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Credit subsidies

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Abstract

In a model with costly financial intermediation and financial disturbances, credit subsidies are desirable, irrespective of how they are financed. They are especially useful when the zero lower bound constraint is reached. They are superior to other credit policies such as direct lending.

Keywords: Credit policy; credit subsidies; monetary policy; zero-lower bound on nominal interest rates; banks; costly enforcement.

JEL Codes: E31, E40, E44, E52, E58, E62, E63.

Non-Technical Abstract

The 2008-2009 financial crisis and the Great Recession have exposed the limitations of standard monetary policy as a tool for macroeconomic stabilization. Even if policy rates have been cut to near-zero levels, the costs of external finance have been kept high by unusually large credit spreads. Since further cuts in the policy rate were prevented by the zero lower bound constraint, alternative tools were considered by central banks, including various forms of credit policies. This paper investigates which policy tools, both monetary and fiscal, may be desirable to address financial market disturbances.

We consider a model where firms borrow from banks in order to pay wages. The banks are subject to an enforcement problem that generates inefficiently high and volatile credit spreads. The main message of the paper is that credit subsidies stand out as the natural policy tool to address inefficient movements in credit spreads.

We first show that in a real model with no outside money, credit subsidies can be used, with lump sum financing, to fully shelter the economy from the effects of the enforcement problems. The first best can be achieved.

In a monetary version of the model, in addition to the distortion from credit spreads, there is also a monetary distortion due to policy rates that may be too high. The goal of policy is to stabilize loan rates, not just credit spreads. This implies that credit subsidies and policy rates must be used jointly. In the presence of lump sum taxes, credit subsidies achieve the first best. In their absence, in a second best setup, the optimal allocation can be implemented in multiple ways. The loan rate can be affected either by varying the policy rate or by adjusting credit subsidies, or by a combination of both instruments. At times, when shocks to spreads are large, credit subsidies can be used to play the role of a negative policy rate, thus removing the constraint posed by the zero lower bound on interest rates.

In a second best setup, there are long-run budgetary implications from the use of credit taxes and subsidies. Adverse financial shocks result in a permanent increase in the level of public debt, in a permanent increase in future taxes and in a permanent reduction in output.

We compare credit subsidies to a form of credit easing, where direct lending can be obtained from the government, provided a resource cost is paid. We show that, as in Gertler and Karadi (2011), direct lending can be desirable in reaction to a large tightening of banks' balance-sheet constraints. The ranking between the two policies is clear in the benchmark case with lump sum taxes. Credit subsidies are then strictly preferable. Not always so, under distortionary taxes. When the financial shock is particularly severe, and real state-contingent debt is not available to the government, a large subsidy is required and the costs of financing it are specially high. In this case, direct lending should also be used together with credit subsidies, but only for a short period. A prolonged reliance on public lending, by lowering spreads, would have the cost of delaying the recapitalization of the financial sector.

1 Introduction

The 2008-2009 financial crisis and the Great Recession have exposed the limitations of standard monetary policy as a tool for macroeconomic stabilization. Even if policy rates were cut down to near-zero levels, the costs of financing for firms and households were kept high by unusually high credit spreads. Since further cuts in the policy rate were prevented by the zero lower bound constraint, alternative tools were considered by central banks, including various forms of credit policies.

In order to contribute to the design of policies that may respond to disturbances in financial markets, we consider a broader set of instruments, both monetary and fiscal, and study optimal policy in models with costly financial intermediation. The main message of the paper is that credit subsidies stand out as the natural policy tool to address the inefficiencies associated with high and volatile credit spreads.

In the model we use, firms borrow from banks in order to pay wages. The banks are subject to an enforcement problem similar to the one in Gertler and Karadi (2011) or Gertler and Kiyotaki (2011). This generates an inefficiency in that loan rates include a spread over the borrowing rate of banks. Credit subsidies can deal directly with the inefficiency associated with those credit spreads.

In order to stress the role of credit subsidies we first study a real model with no outside money, or monetary policy. In that benchmark model, credit subsidies can be used, with lump sum financing, to fully shelter the economy from the effects of the enforcement problems. The first best can be achieved.

In the monetary version of the model, in addition to the distortion from credit spreads, there is also a monetary distortion due to policy rates that may be too high. The goal of policy is to stabilize loan rates, not just credit spreads. This implies that credit subsidies and policy rates must be used jointly to achieve the first best.

Instead, in a second best setup, without lump sum taxation, the optimal allocation can be implemented in multiple ways. The loan rate can be affected either by varying the policy rate or by adjusting credit subsidies, or by a combination of both. These multiple implementations are limited by the zero bound constraint, as well as by an upper bound constraint on credit subsidies.

At times, when shocks to spreads are large, the policy rate that would stabilize the loan rate would have to be negative. In that case, credit subsidies can be used to play the role of a negative policy rate. It follows that the zero lower bound on interest rates no longer constrains policy, once credit subsidies are used.

The features of the allocation which can be achieved through credit subsidies naturally depend on the other financing instruments available to the government. Without lump-sum taxes, credit subsidies cannot be used to correct average distortions, but can be used in response to shocks to stabilize wedges, improving welfare. For the numerical exercises we assume that taxes are distortionary and debt is nominal and noncontingent. It is still the case, however, that state-contingent debt can be replicated through ex-post changes in inflation.[1] This can generate all the desirable variation in the real value of the outstanding nominal public debt. To analyze the policy implications of real noncontingent debt, we limit the ability to implement changes in inflation through instantaneous price adjustments in reaction to shocks. In that case, the use of credit taxes and subsidies is still optimal, but there are budgetary implications. Adverse financial shocks result in a permanent increase in the level of public debt, in a permanent increase in future taxes and in a permanent reduction in output.[2]

Finally we compare credit subsidies to a form of credit easing. As an alternative to private intermediation, we allow for direct lending by the government, provided a

[1] See Chari, Christiano and Kehoe (1991).

[2] These results are consistent with those in Barro (1979) and Aiyagari et al (2002) where, in the absence of state-contingent debt, innovations in fiscal conditions are spread out over time and the optimal tax rate follows essentially a random walk.

resource cost is paid. This cost is meant at solving the enforcement problem. As in Gertler and Karadi (2011) direct lending can be desirable in reaction to a large tightening of banks' balance-sheet constraints. The ranking between the two policies is clear in the benchmark case with lump-sum taxes. Credit subsidies are then strictly preferable. Not so, for second best policy, without state contingent debt. When the financial shock is particularly severe, a large subsidy is required and the costs of financing it are specially high. In this case, direct lending should also be used together with credit subsidies, but only for a short period. A prolonged reliance on public lending, by lowering spreads, would have the cost of delaying the recapitalization of the financial system.

Our case for credit subsidies is robust to, and actually strengthened by, changes in the source of monetary nonneutrality. The very simple monetary distortion that we assume, implies that interest rate policy affects the same margin as the credit subsidy. This implies that the two policy instruments are close substitutes. In particular, interest rate policy could, in normal times away from the zero bound, dispense with the subsidies. We could have considered alternative models where the monetary nonneutrality would be due to sticky prices as in Woodford (2003) or sticky information as in Mankiw and Reis (2002). In those models, interest rate policy would be a poor substitute for credit subsidies, so that the relevance of credit subsidies would be stronger. Both credit subsidies and monetary policy should be used, aimed at different goals. Credit subsidies would be correcting the distortions due to the high spreads, and interest rate policy would be correcting the distortions associated with sticky prices or information, ensuring price or inflation stability.

The paper is related to a recent literature (Curdia and Woodford, 2011, De Fiore and Tristani, 2012, Eggertsson and Krugman, 2012)[3] that analyses the effects of fi-

[3] Another related literature studies the optimal combination of monetary and fiscal policy in reac-

nancial market shocks and the desirability of non-standard monetary policy responses. This literature explores various forms of direct lending by the central bank, but does not explicitly allow for tax instruments. Optimal tax policy when interest rates are at the zero bound has been studied by Eggertsson and Woodford (2006), Correia, Farhi, Nicolini and Teles (2013) among others. These papers abstract from financial market frictions. The friction is sticky prices. Fiscal policy is necessary to overcome the distortions imposed by the interaction of sticky prices with the zero lower bound. Relative to Correia et al. (2013), this paper confirms the result that standard tax instruments can overcome the zero bound constraint on interest rates.

The paper is organized as follows: In section 2, the benchmark monetary model is described. A nonmonetary version of the model is first analyzed in section 3. The purpose is to show how credit subsidies can be used to address financial distortions associated with high and volatile credit spreads, in the absence of monetary frictions and policy. In section 4, the monetary model is analyzed. Credit subsidies are still necessary to deal with the zero bound on interest rates, but there are multiple implementations of policy. In particular, away from the first best, and in response to relatively small shocks, interest rate policy may be sufficient. The zero bound constraint is shown to be irrelevant when credit subsidies are used. A subsection discusses alternative sources of monetary nonneutrality. In section 5, the optimal responses to shocks with and without credit subsidies are computed numerically in a second best environment. Policies with credit subsidies are also compared to direct lending policies.

tion to financial, or other, shocks. See Prestipino (2014) and Bianchi and Mendoza (2013).

2 The model

The main feature of the model is that financial intermediation must be performed by banks that face an enforcement problem. A representative firm needs to borrow to pay for wages. A continuum of banks make those loans and borrow from the household. There is a large household that includes workers and bankers that share consumption. The preferences of the household are over consumption and labor and the technology uses labor only and is linear. Bankers can appropriate a fraction of the assets of the bank, so they must be given an incentive not to do it. In equilibrium there are going to be bank profits that are accumulated as internal funds. The government consumes, raises taxes and pays for subsidies on credit, and issues money and debt.

2.1 The household

The household is composed of workers and bankers. With probability $1-\theta$, bankers exit and become workers. They are replaced by workers that become new bankers, keeping the fractions of bankers and workers constant, respectively f and $1-f$. Bankers and workers share consumption.

The uncertainty in period $t \geq 0$ is described by the random variable $s_t \in \Gamma_t$. $s^t \in \Gamma^t$ is the history of its realizations up to period t. For simplicity we index by t the variables that are functions of s^t.

