t} dj$ and $n_t = \int_0^1 n_{j,t}$. With these, the subscript j in all financial variables would drop

$$\begin{aligned} q_t s^k_t &= \omega_t \left(\frac{\nu^{prim}_t - \lambda^*}{\lambda^* - \nu_t} b^{prim}_{j,t} + \phi_t n_{j,t} \right), \\ b^g_t &= (1 - \omega_t) \left(\frac{\nu^{prim}_t - \lambda^*}{\lambda^* - \nu_t} b^{prim}_{j,t} + \phi_t n_{j,t} \right), \end{aligned}$$

Recall that to rule out the possibility that bankers can self-finance projects with their accumulated net worth so that they would not need deposits; it is assumed that a constant θ share survives to the next period. Also, to make the ratio of bankers in the economy constant, $(1-\theta)$ share of households become bankers. These new entrants are remitted with start-up funds from households equal to a fraction $\frac{\chi}{1-\theta}$ of aggregate net worth n_t at the end of period $t-1$. Aggregate net worth n_t, then, is the sum of total net worth of the banks that continue operating ($n_{c,t}$) and total net worth of newly entering banks

($n_{e,t}$). Summing the net worth equation (A.46) across bankers and then multiplying it with bankers' survival probability rate would give the total net worth of continuing bankers

$$n_{c,t} = \theta\left(\left[(r_t^a - r_t^d)\frac{\nu_{t-1}^{prim} - \lambda^*}{\lambda^* - \nu_{t-1}} + r_t^{prim} - r_t^d\right] b_{t-1}^{prim} + \left[(r_t^a - r_t^d)\phi_{t-1} + 1 + r_t^d\right]\right) n_{t-1}.$$

It follows that $n_{e,t}$ equals χn_{t-1}. Thus, aggregate net worth can be represented

$$n_t = \left\{\theta\left(\left[(r_t^a - r_t^d)\frac{\nu_{t-1}^{prim} - \lambda^*}{\lambda^* - \nu_{t-1}} + r_t^{prim} - r_t^d\right] b_{t-1}^{prim} + \left[(r_t^a - r_t^d)\phi_{t-1} + 1 + r_t^d\right]\right) + \chi\right\} n_{t-1}. \tag{A.47}$$

Using security aggregation issued by intermediate goods producers to bankers along with market clearing conditions

$$s_t^k = k_t. \tag{A.48}$$

Similarly, aggregate bonds issued by the government to banks satisfy

$$b_t^g + b_t^{prim} = b_t. \tag{A.49}$$

The aggregate asset portfolio follows by integrating over individual portfolios:

$$a_t = \int_0^1 a_{j,t} dj = q_t \int_0^1 s_{j,t}^k dj + \int_0^1 b_{j,t}^g dj + \int_0^1 b_{j,t}^{prim} dj = q_t s_t^k + b_t^g + b_t^{prim}. \tag{A.50}$$

Aggregate consumer deposits held in banks follow by integrating over individual balance sheets:

$$d_t = \int_0^1 d_{j,t} dj = \int_0^1 a_{j,t} dj - \int_0^1 n_{j,t} dj = a_t - n_t. \tag{A.51}$$

A.6.2 Factor demands

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

$$\begin{aligned} h_{i,t} &= \frac{(1-\alpha)P_{m,t}y_{f,t}}{w_t}, \\ k_{i,t-1} &= \frac{\alpha P_{m,t}y_{f,t}}{q_{t-1}(1+r_t^k) - q_t(1-\delta)\xi_t}. \end{aligned}$$

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

$$\begin{aligned} h_t &= \frac{(1-\alpha)P_{m,t}y_t\Phi_t}{w_t}, \\ k_{t-1} &= \frac{\alpha P_{m,t}y_t\Phi_t}{q_{t-1}(1+r_t^k) - q_t(1-\delta)\xi_t}, \end{aligned}$$

where Φ_t is a price dispersion and follows $\int_0^1 (P_{f,t}/P_t)^{-\epsilon}df$. Using Yun (1996) distortion, its recursive representation is given as

$$\Phi_t = (1-\psi)(\widetilde{\pi}_t)^{-\epsilon} + \psi\pi_t^{\epsilon}\Phi_{t-1}. \tag{A.52}$$

