Credit Spreads and Credit Policies*

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Abstract

How should monetary and fiscal policy react to adverse financial shocks? If monetary policy is constrained by the zero lower bound on the nominal interest rate, subsidising the interest rate on loans is the optimal policy. The subsidies can mimic movements in the interest rate and can therefore overcome the zero bound restriction. Credit subsidies are optimal irrespective of how they are financed. If debt is not state contingent, they 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.

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


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1 Introduction

The financial crisis and the Great Recession have exposed the limitations of conventional monetary policy as a tool for macroeconomic stabilization. Downward movements in the nominal interest rate have become infeasible, because the zero lower bound constraint has been reached in many countries. Additional macroeconomic stimulus has been sought for through quantitative easing measures. Central banks have also developed new policy instruments aimed to address the specific challenges in the financial sector. Weak balance sheet conditions of financial intermediaries have motivated credit policies, as direct credit provision.

In this paper we investigate how tax policy should be used in conjunction with monetary policy to respond to shocks that deteriorate intermediaries’ balance-sheets causing financial disruption. In particular we consider credit subsidies and show that these can be used effectively to respond to those shocks. We rely on a simple model with the costly enforcement friction of Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). The key friction is that bankers can divert part of the bank’s assets. In order to be able to attract deposits, they must also capitalise the bank with a sufficient amount of own funds. Internal funds receive a higher return than bank deposits, so lending rates include a spread over and above the deposit rate. The lending spread is a distortion that can be particularly severe when banks’ internal funds become too low as a result of exogenous shocks, that can be interpreted as shocks to the value of collateral.

In our model, even if we abstract from sticky prices and monopolistic competition, the zero interest rate level is a binding constraint for monetary policy. The central bank would want to set the policy interest rate to a negative level, so as to lower lending rates towards the value which they would reach in the absence of financial frictions. Even if this policy would not reduce lending spreads, it would minimize the effects of the spreads on lending, and therefore on equilibrium allocations.

Given that interest rate policy is restricted by the zero lower bound, how can monetary policy minimize the implications of financial market distortions on the real economy? In spite of the binding constraint on the nominal interest rate, there is still room for policy in these flexible-price models. Surprise movements in the price level can be very effective in changing
the outstanding level of public debt. In our model, they can additionally affect the real level of internal funds of financial intermediaries.\footnotemark

In order to restrict policy makers’ ability to generate state contingent debt with ex-post volatility of the price level, we look at optimal outcomes when monetary policy is restricted from moving the price level on impact, in response to shocks. When instantaneous price adjustments are prevented, monetary policy alone has very little room for manoeuvre in our model. A negative financial shock—i.e. a shock which destroys banks net worth—can have severely adverse consequences on the economy. Even in our stylized model, an idiosyncratic shock to banks’ net worth which increases spreads by $1.5$ percentage points—an amount comparable to the increase in CDS spreads in the last quarter of 2008—causes a $1.5$ percent impact fall in output—again broadly comparable to the almost $2\%$ fall in U.S. GDP in the first quarter of 2009. Additional policy interventions are intuitively desirable.

As in the original Gertler and Karadi (2011) model, policies of direct lending by the central bank would be desirable in our model when banks are balance-sheet constrained. Balance sheet constraints can disrupt lending through the increase in credit spreads. Replacing the "missing" private intermediation with central bank intermediation is intuitively appealing. Nevertheless, central bank intermediation, even if aggressively carried out, cannot isolate the real economy from the consequences of adverse financial shocks. And, furthermore, it involves resource costs since, presumably the central bank is less efficient in these activities than the private banking sector.

We show that an ideal response to financial disruption when interest rates are at the zero bound is a fiscal policy involving credit subsidies. Rather than replacing the missing private credit, credit subsidies lower the "effective" borrowing cost for the nonfinancial sector. If lending spreads increase because of a weakening of banks’ balance sheets, credit subsidies can potentially completely offset that increase. With lower effective lending rates, lending volumes will not be depressed. In our model, the real economy can be perfectly shielded from the consequences of the financial disruption.

The exact features of the allocation which can be achieved through credit subsidies depend on how subsidies are financed. If lump sum taxes were feasible, credit subsidies could be

\footnotetext{1How exactly these movements in the price level can be implemented is a separate issue, which we do not deal with in this paper. One possible implementation is with money supply policy (see also Adao, Correia and Teles (2013) for a discussion of this implementation issue).}
used to achieve the first best allocation in the economy. Without lump sum taxes, but with state contingent debt, credit taxes and subsidies will only be used in response to shocks. One way to think about state contingent debt in this particular set up where we are interested in understanding the impact of large and rare financial shocks, is to think of a confiscatory tax on wealth that could be justified by the exceptional nature of the shock.

As in Chari, Christiano and Kehoe (1991), state contingent debt could be replicated through unexpected changes in inflation, which would generate all the desirable variation in the real value of the outstanding nominal public debt. When we restrict policy makers' ability to implement instantaneous price adjustments in reaction to shocks, however, public debt is not state-contingent. In this case, credit taxes and subsidies are still optimal, but they have budgetary implications and the economy cannot be perfectly insulated from the consequences of financial shocks. Indeed adverse 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

Credit subsidies in this model play the same role as the policy interest rate, even if acting through very different mechanisms. But they have one main advantage, that they are not subject to the zero bound constraint. This is a central message of this paper, that credit taxes and subsidies can be used to overcome the zero bound constraint on interest rates. Credit subsidies can mimic any movements in the nominal interest rate, but have the advantage of not being subject to the zero bound. With credit subsidies it is therefore possible to implement allocations that would be infeasible for monetary policy, because they would require negative interest rates.

Our paper is related to the recent literature studying the effects of financial market shocks and the desirability of non-standard policy responses (see also Curdia and Woodford, 2011, De Fiore and Tristani, 2012, Eggertsson and Krugman, 2010). This literature explores various forms of direct lending by the central bank, but it does not explicitly allow for tax instruments and it does not study the optimal combination of monetary and fiscal policy in reaction to financial, or other, shocks.

Optimal fiscal policy when interest rates are at zero has been studied by Eggertsson and Woodford (2006) and Werning (2012). These papers however rely on the new Keynesian model

²These 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.
and therefore abstract from financial market distortions. The key benefit of fiscal policy in those models is related to the large fiscal multipliers which arise in theory when monetary policy is constrained by the zero bound (see Christiano, Eichenbaum and Rebelo, 2011; Eggertsson, 2011, Woodford, 2011). In contrast, in our environment the fiscal intervention is desirable to cushion the economy from the consequences of an increase in credit spreads.

Our paper is related to the results in Correia, Farhi, Nicolini and Teles (2013), that show that consumption and other taxes can be used to overcome the zero bound constraint in models with sticky prices. Our paper differs in the type of frictions and shocks which make the zero bound a restriction for monetary policy, but it confirms the result that standard tax instruments can overcome the zero bound constraint. However, while in the sticky price model it is possible to achieve the first best without lump sum revenues (provided the monopolistic competition mark up is close to zero), in our set up with credit frictions this is no longer true.