The household has preferences over consumption and labor, $E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, N_t)$, with the usual properties. The household starts period t with nominal wealth $\mathbb{W}_t$. At the beginning of period t, in an assets market, the household purchases $E_t Q_{t,t+1} B_{t,t+1}$ in one-period state contingent nominal claims. $Q_{t,t+1}$ is the price in period t of a unit of money in period $t+1$, in some state, normalized by the probability of occurrence of the state. The household also purchases non-contingent public debt B_t, and deposits D_t, as well as money M_t. In the beginning of the following period the nominal wealth $\mathbb{W}_{t+1}$ includes the state contingent bonds $B_{t,t+1}$, the gross return on non-contingent public debt R_tB_t, deposits R_tD_t, money M_t, and the dividends received from the banks Π_t^b.[4] It also includes the wage income W_tN_t, which is received in the assets market in the beginning of period $t+1$. The household pays for consumption expenditures P_tC_t in the goods market at the end of the period with money M_t, satisfying the cash-in-advance constraint

$$P_tC_t \leq M_t. \tag{1}$$

The household also pays for lump-sum taxes T_t. The flow of funds constraints are therefore

$$E_tQ_{t,t+1}B_{t,t+1} + B_t + D_t + M_t \leq \mathbb{W}_t, \tag{2}$$

and

$$\mathbb{W}_{t+1} = B_{t,t+1} + R_tB_t + R_tD_t + M_t - P_tC_t + \Pi_t^b + W_tN_t - T_t. \tag{3}$$

The single budget constraint of the households can be written as

$$E_0\sum_{t=0}^{\infty} Q_tP_tC_t \leq E_0\sum_{t=0}^{\infty}\frac{Q_t}{R_t}W_tN_t + E_0\sum_{t=0}^{\infty}\frac{Q_t}{R_t}\Pi_t^b - E_0\sum_{t=0}^{\infty}\frac{Q_t}{R_t}T_t + (1-l_0)\,\mathbb{W}_0. \tag{4}$$

This is derived imposing a no-Ponzi games condition, the cash-in-advance constraint, (1), as well as the arbitrage conditions between contingent and noncontingent bonds, $1 = R_tE_tQ_{t,t+1}$, and $Q_{t+1} = Q_tQ_{t,t+1}$, with $Q_0 = 1$, that defines the price Q_{t+1} of one unit of money at the assets market at $t+1$, in units of money at $t = 0$. l_0 is a tax on initial wealth.[5] The budget constraint is written under the assumption that $R_t \geq 1$. This is the zero bound on interest rates which is an equilibrium restriction. If it were

[4] Since public debt and bank deposits are riskless, their yields are identical in equilibrium.

[5] This initial tax is a lump sum tax. If initial public liabilities are positive and the tax is restricted to be less than one, then this lump sum tax can confiscate the liabilities of the government but it cannot finance the credit subsidies or government consumption.

not satisfied, the households would borrow an arbitrarily large amount and hold cash, making arbitrarily large profits.

The first order conditions of the households problem include

$$-\frac{u_C(t)}{u_N(t)} = \frac{R_t P_t}{W_t}, \tag{5}$$

$$\frac{u_C(t)}{P_t} = R_t E_t \frac{\beta u_C(t+1)}{P_{t+1}}, \tag{6}$$

$$Q_{t,t+1} = \frac{\beta u_C(t+1) P_t}{u_C(t) P_{t+1}}, \tag{7}$$

2.2 Firms

In the economy there is a representative firm endowed with a stochastic technology that transforms N_t units of labor into $Y_t = A_t N_t$ units of output. The firm is required to hold enough funds in advance to pay the wage bill. More precisely, the firm borrows in the beginning of period t funds S_t, at gross interest rate R_t^l, receiving a credit subsidy τ_t^l, on the gross interest. The funds are held as interest bearing deposits to pay for the wage bill in the assets market at $t+1$. Because the firm can hold the borrowed funds as remunerated deposits (or government debt), at gross interest rate R_t, the borrowing constraint is

$$\frac{W_t N_t}{R_t} \leq S_t. \tag{8}$$

The profits of the firm in each period t are $\Pi_t^f = P_t Y_t - W_t N_t - \left[R_t^l \left(1-\tau_t^l\right) - R_t\right] S_t$. Using the borrowing constraint (8), profit maximization implies

$$P_t A_t = \frac{R_t^l \left(1-\tau_t^l\right)}{R_t} W_t, \text{ or } A_t N_t = R_t^l \left(1-\tau_t^l\right) \frac{S_t}{P_t}. \tag{9}$$

It is also an equilibrium restriction on the subsidy that $R_t^l \left(1-\tau_t^l\right) \geq R_t$. Otherwise firms could make arbitrarily large profits borrowing at $R_t^l\left(1-\tau_t^l\right)$ and holding deposits that pay R_t. This is an upper bound constraint on the credit subsidy, similar in substance to the zero bound constraint on interest rates.

2.3 Banks

Each bank j channels funds from depositors to the firm. Because of costly enforcement, banks must have rents that are accumulated as internal funds, $Z_{j,t}$. This implies that there are going to be positive spreads and that internal funds will have high rates of return. There must be exit of bankers, so that internal funds can remain scarce.

The bank borrows $D_{j,t}$ from the households or the government and lends $S_{j,t}^b$. The balance sheet of a bank is such that $S_{j,t}^b = D_{j,t} + Z_{j,t}$. Because the equilibrium return on the internal funds is higher than the alternative return R_t, profits are kept in the bank as internal funds until exit. The net worth of the bank evolves according to $Z_{j,t} = \xi_t\left[R_{t-1}^l S_{j,t-1}^b - R_{t-1}D_{j,t-1}\right]$, where ξ_t is a shock to the value of internal funds, similar to the capital quality shock in Gertler and Karadi (2011). Combining the two conditions, the balance sheet and the evolution of internal funds, it follows that $Z_{j,t} = \xi_t\left[\left(R_{t-1}^l - R_{t-1}\right)S_{j,t-1}^b + R_{t-1}Z_{j,t-1}\right]$.

Bankers exit in the assets market with the gross profits obtained from the intermediation activity in the period before. The value of a surviving bank at the assets market in period t, is $V_{j,t} = E_t\sum_{s=0}^{\infty}\left(1-\theta\right)\theta^s Q_{t,t+1+s}Z_{j,t+1+s}$.

Bankers can appropriate a fraction λ of assets $S_{j,t}^b$, in the assets market at time t. The incentive constraint is thus $V_{j,t} \geq \lambda S_{j,t}^b$. Unless this condition is verified, banks won't be able to attract deposits.

As shown in the Appendix, the solution of this problem is such that loans are $S_{j,t}^b = \phi_t Z_{j,t}$, where ϕ_t is defined as the ratio of assets to internal funds, also referred to as leverage ratio, and given by

$$\phi_t = \frac{\eta_t}{\lambda - \upsilon_t}, \tag{10}$$

for $\upsilon_t = (1-\theta) R_t E_t Q_{t,t+1} \xi_{t+1} \frac{\left(R_t^l - R_t\right)}{R_t} + \theta E_t Q_{t,t+1} \frac{S^b_{j,t+1}}{S^b_{j,t}} \upsilon_{t+1}$ and $\eta_t = (1-\theta) R_t E_t Q_{t,t+1} \xi_{t+1} + \theta E_t Q_{t,t+1} \frac{Z_{j,t+1}}{Z_{j,t}} \eta_{t+1}$. Notice that the growth rates of internal funds and loans and the leverage ratio are the same across banks. This makes it straightforward to aggregate across banks.

The total internal funds of bankers Z_t are the sum of the funds of surviving bankers Z_{et} and entering bankers Z_{nt}. Since a fraction θ of bankers survive, $Z_{et} = \theta \xi_t \left[\left(R^l_{t-1} - R_{t-1}\right) \phi_{t-1} + R_{t-1}\right] Z_{t-1}$. The remaining fraction, $1-\theta$, exit and transfer back the internal funds to the households. The households then transfer to the entering bankers the fraction $\frac{\omega}{1-\theta}$ of these assets, so that $Z_{nt} = \omega \xi_t \left[\left(R^l_{t-1} - R_{t-1}\right) \phi_{t-1} + R_{t-1}\right] Z_{t-1}$.

We can then write $Z_t = Z_{et} + Z_{nt}$ as

$$Z_t = \xi_t \left(\theta + \omega\right) R_{t-1} \left[\left(\frac{R^l_{t-1}}{R_{t-1}} - 1\right) \phi_{t-1} + 1\right] Z_{t-1}, \tag{11}$$

Aggregate dividends transferred by exiting banks to the household in the assets market at $t \geq 1$, net of the transfers to entering banks, are

$\Pi^b_{t-1} = \xi_t \left(1 - \theta - \omega\right) \left[\left(R^l_{t-1} - R_{t-1}\right) \phi_{t-1} + R_{t-1}\right] Z_{t-1}$, which, using (11), can be rewritten as

$$\Pi^b_{t-1} = \left(\frac{1}{\theta + \omega} - 1\right) Z_t. \tag{12}$$

2.4 The government

The government spends G_t, gives credit subsidies τ^l_t and may be able to raise lump-sum taxes, T_t. The policy rate is R_t. Given nominal liabilities $-\mathbb{W}^g_t$, the government issues money M_t, issues noncontingent debt B_t, may also be able to issue contingent debt $B_{t,t+1}$, according to $B_t + E_t Q_{t,t+1} B_{t,t+1} + M_t \geq -\mathbb{W}_t^g$. Liabilities at the beginning of period $t+1$, for $t \geq 1$ are $-\mathbb{W}_{t+1}^g = R_t B_t + B_{t,t+1} + M_t + \tau_t^l R_t^l S_t + P_t G_t - T_t$. At the beginning of period 1, the liabilities are $-\mathbb{W}_1^g = R_{0t} B_0 + B_{0,1} + M_0 + \tau_0^l R_0^l S_0 + P_0 G_0 - T_0 - l_0 \mathbb{W}_0$.

2.5 Market clearing

The market clearing condition in the goods market is

$$C_t + G_t = A_t N_t, \tag{13}$$

and the market clearing condition for loans is $S_t = S_t^b$.

