# Optimal credit, monetary, and fiscal policy under occasional financial frictions and the zero lower bound

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Very preliminary, please do not circulate.

*I study optimal credit, monetary, and fiscal policy under commitment in a model where financial intermediaries face an occasionally binding financial constraint. I find credit policy effective only when monetary policy is constrained by the zero lower bound and fiscal policy is constrained by the government budget. The nonlinear financial constraint has two important precautionary implications. First, the government should exit from its credit policy more slowly than the speed of deleveraging in the financial sector. This leads to a positive balance sheet of the central bank after a financial crisis. Second, the ZLB becomes particularly significant when it binds together with the financial constraint. The central bank tries to avoid that by adjusting nominal interest rates slowly toward zero and often staying above the ZLB even when the underlying shocks would imply a zero nominal interest rate for several periods in a standard New Keynesian model.*
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## I. Introduction

The 2007-2009 financial crisis involved a significant disruption to financial intermediation, as evidenced by limited access to credit (e.g. Ivashina and Scharfstein, 2010) and high credit spreads. To stabilize the financial system, monetary authorities in major economies introduced the so-called unconventional monetary policy after cutting nominal interest rates to zero. This type of policy included the provision of large-scale liquidity[1] and resulted in central bank balance sheets expanding 20 to 30 per cent of GDP. In doing so, policymakers hope to reduce long-term interest rates, boost lending, and stimulate real activity.[2] Unconventional monetary policy may also restore the functioning of financial markets on which the transmission mechanism of the conventional monetary policy depends (Altavilla, Canova and Ciccarelli, 2016). Since then, there is a renewed

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[1]In the last ten years, there have been various policies branded under the name of unconventional monetary policies, including quantitative easing, negative interest rates, forward guidance, etc. A good summary can be found in Borio and Zabai (2016)

[2]It is relatively well established that quantitative easing reduces long-term interest rates. See, among many others, Gagnon et al. (2011) and Krishnamurthy and Vissing-Jorgensen (2011) for the Federal Reserve's QE, and Joyce et al. (2011) and Christensen and Rudebusch (2012) for the Bank of England's QE. However, credit policy can have insignificant or unintended real effects through a bank lending channel, as shown by Chakraborty, Goldstein and MacKinlay (2017) and Acharya et al. (2017).

interest in disturbances to the financial sector as an important driver of the business cycle and credit policy designed to target directly the source of the problem. A decade after the crisis, however, the normative aspect of credit policy is still not fully understood. In the meantime, several major economies have experienced persistent low interest rates and low inflation. A number of achievements towards financial stability have been rolled back. In this course, there are ongoing debates on how monetary policy framework may move away from inflation targeting to get prepared for the next recession. Since real interest rates are low, there is limited room to cut nominal interest rates before hitting the zero lower bound (ZLB) again. In the US, the Fed's balance sheet is shrinking but is still large. In other advanced economies, the unwinding of central banks' balance sheets has not started. It is therefore unclear if similar quantitative easing could be used in the next financial crisis. If central banks have tied hands, coordination between fiscal and monetary policy could be important.

In this paper, I study optimal credit, monetary, and fiscal policy under commitment (Ramsey policy) in tackling financial disturbances in a low-interest-rate-high-public-debt environment. Credit policy is modelled as private asset purchasing, monetary policy controls nominal interest rates, and fiscal policy sets a labour tax. The ability to commit has become more relevant in recent years thanks to improved communication and active implementation of forward guidance to manage expectations. The optimal joint policy is complicated. Broadly speaking, there are two dimensions to the problem. First, how to coordinate the three policies to ease financial inefficiency, taking into account multiple tradeoffs faced by each policy and spillovers from one policy to another. Second, how to finance the government budget given the burden of private asset purchasing and potential labour subsidies.

To study these problems, I adopt a simple New Keynesian model augmented with a banking sector of Gertler and Kiyotaki (2010). Banks face a financial constraint derived from an agency problem between banks and depositors. The constraint is slack in normal times but binds endogenously in periods of financial distress. This is the risk I focus on in this paper. When the constraint is binding, banks have difficulties rolling over their short-term debts, which leads to a collapse in asset prices and investment. Since the root of the problem is inefficient financial intermediation, credit policy is designed to replace constrained intermediaries (banks) by an unconstrained financial intermediary (the government). This, however, naturally crowds out banks from engaging in profitable investment. Furthermore, it encourages risk-taking by banks in normal times, as noted by Bianchi (2016). Both expansionary monetary and fiscal policy is helpful to boost demand, at the cost of high inflation and labour market distortions respectively. If not hitting the ZLB, monetary policy is particularly powerful because it allows both the government and banks to borrow at a cheaper price and hence relaxes both the financial and the government budget constraint. In this way, monetary policy faces the tradeoff between stabilising the financial market and prices. A key feature of this framework is that the value of banks, which is a forward-looking variable, enters the financial constraint. The government can ease policy tradeoffs it faces today by exploiting private agents' expectations. For example, monetary policy can manage expectations through not only the Phillips curve but also the value of banks.

My key findings are as follows. Given reasonable calibration, credit policy is not particularly efficient. This is because the amount of private assets the government need to purchase in order to stabilise the financial sector is often large. In a world where the central bank is unlikely to hit the ZLB and the fiscal authority has access to lump-sum taxes, the primary tools to battle with financial inefficiency are the traditional monetary and fiscal policy, both of which are very effective. However, as many countries are characterised by lower interest rates and high public debts, both the government budget and the ZLB put significant constraints on fiscal and monetary policy. This leaves credit policy the only policy free to adjust. It turns out that, in this case, optimal credit policy is fairly active and persistent. The central bank responds to a financial shock by purchasing a substantial proportion of private assets. Then the central bank unwinds it balance sheet slowly due to the crowding out effect. Moreover, the central bank keeps positive asset purchasing even in a few periods after the financial constraint becoming slack. This is because the nonlinearity of the occasionally binding constraint (OBC) gives the central bank a precautionary motive to safeguard the economy when there is a substantial probability to hit the financial bound again. For the same reason, monetary policy cuts nominal interest rates slowly toward zero. The central bank is reluctant to cut interest rates because it has a precautionary incentive to save ammo. In fact, the ZLB is rarely hit even the underlying shock would imply a zero nominal interest rate for several periods in a standard New Keynesian model. The traditional wisdom of .e.g Eggertsson and Woodford (2003) suggests that the ZLB is not a significant constraint as long as monetary policy can commit to keeping interest rates low for long. However, my result shows that it is painful if both the ZLB and the financial constraint bind, which the government tries to avoid. At last, I find that optimal fiscal policy needs to increase, instead of decrease, labour taxes in order to finance the large scale asset purchasing.

The main contribution of this paper is to showcase mechanisms and quantify channels of a (necessarily) complicated policy problem in an environment that is likely to prevail in the near future. This paper is related to several strands of literature. First, this paper belongs to the literature that conducts normative analysis of unconventional policy[3]. I share Bianchi (2016)'s emphasis on the risk-taking effect of unconventional policy on private agents.[4] In his model, firms need to balance the desire to invest today with the risk of becoming financially constrained in the future. They have an incentive to borrow more, knowing that the more they borrow the larger transfer they can receive from the government in crises. A bailout policy faces the trade-off between the ex-ante overborrowing and the ex-post benefit of a faster recovery from a credit crunch. This paper differs from Bianchi (2016) in an important way that the financial constraint contains forward looking variables. As policymakers try to relax the financial constraint by exploiting expectations, the time-inconsistent problem discussed in Bianchi (2016) could be aggravated. Jiao (2019) studies optimal bailouts in emerging economies subject to sudden stops. These economies are characterised by firms whose revenues are in domestic currency but liabilities are in foreign currency. Bailouts financed by an inflation tax face the cost of depreciated currency and increased liability burden. However, these papers consider either a flexible price model or a sticky price model without the ZLB. Cui and Sterk (2018) study optimal quantitative easing in an heterogeneous-agents New Keynesian model. They find QE effective in mitigating financial crisis at a large cost of inequality. The rest majority of the literature focuses on optimal simple rules. Gertler and Karadi (2011) suggest that credit policy should respond to credit spreads. Foerster (2015) proposes an improvement upon this rule by adding an autoregressive term. He concludes that the persistent credit spread rule allows slow unwinding of the central bank's balance sheet. He and Krishnamurthy (2013) compare three measures of credit policy: borrowing subsidies, equity injections, and public asset purchases.

There is also a literature studying the interaction between conventional and unconventional monetary policy. This literature goes back at least to Eggertsson and Woodford (2003) in which unconventional open-market operations are equivalent to standard ones and the authors focus on the ZLB. Carrillo et al. (2017) study the relevance of Tinbergen's rule in a Bernanke-Gertler financial accelerator model. They compare a monetary policy rule responding to both inflation and credit spreads and a dual rules regime with a Taylor rule and a financial rule targeting spreads. They find the former responding too much to inflation and not enough to spreads, i.e. tight money and tight credit.

Third, our innovative results on the precautionary effects depend on the nonlinearity that orig-

[3]The literature on the positive aspect of unconventional policy is large. Notable work includes Del Negro et al. (2017); Quint and Rabanal (2017).

[4]Here the risk is the binding financial constraint. Note that in the literature, the same name can refer to risky portfolios of banks. See, for example, Tsiaras (2018) in the context of unconventional policy. See Pancost and Robatto (2017), Brunnermeier and Koby (2017), Coimbra and Rey (2017) among others in the context of monetary and macroprudential policy.

inates from OBCs. The emphasis on OBCs is in line with Del Negro, Hasegawa and Schorfheide (2016) and Swarbrick, Holden and Levine (2017), who have shown that occasionally binding financial constraints help capture the sudden and discrete nature of financial crises and eliminate the financial acceleration mechanism during normal times. However, these two papers treat the OBCs in a perfect foresight manner. Bocola (2016) uses a global method to solve a variant of Gertler and Kiyotaki (2010). Banks facing the OBC are reluctant to invest for a precautionary reason. When the precautionary effect is strong, a liquidity facility like the ECB's LTRO has little effect on aggregate demand. In this paper, the same precautionary motive transfers from banks to policymakers. Del Negro et al. (2017) assume a always binding financial constraint and focus instead on the ZLB nonlinearity. This paper allows both constraints to bind occasionally and shows that the ZLB is particularly significant when both bind.

At last, this paper contributes to the literature by taking seriously the government budget constraint. In this sense, this paper is related to the optimal fiscal and monetary policy literature (e.g. Christiano and Kehoe, 1991; Schmitt-Grohé and Uribe, 2004*b*; Siu, 2004, among many others) in which the tradeoff is between tax-smoothing and price stability. The literature shows that, in response to standard macroeconomic shocks, the tradeoff is resolved in favour of price stability even with small degrees of price rigidity. In this paper, I find the tradeoff resolved in favour of tax-smoothing in an environment with financial shocks and credit policy.