The aggregate capital-labor ratio follows as

$$\frac{k_{t-1}}{h_t} = \frac{\alpha}{1-\alpha}\frac{w_t}{q_{t-1}(1+r_t^k) - q_t(1-\delta)\xi_t}. \tag{A.53}$$

A.6.3 Aggregate supply

Integrating $y_{i,t} = z_t(\xi_t k_{i,t-1})^{\alpha}h_{i,t}^{1-\alpha}$ over intermediate goods producers i gives

$$z_t(k_{t-1})^{\alpha}h_t^{1-\alpha}.$$

Integrating equation (A.21) over f yields output of the final good:

$$y_t \Phi_t = z_t (\xi_t k_{t-1})^{\alpha} h_t^{1-\alpha}. \tag{A.54}$$

A.6.4 Goods market clearing

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

$$c_t + i_t + g_t = y_t. \tag{A.55}$$

A.7 Definition of competitive equilibrium

A competitive equilibrium is defined by the set of sequences of prices $\left\{ w_t, q_t, \pi_t, \widetilde{\pi}_t, P_{m,t}, r_t^d, r_t^a, r_t^k, r_t^g, r_t^{prim} \right\}_{t=0}^{\infty}$, shadow prices $\left\{ \lambda_t \right\}_{t=0}^{\infty}$, allocations $\left\{ c_t, h_t, i_t, k_t, y_t, \zeta_t, Z_t, \Phi_t, \omega_t, \nu_t^k, \nu_t^g, \eta_t, \phi_t, n_t, s_t^k, b_t^g, b_t^{prim}, a_t, d_t, b_t \right\}_{t=0}^{\infty}$, fiscal policies $\left\{ g_t, \tau_t, b_t^{prim} \right\}_{t=0}^{\infty}$, a monetary policy $\left\{ r_t^n \right\}_{t=0}^{\infty}$, and sequences of shocks $\left\{ a_t, \xi_t, b_t^{prim} \right\}_{t=0}^{\infty}$ and initial conditions such that conditions (A.1)-(A.55), dropping the subscripts for individual intermediaries where appropriate, and the transversality conditions are satisfied.

- Given exogenous processes, initial conditions, government policy, and prices, the allocations solve the utility maximization problem of households (A.1)–(A.2); the net worth maximization problem of bankers (A.10)–(A.11); and the profit maximization problems of final goods producers (A.20), retail firms (A.24), intermediate goods producers (A.29)–(A.30), and capital producers (A.36).

- Transversality conditions are satisfied, and markets clear out.

The model is solved by a first-order perturbation around the non-stochastic steady state which is derived below.

B The steady state

The non-stochastic steady state is defined as a situation in which all variables are constant and where all sources of uncertainty are held constant at its unconditional mean. We derive our solutions for a steady state with zero inflation for simplicity (so that Fisher relation in equation (A.44) is simplified). This is achieved by setting inflation target rate $\bar{\pi} = 1$ in equation (A.43). In this case, Taylor rule implies $\pi = 1$.

Using the Euler equation in equation (A.5), the steady state real interest rate on deposits

$$r^d = \frac{1}{\beta} - 1,$$

and using the Fisher relation in equation (A.44), the steady state risk-free nominal interest rate is obtained as follows:

$$i^n = r^d.$$

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

To solve the steady state variables of primary dealer banks, we guess and verify that an equilibrium exists with $r^k - r^d = r^{b,B} - r^d = \Gamma > 0$.