2.6 Equilibrium

An equilibrium in this economy is a sequence $\{C_t, N_t\}$, $\left\{\tau_t^l, R_t, Q_{t,t+1}, P_t, W_t, R_t^l\right\}$ and $\{\phi_t, \eta_t, \upsilon_t, S_t, Z_t\}$ that satisfies the intratemporal marginal condition for the households, (5), the firms marginal condition in (9), that together imply

$$-\frac{u_C(t)}{u_N(t)} = \frac{R_t^l\left(1-\tau_t^l\right)}{A_t}, \tag{14}$$

the intertemporal conditions, (6) and (7), as well as (9), (10), (11),

$$S_t = \phi_t Z_t, \tag{15}$$

$$R_t^l\left(1-\tau_t^l\right) \geq R_t \geq 1, \tag{16}$$

$$\upsilon_t = (1-\theta) R_t E_t Q_{t,t+1} \xi_{t+1} \left(\frac{R^l_t}{R_t} - 1 \right) + \theta R_t E_t Q_{t,t+1} \xi_{t+1} \frac{\phi_{t+1}}{\phi_t} \left[\left(\frac{R^l_t}{R_t} - 1 \right) \phi_t + 1 \right] \upsilon_{t+1}, \tag{17}$$

$$\eta_t = (1-\theta) R_t E_t Q_{t,t+1} \xi_{t+1} + \theta R_t E_t Q_{t,t+1} \xi_{t+1} \left[\left(\frac{R^l_t}{R_t} - 1 \right) \phi_t + 1 \right] \eta_{t+1}, \tag{18}$$

and the resource constraints, (13).

The budget constraint of the government does not impose restrictions on the equilibrium variables above because it can always be satisfied with lump-sum taxes, T_t.

The first best allocation that maximizes preferences subject only to the resource constraints, (13), would have $-\frac{u_C(t)}{u_N(t)} = \frac{1}{A_t}$, so that in order for it to be implemented the gross lending rate, net of the subsidy, would have to equal to one, $R^l_t \left(1 - \tau^l_t\right) = 1$. Because the policy rate cannot be negative, i. e. $R_t \geq 1$, and because there must be a spread between the lending and the borrowing rate, there is going to be a wedge in equilibrium, unless the subsidy is used.

Notice also that the shock to internal funds ξ_t affects the equilibrium conditions through equations (9), (11), and (15), and that the price level can be adjusted so that the equilibrium is not affected by the destruction of internal funds. This can indeed be part of optimal policy as will be seen later.

Internal funds are predetermined, even if the timing of transactions is such that financial assets can be adjusted contemporaneously in response to shocks. The reason is that it is optimal for the banks to accumulate all profits as internal funds. Because of the predetermination of internal funds, the nominal quantity of money is not neutral in this economy. If it was possible to increase internal funds in every period, together with all price levels and nominal quantities by the same percentage, this would keep interest rates and allocations unchanged. However, because internal funds, Z_t, are predetermined, increasing all other nominal quantities and price levels would not be possible without changing the real allocation. Equation (11) shows that, for a given

Z_{t-1}, an increase in Z_t would not be consistent with the unchanged levels of the policy rate R_{t-1}, the credit spread, R^l_{t-1}/R_{t-1}, and leverage, ϕ_{t-1}.

Another reason for monetary policy not to be neutral in this economy is that the government may be restricted from issuing state contingent debt. Ex-post inflation could then reduce the cost of public financing by replicating state contingent real debt.

3 Credit subsidies in a nonmonetary economy

Before analyzing policy in the monetary economy, it is useful to study optimal policy in an economy with financial frictions but without outside money. In that economy, there is still a potential distortion due to the credit friction, that has to be dealt with using credit subsidies alone.

The economy in this section has the same features as the economy above, except that there is no outside money, not even as unit of account. The cash-in-advance constraint on the households, (1), is not imposed. The role of money as unit of account is also eliminated, by imposing that the price level is always equal to one, $P_t = 1$. In the resulting real economy, firms must still hold financial assets in advance of production, in the form of real deposits (or government debt). They borrow from banks, so that the cost of holding those assets is a real credit spread.

Since the price level is set equal to one at all times, the wage, W_t, is now a real wage, in units of goods, and the prices of state-contingent assets, $Q_{t,t+1}$, and interest rates, R_t and R^l_t, and asset levels, S_t and Z_t, are now also in units of the good. Similarly bank profits, $\Pi^{b,}_t$ and lump sum taxes, T_t, are also in real units.

The flow of funds constraints of the household are (2) and (3) with $M_t = 0$ and

$P_t = 1$. The single budget constraint is now

$$E_0 \sum_{t=0}^{\infty} Q_{t+1} C_t \leq E_0 \sum_{t=0}^{\infty} Q_{t+1} W_t N_t + E_0 \sum_{t=0}^{\infty} Q_{t+1} \Pi_t^b + E_0 \sum_{t=0}^{\infty} Q_{t+1} T_t + (1 - l_0) \mathbb{W}_0. \quad (19)$$

The intratemporal marginal choices for the household are not distorted by the nominal interest rate, so that instead of (5), the marginal condition is now

$$-\frac{u_C(t)}{u_N(t)} = \frac{1}{W_t}. \quad (20)$$

The intertemporal marginal conditions (6) and (7) become

$$u_C(t) = \beta E_t \left[R_{t+1} u_C(t+1) \right], \quad (21)$$

$$Q_{t+1,t+2} = \frac{\beta u_C(t+1)}{u_C(t)}. \quad (22)$$

Notice that the intertemporal prices that are relevant for the decisions between period t and $t+1$ are prices between the asset market in $t+1$ and $t+2$. This is a feature of Lucas timing, that payments are done in the asset market the period after.

In the cashless version of the model, the problems of the firms and the banks are unchanged. The constraints of the government are also the same except for the issuance of money.

The equilibrium conditions for the variables $\{C_t, N_t\}$, $\left\{\tau_t^l, R_t, Q_{t,t+1}, W_t, R_t^l\right\}$, $\{\phi_t, \eta_t, \upsilon_t\}$, and $\{S_t, Z_t\}$ are (21) and (22), together with

$$-\frac{u_C(t)}{u_N(t)} = \frac{\frac{R_t^l}{R_t}\left(1 - \tau_t^l\right)}{A_t}, \quad (23)$$

$$\frac{R_t^l}{R_t}\left(1 - \tau_t^l\right) W_t = A_t, \quad (24)$$

$$A_t N_t = \frac{R_t^l}{R_t} \left(1 - \tau_t^l\right) S_t, \tag{25}$$

$$R_t^l \left(1 - \tau_t^l\right) \geq R_t, \tag{26}$$

as well as the constraints (10), (11), (13), (15), (17), and (18), which are common to the monetary and the real economy.

In this nonmonetary version of the model, the wedge in the consumption/leisure margin is the credit spread, net of the subsidy. Changes in the interest rate R_t cannot affect that wedge. The credit subsidy is the effective way of dealing with the spread. Optimal policy is conducted with credit subsidies alone.

Proposition 1 In the nonmonetary model with credit subsidies, the set of implementable allocations for consumption and labor, $\{C_t, N_t\}$, is the set of feasible allocations satisfying the resource constraints (13) with a nonnegative wedge, $-\frac{u_C(t)A_t}{u_N(t)} \geq 1$.

The proof is in the Appendix. It follows directly from the proposition that the first best allocation can be achieved. Credit subsidies can be used to restore efficiency, provided they can be financed in a nondistortionary fashion.

Once lump sum taxes are ruled out, then subsidies cannot be positive on average, but they are still useful. They can be adjusted in response to shocks, smoothing wedges across states, according to second best principles of taxation. In the monetary economy that will be analyzed in the next section, this role can be played partly by the policy interest rate.

4 Interest rate policy vs. credit subsidies

We now go back to the monetary model and study the interaction between fiscal and monetary policy. We consider first the comparable case with lump sum taxes, but also study the more interesting case with only distortionary taxation.

4.1 Lump sum taxation and the first best

As in the nonmonetary version of the model, with lump-sum taxes and credit subsidies, the set of competitive equilibrium conditions restricting the allocations for consumption and labor can be summarized by the resource constraint together with the nonnegativity of the wedge, $-\frac{u_C(t)A_t}{u_N(t)} \geq 1$. In order to show this, we take a generic, feasible allocation for consumption and labor and show that, together with the other variables, it satisfies all the other equilibrium conditions. There are multiple implementations of each allocation, so it is sufficient to do the demonstration for a particular one.[6] The particular implementation is the one in which the price level does not change contemporaneously in response to shocks.

Proposition 2 In the monetary economy, with lump sum taxes, the set of implementable allocations for consumption and labor, $\{C_t, N_t\}$, is the set of allocations satisfying the resource constraints (13), with a nonnegative wedge, $-\frac{u_C(t)A_t}{u_N(t)} \geq 1$.

The formal proof is in the Appendix.

As an illustration, it is useful to think of the consequences of a negative shock to the value of internal funds, ξ_t, under the implementation above. Because the price level does not move on impact, the real value of internal funds falls by the full amount of the shock. As a result, leverage and the spread have to go up. Once at the zero bound, it is not possible to further cut interest rates to counteract the effect of the spread on allocations. The subsidy, instead can be adjusted for that purpose. Lump-sum taxes can be used to finance the subsidy.

[6] We thank Joao Sousa, that first suggested the possibility of multiple implementations in the price level.

Another implementation will have the price level adjust on impact in response to shocks. As a result, the dynamics of the financial variables and the credit subsidies would be different. In particular, in response to an i.i.d. shock to the value of internal funds, an adjustment in the price level on impact would be sufficient to completely neutralize all other effects of the shock on the equilibrium.

It is a corollary of Proposition 1, that the first best allocation can be achieved. The distortion created by the financial friction shows up as a positive wedge $R_t^l\left(1-\tau_t^l\right)-1$. Only when policy sets this wedge to zero, it is possible to achieve the first best allocation.

One way to interpret the monetary model in this paper is that there is a cash in advance constraint on households, that must hold outside money in order to make consumption purchases, and there is an inside money constraint on firms, that must hold deposits in advance in order to make payments to workers. The cost of the cash in advance constraint on households is the rate of return on deposits that they forego. The cost of the deposits that the firms must hold is the spread between the lending rate by banks (net of the credit subsidy) and the deposit rate. The joint cost is the lending rate net of the subsidy. Setting that cost to zero amounts to setting the price of outside money for households and inside money for firms equal to zero, which is an application of the Friedman rule. Notice that this extreme result hinges on the assumption that financial intermediation is costless in terms of resources. With a positive intermediation cost, the optimal lending rate would have to include that cost.