I should make it clear that I do not intend to study optimal policy in the context of the recent crisis. Instead, I focus on the implications of one additional factor, the occasional financial frictions, on the optimal joint policy. The rest of the paper is organized as follows. The next section presents the model. The optimal policy problems and policy tradeoffs are discussed in section III. I describe my quantitative method in section IV. The main results concerning the two dimensions of the optimal policy problem are discussed in sections V and VI, respectively. I examine the sensitivity of the results in section VII. I consider simple rules in section VIII. The last section concludes.

## II. Model

The model is a small version of Gertler and Karadi (2011) in which I abstract a number of standard features that only matters quantitatively, e.g. habit, variable capital utilisation, and price indexation. The economy is populated by households, intermediate good producers, capital producers, banks, and a government. Intermediate good producers acquire labour and capital to produce differentiated goods. Only a fixed proportion of them can re-optimise price each period, as in Calvo (1983). Their physical investment is financed by issuing state-contingent securities, which can be purchased by banks and the government. Banks are financial intermediaries who collect deposits from households subject to an agency problem. The government controls nominal interest rate, purchases private securities, sets various taxes, and issues government bonds.

I depart from Gertler and Karadi (2011) by assuming that risk-free assets are denominated in nominal terms instead of real terms. An important implication of this assumption is that monetary policy generating unanticipated inflation can affect the real borrowing costs of banks and the government. In this way, monetary policy interacts with credit and fiscal policy.

### *A. Households*

There is a unit-continuum of infinitely lived households. Households consume final goods $c_t$, supply labour $l_t$. They save in bank deposits $D_t$ and fiat money $M_t$. Deposits are risk-free one-period nominal bonds carrying a gross rate of return $R_t$. Money facilitates consumption purchases. Households also own financial and non-financial firms.

Each household consists of workers and bankers who pool consumption risk perfectly. Workers are hired by intermediate good producers and bring wages to the household. Bankers manage a bank and transfer profits to the household. It is convenient to assume that households do not save in their own banks. Complete consumption insurance allows us to work with a consolidated representative household. Each household chooses consumption, labour supply, and savings to maximize:

$$\mathbb{W}_t = \left[\frac{c_t^{1-\sigma}}{1-\sigma} - \chi \frac{l_t^{1+\varphi}}{1+\varphi}\right] + \mathbb{E}_t \beta_t \mathbb{W}_{t+1}, \tag{1}$$

where $\sigma > 0$ is the measure of relative risk aversion, $\chi > 0$ is the disutility weight on labour, $\varphi > 0$ is the (inverse of) Frisch elasticity of labor supply, and $0 < \beta_t < 1$ is the subjective discount factor. The household faces a budget constraint

$$c_t \left[1 + s\left(v_t\right)\right] + \frac{D_t}{P_t} + \tau_t \leq w_t l_t \left(1 - \tau_{w,t}\right) + D_{t-1} \frac{R_{t-1}}{P_t} + \mathcal{F}_t,$$

where $s\left(v_t\right)$ is a transaction cost of consumption purchases, $P_t$ is the price of final goods, $w_t$ is the real wage rate, $\tau_{w,t}$ is the labour income tax rate, $\tau_t$ is lump-sum taxes, and $\mathcal{F}_t$ is the net real transfers from firms and banks. The specification of transaction costs follows Schmitt-Grohé and Uribe (2004*b*),

$$s\left(v_t\right) = \mathcal{A} v_t + \frac{\mathcal{B}}{v_t} - 2\sqrt{\mathcal{A}\mathcal{B}},$$

where $v_t = \frac{P_t c_t}{M_t}$ is consumption-based money velocity, $\mathcal{A}$ and $\mathcal{B}$ are parameters.

The first-order necessary conditions are:

$$\chi l_t^{\varphi} c_t^{\sigma} \left[1 + 2\mathcal{A} v_t - 2\sqrt{\mathcal{A}\mathcal{B}}\right] = w_t \left(1 - \tau_{w,t}\right), \tag{2}$$

$$\mathbb{E}_t \left[\Xi_{t,t+1} r_{t+1}\right] = 1, \tag{3}$$

$$v_t^2 = \frac{\mathcal{B}}{\mathcal{A}} + \frac{R_t - 1}{\mathcal{A} R_t}, \tag{4}$$

where $\Xi_{t,t+1} \equiv \beta_t \left(\frac{c_{t+1}}{c_t}\right)^{-\sigma} \frac{\left[1+2\mathcal{A}v_t - 2\sqrt{\mathcal{A}\mathcal{B}}\right]}{\left[1+2\mathcal{A}v_{t+1} - 2\sqrt{\mathcal{A}\mathcal{B}}\right]}$ is the stochastic discount factor and $r_{t+1} = \frac{R_t P_t}{P_{t+1}}$ is the real interest rate.

### B. *Non-financial firms*

There are two types of non-financial firms: capital producers and intermediate good producers.

Intermediate good producers. — There is a continuum of mass unity of intermediate good firms indexed by $m \in [0, 1]$. They have access to a Cobb-Douglas technology $y_{m,t} = A_t \left(\xi_t k_{m,t-1}\right)^{\alpha} l_{m,t}^{1-\alpha}$ where $0 < \alpha < 1$ is the capital share, $A_t$ is total factor productivity, and $k_{m,t}$ is the capital stock at the end of period $t$. Let $\delta$ be the depreciation rate and $\xi_t$ the exogenous quality of capital, firm $m$ acquires additional capital $i_{m,t} = k_{m,t} - (1 - \delta)\, \xi_t k_{m,t-1}$. To finance its capital investment, the firm issues $s_{m,t}$ securities. Each unit of the securities is a state-contingent claim to the future returns from one unit of investment. I follow Gertler and Karadi (2011) in assuming that each unit of capital is financed by one unit of securities, $s_{m,t} = k_{m,t}$.[5] As a result, both capital and securities have the same real price $q_t$. The real rate of return of holding the securities for one period is given by

$$r_{k,t+1} \equiv \frac{z_{t+1} + (1-\delta)\,\xi_{t+1} q_{t+1}}{q_t}, \tag{5}$$

where $z_t$ is real gross profits per unit of capital.

Let $mc_t$ denote the real marginal cost, cost minimisation yields

$$w_t = (1-\alpha)\,A_t \left(\frac{\xi_t k_{m,t-1}}{l_{m,t}}\right)^{\alpha} mc_t, \tag{6}$$

$$z_t = \alpha A_t \left(\xi_t\right)^{\alpha} \left(\frac{k_{m,t-1}}{l_{m,t}}\right)^{\alpha-1} mc_t. \tag{7}$$

Firm $m$ faces a downward sloping demand $y_{m,t} = \left(\frac{P_{m,t}}{P_t}\right)^{-\varepsilon_t} y_t$ derived from a final good aggregator $y_t = \left[\int_0^1 y_{m,t}^{\frac{\varepsilon_t - 1}{\varepsilon_t}}\, dm\right]^{\frac{\varepsilon_t}{\varepsilon_t - 1}}$, where $P_{m,t}$ is the price of intermediate good $m$, $\varepsilon_t > 0$ is the elasticity of substitution. With probability $1-\gamma$, the firm can reset its price $P^*_{m,t}$ subject to the demand function to solve

$$\max \mathbb{E}_t \sum_{j=0}^{\infty} \gamma^j \Xi_{t,t+j} \left[\frac{P^*_{m,t}}{P_{t+j}} - (1+\tau_{y,t+j})\, mc_{t+j}\right] y_{m,t+j},$$

where $\tau_{y,t}$ is a production tax. Focusing on a symmetric equilibrium, the first order condition (FOCs) is given by

$$\mathbb{E}_t \sum_{j=0}^{\infty} \gamma^j \Xi_{t,t+j} \left[(1-\varepsilon_t)\left(\frac{1}{\prod_{s=1}^{j} \Pi_{t+s}}\right)^{1-\varepsilon_t} p^*_t + \varepsilon_t \left(\frac{1}{\prod_{s=1}^{j} \Pi_{t+s}}\right)^{-\varepsilon_t} (1+\tau_{y,t+j})\, mc_{t+j}\right] y_{t+j} = 0, \tag{8}$$

where $\Pi_t = \frac{P_t}{P_{t-1}}$ is inflation, $p^*_t = p^*_{m,t} = \frac{P^*_{m,t}}{P_t}$ is the optimised real price of intermediate goods.

Capital producers. — Given the market price $q_t$, capital producers maximise their expected discounted profits:

$$\max_{\{i_{t+j}\}_{j=0}^{\infty}} \mathbb{E}_t \sum_{j=0}^{\infty} \Xi_{t,t+j} \left[q_{t+j} i_{t+j} - f\left(k_{t+j-1}, i_{t+j}\right)\right],$$

[5]Implicitly it is assumed that firms can not borrow directly from households by paying a negative dividend. Otherwise the banking sector becomes trivial. Similar assumptions have been adopted in e.g. Bianchi (2016) where dividend payment is constrained from below.

where the cost function is given by

$$f(\cdot) = i_t + \frac{\eta}{2}\left(\frac{i_t}{\delta k_{t-1}} - 1\right)^2 \delta k_{t-1},$$

and $\eta \geq 0$.[6] The first-order condition pins down the market price of new capital

$$q_t = 1 + \eta\left(\frac{i_t}{\delta k_{t-1}} - 1\right). \tag{9}$$

### *C. Banks*

Banks are financial intermediaries engaging in maturity and liquidity transformation. Bank $i$ receives deposits amounting to $D_{i,t}$ from households and purchases $s_{i,t}$ units of securities from intermediate good producers. The balance sheet of bank $i$ is

$$q_t s_{i,t} = \frac{D_{i,t}}{P_t} + n_{i,t},$$

where $n_{i,t}$ is the bank's real net worth at the beginning of period $t$. $n_{i,t}$ evolves according to

$$\begin{aligned} n_{i,t} &= q_{t-1}s_{i,t-1}r_{k,t} - D_{i,t-1}\frac{R_{t-1}}{P_t} \\ &= q_{t-1}s_{i,t-1}\left(r_{k,t} - r_t\right) + n_{i,t-1}r_t, \end{aligned}$$

where I use the balance sheet equation to substitute for $\frac{D_{i,t}}{P_t}$ in the second equality. Bank $i$'s leverage is defined as

$$\phi_{i,t} = \frac{q_t s_{i,t}}{n_{i,t}}.$$

As in Gertler and Karadi (2011), banks shut down with probability $r_n$ at the end of each period, upon which banks distribute their net worth to households. The notation $r_n$ follows Swarbrick, Holden and Levine (2017)'s suggestion that the shutting down probability can be interpreted as an exogenous dividend rate. Then, bankers become workers. In the meantime, a similar number of workers from the same household randomly become new bankers. New bankers receive "start-up" funds from their household as a proportion $\varpi$ of the total value of capital in the economy.[7] The shutting down probability plays two roles. First, an infinitely lived bank will sooner or later accumulate enough net worth to finance its investment without borrowing from households. In this case, the financial constraint detailed shortly will never bind. Second, it ensures that banks are always "less patient" than households, so funds always flow from households to banks.