The paper is organized as follows. In section 2, we describe the environment. In section 3, we analyze optimal credit policies, in the first and second best, and establish the redundancy of nominal interest rate policy when credit subsidies are used. In section 4, we compute numerically the optimal response to shocks in a second best, without lump sum taxes. We consider two cases. In the first, policy can instantaneously change the price level in response to shocks. In the second case, policy is restricted from affecting prices on impact. Section 5 concludes the paper.

2 A model

The model we use is a model in which banks face an enforcement problem as in Gertler and Karadi (2011). 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 bankers, workers and consumers. 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 reasons not to do so. In equilibrium there are going to be profits that are accumulated as internal funds. The government consumes, raises taxes and pays for subsidies on credit, and issues money and debt.
The uncertainty in period \( t \geq 0 \) is described by the random variable \( \gamma_t \in \Gamma_t \), where \( \Gamma_t \) is the set of possible events at \( t \), and the history of its realizations up to period \( t \) is denoted by \( \gamma^t \in \Gamma^t \). For simplicity we index by \( t \) the variables that are functions of \( \gamma^t \).

2.1 The household

The household is composed of workers and bankers: with probability \( 1 - \theta \) bankers exit and become workers, and with probability \( \theta \) they remain bankers. The fraction of bankers is \( f \) and workers \( 1 - f \). Bankers and workers share consumption.

The household preferences are

\[
\text{Max } E_t \sum_{t=0}^{\infty} \beta^t \left[ \log C_t - \frac{X}{1 + \phi} N_t^{1+\phi} \right]
\]

The household starts period \( t \) with nominal wealth \( W_t \). At the beginning of period \( t \), in an assets market, the household purchases \( E_t Q_{t,t+1} B_{t,t+1} \) in state contingent nominal claims where \( Q_{t,t+1} \) 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. It also purchases noncontingent public debt \( B_t^g \), and deposits \( D^h_t \). In the beginning of the following period the nominal wealth \( W_{t+1} \) includes the state contingent bonds \( B_{t,t+1} \), the gross return on noncontingent public debt, \( R_t B_t^g \), and deposits, \( R_t D^h_t \), the dividends received from the banks \( \Pi_t^b \). It also includes the wage income \( W_t N_t \), which is received in units of money in a goods/labor market at the end of period \( t \). The household pays for consumption expenditures \( P_t C_t \), and lump sum taxes \( T_t \). The flow of funds constraints of the households are therefore

\[
E_t Q_{t,t+1} B_{t,t+1}^g + B_t^g + D_t \leq W_t, \quad (1)
\]

\[
W_{t+1} = B_{t,t+1}^g + R_t B_t^g + R_t D_t + \Pi_t^b + W_t N_t - P_t C_t - T_t
\]

These budget constraints are written under the assumption that \( R_t \geq 1 \). Otherwise, the households would actually borrow an arbitrarily large amount and hold cash. Unless the profits from that activity were fully taxed this would not be an equilibrium. This is the zero bound on interest rates as an equilibrium restriction.

The first order conditions of the households problem include

\[
- \frac{u_C(t)}{u_N(t)} = \frac{P_t}{W_t}, \quad (2)
\]

\[
\frac{u_C(t)}{\beta u_C(t+1)} = \frac{Q_{t+1}^{-1}}{P_{t+1}}, \quad (3)
\]
\[
\frac{u_C(t)}{P_t} = R_t E_t \frac{\beta u_C(t + 1)}{P_{t+1}},
\]  

(4)

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. In the beginning of the period, the firm needs to borrow nominal funds \(S_t\) in order to pay the wage bill. We assume the firms hold those funds as money, \(M_t^f = S_t\), that is not remunerated.\(^3\) The borrowing constraint is

\[
W_t N_t \leq S_t
\]

(5)

The profits in each period \(t\) can be written as\(^4\)

\[
\pi_t^f = P_t Y_t - W_t N_t - \left[ R_t^l \left( 1 - \tau_t^l \right) - 1 \right] S_t,
\]

where \(P_t\) is the price level, \(R_t^l\) is the gross interest rate on the loans to the firms, and \(\tau_t^l\) is a government subsidy on the gross loan rate.

Using the borrowing constraint (5), we can write profits as

\[
\pi_t^f = P_t Y_t - R_t^l \left( 1 - \tau_t^l \right) W_t N_t.
\]

Profit maximization implies

\[
P_t A_t = R_t^l \left( 1 - \tau_t^l \right) W_t.
\]

(6)

which, together with the borrowing constraint (5), implies

\[
A_t N_t = R_t^l \left( 1 - \tau_t^l \right) \frac{S_t}{P_t}
\]

2.3 Banks

Each bank \(j\) channels funds from depositors to the firms. Because of a costly enforcement problem, banks must have rents that are accumulated as internal funds, \(Z_{j,t}.\)\(^5\) This means

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\(^3\)One way to think about the timing of transactions is with an assets market in the beginning of the period where firms borrow the money and a goods/labor market at the end where they use the money to pay wages.

\(^4\)It is an equilibrium restriction that \(R_t^l \left( 1 - \tau_t^l \right) \geq R_t\), otherwise firms could make infinite profits borrowing at \(R_t^l \left( 1 - \tau_t^l \right)\) and holding deposits that would pay \(R_t\).

\(^5\)These internal funds are a balance sheet item defined as the difference between banks’ assets-loans and liabilities-deposits.
that there are going to be positive spreads and that internal funds will have high rates of
return. It also implies that there must be exit of bankers, so that internal funds can remain
scarce.

The bank borrows $D_{j,t}$ from households and firms and lends $S_{j,t}^b$. It follows that the balance
sheet of the bank is described by

$$S_{j,t}^b = D_{j,t} + Z_{j,t}.$$  

Because the return on the internal funds is going to be higher than the alternative return
$R_t$, profits will be kept in the bank, as internal funds, until exit. The net worth of the bank
evolves according to

$$Z_{j,t+1} = \xi_{t+1} \left[ R_t^l S_{j,t}^b - R_t D_{j,t} \right],$$

where $\xi_t$ is a shock to the value of internal funds, similar to the capital quality shock in Gertler
and Karadi (2011). This can be interpreted as a shock to the value of collateral.