The first best cannot be implemented with monetary policy alone. Without credit subsidies, in order for the lending rate, net of the subsidy, to be zero, and given that there must be positive credit spreads in equilibrium, the policy rate would have to be negative. Credit subsidies are needed in order for the first best to be achieved without setting negative interest rates. The policy rate can be zero, $R_t = 1$, the lending rate can include a spread and be strictly positive, $R_t^l > 1$, but the effective cost of funds for firms will still be zero, $R_t^l \left(1 - \tau_t^l\right) = 1$. Since firms are not prevented from holding deposits or government debt, the effective rate at which they borrow cannot be lower than the deposit rate, $R_t^l \left(1 - \tau_t^l\right) \geq R_t$. It follows that the policy rate must indeed be zero at the optimum, $R_t = 1$. There is a single implementation of the first best with credit subsidies and the policy rate. They must be equal to their respective upper and lower bound.

A particular feature of the first best equilibrium which is worth mentioning is that the dynamic response to shocks of variables other than consumption and hours is not uniquely determined. Real allocations are pinned down, but different impact movements in the initial price level could be accompanied by different values of real net worth, leverage, and credit spreads, together with different subsidies τ_t^l. Lending rates net of the subsidy would remain fixed at zero, i.e. $R_t^l \left(1 - \tau_t^l\right) = R_t = 1$. The Ramsey planner would therefore be indifferent between the various adjustment paths of spreads, net worth and leverage in reaction to shocks.

To summarize, we have so far shown that, even if lump-sum taxes were available, monetary policy alone would not achieve the first best, since that would require setting nominal interest rates below zero. Instead, if credit subsidies are used, then the zero bound constraint will not be binding and the first best will be achieved. The first best requires setting both the policy rate at its minimum level and the credit subsidy at its maximum level, resulting in zero effective lending rates.

In the next section, the more interesting case of distortionary taxation is analyzed. But before we discuss alternative sources of monetary nonneutrality.

4.2 Monetary nonneutralities

The model without outside money or monetary policy studied above, in Section 3, makes apparent the usefulness of credit subsidies as a policy tool. In a monetary model, the benefits of credit subsidies will depend on the precise source of monetary nonneutrality.

The monetary friction we assume in this paper is the most unfavorable to credit subsidies. If it was not for the upper and lower bounds on credit subsidies and interest rates, respectively, the two instruments would be fully equivalent. In models with other forms of monetary nonneutrality, such as sticky prices or sticky information, the two policy instruments would be complementary, because they would address different distortions.

The cashless model of Section 3, where the price level is constant at all times, provides the intuition for the results which would arise in a version of the model with sticky prices. To see this, take the cashless model and add sticky prices. The particular form of sticky prices is not very important, but Calvo (1983) is a good benchmark. In that economy, provided there are no other conflicting distortions, it is always optimal to eliminate the distortion from sticky prices by ensuring price stability. To ensure price stability the nominal rate would have to be set equal to the real. Being used fully for this purpose, the policy rate could not be used as a policy tool for any other purpose. Credit subsidies would then be the remaining policy tool to deal with the inefficiency from the financial friction associated with high and volatile spreads, just as in the real model. In this benchmark case with lump sum taxes, credit subsidies and the nominal interest rate would jointly implement the first best allocation.

Similarly, in a model with sticky information such as Mankiw and Reis (2002) in which it is desirable that inflation be stable, the nominal interest rate will also be restricted in how to contribute to the attenuation of the distortions from the financial shocks. It can help reduce the average distortion, but not the one due to volatile spreads.

In the cashless model there are no costs of positive and volatile policy interest rates, but those costs would be present in a model with a money demand distortion. In particular, in our model, if the borrowing rate is high and volatile so will the lending rate. In a model with both sticky prices and monetary frictions, monetary policy would face a trade-off, unless other fiscal instruments were used.

The main conclusion from this discussion, is that credit subsidies are an effective instrument to deal with distortions associated with high and volatile spreads. Depending on the source of nonneutrality in a monetary model, and on other available fiscal instruments, monetary policy can be an imperfect substitute or a complementary policy tool aimed at other distortions such as price dispersion due to sticky prices or information.

4.3 Second best policies

Without lump-sum taxes, the budget constraint of the government, or households, must be taken into account as a restriction on the equilibrium allocations. We now derive a general irrelevance result of the zero lower bound for the case in which the government can issue state contingent bonds. The case with noncontingent debt is solved numerically, and described in section 5.

With state contingent debt but no lump sum taxes, the households budget constraints can be written as the single constraint (4) with $T_t = 0$. We can then use the household and firms marginal conditions, (5), (7), and (9), as well as (12), and (15), to write the budget constraint with equality as

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u_C(t) C_t + u_N(t) N_t\right] + E_0 \sum_{t=0}^{\infty} \beta^{t+1} u_N(t+1) \left(\frac{1}{\theta+\omega} - 1\right) \frac{N_{t+1}}{\phi_{t+1}} - (1-l_0)\, \mathbb{W}_0 = 0. \tag{27}$$

When the government can issue state contingent debt, this budget constraint is also the budget constraint of the government.

The irrelevance of the Zero Lower Bound For a moment we abstract from the zero bound constraint on the nominal interest rates. With negative interest rates, the household could borrow and hold cash, and make arbitrarily large profits. Banks could also do the same arbitrage. We need to assume that the household and banks are prevented from exploiting these profit opportunities. Subject to those restrictions, there is an equilibrium with negative rates, with associated (lower) lending rates. The overall set of feasible equilibria is larger than in the case where the nominal interest rate is restricted to be positive. The extended set of equilibria can always be equivalently implemented with a zero policy rate and with credit subsidies. Equivalence here means that the alternative implementation produces the same wedges and raises the same tax revenues. This means that the zero bound constraint on interest rates is made irrelevant when credit subsidies are used, which is the content of the following proposition.

Proposition 3 When credit subsidies are used, the zero bound on the nominal interest rate is irrelevant for the implementation of allocations.

A formal proof can be found in the Appendix.

Similarly, if we were to start with a path for credit subsidies such that the upper bound is not satisfied, there would be an equivalent path where the credit subsidy is set equal to its upper bound, and nominal interest rates are used instead. The use of both the policy rate and the credit subsidy neutralizes the effects of the upper and lower bound constraints on those policy instruments.

Fiscal policies can therefore overcome the nonnegativity constraint on the nominal interest rate. Allocations can be achieved which, in the absence of fiscal policy, would only be feasible if interest rates could be negative. In the next section we explore the possible practical implications of this result when the policy rate is at the zero lower bound as a result of an adverse financial shock. By setting the policy rate to zero, we also guarantee that the upper bound constraint on the credit subsidy is never binding.

5 The role of credit subsidies: A numerical illustration

In this section we provide a numerical illustration of the properties of credit subsidies in reaction to adverse financial shocks in the case in which lump-sum taxes cannot be levied and government debt is nominal and noncontingent. Throughout the section we focus on the case in which the interest rate is kept constant at the zero bound

In the first part of the section, we show that credit subsidies substantially improve optimal allocations in reaction to financial shocks. We also show that their implications for government finances depend on the behavior of the price level. If surprise changes in the price level can be generated in reaction to shocks, then the real value of government debt can be adjusted in a state-contingent manner and there is no need for further adjustments in spending or taxes. If we rule out the possibility of changes in the price level in reaction to shocks, variations in credit subsidies become costly, as they involve permanent changes in government debt. Nevertheless, the benefits of credit subsidies outweigh their financing costs, and their use in reaction to shocks remains optimal.

In the second part of the section, we focus on the case in which surprise changes in the price level are ruled out and study the relative benefits of credit subsidies compared to credit easing. We show that credit subsidies are always desirable, but they may be combined with a short-lived form of direct lending in reaction to larger shocks.

All results in this section are numerical. There are only five parameters to calibrate. We use standard values for utility parameters: $\beta = 0.99$ and $\varphi = 0$ in $u(C_t, N_t) = \log C_t - \frac{\chi}{1+\phi} N_t^{1+\varphi}$. Concerning the financial sector parameters, we rely on Gertler and Karadi (2011). Specifically we use the same value as in that paper for the fraction of funds that can be diverted from the bank, λ, the bankers survival probability, θ, and the proportional transfer to entering bankers, ω. In the steady state of our model, these parameters imply an annualized spread of 110 basis points and a leverage ratio of 6. These values are roughly comparable to those in Gertler and Karadi (2011), where the annualized spread and leverage are 100 basis points and 4, respectively. Government consumption is set to zero in the numerical analysis.

We study optimal policy under commitment, assuming that the economy starts from the optimal steady state–i. e., the steady state in which government debt and the fiscal subsidy are at their optimal level. The government holds positive assets in order to finance the optimal subsidy.

All figures show the nonlinear adjustment of the economy to the steady state along a perfect foresight path starting from a value of banks' net worth lower than the steady state. We refer to the figures as impulse responses to an adverse financial shock, a negative shock to net worth. We solve the joint system of constraints and first order conditions of the Ramsey planner at all points in time between $t = 1$ and $t = T$, for given state variables at $t = 0$ and jump variables at $t = T + 1$. The horizon of the simulation is made sufficiently long to ensure that at $t = T$ the system settles in a (possibly new) steady state. For government debt, we also need to ensure a terminal condition. We do so by requiring that the evolution of government debt between $t = T$

and $t = T + 1$ must also satisfy the government budget constraint.

When we impose a constraint on the planner's ability to change the price level on impact after the shock (see subsection 5.1), we do so only in period 1. The system is therefore non-recursive.

The quantitative results could change if we studied the response to shocks starting from different steady states, notably points where the government does not have enough assets to pay for the steady state level of the subsidy. In this case fiscal policy would have the additional incentive to build assets and move towards the efficient steady state. This numerical analysis should therefore be understood as merely illustrative of the merits of credit subsidies as a policy tool when the nominal interest rate is at the zero bound.

5.1 The benefits of credit subsidies

Figure 1 illustrates the benefits of credit subsidies. It shows responses to a 1% exogenous fall in the value of banks' nominal internal funds with and without credit subsidies. The figure compares the case when the credit subsidy τ^l is kept constant at its optimal steady state level to a case when the credit subsidy is adjusted in reaction to the shock.

To understand the impulse responses, it is useful to consider first what would happen if government debt were state-contingent. Everything else constant, the shock would lead to a one-to-one reduction in real internal funds $z_t \equiv Z_t/P_t$ and, for given amount of loans, an increase in banks' leverage ϕ_t. Policy could however respond through a cut in the price level equal to the size of the shock. This response would completely stabilize the real value of internal funds, leverage and output. State-contingent debt would be used to neutralize any consequences on government finances.