Bank $i$ chooses an investment plan $(s_{i,t})$ to maximize its expected present value of net worth

[6]Another popular specification of the cost function is $f(\cdot) = i_t + \frac{\eta}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t$, which renders a more complicated FOC. However, the results under both specifications are similar quantitatively.

[7]In Gertler and Karadi (2011), the start-up funds are proportional to the assets held by incumbent banks. I make this minor change to ensure that start-up funds are not affected by the central bank's asset purchasing.

upon closure

$$\begin{aligned} V_t\left(n_{i,t}\right) &= \max \mathbb{E}_t \sum_{j=0}^{\infty} r_n \left(1-r_n\right)^j \Xi_{t,t+j+1} n_{i,t+1+j} \\ &= \max \mathbb{E}_t \Xi_{t,t+1}\left[r_n n_{i,t+1} + \left(1-r_n\right) V_{t+1}\left(n_{i,t+1}\right)\right] \\ &= \nu_{n,t} n_{i,t}, \end{aligned}$$

where the third equality follows the conjecture that the value function is linear in net worth, and the unknown time-varying coefficient $\nu_{n,t}$ is independent of $i$. The bank faces an agency problem represented by the following occasionally binding constraint (the financial constraint)

$$\nu_{n,t} n_{i,t} - \theta_t q_t s_{i,t} \geq 0,$$

where $\theta_t \in [0,1]$ is an exogenous process controlling the tightness of the constraint, shocks to $\theta_t$ can be interpreted as financial shocks (e.g. a disturbance to haircut changing the effective value of net worth) following the literature (Dedola and Lombardo, 2012; Del Negro et al., 2017; Perri and Quadrini, 2018). Schularick and Taylor (2012) conclude that there should be shocks as independt sources of financial instability so that the financial system is not just an accelerator macroeconomic shocks. Indeed, Jermann and Quadrini (2012) find this kind of shocks important in DSGE models. The financial constraint can be expressed as an upper bound on leverage,

$$obc_{i,t} \equiv \frac{\nu_{n,t}}{\theta_t} - \phi_{i,t} \geq 0. \tag{10}$$

where I use $obc_{i,t}$ to measure how far the bank is from hitting the bound. The intuition behind the financial constraint is as follows. Banks are able to declare bankruptcy and exit from the market. Should this happens, bankers would divert to their family a proportion $\theta_t$ of the total assets. Creditors can reclaim only the remaining. Therefore, creditors are willing to lend to a banks only if banks have no incentive to default, i.e. (10) not being violated.

Let the multiplier associated with (10) be $\lambda_t \geq 0$, the necessary conditions of banks' problem include the slackness condition

$$obc_{i,t} \lambda_t = 0, \tag{11}$$

and the first-order condition

$$\begin{aligned} \mathbb{E}_t \Xi_{t,t+1}\left(r_n + \left(1-r_n\right)\nu_{n,t+1}\right)\left(r_{k,t+1} - r_{t+1}\right) &\equiv \nu_{s,t} \\ &= \tfrac{\lambda_t}{1+\lambda_t}\theta_t \geq 0, \end{aligned} \tag{12}$$

which confirms $\lambda_t$ independent of $i$. The unknown coefficient $\nu_{n,t}$ can be solved using (10) and (12):

$$\nu_{n,t} = \nu_t \left(\frac{\nu_{s,t}}{\theta_t - \nu_{s,t}} + 1\right), \tag{13}$$

where $\nu_t \equiv \mathbb{E}_t \Xi_{t,t+1}\left(r_n + \left(1-r_n\right)\nu_{n,t+1}\right) r_t$ is defined similarly to $\nu_{s,t}$. (13) verifies the earlier conjecture. It follows that heterogeneity in banks' net worth and asset holdings does not affect aggregate dynamics.

If the financial constraint never binds, $\nu_{s,t} = 0$ and $\nu_{n,t} = \nu_t = 1$ $\forall t$ collapse to the standard

Euler equations. Except this special case, (12) suggests that generally there are rich dynamics in the spread between the long-term interest rate $r_{k,t}$ and the short-term interest rate $r_t$. Following Bocola (2016), the spread can be decomposed into a liquidity premium and a risk premium:

$$\begin{aligned}\mathbb{E}_t\left(r_{k,t+1}-r_{t+1}\right) &= \underbrace{\frac{\frac{\lambda_t}{1+\lambda_t}\theta_t}{\mathbb{E}_t\Xi_{t,t+1}\left(r_n+\left(1-r_n\right)\nu_{n,t+1}\right)}}_{\text{Liquidity premium}} \\ &+ \underbrace{COV_t\left[\frac{-\Xi_{t,t+1}\left(r_n+\left(1-r_n\right)\nu_{n,t+1}\right)}{\mathbb{E}_t\Xi_{t,t+1}\left(r_n+\left(1-r_n\right)\nu_{n,t+1}\right)},\left(r_{k,t+1}-r_{t+1}\right)\right]}_{\text{Risk premium}}. \end{aligned} \tag{14}$$

When the financial constraint binds, $\frac{\lambda_t}{1+\lambda_t}\theta_t > 0$. The liquidity premium is positive, reflecting banks' inability to raise external funds. Because the current period net worth $n_t$ is exogenous to individual banks, hitting the bound forces banks to deleverage and sell their assets. As long as $\eta > 0$ in (9), the fire sale depresses asset price and further impairs the net worth, a consequence that banks do not internalise. This completes a vicious loop, which is known as the financial acceleration mechanism. In this case, $\nu_{s,t} > 0$ and $\nu_{n,t} > \nu_t$. Net worth is more valuable than deposits because the former helps relax the financial constraint. Furthermore, the possibility of hitting the bound in the future implies a positive risk premium. As we have just shown, $r_{k,t+1} - r_{t+1}$ and $\nu_{n,t}$ move in opposite directions when the financial constraint binds. Hence banks demand a higher return on securities to compensate such risk. When the financial constraint is not binding, $\nu_{s,t} = 0$ but $\nu_{n,t} = \nu_t > 1$. This is because $\nu_{n,t}$ is a forward looking variable by construction and the financial constraint will bind in some $T > t$ such that $\nu_{n,T} > 1$. The positive risk premium and $\nu_{n,t} > 1$ in normal times can be interpret as banks' precautionary efforts to avoid hitting the bound. It follows that efficiency of financial intermediation in normal times depend on expectations of financial conditions in the future.

### D. *The government*

Following the standard approach in the public finance literature, the specific agency that implements each policy is abstracted from the model. As argued in Del Negro and Sims (2015), to avoid central bank insolvency, it would be appropriate for central banks conducting unconventional policy receiving fiscal backing from fiscal authorities. The government controls the nominal interest rate as monetary policy. Credit policy is a private asset purchasing programme in which the government holds a proportion $\mathcal{P}_t \in [0, 1]$ of total securities issued by intermediate good producers $s_t$.[8] The government must pay a quadratic resource costs on its holding of securities

$$\tau_{\mathcal{P}}\left(\mathcal{P}_t q_t s_t\right)^2,$$

where $\tau_{\mathcal{P}} \geq 0$ is a parameter. As in the literature (Gertler and Karadi, 2011; Dedola, Karadi and Lombardo, 2013; Foerster, 2015), these costs represents inefficient public activities in private financial markets or the costs of strengthened financial surveillance.[9] Fiscal policy consists of a labour income tax $\tau_{w,t}$, a production tax $\tau_{y,t}$, a lump-sum tax $\tau_t$.

[8] In an early working paper, Jiang (2018) compares the three credit measures laid out by Gertler and Kiyotaki (2010), namely asset purchases, liquidity facilities, and equity injections. It is shown that, without further distortions introduced in the model, the three measures differ only in a trivial way. I focus on an asset purchase programme in this paper because it is the easiest to understand and present.

[9] Dedola, Karadi and Lombardo (2013) add also a linear term to the cost function but they find only the coefficient on the quadratic term playing an important role.

The government faces a consolidated budget constraint:

$$g_t + \frac{R_{t-1}}{\Pi_t} b_{t-1} + \frac{m_{t-1}}{\Pi_t} + \mathcal{P}_t q_t s_t + \tau_{\mathcal{P}} \left(\mathcal{P}_t q_t s_t\right)^2 = \tau_t + w_t l_t \tau_{w,t} + \int_0^1 \tau_{y,t} mc_t y_{m,t} dm + b_t + m_t + \mathcal{P}_{t-1} q_{t-1} s_{t-1} r_{k,t}, \tag{15}$$

where $g_t$ is exogenous wasteful government consumption, $m_t = \frac{M_t}{P_t}$ is real money balances, $b_t = \frac{B_t}{P_t}$, and $B_t$ is a state-noncontingent nominal asset. As in Gertler and Karadi (2011), $B_t$ can be interpreted as either government bonds or reserves. In the former case, $D_t$ denotes the sum of bank deposits and government bonds held by households. In the latter case, $B_t$ is banks' assets. Assuming that the agency problem does not applies to reserves, $B_t$ simply drops out of banks' problem.

### E. *Competitive equilibrium*

DEFINITION 1: *Given policies* $\{\tau_{w,t}, \tau_{y,t}, R_t, \mathcal{P}_t, \tau_t\}$, *exogenous processes* $\{\beta_t, A_t, \xi_t, \theta_t, g_t, \varepsilon_t\}$, *and initial conditions, a competitive equilibrium is a set of plans*

$$\{c_t, l_t, m_t, P_t^*, \Pi_t, pd_t, y_t, mc_t, k_t, s_t, w_t, z_t, q_t, i_t, \nu_{n,t}, n_t, b_t\},$$

*satisfying the households' FOCs (2, 3, 4), optimal pricing of intermediate goods (8), the law of motion for the aggregate price index*

$$1 = (1-\gamma) p_t^{*1-\varepsilon_t} + \gamma \Pi_t^{\varepsilon_t - 1}, \tag{16}$$

*the law of motion for price dispersion*

$$pd_t = (1-\gamma) p_t^{*-\varepsilon_t} + \gamma \Pi_t^{\varepsilon_t} pd_{t-1}, \tag{17}$$

*the aggregate production function*

$$y_t pd_t = A_t \left(\xi_t k_{t-1}\right)^{\alpha} l_t^{1-\alpha}, \tag{18}$$

*the law of motion for aggregate capital*

$$k_t = i_t + (1-\delta) \xi_t k_{t-1}, \tag{19}$$

*the cost minimisation conditions (6, 7) without subscript m, the FOC of capital producers (9), the FOC of banks' problem*

$$\nu_{s,t} \geq 0, \tag{20}$$

*the aggregate financial constraint*

$$\frac{\nu_{n,t}}{\theta_t} - \phi_t \left(1 - \mathcal{P}_t\right) \geq 0, \tag{21}$$

*the complementary slackness condition*

$$\nu_{s,t}\left[\frac{\nu_{n,t}}{\theta_t}-\phi_t\left(1-\mathcal{P}_t\right)\right]=0, \tag{22}$$

*the solution of banks' value function (13), the law of motion of aggregate net worth*

$$n_t=\left(1-r_n\right)\left(q_{t-1}s_{i,t-1}\left(r_{k,t}-r_t\right)+n_{i,t-1}r_t\right)+\varpi q_t s_s, \tag{23}$$

*the government budget constraint (15), and finally two market clearing conditions*

$$y_t=c_t\left[1+s\left(v_t\right)\right]+f\left(k_{t-1},i_t\right)+\tau_{\mathcal{P}}\left(\mathcal{P}_t q_t s_t\right)^2+g_t, \tag{24}$$

$$s_t=k_t, \tag{25}$$

*where* $pd_t\equiv\int_0^1\left(\frac{P_{m,t}}{P_t}\right)^{-\varepsilon_t}dm$*;* $v_t$*,* $r_{k,t}$*,* $\nu_{s,t}$*, and* $\nu_t$ *are defined in the text, aggregate leverage is defined as* $\phi_t=\frac{q_t s_t\left(1-\mathcal{P}_t\right)}{n_t}$.