Combining the two conditions above, we can write

$$Z_{j,t+1} = \xi_{t+1} \left[ (R_t^l - R_t) S_{j,t}^b + R_t Z_{j,t} \right]$$

Bankers exit in the beginning of the period, before the assets market. At the assets market
in period $t$, terminal wealth, $V_{j,t}$, is

$$V_{j,t} = E_t \sum_{s=0}^{\infty} (1 - \theta)^s Q_{t+1+s} Z_{j,t+1+s} = E_t \sum_{s=0}^{\infty} (1 - \theta)^s Q_{t+1+s} \xi_{t+s} \left[ (R_t^l + \theta Q_{t+1} S_{j,t+1+s} + R_t Z_{j,t+s} \right]$$

As in Gertler and Kiyotaki (2010), bankers can appropriate a fraction $\lambda$ of assets $S_{j,t}$. This
takes place in the asset market at time $t$. The incentive compatibility constraint is, thus.

$$V_{j,t} \geq \lambda S_{j,t}^b.$$  

As shown in appendix A, the value $V_{j,t}$ can be written as:

$$V_{j,t} = v_t S_{j,t}^b + \eta_t Z_{j,t}$$

where

$$v_t = E_t \left\{ (1 - \theta) Q_{t+1} R_t \frac{R_t^l - R_t}{R_t} \right\} + E_t \frac{S_{j,t+1}^b}{S_{j,t}^b} v_{t+1}$$

and

$$\eta_t = E_t \left\{ (1 - \theta) R_t Q_{t+1} \xi_{t+1} + Q_{t+1} \theta Z_{j,t+1} \right\} \eta_{t+1}.$$
The incentive constraint can then be written with equality as

\[ v_t S_{j,t}^b + \eta_t Z_{j,t} = \lambda S_{j,t}^b. \]  \hspace{1cm} (7)

It follows that

\[ S_{j,t}^b = \frac{\eta_t}{(\lambda - v_t)} Z_{j,t} \equiv \phi_t Z_{j,t}, \]

where \( \phi_t \) is the private assets to equity ratio, which we refer to as leverage ratio. More specifically the debt to equity ratio is

\[ \frac{S_{j,t}^b - Z_{j,t}}{Z_{j,t}} = \phi_t - 1 > 0. \]

The evolution of net worth can now be simplified to

\[ Z_{j,t+1} = \xi_{t+1} \left[ \left( R_{t} - R_t \right) \phi_t + R_t \right] Z_{j,t}. \]

The growth rates of \( Z_j \) and \( S_j^b \) are given by

\[ \zeta_{t,t+1} = \frac{Z_{jt+1}}{Z_{jt}} = \xi_{t+1} \left[ \left( R_{t} - R_t \right) \phi_t + R_t \right] \]

\[ \zeta_{t,t+1} = \frac{S_{jt+1}}{S_{jt}} = \frac{\phi_{t+1}}{\phi_t} \xi_{t+1} \left[ \left( R_{t} - R_t \right) \phi_t + R_t \right] \]

We can now write the expressions for \( v_t \) and \( \eta_t \) as

\[ v_t = E_t \left\{ (1 - \theta) Q_{t,t+1} R_{t} \xi_{t+1} \frac{\left( R_{t} - R_t \right)}{R_t} + Q_{t,t+1} \theta \zeta_{t,t+1} v_{t+1} \right\} \]

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 internal funds of bankers are the sum of the funds of surviving bankers \( Z_{et+1} \) and entering bankers \( Z_{nt+1} \). Since a fraction \( \theta \) of bankers survive,

\[ Z_{et} = \theta \xi_t \left[ \left( R_{t-1}^e - R_{t-1} \right) \phi_{t-1} + R_{t-1} \right] Z_{t-1}. \]

The remaining fraction, \( 1 - \theta \), die and transfer back the internal funds to the households at the end of the period. The households then transfer to the entering banks the fraction \( \frac{\omega}{\omega - \theta} \) of these assets at \( t \),

\[ Z_{nt} = \omega \xi_t \left[ \left( R_{t-1}^e - R_{t-1} \right) \phi_{t-1} + R_{t-1} \right] Z_{t-1}. \]
We can then write
\[ Z_t = Z_{et} + Z_{nt} = (\theta + \omega) \xi_t \left[ \left( R_{t-1} - R_{t-1} \right) \phi_{t-1} + R_{t-1} \right] Z_{t-1}. \] (8)

Exiting bankers transfer their net worth (after the shock) to the households as dividends. Aggregate dividends transferred by exiting banks to households are
\[ \Pi_{n,t}^b = \xi_t (1 - \theta) \left[ \left( R_{t-1} - R_{t-1} \right) \phi_{t-1} + R_{t-1} \right] Z_{t-1}. \]

It follows that dividends to households net of the transfer to entering banks are therefore
\[ \Pi_t^b = \xi_t (1 - \theta - \omega) \left[ \left( R_{t-1} - R_{t-1} \right) \phi_{t-1} + R_{t-1} \right] Z_{t-1} \]
which, using (8), can be rewritten as
\[ \Pi_t^b = \left( \frac{1}{\theta + \omega} - 1 \right) Z_t \] (9)

### 2.4 Government

The government spends \( G_t \), issues money \( M_t \), issues noncontingent debt \( B_t^g \), remunerated at rate \( R_t \), and contingent debt \( B_{t,t+1}^g \) priced at \( Q_{t,t+1} \), gives credit subsidies \( \tau_t R_t^l S_t \), and raises lump sum taxes \( T_t \).

The government budget constraint is given by
\[ B_t + E_t Q_{t,t+1} B_{t,t+1}^g + M_t \leq -W_t, \] (10)
where \(-W_{t+1}\) are government liabilities
\[ -W_{t+1} = R_t B_t^g + B_{t,t+1}^g + M_t + R_t^l S_t + P_t G_t - T_t \] (11)

The government budget constraint can therefore be written as
\[ B_t^g + E_t Q_{t,t+1} B_{t,t+1}^g + M_t \leq R_{t-1} B_{t-1}^g + B_{t-1,t}^g + M_{t-1} + \tau_{t-1} R_{t-1}^l S_{t-1} + P_{t-1} G_{t-1} - T_{t-1} \]

### 2.5 Market clearing

The market clearing condition in the goods market is
\[ C_t + G_t = A_t N_t \]
and the market clearing condition for loans is
\[ S_t = S_t^b. \]
2.6 Equilibrium conditions