When, as in figure 1, government debt is noncontingent, the cut in the price level may not be possible. Suppose the credit subsidy is fixed at the steady state level (solid lines in the figure). A price cut that would restore the initial level of internal funds, would also increase the real value of government assets. This is inconsistent with unchanged future net revenues for the government. Instead if the price level increases, the adverse effect of the shock on internal funds is reinforced, increasing spreads and contracting economic activity. For an unchanged subsidy rate, and in spite of the increase in the lending rate, the expenditure due to the subsidy goes down. This is consistent with the decrease in the real value of government assets induced by the increase in the price level. Because of the increase in leverage and credit spreads, banks' profits also increase and net worth can be slowly rebuilt. Along the adjustment path, lending volumes ($s_t \equiv S_t/P_t$) and output remain below the steady state. These impulse responses to a shock to net worth are third best.

The second best responses, which happen to coincide with the first best responses in this economy, will have allocations not vary with the net worth shock. Those responses can be implemented when time-varying credit subsidies (dashed lines in the figure) are allowed for. Following the shock, the price level falls and cushions the reduction in net worth (by almost 50% compared to the case when credit subsidies are constant). However lending is kept unchanged in real terms. Leverage must increase and so do lending rates, but output is insulated from these financial developments through an impact increase in the credit subsidy. The increase in bank profits is such that net worth can be rebuilt in one quarter. After one quarter, inflation returns to steady state and so does the real value of government debt. The adjustment process is complete.

The idea that the real value of the whole stock of government debt may be adjusted through instantaneous changes in the price level, replicating state contingent real debt, is not very appealing. In practice, the price level may change more slowly. For this reason, the results in Figure 1 should be interpreted as an illustration for an admittedly polar case.

Figure 2 shows the opposite polar case in which we do not allow for surprise movements in the price level (the dashed lines in the figure), so that real debt must be noncontingent. In this case, the impulse response of output is close, but not identical, to the first best response. The economy does not return to the original steady state. To reduce the contractionary consequences of the shock, leverage must increase. An increase in the subsidy τ_t^l neutralizes the effects on the real economy from the increase in lending rates. However, the increase in the credit subsidy is financed through a small, but permanent increase in real government debt. The economy settles on a new steady state, where the higher debt is financed through a slightly lower level of the subsidy. Output also falls permanently.

To summarize, we have shown that credit subsidies improve allocations substantially in reaction to adverse financial shocks. More specifically, they avoid a prolonged adjustment process in lending rates, banks' leverage and credit creation. Even if they can generate permanent implications for government debt, they significantly reduce the amplitude of the inefficient downturn after the financial shock.

5.2 Credit subsidies vs. credit easing

We now compare the benefits and costs of credit subsidies to an alternative unconventional instrument, credit easing, interpreted as direct lending by the government.

In an environment with noncontingent public debt, credit easing has the advantage of not (necessarily) generating implications in terms of the government budget. Credit easing does, however, have costs, as under normal circumstances the banking sector is more efficient in intermediating credit. Gertler and Karadi (2011) capture these costs through a drag on resources, which can be motivated as a direct enforcement cost. Only in the case in which the resource cost of credit easing is zero, $c = 0$, can credit easing also achieve the first best (together with an appropriate policy for the nominal interest rate). In general, the desirability of the two unconventional measures will depend on the relative size of the resource cost c, in the case of credit easing, and of the deadweight cost of higher future taxes, in the case of credit subsidies.

To be more concrete, we introduce credit easing in our model exactly as in Gertler and Karadi (2011). The government can directly provide intermediation S_t^g to non-financial firms at the lending rate R_t^l. In its intermediation activity the government is not subject to the incentive constraint, but has to pay an intermediation cost c per unit of real lending. The real deadweight cost is $c\frac{S_t^g}{P_t}$.

Government intermediation can be written as a fraction of total intermediation $S_t^g = \psi_t S_t$.[7] The government flow of funds constraints have to be modified to include credit easing as $B_t + E_t Q_{t,t+1} B_{t,t+1} + M_t - \psi_t S_t \geq -\mathbb{W}_t^g$ and $-\mathbb{W}_{t+1}^g = R_t B_t + B_{t,t+1} + M_t + \tau_t^l R_t^l S_t + \left(c - R_t^l\right) \psi_t S_t + P_t G_t - T_t$. The resource constraint becomes $C_t + G_t + c\psi_t \frac{S_t}{P_t} = A_t N_t$ and the market clearing condition for loans is now $S_t = S_t^b + \psi_t S_t$.

Since the parameter c is hard to calibrate, we show numerical results for different values of it.

The desirability of the two policy instruments in response to shocks of different sizes is analyzed in Figures 3a and 3b. The figures compare optimal policy when both credit easing and credit subsidies are chosen optimally.

Figure 3a focuses again on a 1% negative shock to net worth for two values of c ($1.0e^{-5}$ and $1.0e^{-6}$).[8] It shows that, even for such small values of the resource cost, credit subsidies are used as much as in the case in which credit easing is not available (the case in Figure 2). Only when the resource cost becomes really small ($c = 1.0e^{-6}$) does optimal policy start involving a small amount of credit easing– approximately 0.003% of total lending. Albeit very small, this intervention is welfare

[7] Gertler and Karadi (2011) assume that policy is a simple rule for ψ_t as a function of credit spreads.
[8] Note that for higher values of c credit easing is always zero.

improving because it helps cushion the impact fall in consumption after the shock. However, credit easing is immediately reabsorbed: it goes back to zero after one period. The reason has to do with the trade-off between cushioning the fall in consumption and favouring a fast accumulation of banks' internal funds after the shock. Public intervention via credit easing tends to reduce banks' profits and thus slow down the accumulation of internal funds after the shock. If it were implemented on a persistent basis, leverage would remain high for a prolonged period and the economy would recover more slowly.

Figure 3b points out that the optimal combination of credit subsidies and credit easing also depends on the size of the shock. The figure shows impulse responses to a larger shock, which destroys 10% of banks' net worth. In this case, the amount of credit easing is a bit larger–it reaches 0.006% of total lending–and it is deployed for a smaller value of the resource cost parameter ($c = 1.0e^{-5}$). Nevertheless, credit easing is again reabsorbed entirely after one period. A credit subsidy which completely offsets the increase in lending spreads remains optimal in reaction to the shock.

To summarize, our results suggest that, compared to credit easing, credit subsidies have the crucial advantage of not slowing down the adjustment process after an initial disturbance. They are always desirable in response to financial shocks. In contrast, when credit subsidies are available, credit easing is attractive only as an emergency response, to be immediately, but temporarily deployed when the economy is hit by a very severe financial shock.

6 Concluding remarks

Credit subsidies can be employed to shield the economy from the adverse consequences of financial shocks on credit spreads. This is the main message of the paper.

We have analyzed optimal monetary and fiscal policy in a monetary model in which financial intermediaries are subject to an incentive problem. In this economy, the nonnegativity of the policy rate is a binding constraint to monetary policy, especially in response to a severe financial shock. Credit subsidies can play the role of the policy interest rate, and therefore can be used to overcome the zero bound constraint on the policy rate. But credit subsidies have a more relevant role. They are an effective tool to deal with distortions associated with high and volatile spreads. They are especially useful when the policy interest rate is used to deal with other distortions, such as those arising from sticky prices or sticky information.

Combined with interest rate policy, credit subsidies can implement the first best if they can be financed in a lump-sum fashion. Without lump-sum taxation, interest rate policy can be used instead of the subsidies in response to relatively small shocks, provided the zero bound is not attained. When debt cannot be made state contingent, the financing of the credit subsidy, or the financing of variable interest rates, is costly. In response to a financial shock, there will be permanent effects on taxes, government debt, and output, which will be particularly costly in the event of large shocks.

While interest rate policy, or credit subsidies, in this economy, aim at minimizing the costs of ensuring the private incentives to the financial intermediaries, credit easing by central banks directly overcomes the need for those incentives, presumably at a cost in terms of resources. In a benchmark with lump-sum taxation, credit subsidies would always be preferable to central bank lending. If, instead, there are relevant restrictions to the financing of credit subsidies, then there may still be a role for credit easing by the central bank.

The production structure of the model is very simple, with a technology that uses labor only. If the model had capital, and financial intermediation was necessary to facilitate investment, then credit spreads would also distort the accumulation of capital.

Credit subsidies would have a more relevant role in that economy.

The model is a simple model with a single incentive problem and with full information on banks conditions. The operationalization of the optimal credit subsidies could be a challenge in actual economies with multiple inefficiencies and heterogeneity and private information in types and actions. That could be particularly hard if credit subsidies were to treat different banks differently, depending on their exposure to the incentive problem. There would be room for misrepresentation. If all financial intermediaries are treated alike, then the difficulties in using credit subsidies are the same difficulties in using interest rate policy to affect loan rates. Either instrument will be set incorrectly with incomplete information.