To solve for the variables that are determined by the financial intermediaries' problem, we guess and verify that there is an equilibrium. 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. Given r^d, we obtain $r^k = r^d + \Gamma$ and $r^{b,B} = r^k$. From the equation for r^p, it follows that $r^p = r^k$. Using equations

A.17, A.14, A.15 and A.47 we obtain

$$\begin{aligned}
\nu &= \frac{\beta(1-\theta)(r^p - r^d)}{1-\beta\theta}, \\
\nu^{prim} &= \frac{\beta(1-\theta)(r^{prim} - r^d)}{1-\beta\theta}, \\
\eta &= \frac{\beta(1-\theta)(1+r^d)}{1-\beta\theta}, \\
\lambda &= \nu + \frac{\eta}{\phi}, \\
\chi &= 1 - \theta b^{prim}\left[\Gamma\frac{\nu^{prim}-\lambda^*}{\lambda^*-\nu} + r^{prim} - r^d\right] - \theta\left(\Gamma\phi + 1 + r^d\right).
\end{aligned}$$

We can also ensure that the incentive constraint binds in the steady state as $\lambda - \nu = \eta/\phi = (1-\theta)\beta(1+r^d)\phi^{-1}(1-\theta\beta)^{-1} > 0$.

Further, the interest rate on the debt that is offloaded on primary dealer banks satisfies $r^{prim} = r^d$.

The steady state solutions for the production allocation are obtained for a zero inflation steady state by setting the inflation target to 1. Using equation (A.28), we obtain

$$\begin{aligned}
\widetilde{\pi} &= \Phi = 1, \\
\zeta &= \frac{P_m \lambda y}{1-\beta\psi}, \\
Z &= \frac{\lambda y}{1-\beta\psi},
\end{aligned}$$

such that $\frac{\zeta}{Z} = P_m$, $P_m = \frac{\epsilon-1}{\epsilon}$. With a and u in the production function both equal 1, the final output reads $y = k^\alpha h^{1-\alpha}$. Using equation (A.34) under intermediate goods producers problem, real wage is derived as

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

The capital-labor ratio follows

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

Using the resource constraint, consumption to output at the steady state follows

$$\frac{c}{y} = 1 - \frac{i}{y} - \frac{g}{y},$$

where $\frac{g}{y}$ is calibrated to the data. Using the household's first-order conditions, following steady state values for λ and hours worked are obtained:

$$\begin{aligned} \lambda &= \frac{1-\beta v}{(1-v)(c/y)y}, \\ h^{\varphi} &= \frac{(1-\beta v)w}{(1-v)(c/y)y}. \end{aligned} \tag{B.1}$$

Steady state final output is then obtained using $y = k^{\alpha}h^{1-\alpha}$ and equation (B.1) as

$$y^{1+\frac{1}{\varphi}} = \left(\frac{k}{h}\right)^{\alpha}\left(\frac{(1-\beta v)w}{(1-v)(c/y)}\right)^{\frac{1}{\varphi}}.$$

Using the capital accumulation in equation A.38, steady state investment can be obtained $i = \delta k$. Re-writing this as $i = \delta\frac{k}{h}h$ helps when deriving the steady state ratio of investment over GDP so that we can use capital-labor ratio and the steady state real wage obtained above. Thus,

$$\frac{i}{y} = \delta\left(\frac{k}{h}\right)^{1-\alpha} = \frac{\delta\alpha P_m}{r^k+\delta}.$$

Therefore, steady state consumption, investment, and government spending then are:

$$\begin{aligned} c &= \frac{c}{y}y, \\ i &= \frac{i}{y}y, \\ g &= \frac{g}{y}y. \end{aligned}$$