## III. Ramsey policy

The jointly optimal credit, monetary, and fiscal policy is a set of plans $\{\tau_{w,t},\tau_{y,t},R_t,\mathcal{P}_t,\tau_t\}$ that maximises 1 subject to the competitive equilibrium. The problem can be simplified a bit by noting that (20) is a redundant constraint. I confirm this statement in quantitative exercises. Intuitively, the government has no incentive to over-invest in physical capital. There are three inefficiencies in the model, stemming from the financial constraint, nominal rigidity, and imperfect competition respectively. I focus on the first two inefficiencies so, through the paper, I assume that the inefficiency of imperfect competition has been offset by a constant production subsidy $\tau_y=-\frac{1}{\bar{\varepsilon}}$.[10] The financial constraint and nominal rigidity reinforce each other and should be tackled by $\{\tau_{w,t},R_t,\mathcal{P}_t,\tau_t\}$.

### A. *Policy trade-offs*

Before describing optimal policy in more details, it is helpful to discuss the policy trade-offs in dealing with financial inefficiency. Given the number of instruments, the policy trade-offs are rather complicated.

Credit policy. — By purchasing private securities, the government acts as a financial intermediary. It faces no financial friction but needs to pay the resource costs. The credit policy replaces inefficient financial intermediaries (banks) with the efficient one (the government). The optimal policy can be deemed as the optimal size of central banks' balance sheets relative to private banks', as reflected by our definition of $\mathcal{P}_t$. There is a trade-off between the resource costs and the benefit of making the economy financially less constrained. Specifically, the policy pass-through is as follows. As discussed eairlier, the binding financial constraint forces banks to sell their assets. The credit

[10]Schmitt-Grohe and Uribe (2004*a*) show that imperfect competition shifts average optimal inflation upwards to the extent of price markups. This is because the social planner would like to tax money balances as an indirect way to tax monopoly profits. One should be careful though if imperfect competition is offset by a production subsidy and the subsidies are not financed by lump-sum taxes. In this case, a production subsidy (i.e. perfect competition) tends to push average optimal inflation up instead of down because the subsidies must be partially financed by inflation.

policy increase asset demand and supports asset price, from which banks enjoy capital gains and stronger net worth. The externality that banks do not internalise the effect of their asset selling on asset price becomes irrelevant. This is the capital gain channel of credit policy. Since the binding financial constraint creates a fall in aggregate demand (investment). Both output and inflation go down as in standard New Keynesian models. This negative impact on the real side of the economy is also eased by credit policy.

Credit policy also benefits the economy when the financial constraint is slack (referred to as normal times). If the government promises to address the financial friction when appearing, banks expect a higher asset price. Knowing that future financial crises will have smaller impacts on them, banks are willing to take higher leverage in normal times, resulting in more investment in capital and smaller risk premium in (14). This is the risk-taking channel of credit policy. However, the higher leverage means a higher likelihood of hitting the financial bound. Consequently, the government has to implement costly interventions more often. In this way, the government faces a trade-off in encouraging risk-taking behaviour (or discouraging prevautionary behaviour).

In Ramsey equilibrium. the resolution to the second trade-off must imply transference of precautionary motives from private agents to the government. To see this point, consider the following constraints in policymakers' problem

$$\mathbb{E}_t \Xi_{t,t+1} \left( r_n + (1 - r_n) \nu_{t+1} \left( \frac{\nu_{s,t+1}}{\theta_t - \nu_{s,t+1}} + 1 \right) \right) (r_{k,t+1} - r_{t+1}) = \nu_{s,t}, \tag{26}$$

$$\nu_{s,t} \geq 0.$$

Let the lagrange multiplier associated the first constraint be $\lambda_{12,t}$. The government would like to bring $\nu_{s,t}$ close to zero to improve financial effiency. In doing so, it is helpful to stablise expected $\nu_{s,t+1}$ near zero and hence lower risk premium in (14). Furthermore, as discussed in Bocola (2016) in a similar model, credit policy tends to be more efficient in states with low risk premium[11]. To exploit private agent expectations, the entire path of credit policy matters to financial effiency today. The FOCs of the optimal policy problems contains lagged multiplier $\lambda_{12,t-1}$, which generally adds some persistence in optimal policy. For the same reason, the optimal policy under commitment is time-inconsistent.[12]

At last, it is useful to note a native benchmark credit policy strategy that the government commits to $\nu_{s,t} = 0$ for all $t$. In this way, the government won't tolerate any degree of financial friction regardless the cost to achieve that. This naive strategy incorporates both channels discussed above. It can be a fairly good approximation to the Ramsey policy when the cost parameter $\tau_{\mathcal{P}}$ is small.

Monetary policy. — Since output (same as the output gap) and inflation move in the same direction in response to a financial shock, monetary policy ought to be a powerful tool. However, as noted in Carrillo et al. (2017), monetary policy may not be able to stablise simultaneously both the output gap and inflation because of the financial accelerator. In addition to the standard channel through the Euler equation, monetary policy boosts demand also by lowering banks' borrowing costs. This improves banks' net worth upon the shock and relaxes the financial constraint, see (23) and (21). The relative stronger effects on aggregate demand come at the cost of higher inflation. Putting credit and monetary policy together, the government's problem is to find the least costly

[11]The policy measure in Bocola (2016) is a liquidity facility i.e. lending to banks. After borrowing from the central bank, banks are reluctend to invest if they expect significant financial frictions in the future, hence high risk premium. Instead, banks simply use central bank funds to replace household funds. While in our model banks don't receive funds directly from the central bank, they do enjoy capital gain. Hence a similar mechnisam works for policy of asset purchases.

[12]See also the discussion of Bianchi (2016).

way to relax the financial constraint, i.e. to balance the cost of credit policy (resource costs) and the cost of monetary policy (inflation). The optimal allocation can be further distorted if the government also faces the ZLB. In this case, the burden of relaxing the financial constraint could be more on credit policy. Again, expectation management is an important aspect of the optimal monetary policy. The literature (e.g. Eggertsson and Woodford, 2003, among many others) suggests that optimal monetary policy in a standard New Keynesian model features a late departure from the ZLB. In our model, expectation management is through not just the Phillips curve but also the forward-looking $\nu_{s,t}$ in (26). The conventional wisdom may or may not hold because of this.

FISCAL POLICY AND PUBLIC FINANCE. — How should the government's asset purchasing be financed? The answer is simple if the government can very lump-sum taxes. In the reality, however, credit policy is financed by reserves. In this case, the government budget is an important constraint to optimal policy.[13] Taking the government budget constraint seriously is particularly important because our model is non-Ricardian. Following the literature of optimal monetary and fiscal policy (e.g. Christiano and Kehoe, 1991; Schmitt-Grohé and Uribe, 2004*b*; Siu, 2004, among many others), I assume that reserves are state-noncontingent in nominal terms. On one hand, the government would like to smooth the distortionary labour tax[14] using unexpected inflation as a lump-sum tax on nominal wealth. On the other hand, the government would like to stabilise inflation due to price stickiness. In the literature, this trade-off is resolved in favour of price stability. In our model, however, there is an extra factor affecting each side of the argument. First, the need to boost demand has already called easing monetary policy, tilting the balance in favour of tax smoothing. Second, lowering the labour tax has some stimulation effect itself, tilting the balance in favour of price stability. It turns out that a labour subsidy can be used to address the real friction of capital adjustment costs.[15] As the movements in Tobin's Q is a main source of inefficiency in financial crunches, the labour subsidy must help stablise the financial sector. On balance, the optimal policy needs find the least distortionary combination of policies to finance the government's budget.

### B. *Ramsey policy problems*

Summrising the discussion so far, policy trade-offs can be categorised along two dimensions. First, what is the least costly way to relax the financial constraint? Second, what is the least costly way to finance the government's budget? I study one dimension at a time in the next two sections. To start, I abstract public finance by assuming that the government can very lump-sum taxes. To tease out the net effect of each policy, I study the following 4 problems step by step.

In the first two steps, I shut down nominal rigidity. Only credit policy is available in problem 1 then fiscal policy becomes available in problem 2.

PROBLEM 1: *Given* $\tau_y = -\frac{1}{\bar{\varepsilon}}$, $\tau_{w,t} = 0$, *and* $\gamma = 0$, *solving* $\{\mathcal{P}_t\}$ *that maximises (1) subject to the competitive equilibrium.* $\tau_t$ *is set to satisfy the government budget constraint and there is no public debts. Inflation is undetermined and is fixed as* $\Pi_t = 1$.

[13] In most papers studing credit or similar policy, it is assumed explicitly or implicitly that the government controls lump-sum taxes. The only exception is Bianchi (2016) in which the government finances its bailout policy by a payroll tax and potentially a debt tax. However, Bianchi (2016) does not allow the government to borrow because this would allow the government to would "lend" its borrowing capacity to financially constrained firms.

[14] Correia, Nicolini and Teles (2008) show that, when the menu of taxes available to the fiscal authorities is sufficiently rich, sticky price become irrelevant. In this case, the optimal credit policy might be studied in a real model, which is indeed considered in this paper. However, the result under less fiscal instruments is more interesting. In practice, the fiscal authory pursues goals other than macroeconomic stabilization and is often constrained by political factors.

[15] I note this in Christiano and Kehoe (1991)'s model augmented with capital adjustment costs. I solve optimal fiscal policy in a flexible price economy with state-contingent government debts. When there is no capital adjustment costs, the labour tax is a constant in all states of the world because government expenditures can be financed efficiently by state-contingent government debts. However, in the presence of capital adjustment costs, the labour tax responds negatively to a government consumption shock, putting even a higher burden on the government budget.

PROBLEM 2: *Given* $\tau_y = -\frac{1}{\bar{\varepsilon}}$ *and* $\gamma = 0$*, solving* $\{\tau_{w,t}, \mathcal{P}_t\}$ *that maximises (1) subject to the competitive equilibrium.* $\tau_t$ *is set to satisfy the government budget constraint and there is no public debts. Inflation is undetermined and is fixed as* $\Pi_t = 1$*.*

In the next two steps, the Calvo parameter is set to its calibrated value. The nominal interest rate becomes relevant and the government faces the ZLB in problem 4.