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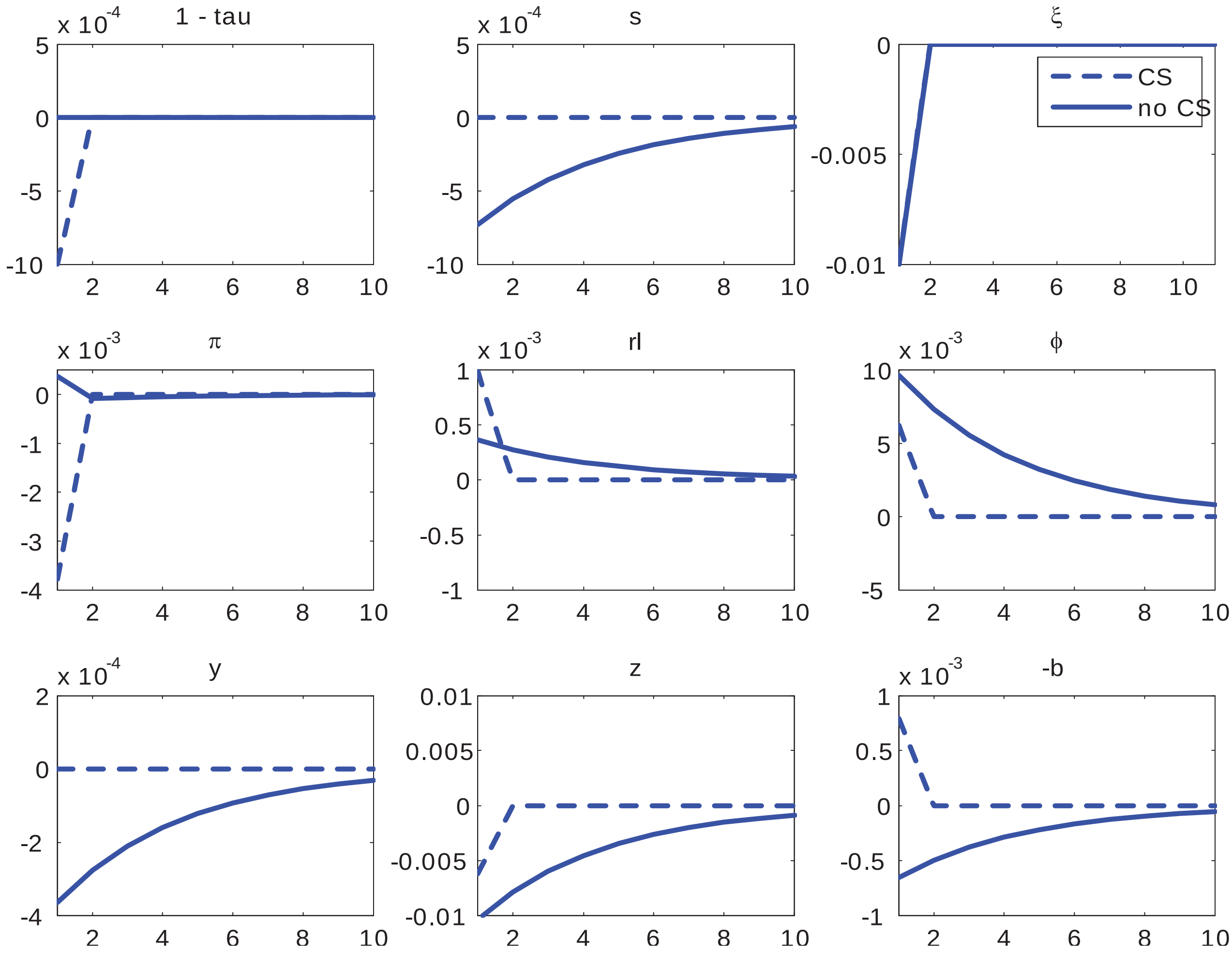

Figure 1: The role of credit subsidies following a 1% destruction of net worth

Note: based on a deterministic nonlinear solution of the model; all variables are reported in terms of logarithmic deviations from the initial steady state.
Solid lines, denoted by "no CS", denotes the case in which credit subsidies are kept constant at the optimal steady state level. Dashed lines, denoted by "CS", denotes the case in which policy can use time-varying fiscal subsidies.
Legend: "tau": fiscal subsidy; "s": total lending; "ξ": initial destruction of banks' net worth; "π": inflation; "rl": lending rate; "ϕ": leverage ratio; "y": output; "z": real value of banks' net worth; "b": real value of government debt.

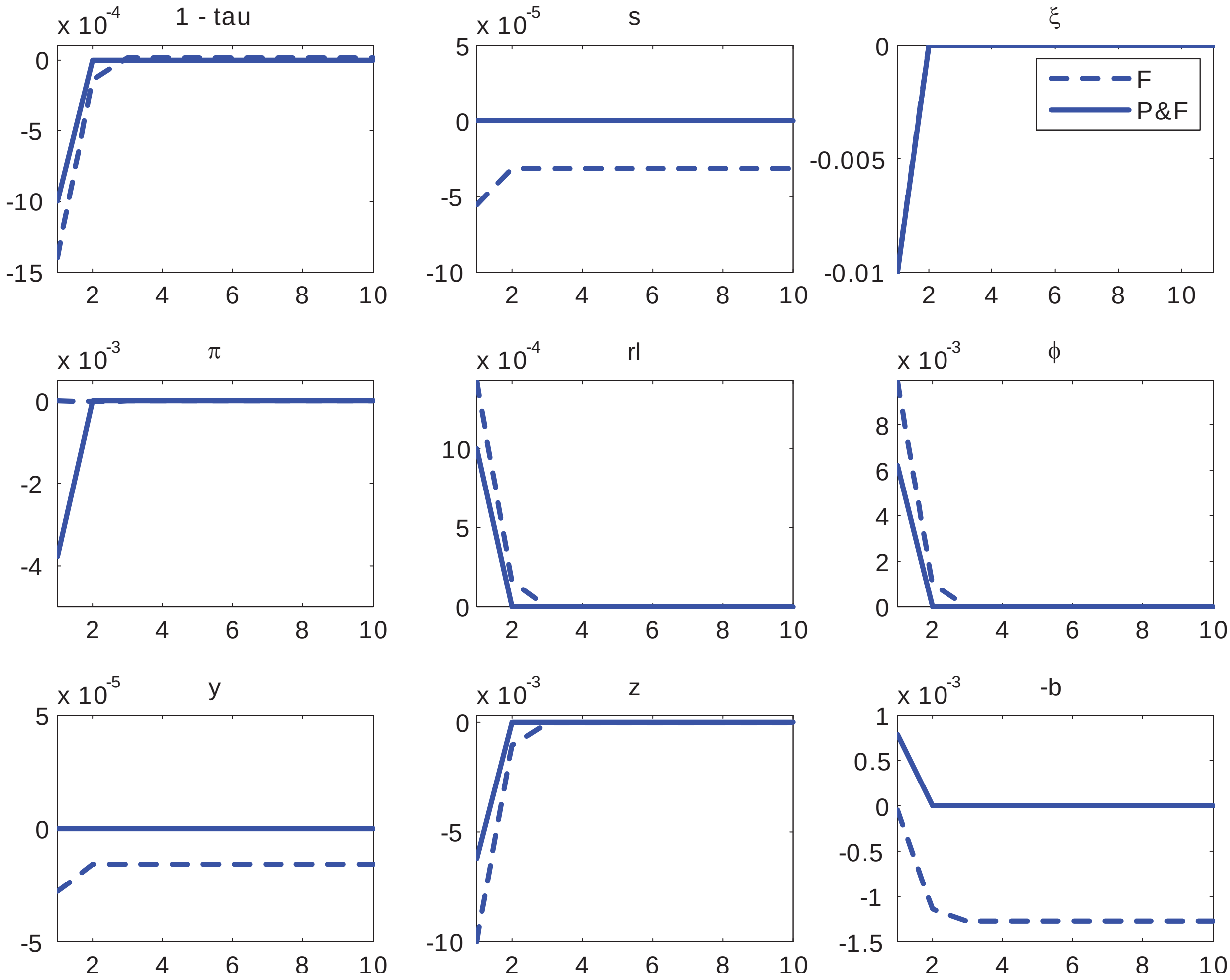

Figure 2. Credit subsidies following a 1% destruction of net worth:

the role of surprise adjustments in the price level

Note: based on a deterministic nonlinear solution of the model; all variables are reported in terms of logarithmic deviations from the initiaFig8.psy state.
Solid lines, denoted by "P&F", show the case in which policy can use both time-varying fiscal subsidies and surprise adjustments in the price level. Dashed lines, denoted by "F", show the case in which policy can adjust fiscal subsidies over time, but it cannot engineer surprise adjustments in the price level.
Legend: "tau": fiscal subsidy; "s": total lending; "ξ": initial destruction of banks' net worth; "π": inflation; "rl": lending rate; "ϕ": leverage ratio; "y": output; "z": real value of banks' net worth; "b": real value of government debt.

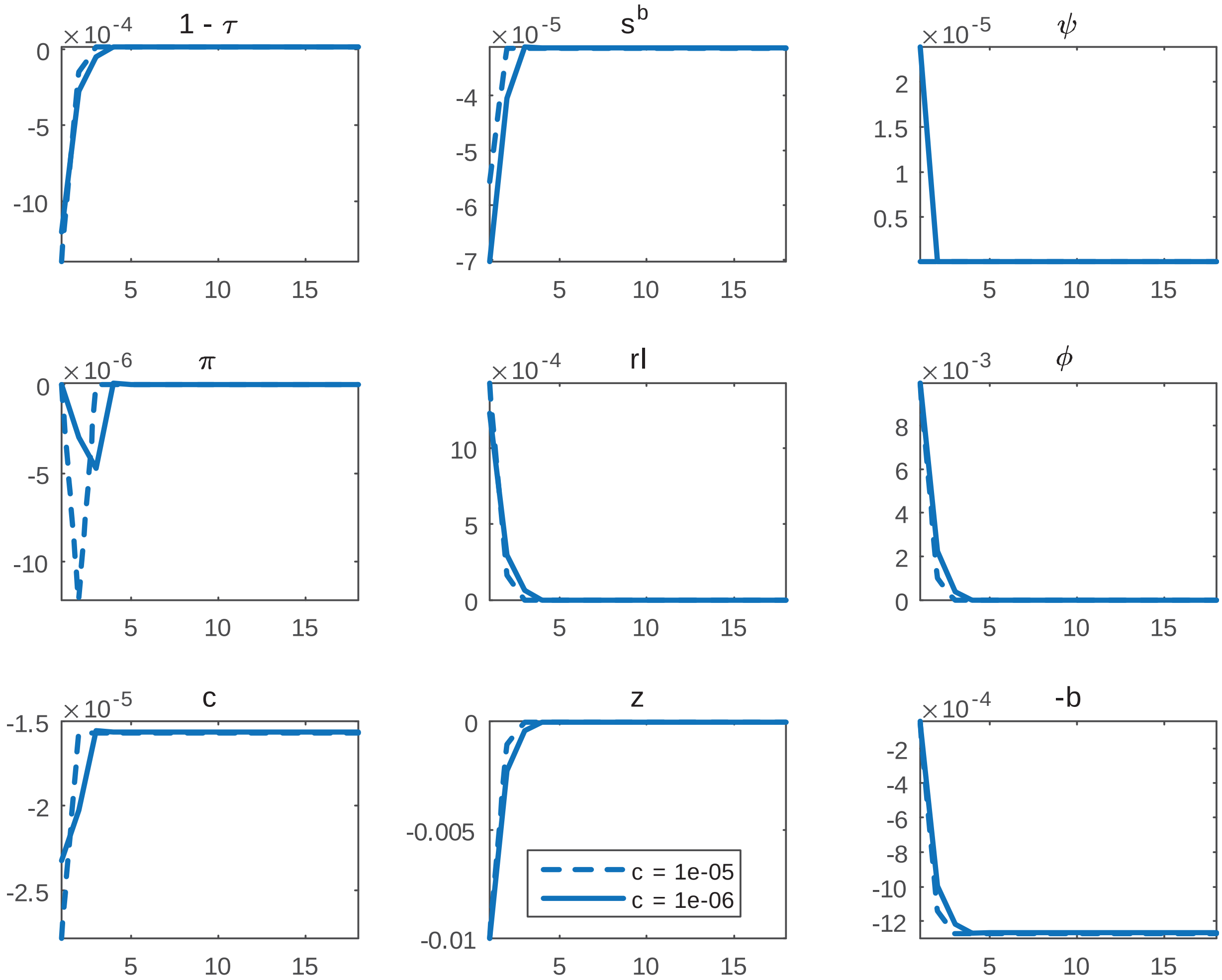

Figure 3a: Credit subsidies vs. credit easing following a 1% destruction of net worth

(when government debt is not state-contingent)

Note: based on a deterministic nFig4.psr solution of the model; all variables except "ψ" are reported in terms of logarithmic deviations from the initial steady state; "ψ" is in levels.