We now specify the government spending and borrowing processes such that $\frac{g}{y}$ $\frac{b^{prim}}{y}$ are taken as given by setting $\overline{g} = g$ and $\overline{b^{prim}} = b^{prim}$. The steady state level of claims on firms by banks are obtained using the market clearing condition $s^k = k$, where steady state capital stock follows from $i = \delta k$. The steady state ratio of anticipated and unanticipated government debt over GDP, b^g/y and b^{prim}/y, are taken as given and the steady state level of taxes $\overline{\tau}$ follows,

$$\begin{aligned} b^g &= \frac{b^g}{y} y, \\ b^{prim} &= \frac{b^{prim}}{y} y, \\ \overline{\tau} &= g + b^g r^g + b^{prim} r^{prim}. \end{aligned}$$

With $\overline{\tau}$, the steady state level of the banks' outstanding government bond holdings follows from its law of motion provided in equation (A.41):

$$b^g = \frac{\overline{\tau} - g - b^{prim} r^{prim}}{r^g}.$$

The steady state portfolio weight of bank claims on intermediate goods producers follows as $\omega = s^k/(b^g + s^k)$. The remaining steady state financial variables are as follows

$$\begin{aligned} n &= \frac{1}{\phi}\left(\frac{s^k}{\omega} - \frac{\nu^{prim} - \lambda^*}{\lambda^* - \nu} b^{prim}\right), \\ a &= b^{prim}\left(1 + \frac{\nu^{prim} - \lambda^*}{\lambda^* - \nu}\right) + \phi n, \\ d^B &= a - n, \\ b^{prim} &= b - b^g, \\ d &= d^B. \end{aligned}$$

Rearranging these terms, we can then write steady state s^k with its relation to b^{prim} as follows:

$$s^k = \omega \frac{\phi}{1-\phi} \left(1 + \frac{1}{\phi} \frac{\nu^{prim} - \lambda^*}{\lambda^* - \nu}\right) b^{prim} - \omega \frac{\phi}{1-\phi} d^B. \tag{B.2}$$

Using steady state values of ν^{prim} and ν, we can compute the elasticity between changes in the exogenous government debt holdings (b^{prim}) and changes in the loans to firms (s^k). In particular,

$$\frac{\partial ln(s^k)}{\partial ln(b^{prim})} = \frac{\partial s^k}{\partial b^{prim}} \frac{b^{prim}}{s^k} = \kappa_\nu \frac{b^{prim}}{\kappa_\nu b^{prim} - \kappa_\omega}, \tag{B.3}$$

where κ_ν and κ_ω are $\omega \frac{\phi}{1-\phi} \left(1 + \frac{1}{\phi} \frac{\nu^{prim} - \lambda^*}{\lambda^* - \nu}\right)$ and $\omega \frac{\phi}{1-\phi} d^B$, respectively.

Thus, using the steady-state values of ν^{prim} and ν, which are mainly dependent on spreads and deposits, we can pin-down partial equilibrium responses of loans to changes in b^{prim} and target this elasticity. Thus, the main parameter in equation (B.2) to target this elasticity is ϕ. As a word of caution, one needs to verify that proportional transfer to the entering bankers remains positive while targeting ϕ to match the elasticity.

C Results when the return of b^{prim} is equalized to b^g

In this section, we equalize the return of b^{prim} to b^g to repeat our model analysis. Recall that our identifying assumption in Section 3.1 in the main text is based on the fact that a part of bond purchases in the primary dealer market is exogenous (i.e. the amount that would have not otherwise been acquired). Thus, this slightly lower rate of return on b^{prim} works as the cost of being a primary dealer as this is the amount that would have not otherwise been acquired. For this, we used the interest rate spread Γ = 0.0330/4 to determine the rate of return difference. The motivating assumption we have in the main text is that banks would have lent to firms otherwise. Yet, as we plot below in Figure C.1, these IRFs of the two rates of returns are highly similar. We also repeat the analysis by assuming that both exogenous and endogenous components of public debt holdings have the same rate of return. Below, without changing any parameter values, we report the model outcome when the return on the exogenous component of government debt holdings is taken to be the same as the endogenous one.

Table 1 shows that Business Cycle Statistics: Data vs. Model Economy remains almost identical to the one provided in the main text.