The equilibrium conditions for the variables \(\{C_t, N_t\}, \{\tau^l_t, R_t, Q_{t,t+1}, P_t\}\) and \(\{R^l_t, \phi_t, \eta_t, v_t, S_t, Z_t\}\) can be summarized by the following conditions

\[- \frac{u_C(t)}{u_N(t)} = \frac{R^l_t (1 - \tau^l_t)}{A_t}, \quad (12)\]

\[C_t + G_t = A_t N_t, \quad (13)\]

\[A_t N_t = R^l_t \left(1 - \tau^l_t\right) \frac{S_t}{P_t}, \quad (14)\]

\[S_t = \phi_t Z_t, \quad (15)\]

\[\phi_t = \frac{\eta_t}{\lambda - v_t}, \quad (16)\]

\[Z_t = \xi_t (\theta + \omega) R_{t-1} \left[ \left( \frac{R^l_{t-1}}{R_t} - 1 \right) \phi_{t-1} + 1 \right] Z_{t-1}, \quad (17)\]

\[- \frac{u_C(t)}{P_t} = R_t E_t \frac{\beta u_C(t+1)}{P_{t+1}}, \quad (18)\]

\[Q_{t,t+1} = \frac{\beta u_C(t+1) P_t}{u_C(t) P_{t+1}}, \quad (19)\]

\[R_t \geq 1, \quad (20)\]

and

\[v_t = (1 - \theta) E_t R_t Q_{t,t+1} \xi_{t+1} \left( \frac{R^l_t}{R_t} - 1 \right) + \theta E_t R_t Q_{t,t+1} \xi_{t+1} \frac{\phi_{t+1}}{\phi_t} \left[ \left( \frac{R^l_t}{R_t} - 1 \right) \phi_t + 1 \right] v_{t+1} \quad (21)\]

\[\eta_t = (1 - \theta) E_t R_t Q_{t,t+1} \xi_{t+1} + \theta E_t R_t Q_{t,t+1} \xi_{t+1} \left[ \left( \frac{R^l_t}{R_t} - 1 \right) \phi_t + 1 \right] \eta_{t+1} \quad (22)\]

The budget constraint of the government does not restrict the variables in the conditions above because the budget constraint of the government, or households, can always be satisfied with lump sum taxes, \(T_t\).

Notice that the shock to internal funds \(\xi_t\) affects the equilibrium conditions through

\[\frac{A_t}{R^l_t (1 - \tau^l_t)} N_t = \frac{\phi_t Z_t}{P_t} \quad (23)\]

and

\[Z_t = \xi_t (\theta + \omega) R_{t-1} \left[ \left( \frac{R^l_{t-1}}{R_t} - 1 \right) \phi_{t-1} + 1 \right] Z_{t-1} \quad (24)\]

and that the price level can adjust 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.
The nominal quantity of money is not neutral in this economy, the reason being that internal funds are predetermined. If it was possible to increase $Z_0$, together with all price levels and nominal quantities by the same percentage, this would keep interest rates and allocations unchanged. Because $Z$ is predetermined, however, increasing all nominal quantities and price levels would not be possible without changing the real allocation. Equation (17) shows that, for a given $Z_{t-1}$, an increase in $Z_t$ would not be consistent with the observed levels of the policy rate $R_{t-1}$, the credit spread, $R_{t-1}/R_{t-1}$, and leverage, $\phi_{t-1}$. The level of prices is not irrelevant in this economy.

It is useful to compare the equilibrium allocation with the one that would arise in the absence of distortions. The first-best allocation can be obtained as the solution to the maximization of households’ preferences subject to the resource constraint. The efficiency conditions are given by

\begin{equation}
\frac{-u_C(t)}{u_N(t)} = \frac{1}{A_t},
\end{equation}

\begin{equation}
C_t + G_t = A_t N_t.
\end{equation}

Comparison of condition (25) with (12) shows that the distortion introduced by costly enforcement and by the death probability of bankers, which limit their ability to accumulate internal funds, shows up as a positive wedge $R_{t-1}/(1 - \tau_t) - 1$. Only when this is zero, it is possible to achieve the first best allocation in our economy.

3 Credit policies

In the economy with lump sum taxes and credit subsidies there is a complete set of instruments in the sense that the set of implementable allocations can be characterized by the resource constraints alone. It follows that the first best can be implemented. If credit subsidies could not be used and only interest rate policy had to be used in response to shocks, then because of the zero bound, there would be an additional restriction corresponding to the zero bound constraint. We now show these results.

3.1 Lump sum taxes

With lump sum taxes, the set of competitive equilibrium conditions restricting the allocations of consumption and labor can be summarized by the resource constraints only. In order to show this, we take a particular feasible allocation and show that there are prices, or policies, or other
variables that satisfy all the other equilibrium conditions. There are multiple implementations of each allocation, so that it is easier if we fix a particular one.\textsuperscript{6} The implementation is restricted to set the policy rate to the zero lower bound and not to change the price level contemporaneously in response to shocks.

We then take a path for consumption and labor that satisfies the resource constraints (13). The intratemporal condition (12) determines \( r_t \) given \( R_t \). The borrowing constraint (14) determines the nominal lending \( S_t \). The leverage condition (15) determines the leverage rate \( \phi_t \). The incentive constraint (16) determines one of the weights, say \( \eta_t \). The accumulation condition (17) determines the internal funds \( Z_t \). The intertemporal marginal condition (18), given the policy rate that is set at the zero bound, determines \( P_{t+1} \) that was restricted to be predetermined and the condition for the state contingent prices \( Q_{t,t+1} \), (19) determines those prices. The conditions for the weights, (21) and (22), determine \( R_t \) and the weight, \( v_t \).

It may be useful to interpret this implementation, in response to a negative shock to the value of internal funds, \( \xi_t \). Because the price level does not move on impact, the real value of internal funds moves down by the full amount of the shock. As a result, leverage and the spread have to go up. Because of the zero bound, it is not possible to cut interest rates to counteract the effect of the spread on allocations. The subsidy, instead can be adjusted for that purpose. Because there are lump sum taxes, they can be used to finance the subsidy. If there were lump sum taxes on average but they could not be adjusted in response to shocks, and debt was state contingent, the response to the shock would be the same.

There are other implementations of each equilibrium. Suppose there can be an average credit subsidy, but subsidies cannot move in response to shocks. Then, if the subsidy is high enough, so that the policy rate can also be relatively high in the steady state, then depending on the size of shocks, it might actually be possible to implement the full set of allocations with movements in the policy rate.

The particular implementation of the whole equilibrium set described above was restricting the price level not to move on impact. Another implementation will have the price level adjust and therefore, the movements in the financial variables and in the credit subsidies, may not be as pronounced. In particular, in response to an i.i.d. shock to the value of internal funds, a decrease in the price level on impact by the full amount of the shock, will be all the adjustment that is needed to neutralize the effect of the shock on the equilibrium.

\textsuperscript{6}We thank Joao Sousa, that first suggested the possibility of multiple implementations.
The first best allocation with lump sum taxes Since, with lump sum taxes, the implementable set is all feasible allocations, i.e. the ones restricted by the resource constraints (13), it follows that the first best can be achieved. It is possible to achieve the first best by using credit subsidies rather than setting negative interest rates and $R_l^t = 1$.

The first best allocation requires

$$R_t^l (1 - \tau_t^l) = 1$$

Optimal policy can achieve the first-best by setting $R_t = 1$ and $R_t^l (1 - \tau_t^l) = 1$. The same allocation can also be achieved with a path for the policy rate that is higher than zero, $R_t > 1$, and with a higher subsidy $\tau_t^l$ that compensates not only the spread but also the policy rate.