PROBLEM 3: *Given* $\tau_y = -\frac{1}{\bar{\varepsilon}}$*, solving* $\{\tau_{w,t}, R_t, \mathcal{P}_t\}$ *that maximises (1) subject to the competitive equilibrium.* $\tau_t$ *is set to satisfy the government budget constraint and there is no public debts.*

PROBLEM 4: *Given* $\tau_y = -\frac{1}{\bar{\varepsilon}}$*, solving* $\{\tau_{w,t}, R_t, \mathcal{P}_t\}$ *that maximises (1) subject to the competitive equilibrium and* $R_t \geq 1$*.* $\tau_t$ *is set to satisfy the government budget constraint and there is no public debts.*

Turning to the public finance dimension, I revisit problem 2 and 4 with zero lump-sum taxes. Instead, the government has to issue state-noncontingent nominal government debts to finance its budget. Initial level of public debts is calibrated. Note that in this case, except problem 6, the Ramsey equilibrium features a unit root. (see e.g. Schmitt-Grohé and Uribe (2004*b*))

PROBLEM 5: *Problem 2 with* $\tau_t = 0$*.*

PROBLEM 6: *Problem 2 with* $\tau_t = 0$ *and endogenously determined inflation. Thanks to price flexibility, this is equivalent to let the government issue state-contingent government debts in real terms.*

PROBLEM 7: *Problem 4 with* $\tau_t = 0$*.*

In solving these problems, I follow the "timeless" perspective advocated by Woodford (2003).

## IV. Quantitative method

Since risk plays an important role in policy trade-offs, ideally the model should be solved by global methods. However, the solutions to our Ramsey problems contain too many state variables, 6 of which are multipliers associated with forward-looking constraints.[16] The model is therefore difficult to solve even by methods that are explicitly designed to deal with a large state space, such as that of Maliar and Maliar (2015). Fast algorithms such as that of Guerrieri and Iacoviello (2015) based on piecewise linearization gives, however, certainty equivalent results.

I employ the approach of Holden (2016*b*,*a*), which can be implemented easily by the toolkit DynareOBC[17]. Holden (2016*b*) develops the basic algorithm in perfect-foresight models that are linear apart from one OBC. The idea is to hit the inequality-constrained variables with news shocks such that the inequality constraint is always satisfied. Solving the model amounts to finding the appropriate news shocks, which can be represented as a linear complementarity problem. In the perfect-foresight model, agents act as if they knew the status of OBCs in every future period. Holden (2016*a*) generalised the basic algorithm to solve models that are nonlinear (by high order approximation of the fully nonlinear model around the deterministic steady state) apart from multiple OBCs. Importantly, risk of hitting OBCs in the future can be taken into account in the spirit of Adjemian and Juillard (2013)'s stochastic extended path algorithm. This algorithm involves integrating the model over a certain number of periods of future uncertainty to calculate

[16] Bianchi (2016) solves Ramsey policy in a model with occasionally binding financial constraints using a policy function iteration algorithm. When there are not enough instruments to render constrained-efficient allocations, the problem contains 7 state variables, 2 of which are multipliers associated with forward-looking constraints.

[17] It is available at https://github.com/tholden/dynareOBC.

expectations. I use 32 periods, a reasonable balance between accuracy and the speed. The necessary integration is done by quasi-Monte Carlo with at least $2^{11}$ sample (more if necessary) drawn from third order Sobel sequences.

Through out the paper, I compute second order approximations of the model without perfect-foresight (PF). In doing so, I capture precuationary effects stemming from nonlinearity of both the OBC and second order terms. PF solutions are reported and compared with the non-PF solutions where the difference is interesting.

### A. *Calibration*

TABLE 1—CALIBRATION

| Description | Parameter | Value |
|---|---|---|
| Discount factor (steady state) | $\beta$ | 0.9987 |
| Relative risk aversion | $\sigma$ | 2 |
| labour disutility weight | $\chi$ | 14 |
| Frisch elasticity (inverse) | $\varphi$ | 0.4 |
| Parameter of consumption transaction costs | $\mathcal{A}$ | 0.0111 |
| Parameter of consumption transaction costs | $\mathcal{B}$ | 0.07524 |
| Calvo parameter | $\gamma$ | 0.779 |
| Markup (steady state) | $\frac{\bar{\varepsilon}}{\bar{\varepsilon}-1}-1$ | 0.2 |
| Capital share | $\alpha$ | 0.33 |
| Depreciation rate | $\delta$ | 0.025 |
| Elasticity of investment (inverse) | $\eta$ | 1.728 |
| Survival probability of banks | $1-r_n$ | 0.972 |
| Transfer rate from households to new banks | $\varpi$ | $\frac{1-(1-r_n)/\beta}{4}$ |
| Fraction of divertable assets (steady state) | $\bar{\theta}$ | 0.247 |
| Government consumption to GDP ratio | $\frac{\bar{g}}{\bar{y}}$ | 0.2 |
| Initial government debts to GDP ratio | $\frac{b}{\bar{y}}$ | 1 |
| Credit policy costs | $\tau_{\mathcal{P}}$ | 0.0005 |

Table 1 summarise parameter values. I use a relatively high discount factor $\beta$ as a simple device to capture low real interest rates since the recent financial crisis so that the ZLB is relevant to financial shocks. $\beta = 0.9987$ implies a steady state real interest rate of 0.52%, matching the average yield on US 10-year treasury inflation-indexed securities since 2009. I choose $\chi = 14$ to target a steady state value of hours to equal about 1/3 with zero labour taxation. The inverse Frisch elasticity $\varphi$ is set to 0.4 and the relative risk aversion is set to 2, both within typical ranges from the literature. The Calvo parameter $\gamma$, the inverse elasticity of investment $\eta$ are borrowed from Gertler and Karadi (2011). Parameters of consumption transaction costs are borrowed from Schmitt-Grohé and Uribe (2004*b*). The depreciation rate $\delta$, the capital share $\alpha$, the average markup $\frac{\bar{\varepsilon}}{\bar{\varepsilon}-1}-1$, and the government consumption to GDP ratio $\frac{\bar{g}}{\bar{y}}$ are set to conventional values. The government debts to GDP ratio is set to 1, reflecting relatively high public debts in many advanced economies in recent years. The parameter of credit policy costs is set to 0.0005. As there is no hard evidence to quantify the parameter of credit policy costs, this number is picked rather arbitrarily only to ensure that credit policy is not dominated by other policies. I will return to this parameter in sensitivity analysis.

There are three parameters in the financial sector, namely $r_n$, $\bar{\theta}$, and $\varpi$. Following Gertler and Karadi (2011), I choose the survival rate $1-\bar{r}_n$ that implies a decade of average banks' lifetime.

I set the steady-state leverage ratio $\bar{\phi}$ to 4, which is considered as an average across sectors with vastly different financial structures.[18] Next, I depart from the majority of the literature by choosing a steady state in which the financial constraint is slack[19]. Indeed, Bocola (2016) estimates a similar model using global methods and find the Lagrange multiplier associated with the financial constraint close to zero in average. Also note that our choices of $\eta$ and $r_n$ are broadly consistent with the estimates of Bocola (2016). In such a steady state, the transfer rate to new banks is pined down by the leverage ratio $\varpi = \frac{1-(1-r_n)/\beta}{\bar{\phi}}$. The steady-state proportion of divertable assets $\bar{\theta}$ is adjusted so that the financial constraint is close to its bound in the steady state. Using (10), $\bar{\phi} = 4$, and $\bar{\nu}_n = 1$, we set $\bar{\theta}$ close to 0.25. This is to ensure reasonable accuracy of approximation around the steady state when the financial constraint is binding. In fact, the financial constraint binds (not too tightly) in most times with our parameterisation, meaning that the model's quantitative results are comparable to those assuming always binding constraints. Despite the similar quantitative results, our OBC set-up matters for optimal policy.

In our nonlinear model, shocks need to be specified carefully. I assume that $\theta_t$ follows an log-AR(1) process with persistence of 0.8. Its stadnard deviation is calibrated to match the standard deviation of the annulised spread about 0.7%, calculated from Moody's seasoned Bbb corporate bond yield relative to the yield on 10-year treasury, 1983q1-20019q1. However, without features such as liquidity premia and true default risk, I inevitably underestimate the mean of the spread (2.07% in data and 0.19% in the model). Or I would overestimate the standard deviation if I calibrated the model to match the mean.[20][21] Since the financial constraint binds occasionally, the standard deviation appears to be a more natural choice for calibration. All other shocks are shut down. I do this for two reasons. First, the difference between the impact of a non-financial shock, such as the capital quality shock considered in Gertler and Karadi (2011)[22], in an economy without the financial constraint and an economy with the financial constraint is roughly the impact of the financial shock. Thus, studying a single financial shock is informative enough to our research question, i.e. how should policies be used to tackle financial inefficiency. The second reason is technical. When the model is approximated beyond the first order, DynareOBC centre the solved model around a risky steady state (or approximate mean), which is not well defined in the presence of a unit root (as in problem 5 and 7). Fortunately, the economy will return to its initial steady state after hit by the financial shock. Thus, we are able to compute second order approximations for all the problems, maintaining consistency.

For further reference, I define a financial crisis as an occasion when the financial constraint is binding tightly such that the spread is two standard deviations above its mean. This definition corresponds to the dot-com bubble and the 2007 - 2009 financial crisis in the US since 1983. Normal times are when the financial constraint is not binding. Assuming a Taylor rule responding to the net rate of inflation by 1.5 and no credit nor fiscal policy, under our calibration, the model generates

[18]The literature has suggested alternative values. For example, $\bar{r}_n$ can be set to match a dividend rate of 5.15% made by the largest 20 U.S. banks during 1965–2013. This dividend rate is calculated by Swarbrick, Holden and Levine (2017) using Baron (2017) dataset. The steady-state leverage can be set to 16, the estimate of Quint and Rabanal (2017) in which the authors use GMM to estimate a similar model with the financial constraint always binding. Alternative calibrations change our results results quantitatively but not qualitatively.

[19]Furthermore, we focus on the steady state with a positive nominal interest rate and silent credit policy.

[20]With the financial constraint always binding , Gertler and Kiyotaki (2010) and Dedola, Karadi and Lombardo (2013) target the average spread of 1%, which is roughly the mean of Moody's seasoned Aaa corporate bond yield relative to the yield on 10-year treasury constant maturity.

[21]To be clear, the focus on one particular occasionally binding frictional constraint does not rules out other types of financial frictions, which are abstracted from the model. What the model tries to capture is the frictions that occasionally push the economy further into credit crunches.

[22]It is worth noting that the typical standard deviation of the capital quality shock 5%, about 10 times larger than a typical productivity shock. In Gertler and Karadi (2011), a 5% fall in capital quality is considered as a rare event and is used to study the recent financial crisis. Due to certainty equivelance in linear models, standard deviations of shocks play no role as long as the size of the shock is fixed (e.g. 5%) in impulse response analyses. This is not true in our nonlinear model and using the typical specification would introduce too much risk. It is unclear what the normal standard deviation of the capital quality shock should be.