Our IRF figures are also very similar qualitatively to its counterpart in the main text, albeit with some minor differences. In the model, an increase in b^{prim} leads to a decrease in loans because incentive compatibility constraint prevents the possibility of expanding the size of banks' balance sheets, and therefore induces a reduction in the other assets (endogenous public debt holdings and loans to firms). We still retain this main mechanism, but the financial accelerator mechanism is somewhat muted as the cost of holding b^{prim} is now reduced. Notice that in Figures C.2 and C.4, with muted effects on the cost of holding b^{prim}, bank's net worth responds slightly positively to a b^{prim} which the bank uses to smooth the adverse effects of the shock. Thus, even though crowding out effects remain, they are quantitatively lower without new calibration.

Again, we observe qualitatively similar results in Figures C.3 and C.5 with their counterparts in the main text. These figures show that the entire economy is affected by this chain reaction as the effects feed through by lowering workers' wages and discouraging labor supply which tightens household's budget constraint and leads to a decline in consumption. Lastly, our welfare analysis in Figure C.6 also shows that welfare is always lower in the economy with borrowing shocks and the degree of the fall in welfare varies depending on the size of the shock.

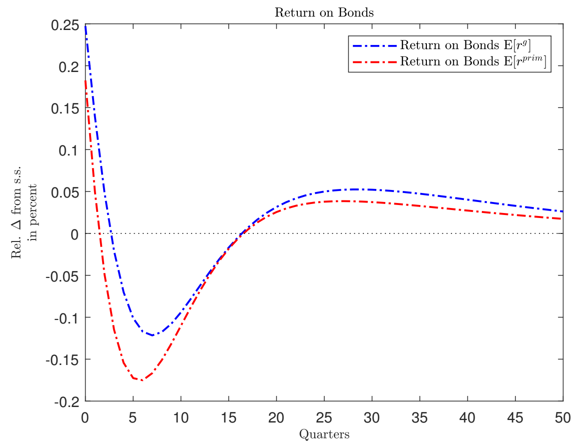

Figure C.1: Impulse-response functions of asset returns.