A steady state distortion and the costs of the ZLB In this economy the subsidy would have to be positive in the steady state. Indeed, this is an economy where the need for rents that provide incentives for bankers distorts allocations on average. If the policy rate could be negative, that would be a way of subsidizing the firms that are borrowing, eliminating the distortion. In this sense, there is a cost of the zero lower bound in the steady state, if credit subsidies cannot be used.

The expression for the equilibrium spread in the steady state is

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

with $\beta > \theta + \omega$, so that the spread in the steady state is strictly positive. With lump sum taxes, if the nominal interest could be negative, $R < 1$, the Ramsey planner could implement the first best with monetary policy only, i.e. by setting $\tau^l = 0$. The spread is still positive, but because the policy rate is negative, $R < 1$, the net lending rate can be zero, $R^l = 1$.

The same allocation could also be achieved with an appropriate choice of credit subsidy $\tau^l$, when the zero-lower bound on nominal interest rates is imposed, $R \geq 1$. In this case, the first-best allocation can be achieved through a combination of $R^l > 1$, $R = 1$ and $\tau^l$ such that $R^l (1 - \tau^l) = 1$.

As seen above, another feature of all the implementable allocations, and therefore also of the first best equilibrium, is that the dynamic response to shocks of other variables is indeterminate. Real allocations are pinned down, but different impact movements in the initial price level would be accompanied by different subsidies $\tau^l$ and different values of real
net worth, leverage, and credit spreads. However, lending rates net of the subsidy would remain fixed at zero, i.e. \( R_t^l (1 - \tau_t^l) = 1 \). The Ramsey planner would therefore be indifferent between the different adjustment paths of spreads, net worth and leverage in reaction to shocks. As it turns out, this is also a feature of an economy where the first best cannot be achieved but there is state contingent debt.

3.2 Second best policies

Without lump sum taxes, the budget constraints of the government, or households, must be taken into account. We assume that in addition to nominal debt being state contingent, there is a tax on initial wealth \( l_0 \).\(^7\) With state contingent debt, the households budget constraints can be written as the single constraint

\[
\sum_{t=0}^{\infty} E_0 \frac{Q_t}{R_t} P_t C_t \leq \sum_{t=0}^{\infty} E_0 \frac{Q_t}{R_t} W_t N_t + \sum_{t=0}^{\infty} E_0 \frac{Q_t}{R_t} \Pi_t^b + (1 - l_0) W_0.
\]

We can then use the firms and households marginal conditions, (6), (2), and (3), and the expression for the net profits of the banks that can be written, from (9), as

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

to write the budget constraint, with equality, as

\[
\sum_{t=0}^{\infty} E_0 \beta^t \pi_t u_C (t) C_t = - \sum_{t=0}^{\infty} E_0 \beta^t \pi_t u_N (t) N_t - \sum_{t=0}^{\infty} E_0 \beta^t \pi_t u_N (t) \left( \frac{1}{\theta + \omega} - 1 \right) \frac{N_t}{\phi_t} + (28)
\]

\[
R_0 u_C (0) \frac{(1 - l_0) W_0}{P_0}.
\]

In this case without lump sum taxes, it is not possible to summarize the set of implementable allocations with a small set of conditions. In particular, the implementable set cannot be described by the implementability condition (28) and the resource constraints, (13). There are restrictions on the leverage rate \( \phi_t \) imposed by the other equilibrium conditions.

To be more specific, the other equilibrium conditions, other than (28) and (13), impose one restriction across all possible occurrences of uncertainty in each period, but they don’t impose further restrictions. Let \#\( \Gamma_t \) be the number of possible occurrences of uncertainty in period \( t \). Then for a given path for \( \{ C_t, N_t \} \) in the implementable set, the intratemporal condition

\(^7\)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 but cannot finance the credit subsidies/taxes or government spending.
(12) in each period $t \geq 0$ and each state is satisfied by $\tau^1_t$; the borrowing constraints (14) in each period $t \geq 0$ are satisfied with the price level in $\#\Gamma_t - 1$ states and $S_t$ in one state, at time $t \geq 0$; the condition for the leverage (15) in each period $t \geq 0$ is satisfied with loans $S_t$, in $\#\Gamma_t - 1$ states, and one $\phi_t$; the incentive constraint (16) in each period $t \geq 0$ is satisfied with the choice of the weight $\eta_t$; the accumulation equation (17) in each period $t \geq 0$ is satisfied with $Z_t$; the intertemporal condition (18) in period $t \geq 0$ is satisfied with $P_{t+1}$ in one state, since in each period there is one degree of freedom in picking the price level; (21) is satisfied by $R^l_t$. Finally, because all these other constraints did not impose restrictions on $R_t$, it is possible to choose it so that the zero bound constraint (20) is satisfied.

3.2.1 The redundancy of the policy rate and irrelevance of the zero bound on interest rates

We have just shown that in addition to the constraints (28) and (13) in \{C_t, N_t\} and \{\phi_t, R_0, P_0, l_0\} the other equilibrium conditions impose one more restriction on $\phi_t$, per state in period $t - 1$, i.e. $\#\Gamma^{t-1}$ restrictions in each period. The interesting thing however is that those restrictions on $\phi_t$, other than the zero lower bound constraint itself, are independent of $R_t$. This means that the implementable set for \{C_t, N_t\} and \{\phi_t, R_0, P_0, l_0\} is independent of the path of the interest rate \{R_t\}. It also means that the restriction that the nominal interest rate must be nonnegative is irrelevant.

The role of the policy rate in this economy is the same as the role of credit taxes and subsidies, with one difference: the zero bound constraint on interest rates. This constraint does not apply to the credit taxes, which can become subsidies. We now state the redundancy of the policy rate as a policy instrument and the irrelevance of the zero bound constraint.

**Proposition 1** (Redundancy of the policy interest rate) The policy interest rate is a redundant policy instrument in the economy with credit subsidies.

The redundancy of the policy rate for the implementation of each allocation can be made more clear with the following argument. Each allocation in the implementable set can be implemented with multiple paths for the nominal interest rate, with the credit subsidies and other variables compensating for the effects of the policy interest rates. In particular, let’s take an equilibrium allocation, \{C_t, N_t\} and \{\phi_t, R^l_t, \eta_t, v_t, S_t, Z_t\}, where $R^l_t \geq 1$. Suppose now that the path for the nominal interest rate was $\bar{R}_t$. The variables (with a tilde) that will have
to be adjusted to keep all those variables constant, are \( \{\tau'_t, \tilde{R}_t, \tilde{Q}_{t,t+1}, t \geq 0\} \) as well as the nominal variables \( \tilde{S}_t, \tilde{Z}_t, \tilde{P}_t, t \geq 1 \), that will be growing at different rates, because the nominal interest rates will be different. The relation between those variables in the two economies will be

\[
R'_t \left( 1 - \tau'_t \right) = \tilde{R}'_t \left( 1 - \tau'_t \right), \quad t \geq 0,
\]

so that the wedges are the same;

\[
\frac{R'_t}{R_t} = \frac{\tilde{R}'_t}{\tilde{R}_t}, \quad t \geq 0,
\]

so that the spreads are the same; as well as

\[
\tilde{Q}_{t,t+1}\tilde{R}_t = Q_{t,t+1}R_t, \quad t \geq 0,
\]

and

\[
\frac{\tilde{R}_t}{\tilde{P}_t} = \frac{R_t}{P_{t+1}}, \quad t \geq 0,
\]

so that the growth rates of the nominal variables are adjusted by the change in the nominal rates. Because \( Z_0 \) is predetermined, the initial price level, \( P_0 \), and nominal loans, \( S_0 \), must be the same in the two economies. Because \( R_0 \) affects the value of the initial wealth, in (28), the initial levy \( l_0 \), will have to be adjusted to keep the budget constraint from being affected.