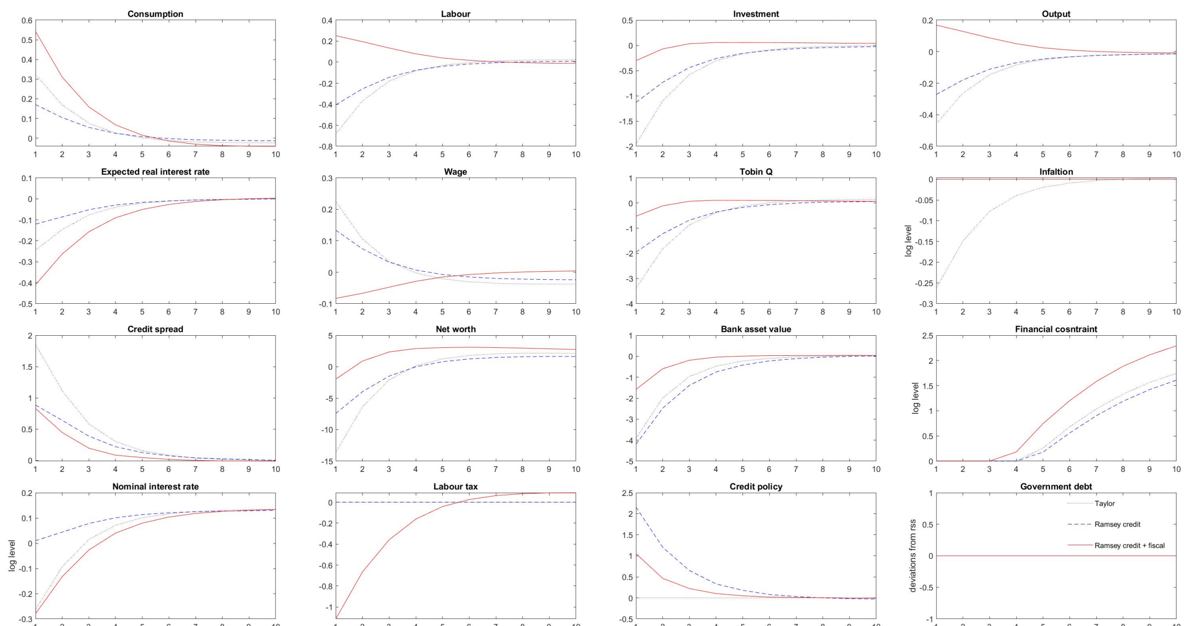
financial crises by an 17% unconditional probability per year. As a rough comparison, the frequency of financial crises during 1945-2016 across 17 advanced economies is 3.6% in Jordà, Schularick and Taylor (2017)' dataset. This difference is not surprising because we use different definitions. Our definition is arguably a lot looser as the dot-com bubble is not considered as a financial crisis in Jordà, Schularick and Taylor (2017).

## V. The least costly way to relax the financial constraint

In this and the next section, I study impulse response functions (IRFs) to a financial shock. The size of the shock is such that the calibrated economy with a Taylor rule and no credit nor fiscal policy hits the financial constraint for 4 quarters and just touches the ZLB. However, optimal policy may hit the ZLB.

### A. *Problem 1 - 2*

Figure 1. IRFs under flexible prices with a Taylor rule / Ramsey credit / Ramsey credit + fiscal policy

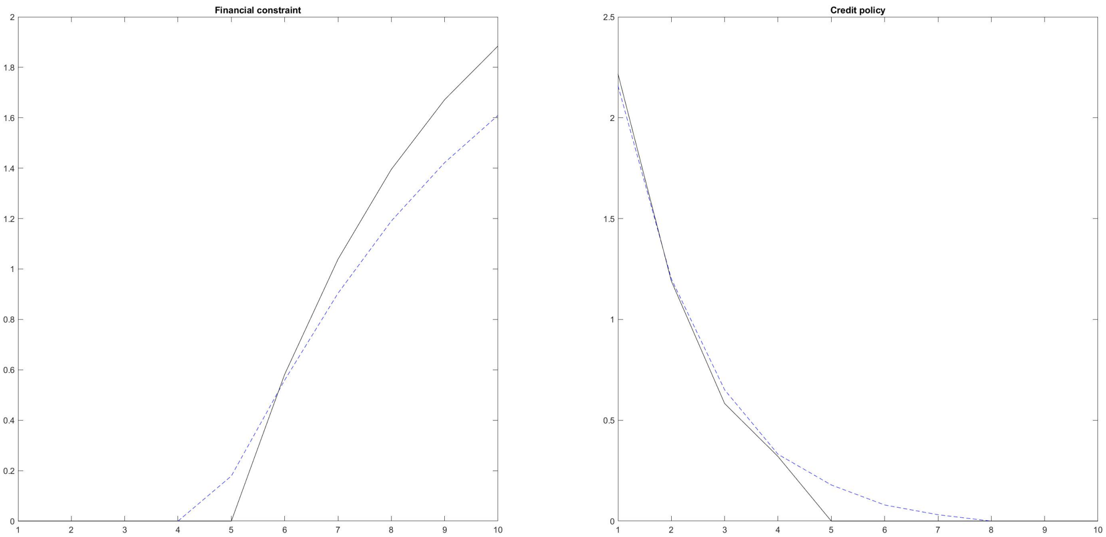



*Note:* All variables are expressed in percentage point deviations from their risky steady state (rss) unless stated otherwise.

Figure 1 shows IRFs in a flexible price model where the policy regime is one of the following three: a Taylor rule (black dotted lines), optimal credit policy (blue dashed lines), or both optimal credit and fiscal policy (red solid lines). In the first regime, they Taylor rule is only used to pin down the nominal interest rate and inflation. Banks hit by the shock must sell assets to satisfied the financial constraint. Asset prices and net worth fall sharply by about 3.2% and 13% respectively. The credit spread surges reflecting a large liquidity premium. Since households save less, they consume more instead. This somewhat compensates the low investment but output still goes down by more than 0.4% in the first period.

Optimal credit policy, when used alone, is to purchase 2.2% of securities $s_t$, mitigating the negative impact on asset prices. Thanks to the capital gain channel outlined in section III.A, the losses on net worth are smaller. However, public asset purchasing crowds out banks from the

Figure 2. Optimal credit policy with and without perfect foresight




*Note:* Black solid (blue dashed) lines are (not) under perfect foresight.

security markets by 100%. The blue dashed line of bank asset value shifts downwards from the black dotted line (not by 100% because of high asset prices). This crowding-out effect results in low profitability of banks so their net worth grows at a rate slower than it would be without credit policy. As banks deleverage slowly, the government must exit from credit policy slowly until banks deleverage enough to carry fund intermediation on their own, see (21). However, credit policy does not end thereafter. In quarter 4 to 10 after the shock, there is still a substantial probability that banks may hit the financial bound again (i.e. when the financial constraint is still close to zero). The government find it optimal to hold private securities in this period as a precautionary protection. This feature turns out characterising optimal credit policy in all policy regimes. The precautionary effect is illustrate in figure 2 where I compare the baseline results (blue dashed lines) with the results obtained under perfect foresight (black solid lines). If all agents in the model do not take into account the risk of hitting the financial bound in the future, credit policy ends in the same period when the economy escapes from the constraint. Removing this assumption allows a faster departure from the financial bound but slower exit from credit policy. Persistent credit policy also stabilise expected marginal value of banks' assets $\nu_{s,t+1}$, which, according to (26), eases the financial constrained today. Consequently, less interventions are needed today, and the whole path of credit policy is smoothed. In models where there are true default risks and bank runs, such as those of Coimbra and Rey (2017) and Gertler, Kiyotaki and Prestipino (2017), the precautionary motives are arguably stronger.[23]

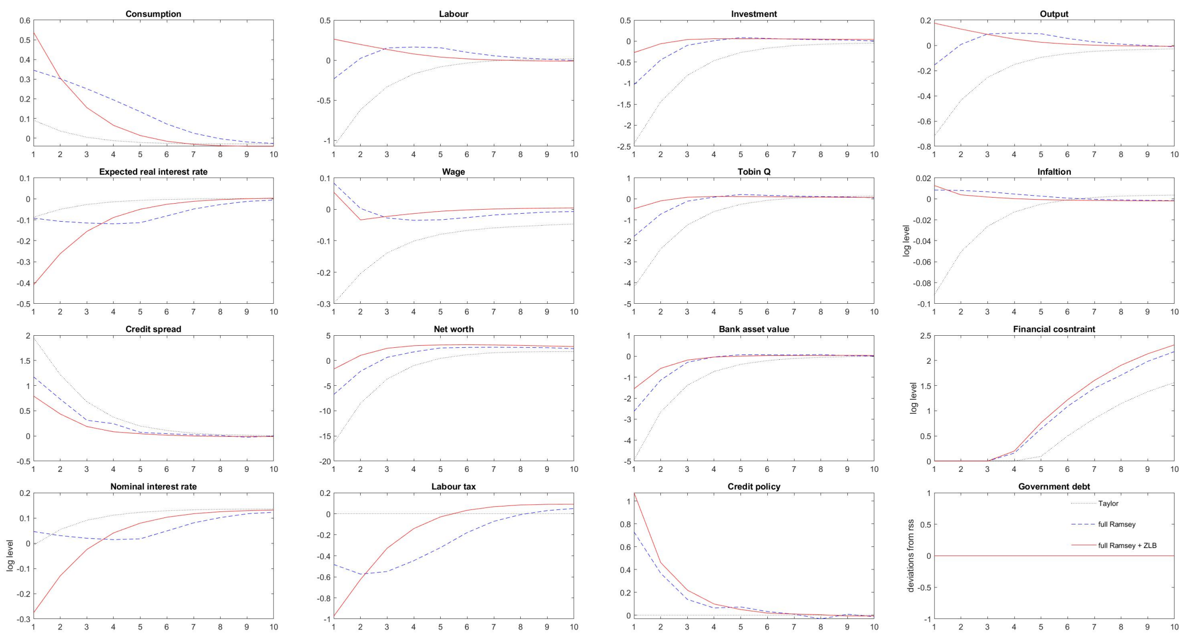
The net effect of credit policy appears to be relatively small, at least for the given cost parameter $\tau_{\mathcal{P}}$. Indeed, due to the crowding out effect, in figure 1, blue dashed lines are not obviously distinguishable from black dotted lines after 4 quarters. When a labour tax becomes available, the optimal credit interventions fall by more than a half. It turns out that a labour subsidy is

[23]To emphasise on the precautionary motives, it seems natural to use the recursive preferences of Epstein and Zin (1989) where risk aversion can be greater than the inverse of the intertemporal elasticity of substitution. It should also help match risk premiums. However, as noted by Karantounias (2018), the Epstein-Zin preference added non-trivial complications to the numerical analysis of Ramsey policy.

a very powerful tool in preserving banks' profitability. As the increase in labour supply must be matched by an increase in investment, the boost in demand is so strong that asset prices are barely dragged down by the tightened credit condition. Even better, labour subsidies do not suffer from the crowding out effect. Banks' asset holding only falls mildly. The financial market still suffers from credit crunches but to a less extend, as evidenced by the smaller credit spread. In fact, banks make a fortune from the positive spread and enjoy higher net worth since quarter 2. As a result, the economy escapes from the financial constrain quickly. Nonetheless, we should keep in mind that labour subsidies put are a heavy burden on the government budget, which is abstracted from the problem for now.