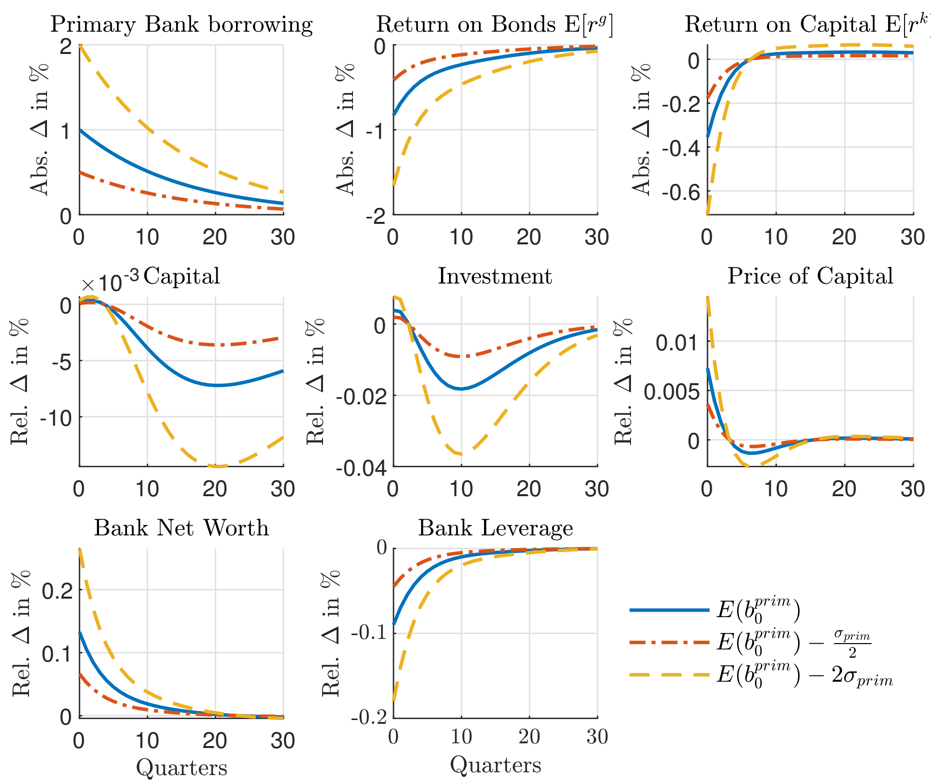

Figure C.2: Impulse-response functions of selected model variables to a surprise borrowing shock of 1% of GDP relative to steady state in quarter 0. The figures show deviations from the steady state.

Table 1: Business Cycle Statistics: Data vs. Model Economy

	Standard dev		Autocorrelations		Cross corr. to GDP	
	Data (1)	Model (2)	Data (3)	Model (4)	Data (5)	Model (6)
GDP (Y)	1.27	1.40	0.74	0.89	1.00	1.00
	(0.15)	[-0.92]	(0.23)	[-0.65]		
Consumption (C)	1.06	0.89	0.80	0.94	0.82	0.90
	(0.10)	[1.79]	(0.18)	[-0.76]		
Investment (I)	6.31	6.28	0.34	0.92	0.64	0.78
	(0.95)	[0.04]	(0.13)	[-4.34]		
Government spending (G)	4.96	3.64	0.68	0.63	0.35	0.15
	(1.14)	[1.16]	(0.31)	[0.15]		
Government debt	3.96	3.68	0.61	0.63	-0.38	0.18
	(0.44)	[0.62]	(0.20)	[-0.10]		
CPI inflation	0.95	0.64	0.00	0.44	0.13	-0.21
	(0.08)	[4.03]	(0.06)	[-7.42]		
Policy rate	1.40	1.36	0.90	0.84	0.53	-0.78
	(0.19)	[0.20]	(0.25)	[0.20]		
Credit spread	1.37	1.76	0.87	0.63	-0.52	0.13
	(0.15)	[-2.67]	(0.20)	[1.18]		
Bank credit	3.57	1.69	0.92	0.72	0.60	0.55
	(0.53)	[3.52]	(0.28)	[0.69]		
Bank capital	33.73	8.40	0.65	0.61	-0.05	-0.27
	(10.96)	[2.31]	(0.39)	[0.10]		

Columns (1), (3) and (5) report the data volatilities, autocorrelations and correlations with output, respectively. The data spans the period between 2000Q1 and 2020Q1. Remaining columns report the corresponding model moments of the 10,000 simulated time series. Round brackets show standard errors, whereas square brackets display the t-statistics. Cyclical components of both the model and the data are estimated using a HP filter with a smoothing parameter of 1600.