Except for the effect on the initial wealth, this change in the path of nominal interest rates and credit subsidies is revenue neutral. With the adjustment in the initial levy it is indeed revenue neutral.

The redundancy of the policy rate means that if we were to impose additional restrictions on the policy rate, those restrictions would not be relevant for the set of implementable allocations. Suppose we were to free the nominal interest rate from the constraint that it must be nonnegative. Then as the equilibria are defined, the lifting up of that restriction would not be relevant. Lifting up the zero bound constraint has two implications. One is that with a negative interest rate it is possible to subsidize credit. That can be done by the credit subsidy directly. Another implication is that agents would be able to make very large profits out of arbitrage. But those choices are not taken into account when the equilibrium is defined by the equilibrium conditions above.

The corollary follows

**Corollary 2** The zero bound on the nominal interest rate is irrelevant for the implementation of allocations.
Yet another way to think about this irrelevance is the following: Suppose we were to allow for negative policy 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 assume that the household and banks are prevented from doing this. Banks can give cash to the firms, but they cannot hold it. Subject to these restrictions, there is an equilibrium with negative rates. We still take into account the effect that lower (negative) rates have on the lending rates and on the government financing. There is thus an extended set of equilibria where the nominal interest rate is not restricted to be positive. That set of equilibria with negative interest rates can be implemented with positive rates and with credit subsidies. In other words, for given allocations, and for any path for the policy rate, corresponding to a particular path of credit taxes, there is an alternative implementation with the policy rate set at zero and alternative paths of credit taxes. That alternative implementation will produce the same wedges and raise the same tax revenues. This means that if nominal interest rates taxes could be negative, the credit taxes would be redundant policy instruments. It also means that the fiscal policies can overcome the nonnegativity constraint on the nominal interest rate allowing to achieve better allocations.

3.3 Credit subsidies vs credit easing

Credit subsidies are not conventional policy, but they affect the economy in the same way as interest rate policy, except when the interest rate ought to be negative in which case they can still be effective. Instead, the unconventional credit easing policies, such as the direct central bank lending to firms explored in Gertler and Karadi (2011), act in a very different way. While interest rate policy, or credit subsidies, in this economy aim at minimizing the costs of ensuring the private incentives to the financial intermediaries, direct lending by the central banks directly overcomes the need for those incentives. As in Gertler and Karadi (2011) we assume there is a resource cost of direct lending. The rationale for the resource cost can be a direct enforcement cost.

The government is assumed to provide intermediation $S_{it}^0$ directly to non-financial firms at the market rate $R_l^t$. In its intermediation activity the government is not subject to the incentive constraint, but it has an intermediation cost $\tau$ per unit of real lending. The aggregate deadweight cost is $\tau S_{it}^0 R_l^t$. 18
Government intermediation can be written as a fraction of total intermediation $S_t^g = \psi_t S_t$. The government flow of funds constraints would have to be modified to include direct lending as

$$\bar{B}_t^g + E_t Q_{t,t+1} B_{t,t+1}^g + M_t - \psi_t S_t \leq -\bar{\psi}_t^g,$$

and

$$-\bar{\psi}_{t+1}^g = R_t \bar{B}_t^g + B_{t,t+1}^g + M_t + \tau_t R_t^l S_t + \tau \psi_t S_t - \psi_t S_t R_t^l + P_t G_t - T_t$$

(34)

The resource constraints would be

$$C_t + G_t + \tau \psi_t \frac{S_t}{P_t} = A_t N_t$$

and the market clearing condition for loans,

$$S_t = S_t^b + \psi_t S_t.$$

In order to be able to achieve the first best it would have to be the case that either $\tau = 0$ or $\psi_t = 0$. This means that in the benchmark with lump sum taxes, credit subsidies are superior to direct lending policies. In the second best, without lump sum taxes, the ranking is no longer obvious. The comparison is between a resource cost (and possibly also the deadweight costs of financing that cost) and the deadweight cost of the subsidy. Suppose the resource cost is such that in the steady state, direct lending would not be used. Then, with state contingent debt, it should also not be used in response to shocks. Even if the optimal proportionate wedge in response to a particular shock was high, the reason for that is that the high wedge is not very costly, and therefore in general it would be better to subsidize rather than spending the resource cost. Instead, without state contingent debt, there is a cost of financing the credit subsidies that may justify the use of direct lending.

Whether a credit subsidy or direct central bank intermediation are preferable will depend on how severe is the financial friction relative to the resource cost. If the resource loss is deemed to be large, credit subsidies will be preferable in reaction to severe financial impairments. If the resource loss is small, central bank intermediation is preferable, since credit subsidies have budgetary implications, increasing public deficit and debt at times of crisis.

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8Gertler and Karadi assume that policy is an arbitrary rule for $\psi_t$ as a function of credit spreads.
4 Numerical analysis

This section illustrates the quantitative features of the model described in section 2 through an impulse response analysis.

We only have five parameters to calibrate. We use standard values for utility parameters: $\beta = 0.99$ and $\varphi = 0$. 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, $\lambda$, bankers’ survival probability, $\theta$, and the proportional transfer to entering bankers, $\omega$. In the steady state of our model, these parameters imply an annualized spread of 1.1 percent 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 expenditure is set to zero in the figures.

We assume that the economy starts from the optimal steady state—that is, the steady state in which government debt and the fiscal subsidy are at their optimal level—and then look at impulse responses to i.i.d. shocks. The level of government debt must then be negative in the optimal steady state. The government holds positive assets in order to finance the optimal subsidy.

The impulse responses are the ones that would be obtained under commitment at an arbitrarily distant date in the future—assuming commitment is at time zero. We first abstract from fiscal policy, so that $\tau^f$ is kept constant at its optimal level. The policy interest rate is set at zero, but there is still room for price level policy. How this price level policy can actually be directly implemented is beyond the scope of this paper.