Solid and dashed lines show results for two values of the resourc cost – see the variable c in section 5.1.

Legend: "tau": fiscal subsidy; "s^b": lending by banks; "ψ": share of government lending; "π": inflation; "rl": lending rate; "ϕ": leverage ratio; "c": consumption; "z": real value of banks' net worth; "b": real value of government debt.

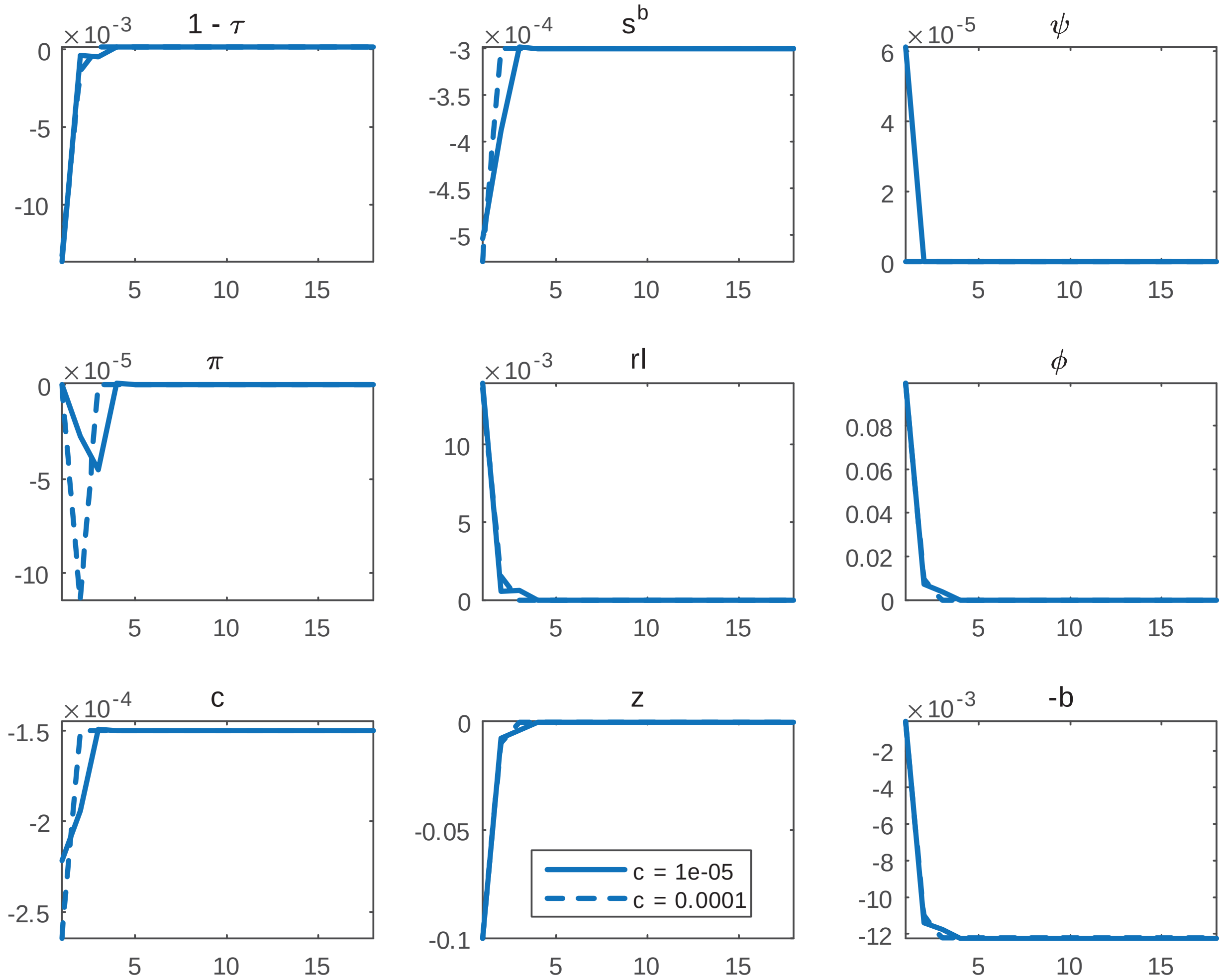

Figure 3b: Credit subsidies vs. credit easing following a 10% destruction of net worth (when government debt is not state-contingent)

Note: based on a deterministic nonlinear solution of the model; all variables except "ψ" are reported in terms of logarithmic deviations from the initial steady state; "ψ" is in levels.
Solid and dashed lf3a.pshow results for two values of the resourc cost – see the variable c in section 5.1.
Legend: "tau": fiscal subsidy; "s^b": lending by banks; "ψ": share of government lending; "π": inflation; "rl": lending rate; "ϕ": leverage ratio; "c": consumption; "z": real value of banks' net worth; "b": real value of government debt.

Appendix

Proof of Proposition 1: Take a path for consumption and labor that satisfies the resource constraints (13) together with $-\frac{u_C(t)A_t}{u_N(t)} \geq 1$. The intratemporal condition (23) determines τ_t^l given $\frac{R_t^l}{R_t}$. Given that the wedge is nonnegative, from (23) it must be that $\frac{R_t^l}{R_t}\left(1-\tau_t^l\right) \geq 1$, and therefore it is possible to find a τ_t^l such that the upper bound constraint on the subsidy is satisfied, (26). The incentive constraint (10) determines one of the weights, say η_t. The accumulation condition (11) determines the internal funds Z_t. f3b.psverage condition (15) determines the leverage rate ϕ_t. The conditions for the weights, (17) and (18), determine R_t^l and the weight, υ_t. The marginal condition for the firm (24) determines W_t. The borrowing constraint (25) determines the real lending S_t. The intertemporal marginal condition (21) determines the real rate R_t. The condition for the state contingent prices $Q_{t+1,t+2}$, (22), determines those prices.■

Proof of Proposition 2: Take a path for consumption and labor that satisfies the resource constraints (13) and such that $-\frac{u_C(t)A_t}{u_N(t)} \geq 1$. The intratemporal condition (14) determines τ_t^l given R_t^l. The borrowing constraint (9) determines the nominal lending S_t. The leverage condition (15) determines the leverage rate ϕ_t. The incentive constraint (10) determines one of the weights, say η_t. The accumulation condition (11) determines the internal funds Z_t. The intertemporal marginal condition (6) determines P_{t+1} that was restricted to be predetermined. The condition for the state contingent prices $Q_{t+1,t+2}$, (7), determines those prices. The conditions for the weights, (17) and (18), determine R_t^l and the weight, υ_t. Given that the wedge is positive, it must be that $R_t^l\left(1-\tau_t^l\right) \geq 1$, and therefore it is possible to find an R_t, such that $R_t^l\left(1-\tau_t^l\right) \geq R_t \geq 1$, so that the zero bound constraint on the interest rate and the upper bound constraint on the subsidy are both satisfied, (16). The nominal interest rate at the zero bound would always satisfy both constraints.■

Proof of Proposition 3 Let $\{C_t, N_t\}$ and $\left\{\phi_t, \frac{R_t^l}{R_t}, \eta_t, \upsilon_t, \frac{S_t}{P_t}, \frac{Z_t}{P_t}\right\}$ be an equilibrium allocation in which the nominal interest rate is allowed to be negative. Suppose now that whenever $R_t < 1$, the path for the nominal interest rate is modified to $\widetilde{R}_t = 1$. The equilibrium allocation will remain unchanged provided there are appropriate changes in $\tau_t^l, R_t^l, Q_{t,t+1}$ and in the growth rate of nominal variables S_t, Z_t, P_t. More precisely in the equilibrium with nominal interest rate given by $\widetilde{R}_t = 1$ these variables (also denoted with a tilde) will have to be adjusted so as to respect the following conditions:

$$R_t^l \left(1 - \tau_t^l\right) = \widetilde{R}_t^l \left(1 - \widetilde{\tau}_t^l\right), \, t \geq 0, \tag{28}$$

so that the wedges between marginal rate of substitution and marginal rate of transformation is unchanged;

$$\frac{R_t^l}{R_t} = \frac{\widetilde{R}_t^l}{\widetilde{R}_t}, \, t \geq 0, \tag{29}$$

so that the lending spreads are unchanged; and

$$\widetilde{Q}_{t,t+1}\widetilde{R}_t = Q_{t,t+1}R_t, \, t \geq 0, \tag{30}$$

and

$$\widetilde{R}_t \frac{\widetilde{P}_t}{\widetilde{P}_{t+1}} = R_t \frac{P_t}{P_{t+1}}, \, t \geq 0,$$

so that the growth rates of the nominal variables are adjusted by the change in the nominal rates.

With an appropriate adjustment in the initial levy l_0, the change from the original path R_t to the modified path $\widetilde{R}_t$ is also revenue neutral for the government. Since Z_0 is predetermined, the initial price level, P_0, and nominal loans, S_0, must be the same in the two cases. However, because R_0 affects the value of the initial wealth in (27), the movement to $\widetilde{R}_0$ can produce effects on the initial wealth. These effects can be neutralized by an adjustment in the initial levy.