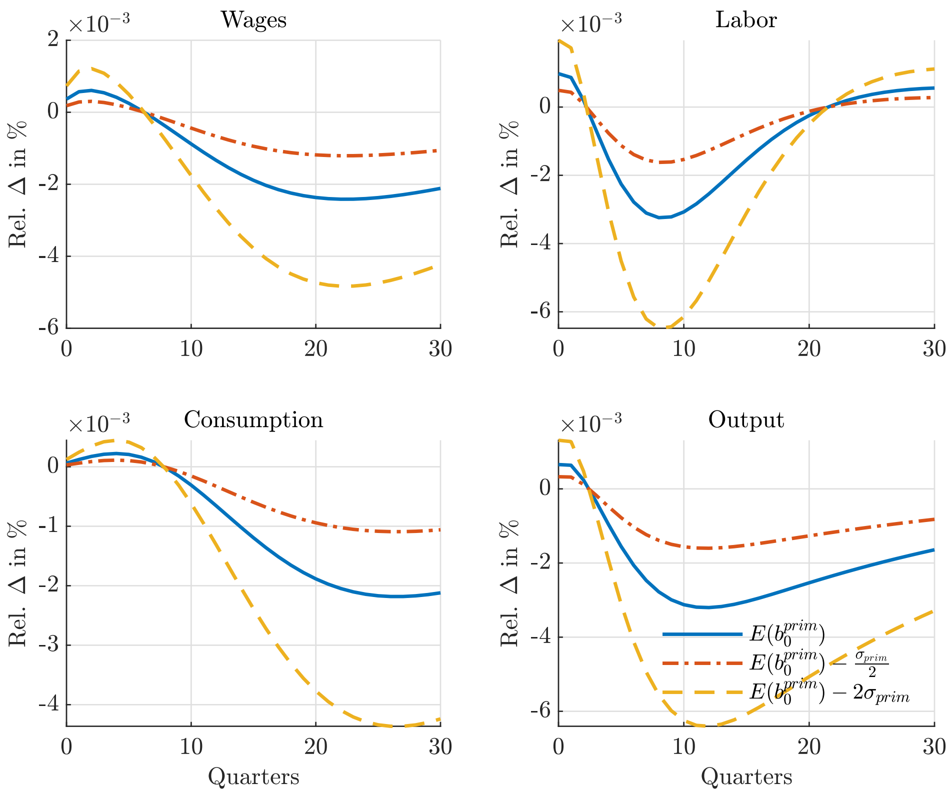

Figure C.3: Impulse-response functions of wages, labor, consumption and output to a surprise borrowing shock of 1% of GDP relative to steady state in quarter 0. The figures show deviations from the steady state.

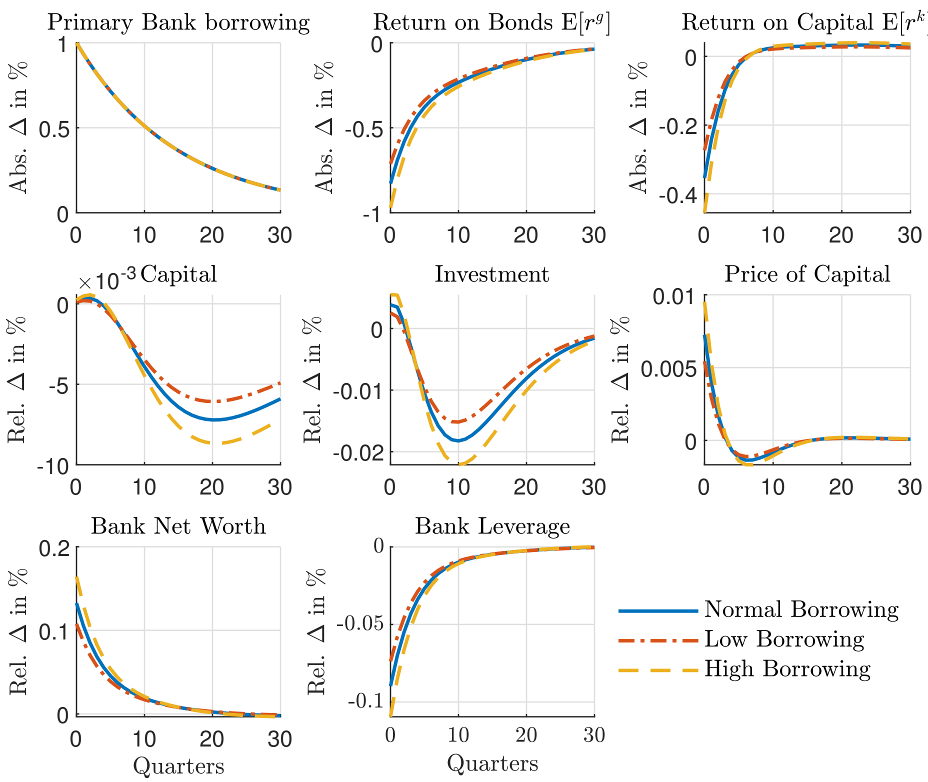

Figure C.4: Impulse-response functions of wages, labor, consumption and output to a surprise borrowing shock of 1% of GDP relative to steady state in quarter 0. The figures show deviations from the steady state.