In this economy, the price level can move on impact and thus affect the real value of both banks’ internal funds and government debt. This policy is extremely powerful since it can make real government debt and real internal funds effectively state contingent. In general, mimicking both state contingent government debt and state contingent internal funds through a single change in the price level is infeasible. For the particular example with a technology shocks that we compute, the optimal response of the price level achieves both goals.

In order to restrict the possibility of replicating state contingent debt (or money) and because, in practice, central banks are not able to change the price level on impact in response to shocks, we move on to study the case in which policy is exogenously prevented from changing
prices on impact after the shock. In this case, fiscal policy can still improve allocations through credit subsidies and taxes.

All impulse responses are computed after solving the fully nonlinear, deterministic version of the model.

4.0.1 Optimal response to shocks at the ZLB

The impulse responses in Figures 1 through 5 are all under the assumption that lump sum taxes cannot be levied. The differences are between the case where only monetary and price level policy are considered (Figures 1 and 2), and the case when credit taxes and subsidies are also considered (Figures 3-5). In the exercises in Figures 4 and 5 policy is restricted not to move the price level on impact.

Figure 1 shows the impulse responses to a 1% innovation in technology—the shock is assumed to be serially uncorrelated—when optimal policy is constrained by the zero bound on nominal interest rates. All variables are in deviation from the steady state.

As seen in figure 1, output responds to the shock exactly as it would in the first best. It increases one-to-one with the shock, while hours (not reported in the figure) remain constant. To deliver this outcome, optimal policy must ensure that leverage, hence spreads, do not change in reaction to the shock. In turn, this requires that the increase in the real value of loans necessary to finance the increase in production, \( s_t = S_t / P_t \), is accompanied by a one-to-one increase in real value of net worth \( z_t = Z_t / P_t \). This can be achieved through an impact fall in the price level, which must be reversed after one period to ensure that \( s_t \) and \( z_t \) return to their steady state values once the shock is reabsorbed. In the third period after the shock, all variables are back to steady state. In this exercise the movements in the price level needed to adjust the real value of internal funds is the same as the movement needed to adjust the real value of debt.

Figure 2 shows responses to a financial shock \( \xi_t \), which causes a 1% exogenous fall in the value of banks’ nominal internal funds—this shock is also assumed to be serially uncorrelated. As in Figure 1, optimal policy is constrained by the zero bound on nominal interest rates. Ceteris paribus, the shock would lead to a one-to-one reduction in real internal funds \( z_t \) and, for given amount of loans, an increase in banks’ leverage \( \phi_t \). If lump sum taxes were available, policy would respond through a cut in the price level equal to the size of the shock. This response would completely stabilise the real value of internal funds, leverage and output. The
same response would be optimal without lump sum taxes if credit subsidies could be used. Instead, when only price level policy can be used, the change in the price level that would be needed to adjust both the value of internal funds and debt, results in the price level actually increasing, reinforcing the drop in the real value of internal funds. That way, output drops, and in spite of the increase in the increase in the lending rate, the expenditure in the subsidy goes down. With lower outlays, the outstanding real value of government assets must go down, which is indeed the case when the price level goes up. In other words, to ensure a stationary level of government debt in steady state, the price level must increase slightly on impact. In real terms, the government debt increases and banks’ net worth falls a bit more than implied by the size of the shock. Leverage and credit spreads must increase, so that banks profits increase and net worth can be slowly rebuilt. Along the adjustment path, lending volumes and output remain below the steady state. This exercise also shows that the effects on the price level depend on the calibration that has the economy start from the efficient steady state where the government has enough assets to pay for the steady state level of the subsidy. Still, the general result that price level policy is not sufficient to deal with the effect of the shock, at the zero lower bound, is there, independently of the particular calibration.

When only price level policy is used, the impulse responses to a net worth shock are third best. The second best responses, which coincide with the first best responses in this economy, will have allocations not vary with the net worth shock. Figure 3 shows that the first best responses are implemented when we allow for time-varying fiscal subsidies (the impulse responses of figure 2 are also shown for comparison). Following the shock, the price level falls which cushions the reduction in net worth (by almost 50% compared to the case shown in Figure 2). However lending is kept unchanged in real terms. Net worth and 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, prices return to steady state and so does the real value of government debt. The adjustment process is complete.

One way to understand the impulse responses with a time-varying credit subsidy in Figure 3 is to note that in this case price level policy can be used to guarantee that government bonds are state contingent, without other conflicting objectives such as guaranteeing also that real internal funds are adjusted optimally. The role of the credit subsidy is to ensure that real allocations are optimal, irrespective of the real value of banks’ internal funds and leverage.
Changes in the initial price level can thus be targeted to ensure that real government debt is state-contingent, and thus ensure the necessary financing of the credit subsidy.

Figures 4 and 5 show how this outcome is altered when government bonds cannot be made state-contingent because of a restriction to policy that does not allow for the price level to be moved on impact.

Following a technology shock, shown in Figure 4, the real value of banks’ net worth cannot be changed on impact. To allow for an increase in production, leverage must increase. The ensuing increase in loan rates, however, has almost no effect on the real economy, thanks to a parallel increase in the subsidy $\tau_l$. Real allocations are similar to the first best, but the economy does not return to the original steady state. The increase in the subsidy ultimately leads to a small, permanent increase in the real value of 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 a marginally lower level.

Qualitatively similar results are obtained in response to a shock to the value of internal funds—see Figure 5. The impulse response of output is relatively close to the first best, but this requires an initial increase in the credit subsidy which leads to a permanent increase in real government debt. A 12% shock to internal funds, which in our model would cause an increase in spreads by 1.5% as in the last quarter of 2008, would lead to a 1.4% increase in real government debt in the new steady state.

## 5 Concluding remarks

We have analyzed optimal monetary and fiscal policy in reaction to financial shocks in an economy where the nonnegativity of the policy rate is a binding constraint to monetary policy.

We have shown that credit subsidies and taxes can be employed to shield the economy from the adverse consequences of financial shocks on credit spreads. The subsidy can implement the first best when monetary policy is constrained if it can be financed in a lump sum fashion. However, without lump sum taxes, or without state contingent debt, a policy of credit subsidies and taxes is not fully effective. When debt cannot be made state contingent, the financing of the credit subsidy induces permanent effects on taxes, government debt, and output.

Credit subsidies are not conventional policy, but they affect the economy in a very similar fashion to interest rate policy, except when the interest rate ought to be negative. Instead, the
unconventional credit easing policies, such as the direct central bank lending to firms explored in Gertler and Karadi (2011), act in a very different way. While interest rate policy, or credit subsidies, in this economy aim at minimizing the costs of ensuring the private incentives to the financial intermediaries, direct lending by the central banks directly overcomes the need for those incentives, at a cost in terms of resources. The rationale for the resource cost can be a direct enforcement cost.

Whether a credit subsidy or direct central bank intermediation are preferable will depend on how severe is the financial friction relative to the resource cost. If the resource loss is deemed to be large, credit subsidies will be preferable in reaction to severe financial impairments. If the resource loss is small, central bank intermediation is preferable, because credit subsidies have budgetary implications, increasing public deficit and debt at times of crisis.