Expressions for υ_t and η_t The value of a bank is

$$V_{j,t}\left(S^b_{j,t}, Z_{j,t}\right) = (1-\theta)\, E_t Q_{t,t+1} Z_{j,t+1} + E_t \sum_{s=1}^{\infty} (1-\theta)\, \theta^s Q_{t,t+1+s} Z_{j,t+1+s} =$$
$$= (1-\theta)\, E_t Q_{t,t+1} Z_{j,t+1} + E_t Q_{t,t+1} \theta V_{j,t+1}\left(S^b_{j,t+1}, Z_{j,t+1}\right)$$

The conjecture for $V_{j,t}\left(S^b_{j,t}, Z_{j,t}\right)$ is $V_{j,t}\left(S^b_{j,t}, Z_{j,t}\right) = \upsilon_t S^b_{j,t} + \eta_t Z_{j,t}$. Imposing that the incentive constraint binds gives

$$\upsilon_t S^b_{j,t} + \eta_t Z_{j,t} = \lambda S^b_{j,t}.$$

From

$$V_{j,t}\left(S^b_{j,t}, Z_{j,t}\right) = (1-\theta)\, E_t Q_{t,t+1} Z_{j,t+1} + E_t Q_{t,t+1} \theta V_{j,t+1}\left(S^b_{j,t+1}, Z_{j,t+1}\right),$$

$$Z_{j,t+1} = \xi_{t+1}\left[\left(R^l_t - R_t\right) S^b_{j,t} + R_t Z_{j,t}\right],$$

and

$$S^b_{j,t} = \frac{\eta_t}{\lambda - \upsilon_t} Z_{j,t} \equiv \phi_t Z_{j,t},$$

we have

$$\begin{aligned}\upsilon_t S^b_{j,t} + \eta_t Z_{j,t} &= (1-\theta)\, E_t Q_{t,t+1} \xi_{t+1}\left[\left(R^l_t - R_t\right) S^b_{j,t} + R_t Z_{j,t}\right] + \\ &\quad E_t Q_{t,t+1} \theta \left[\upsilon_{t+1} \varkappa_{t,t+1} S^b_{j,t} + \eta_{t+1} \zeta_{t,t+1} Z_{j,t}\right]\end{aligned}$$

where

$$\zeta_{t,t+1} = \xi_{t+1}\left[\left(R_t^l - R_t\right)\phi_t + R_t\right]$$

and

$$\varkappa_{t,t+1} = \frac{\phi_{t+1}}{\phi_t}\xi_{t+1}\left[\left(R_t^l - R_t\right)\phi_t + R_t\right].$$

It follows that

$$\upsilon_t = E_t\left\{(1-\theta)\,Q_{t,t+1}\xi_{t+1}\left(R_t^l - R_t\right) + Q_{t,t+1}\theta\varkappa_{t,t+1}\upsilon_{t+1}\right\}$$

and

$$\eta_t = E_t\left\{(1-\theta)\,R_t Q_{t,t+1}\xi_{t+1} + Q_{t,t+1}\theta\zeta_{t,t+1}\eta_{t+1}\right\}$$

or

$$\upsilon_t = \left\{(1-\theta)\,E_t Q_{t,t+1} R_t \xi_{t+1}\frac{\left(R_t^l - R_t\right)}{R_t} + E_t Q_{t,t+1}\theta\frac{\phi_{t+1}}{\phi_t}\xi_{t+1}\left[\left(R_t^l - R_t\right)\phi_t + R_t\right]\upsilon_{t+1}\right\}$$

and

$$\eta_t = E_t\left\{(1-\theta)\,R_t Q_{t,t+1}\xi_{t+1} + Q_{t,t+1}\theta\zeta_{t,t+1}\eta_{t+1}\right\}$$

The steady state (for online publication) In a steady state with constant gross inflation Π, we have $\frac{P_{t+1}}{P_t} = \frac{W_{t+1}}{W_t} = \frac{S_{t+1}}{S_t} = \frac{Z_{t+1}}{Z_t} = \Pi$. The steady state conditions, with $\psi_t = 0$ are given by

$$\frac{1}{\chi C N^{\varphi}} = \frac{R^l\left(1-\tau^l\right)}{A}$$

$$C + G = AN$$

$$R\frac{\beta}{\Pi} = 1$$

$$\frac{A}{R^l\left(1-\tau^l\right)}N = \phi\frac{Z_t}{P_t}$$

$$\Pi = (\theta + \omega)\left[\left(R^l - R\right)\phi + R\right] \tag{31}$$

where

$$\phi = \frac{\eta}{\lambda - \upsilon}$$

$$\upsilon = (1-\theta)\frac{\beta}{\Pi}\left(R^l - R\right) + \frac{\beta}{\Pi}\theta\varkappa\upsilon \tag{32}$$

$$\eta = (1-\theta) + \frac{\beta}{\Pi}\theta\zeta\eta \tag{33}$$

$$\varkappa = \zeta = \left(R^l - R\right)\phi + R \tag{34}$$

Manipulating the conditions (32) with (34) above, we get

$$\eta = \frac{1-\theta}{1-\theta\left[\left(\frac{R^l}{R}-1\right)\phi + 1\right]} \tag{35}$$

and

$$\upsilon = \frac{(1-\theta)\left(\frac{R^l}{R}-1\right)}{1-\theta\left[\left(\frac{R^l}{R}-1\right)\phi + 1\right]}. \tag{36}$$

It follows that

$$\phi = \frac{\eta}{\lambda - \upsilon} = \frac{1-\theta}{\lambda\left[1-\theta\left[1+\left(\frac{R^l}{R}-1\right)\phi\right]\right] - (1-\theta)\left(\frac{R^l}{R}-1\right)}$$

implying that

$$1-\theta-(1-\theta)\left[\lambda - \left(\frac{R^l}{R}-1\right)\right]\phi + \theta\lambda\left(\frac{R^l}{R}-1\right)\phi^2 = 0. \tag{37}$$

Notice that equation (31) can be written as

$$\frac{\beta-\omega-\theta}{\theta+\omega} = \left(\frac{R^l}{R}-1\right)\phi,$$

where it must be that $\frac{\beta}{\theta+\omega} > 1$, or $\beta > \theta + \omega$. This expression together with equation (37) can be used to obtain an expression for leverage

$$\phi = \frac{\beta (1-\theta)}{\lambda [\theta (1-\beta) + \omega]}. \tag{38}$$

The spread is given by

$$\frac{R^l}{R} - 1 = \frac{\lambda (\beta - \theta - \omega) [\theta (1-\beta) + \omega]}{(\theta + \omega) \beta (1-\theta)} \tag{39}$$

and is thus independent of inflation.

With lump-sum taxes, if the nominal interest could be negative, the Ramsey planner could implement the first best with monetary policy only, i.e. by setting $\tau^l = 0$. The optimal policy is to set $R^l = 1$. There is always a $R < 1$ that can satisfy the remaining equilibrium conditions, for a given P:

$$R\frac{\beta}{\Pi} = 1$$

$$AN = \phi\frac{Z}{P}$$

$$\Pi = (\theta + \omega) [(1-R) \phi + R]$$

where

$$\phi = \frac{\beta (1-\theta)}{\lambda [\theta (1-\beta) + \omega]}.$$

The solution requires $R < 1$ because otherwise the bank would not be willing to lend.

As seen above, the same allocation could be achieved when the zero-lower bound on nominal interest rates is imposed, $R \geq 1$, with an appropriate choice of credit subsidy τ^l. In this case, the first-best allocation can be achieved through a combination of $R^l > 1$, $R = 1$ and τ^l such that $R^l \left(1 - \tau^l\right. = 1$. The optimal subsidy can be obtained using equation () and is given by

$$\frac{\tau^l}{1-\tau^l} = \frac{\lambda\left(\beta-\theta-\omega\right)\left[\theta\left(1-\beta\right)+\omega\right]}{\left(\theta+\omega\right)\beta\left(1-\theta\right)} > 0.$$

The implementability condition (for online publication) The budget constraint of the households, (4) without lump sum taxes and with equality, is

$$E_0\sum_{t=0}^{\infty} Q_tP_tC_t = E_0\sum_{t=0}^{\infty} Q_{t+1}W_tN_t + E_0\sum_{t=0}^{\infty} Q_{t+1}\Pi_t^b + \left(1-l_0\right)\mathbb{W}_0,$$

with

$$\Pi_t^b = \left(\frac{1}{\theta+\omega}-1\right)Z_{t+1},$$

and

$$S_{t+1} = \frac{W_{t+1}N_{t+1}}{R_{t+1}},$$

can be written as

$$E_0\sum_{t=0}^{\infty} Q_tP_tC_t = E_0\sum_{t=0}^{\infty} Q_tP_t\frac{W_t}{R_tP_t}N_t + E_0\sum_{t=0}^{\infty} Q_{t+1}P_{t+1}\left(\frac{1}{\theta+\omega}-1\right)\frac{\frac{W_{t+1}N_{t+1}}{P_{t+1}R_{t+1}}}{\phi_{t+1}} + \left(1-l_0\right)\mathbb{W}_0$$

which, using the conditions for the households (5) and (7) can be written as

$$E_0\sum_{t=0}^{\infty}\beta^t u_C\left(t\right)C_t = -E_0\sum_{t=0}^{\infty}\beta^t u_N\left(t\right)N_t - E_0\sum_{t=0}^{\infty}\beta^{t+1}u_N\left(t+1\right)\left(\frac{1}{\theta+\omega}-1\right)\frac{N_{t+1}}{\phi_{t+1}} + \left(1-l_0\right)\mathbb{W}_0.$$

Alternatively, the constraint can be written as

$$E_0\sum_{t=0}^{\infty} Q_tP_tC_t = E_0\sum_{t=0}^{\infty}\frac{Q_tP_t}{R_tP_t}W_tN_t + E_0\sum_{t=0}^{\infty}\frac{Q_tP_t}{R_t}\frac{\Pi_t^b}{P_t} + \left(1-l_0\right)\mathbb{W}_0.$$

which, together with

$$\Pi_t^b = \xi_{t+1}(1-\theta-\omega)\left[\left(R_t^l - R_t\right)\phi_t + R_t\right]\frac{S_t}{\phi_t},$$

and

$$\frac{W_t N_t}{R_t} = S_t,$$

as well as (5) and (7), gives

$$\begin{aligned} & E_0 \sum_{t=0}^{\infty} \beta^t \left[u_C(t) C_t + u_N(t) N_t\right] + E_0 \sum_{t=0}^{\infty} \beta^t u_N(t) \xi_{t+1}(1-\theta-\omega)\left[\left(\frac{R_t^l}{R_t} - 1\right)\phi_t + 1\right]\frac{N_t}{\phi_t} \\ = \; & u_C(0)(1-l_0)\frac{\mathbb{W}_0}{P_0}. \end{aligned}$$

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