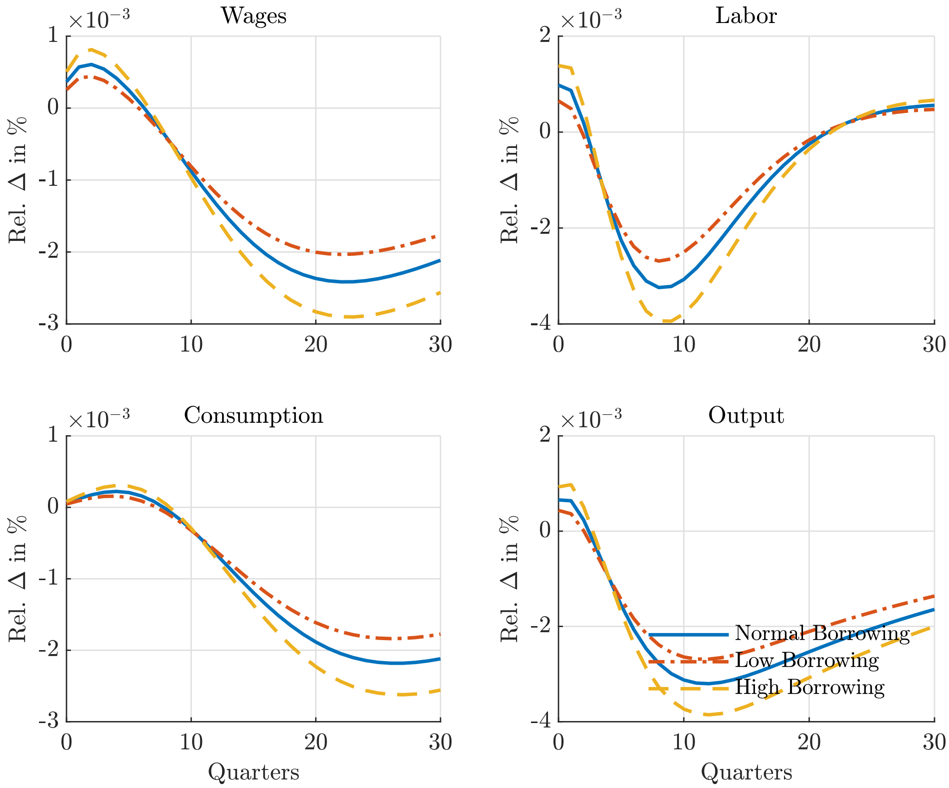

Figure C.5: Impulse-response functions of selected model variables to a surprise borrowing shock of 1% of GDP relative to steady state in quarter 0. The figures show deviations from the steady state.

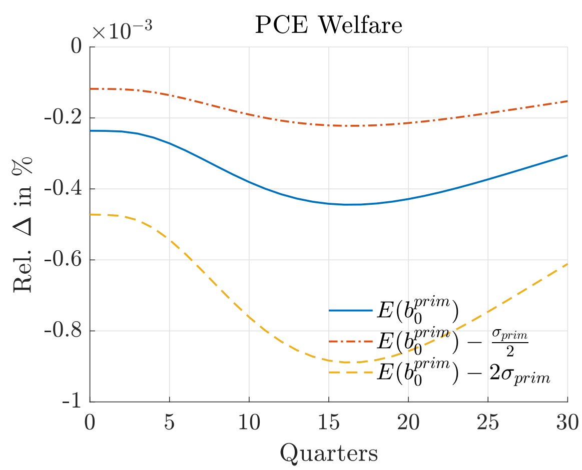

Figure C.6: The effects of a borrowing shock on welfare measured in permanent consumption equivalent (PCE) terms.

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