### *B. Problem 3 - 4*

FIGURE 3. IRFs UNDER STICKY PRICES WITH A TAYLOR RULE / FULL RAMSEY / FULL RAMSEY + ZLB




*Note:* All variables are expressed in percentage point deviations from their risky steady state (rss) unless stated otherwise.

Let us now turn on nominal rigidity. Figure 3 shows IRFs when the policy regime is one of the following three: a Taylor rule (black dotted lines), full optimal policy with (blue dashed lines) or without (red solid lines) the ZLB. Focusing on the Taylor rule case, the first observation is that nominal rigidity and financial frictions reinforce each other. Comparing to the flexible price case, the economy is now in a deeper recession. In particular, financial conditions deteriorate as asset prices and net worth fall sharply by about 4% and 16% respectively. The compensation from consumption is weaker because of a fall in real wages.

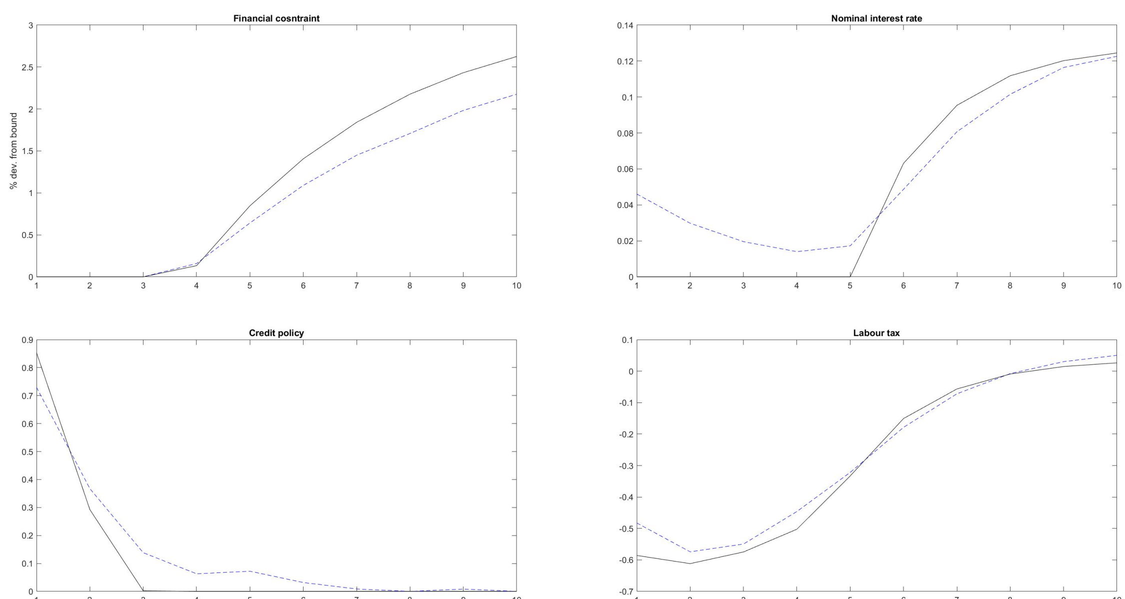
With full optimal policy but not the ZLB, though, the sticky price model behaves to a large extent similar to the flexible price model with credit and fiscal policy (both in red solid lines). As we suspect in section III.A, monetary policy can not fully stability prices so the sticky price model suffers from some but moderate inflation. Inflation becomes negligible from the quarter 2. It appears that each policy achieves their respective primary goals very well. The optimal asset purchase is about 1.05% and labour subsidy is about 1.2% both consistent with their respective readings in figure 1. However, an -0.27% nominal interest rate is needed for this beautiful result.

Therefore the ZLB emerges as a significant constraint.

Let us now turn to the ZLB case shown in blue dashed lines. Surprisingly, the ZLB reduces all policy responses. Specifically, labour subsidies become more persistent while credit interventions are weaker in all periods. This suggests that credit and monetary policy is to some extent complementary to each other. (23) reveals that, when the government has tied hands to lower real interest rate, cutting the long run interest rate alone too much slows down the recovery of banks net worth. The optimal monetary policy commits to generate a positive inflation and output gap when the unconstrained nominal interest rate becomes non-negative (at about the third quarter), as in Woodford (2003). However, the path of the nominal interest rate here behaves differently from the one that faces no financial frictions. Woodford (2003) suggests the nominal interest rate should hit the ZLB on the impact of the shock and stay there as long as necessary. However, in our case, the government does want to save some ammo. As the ZLB shows as a constraint to both credit and monetary policy, due binding constraints (the financial constraint and the ZLB) are very costly. As shown in the lower left panel, the government has precautionary motives to cut nominal interest rate slowly, tolerating weak output and inflation. In fact, the nominal interest rate does not hit the ZLB before being lifted up.

To show the precautionary effect more clearly, I compare PF with non-PF solutions in figure 4. When the government does not take into account the probability of hitting the financial bound in the future, optimal monetary policy behaves as Woodford (2003) prescribes. Results in the discussion of figure 2 also applies here.

Figure 4. Optimal policy under sticky prices with and without perfect foresight




*Note:* Black solid (blue dashed) lines are (not) under perfect foresight.

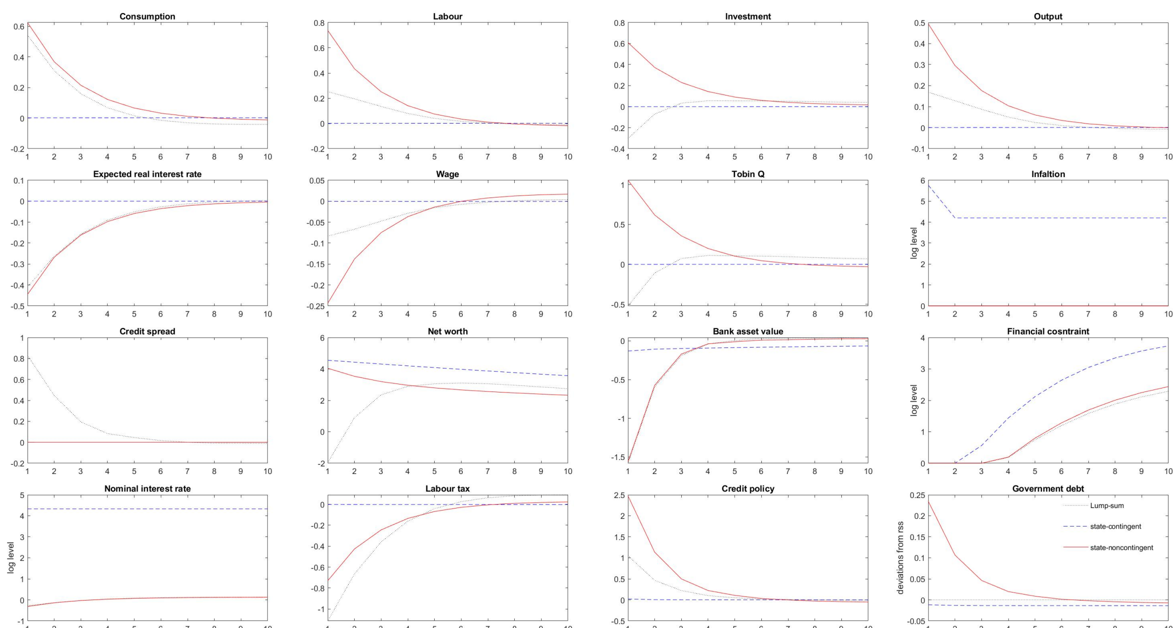
## VI. The cheapest public finance

So far we have been giving fiscal policy an advantage by abstracting the public finance issue. The optimal fiscal stimulation is shown to be large in scale (1% cut in the tax rate) and persistent over time. If fiscal deficits must be financed by government debts, however, the optimal fiscal policy literature suggests tax-smoothing. The credit policy is less constrained by the government budget because it is to a large extend self-financed except in the first period. The less private securities purchasing, the lower asset price below its fundamental value, and the more (less) relaxed the government budget (financial) constraint per unit of asset purchasing. In this section, I compare optimal policy with and without lump-sum taxes. Note that these two cases differ also in the steady state. While most IRFs are reported in deviations from the steady state, a few exceptions are shown in log level, including inflation.

### A. *Problem 5 and 6*

To fully understand the government budget constraint, I go back to the flexible price model and compare three ways of public finance: lump-sum taxes (black dotted lines), state-contingent real government debts (blue dashed lines), and state-noncontingent real government debts (red solid lines). Government debts can be state-contingent in real terms if monetary policy choose properly inflation. IRFs under these three cases are reported in figure 5.

Figure 5. IRFs under flexible prices with lump-sum taxes / state-(non)contingent real government debts




*Note:* All variables are expressed in percentage point deviations from their risky steady state (rss) unless stated otherwise.

Let us focus on state-contingent debts first. This case is significantly different from the other two because monetary policy is dominating. Since inflation is costless, optimal monetary policy simply inflating away part of banks' debts such that the binding financial constraint is not very tight. Note that the expected real interest rate stays constant because the surge in inflation is a surprise. As the blue dashed lines show, the financial shock has virtually no effect on real activities and relative prices.

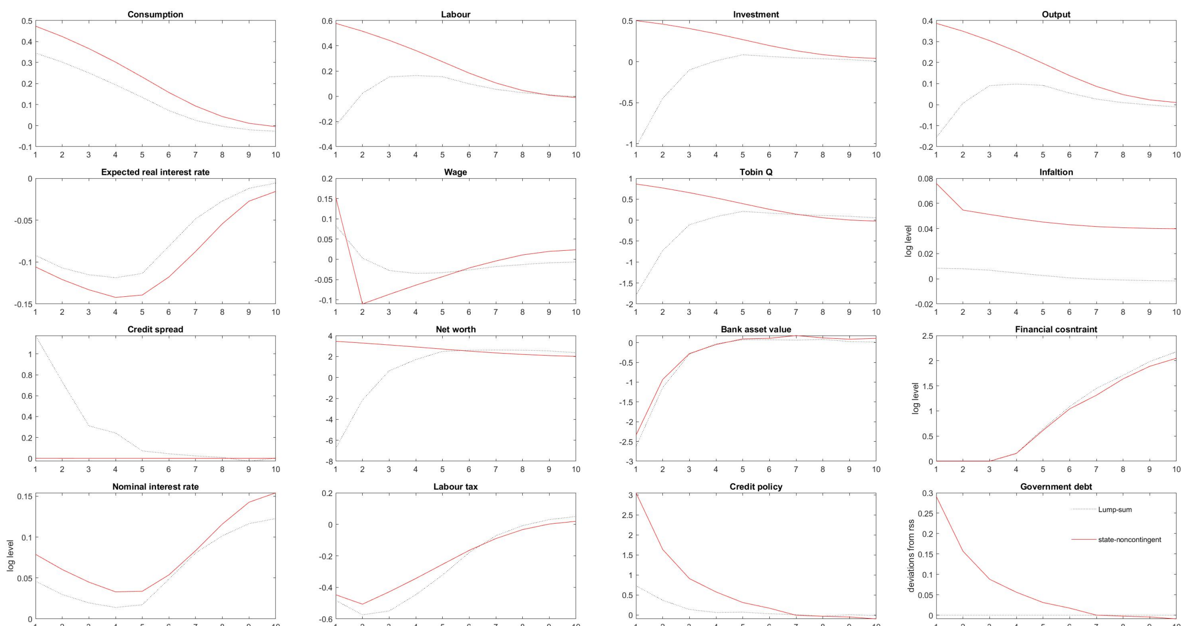
State-noncontingent debts are more interesting. Comparing with the lump-sum tax case, labour subsidies are a less powerful tool because there must be taxes in the future, which casts persistent distortions on the economy. To minimise the distortionary effect, the government would like to smooth fiscal policy. As a result, there are only modest subsidies in the first period followed by persistent taxes to finance the deficit created by credit policy, which is now the main policy. The economy behaves in a similar way as under only credit policy, i.e. problem 1.