Appendix

Derivation of the coefficients in the leverage function

\[ V_{j,t} \left( S_{j,t}^b, Z_{j,t} \right) = (1 - \theta) E_t Q_{t,t+1} Z_{j,t+1} + E_t \sum_{s=1}^{\infty} (1 - \theta) \theta^s Q_{t,t+1+s} Z_{j,t+1+s} = \]

\[ = (1 - \theta) E_t Q_{t,t+1} Z_{j,t+1} + E_t Q_{t,t+1} \theta \sum_{s=0}^{\infty} (1 - \theta) \theta^s Q_{t+1,t+2+s} Z_{j,t+2+s} = \]

\[ = (1 - \theta) E_t Q_{t,t+1} Z_{j,t+1} + E_t Q_{t,t+1} \theta V_{j,t+1} \left( S_{j,t+1}^b, Z_{j,t+1} \right) \]

The conjecture for \( V_{j,t} \left( S_{j,t}^b, Z_{j,t} \right) \) is \( V_{j,t} \left( S_{j,t}^b, Z_{j,t} \right) = v_t S_{j,t}^b + \eta_t Z_{j,t} \). Imposing that the incentive compatibility constraint binds gives

\[ v_t S_{j,t}^b + \eta_t Z_{j,t} = \lambda S_{j,t}^b \]

\[ V_{j,t} \left( S_{j,t}^b, Z_{j,t} \right) = (1 - \theta) E_t Q_{t,t+1} Z_{j,t+1} + E_t Q_{t,t+1} \theta V_{j,t+1} \left( S_{j,t+1}^b, Z_{j,t+1} \right) \]

\[ Z_{j,t+1} = \xi_{t+1} \left[ \left( R_t^i - R_t \right) S_{j,t}^b + R_t Z_{j,t} \right] \]

\[ S_{j,t}^b = \frac{\eta_t}{\lambda - v_t} Z_{j,t} \equiv \phi_t Z_{j,t} \]

or

\[ v_t S_{j,t}^b + \eta_t Z_{j,t} = (1 - \theta) E_t Q_{t,t+1} \xi_{t+1} \left[ \left( R_t^i - R_t \right) S_{j,t}^b + R_t Z_{j,t} \right] + \]

\[ E_t Q_{t,t+1} \theta \left[ v_{t+1} \xi_{t+1} S_{j,t}^b + \eta_{t+1} \xi_{t+1} Z_{j,t} \right] \]
It follows that
\[ v_t = E_t \left\{ (1 - \theta) Q_{t,t+1} \xi_{t+1} \left( R_t' - R_t \right) + Q_{t,t+1} \theta \zeta_{t,t+1} v_{t+1} \right\} \]
and
\[ \eta_t = E_t \left\{ (1 - \theta) R_t Q_{t,t+1} \xi_{t+1} + Q_{t,t+1} \theta \zeta_{t,t+1} \eta_{t+1} \right\} \]
together with
\[ \zeta_{t,t+1} = \xi_{t+1} \left( R_t' - R_t \right) \phi_t + R_t \]
\[ \xi_{t,t+1} = \frac{\phi_{t+1}}{\phi_t} \xi_{t+1} \left( R_t' - R_t \right) \phi_t + R_t \]
It follows that
\[ v_t = E_t \left\{ (1 - \theta) R_t Q_{t,t+1} \xi_{t+1} \frac{R_t'}{R_t} + E_t Q_{t,t+1} \theta \phi_{t+1} \xi_{t+1} \left( R_t' - R_t \right) \phi_t + R_t \right\} v_{t+1} \]
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 In a steady state with constant gross inflation \( \Pi \), 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
\[ \frac{1}{\lambda C N^\phi} = R^\beta \frac{(1 - \tau^i)}{A} \]
\[ C + G = AN \]
\[ R^\beta \frac{\Pi}{\Pi} = 1 \]
\[ \frac{A}{R^\beta (1 - \tau^i)} N = \phi \frac{Z_t}{P_t} \]
\[ \Pi = (\theta + \omega) \left[ \left( R_t' - R \right) \phi + R \right] \] (35)
where
\[ \phi = \frac{\eta}{\lambda - \nu} \]
\[ v = (1 - \theta) \frac{\beta}{\Pi} \left( R_t' - R \right) + \frac{\beta}{\Pi} \theta \nu \]
\[ \eta = (1 - \theta) + \frac{\beta}{\Pi} \theta \zeta \eta \] (37)
\[ \zeta = \zeta = \left( R_t' - R \right) \phi + R \] (38)
\[ 25 \]
Manipulating the conditions (36) with (38) above, we get

$$\eta = \frac{1 - \theta}{1 - \theta \left[ \left( \frac{R^l}{R} - 1 \right) \phi + 1 \right]} \quad (39)$$

and

$$v = \frac{(1 - \theta) \left( \frac{R^l}{R} - 1 \right)}{1 - \theta \left[ \left( \frac{R^l}{R} - 1 \right) \phi + 1 \right]}. \quad (40)$$

It follows that

$$\phi = \frac{\eta}{\lambda - v} = \frac{1 - \theta}{\lambda \left[ 1 - \theta \left( 1 + \left( \frac{R^l}{R} - 1 \right) \phi \right) \right] - (1 - \theta) \left( \frac{R^l}{R} - 1 \right)} \quad (41)$$

implying that

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

Notice that equation (35) 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 (41) can be used to obtain an expression for leverage

$$\phi = \frac{\beta (1 - \theta)}{\lambda \left[ \theta (1 - \beta) + \omega \right]} \quad (42)$$

The spread is given by

$$\frac{R^l}{R} - 1 = \frac{\lambda (\beta - \theta - \omega) \left[ \theta (1 - \beta) + \omega \right]}{(\theta + \omega) \beta (1 - \theta)} \quad (43)$$

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 $P$:

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

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

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

where

$$\phi = \frac{\beta (1 - \theta)}{\lambda \left[ \theta (1 - \beta) + \omega \right]}.$$
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 $\tau^I$. In this case, the first-best allocation can be achieved through a combination of $R^I > 1$, $R = 1$ and $\tau^I$ such that $R^I (1 - \tau^I) = 1$. The optimal subsidy can be obtained using equation (43) and is given by

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

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Figure 1: Impulse responses to a technology shock: optimal price level policy
Figure 2: Impulse responses to a net worth shock: optimal price level policy
Figure 3: Impulse responses to a technology shock: optimal price level (P) vs. price level and fiscal (P&F) policy
Figure 4: impulse responses to a technology shock: optimal price level and fiscal (P&F) vs. fiscal policy (F).
Figure 5: impulse responses to a net worth shock: optimal price level and fiscal (P&F) vs. fiscal policy (F).