These results are sensitive to the steady state level of government debts. If the government is a net lender by running constant deficits, it faces a trade of between relaxing the government budget (lifting real interest rates) and relaxing the financial constraint (cutting the real interest rates). As this case is not very relevant to most countries in recent years, I return to it in sensitivity analysis.

### *B. Problem 7*

Finally, we reach our last problem. The IRFs are reported in figure 6 together with the same set of IRFs under lump-sum taxes (i.e. problem 4).

FIGURE 6. IRFs UNDER STICKY PRICES WITH LUMP-SUM TAXES / STATE-NONCONTINGENT NOMINAL GOVERNMENT DEBTS




*Note:* All variables are expressed in percentage point deviations from their risky steady state (rss) unless stated otherwise.

On the impact of the shock, the government would like to cut interest rates to relax both the financial constraint and the government budget constraint.[24] However, the government faces both price stickiness and the ZLB so the optimal inflation is only mild. The traditional tradeoff between tax-smoothing and price stability is resolved not particularly in favour of one or another, but the government strives to find the balance in between. As both the monetary and fiscal policy is to some extent constrained, the government find it optimal to use credit policy aggressively. The first period asset purchases worth 3% of total private securities. Such strong credit interventions close credit spread and (together with other policies) have a strong stimulation effect on real activities. At last, note that asset purchases and labour subsidies are mainly financed by government debts, which returns to steady state along with credit policy.

[24]The nominal interest rate in red solid line appears to be higher than the black dotted lines because the former has a higher steady state.

## VII. Sensitivity

### A. Costs of credit policy

TODO

### B. Net lender v.s net borrower

TODO

## VIII. Simple rules

TODO

## IX. Conclusions

TODO

## REFERENCES

**Acharya, Viral V, Tim Eisert, Christian Eufinger, and Christian W Hirsch.** 2017. "Whatever it takes: The real effects of unconventional monetary policy."

**Adjemian, Stéphane, and Michel Juillard.** 2013. "Stochastic extended path approach." *Unpublished manuscript.*

**Altavilla, Carlo, Fabio Canova, and Matteo Ciccarelli.** 2016. "Mending the broken link: heterogeneous bank lending and monetary policy pass-through."

**Baron, Matthew D.** 2017. "Countercyclical bank equity issuance."

**Bianchi, Javier.** 2016. "Efficient bailouts?" *American Economic Review*, 106(12): 3607–59.

**Bocola, Luigi.** 2016. "The pass-through of sovereign risk." *Journal of Political Economy*, 124(4): 879–926.

**Borio, Claudio, and Anna Zabai.** 2016. "Unconventional monetary policies: a re-appraisal." Bank for International Settlements.

**Brunnermeier, Markus K, and Yann Koby.** 2017. "The reversal interest rate: An effective lower bound on monetary policy."

**Calvo, Guillermo A.** 1983. "Staggered prices in a utility-maximizing framework." *Journal of monetary Economics*, 12(3): 383–398.

**Carrillo, Julio A, Enrique G Mendoza, Victoria Nuguer, and Jessica Roldán-Peña.** 2017. "Tight money-tight credit: coordination failure in the conduct of monetary and financial policies." National Bureau of Economic Research.

**Chakraborty, Indraneel, Itay Goldstein, and Andrew MacKinlay.** 2017. "Monetary stimulus and bank lending."

**Christensen, Jens HE, and Glenn D Rudebusch.** 2012. "The response of interest rates to US and UK quantitative easing." *The Economic Journal*, 122(564).

**Christiano, VV Chari Lawrence J, and Patrick J Kehoe.** 1991. "Optimal fiscal and monetary policy: Some recent results." *Journal of Money, Credit and Banking*, 23(3): 519–539.

**Coimbra, Nuno, and Hélene Rey.** 2017. "Financial cycles with heterogeneous intermediaries." National Bureau of Economic Research.

**Correia, Isabel, Juan Pablo Nicolini, and Pedro Teles.** 2008. "Optimal fiscal and monetary policy: Equivalence results." *Journal of political Economy*, 116(1): 141–170.

**Cui, Wei, and Vincent Sterk.** 2018. "Quantitative Easing." Centre for Macroeconomics (CFM) Discussion Papers 1830.

**Dedola, Luca, and Giovanni Lombardo.** 2012. "Financial frictions, financial integration and the international propagation of shocks." *Economic Policy*, 27(70): 319–359.

**Dedola, Luca, Peter Karadi, and Giovanni Lombardo.** 2013. "Global implications of national unconventional policies." *Journal of Monetary Economics*, 60(1): 66–85.

**Del Negro, Marco, and Christopher A Sims.** 2015. "When does a central bank's balance sheet require fiscal support?" *Journal of Monetary Economics*, 73: 1–19.

**Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero, and Nobuhiro Kiyotaki.** 2017. "The great escape? A quantitative evaluation of the Fed's liquidity facilities." *The American Economic Review*, 107(3): 824–857.

**Del Negro, Marco, Raiden B Hasegawa, and Frank Schorfheide.** 2016. "Dynamic prediction pools: an investigation of financial frictions and forecasting performance." *Journal of Econometrics*, 192(2): 391–405.

**Eggertsson, Gauti B, and Michael Woodford.** 2003. "Optimal monetary policy in a liquidity trap." National Bureau of Economic Research.

**Epstein, Larry G., and Stanley E. Zin.** 1989. "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework." *Econometrica*, 57(4): 937–969.

**Foerster, Andrew T.** 2015. "Financial crises, unconventional monetary policy exit strategies, and agents' expectations." *Journal of Monetary Economics*, 76: 191–207.

**Gagnon, Joseph, Matthew Raskin, Julie Remache, Brian Sack, et al.** 2011. "The financial market effects of the Federal Reserveâs large-scale asset purchases." *International Journal of Central Banking*, 7(1): 3–43.

**Gertler, Mark, and Nobuhiro Kiyotaki.** 2010. "Financial intermediation and credit policy in business cycle analysis." *Handbook of monetary economics*, 3(3): 547–599.

**Gertler, Mark, and Peter Karadi.** 2011. "A model of unconventional monetary policy." *Journal of monetary Economics*, 58(1): 17–34.

**Gertler, Mark, Nobuhiro Kiyotaki, and Andrea Prestipino.** 2017. "A Macroeconomic Model with Financial Panics."

**Guerrieri, Luca, and Matteo Iacoviello.** 2015. "OccBin: A toolkit for solving dynamic models with occasionally binding constraints easily." *Journal of Monetary Economics*, 70: 22–38.

**He, Zhiguo, and Arvind Krishnamurthy.** 2013. "Intermediary asset pricing." *The American Economic Review*, 103(2): 732–770.

**Holden, Tom D.** 2016*a*. "Computation of solutions to dynamic models with occasionally binding constraints."

**Holden, Tom D.** 2016*b*. "Existence and uniqueness of solutions to dynamic models with occasionally binding constraints."

**Ivashina, Victoria, and David Scharfstein.** 2010. "Bank lending during the financial crisis of 2008." *Journal of Financial economics*, 97(3): 319–338.

**Jermann, Urban, and Vincenzo Quadrini.** 2012. "Macroeconomic effects of financial shocks." *American Economic Review*, 102(1): 238–71.

**Jiang, Shifu.** 2018. "Optimal cooperative and non-cooperative unconventional monetary policy under commitment."

**Jiao, Yang.** 2019. "Financial Crises, Bailouts and Monetary Policy in Open Economies."

**Jordà, Òscar, Moritz Schularick, and Alan M Taylor.** 2017. "Macrofinancial history and the new business cycle facts." *NBER macroeconomics annual*, 31(1): 213–263.

**Joyce, Michael, Ana Lasaosa, Ibrahim Stevens, Matthew Tong, et al.** 2011. "The financial market impact of quantitative easing in the United Kingdom." *International Journal of Central Banking*, 7(3): 113–161.

**Karantounias, Anastasios G.** 2018. "Optimal fiscal policy with recursive preferences." *The Review of Economic Studies*, 85(4): 2283–2317.

**Krishnamurthy, Arvind, and Annette Vissing-Jorgensen.** 2011. "The effects of quantitative easing on interest rates: channels and implications for policy." National Bureau of Economic Research.

**Maliar, Lilia, and Serguei Maliar.** 2015. "Merging simulation and projection approaches to solve high-dimensional problems with an application to a new Keynesian model." *Quantitative Economics*, 6(1): 1–47.

**Pancost, N, and Roberto Robatto.** 2017. "The Effects of Capital Requirements on Good and Bad Risk Taking."

**Perri, Fabrizio, and Vincenzo Quadrini.** 2018. "International recessions." *American Economic Review*, 108(4-5): 935–84.

**Quint, Mr Dominic, and Mr Pau Rabanal.** 2017. *Should Unconventional Monetary Policies Become Conventional?* International Monetary Fund.

**Schmitt-Grohe, Stephanie, and Martın Uribe.** 2004*a*. "Optimal fiscal and monetary policy under imperfect competition." *Journal of Macroeconomics*, 26(2): 183–209.

**Schmitt-Grohé, Stephanie, and Martın Uribe.** 2004*b*. "Optimal fiscal and monetary policy under sticky prices." *Journal of economic Theory*, 114(2): 198–230.

**Schularick, Moritz, and Alan M Taylor.** 2012. "Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008." *American Economic Review*, 102(2): 1029–61.

**Siu, Henry E.** 2004. "Optimal fiscal and monetary policy with sticky prices." *Journal of Monetary Economics*, 51(3): 575–607.

**Swarbrick, Jonathan, Tom Holden, and Paul Levine.** 2017. "Credit crunches from occasionally binding bank borrowing constraints."

**Tsiaras, Stylianos.** 2018. "Financial Crisis, Monetary Base Expansion and Risk." School of Economics, University of Surrey.

**Woodford, Michael.** 2003. *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton University Press.