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# Financial Disruption and State Dependant Credit Policy

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## Abstract

This paper analyses how long credit policy measures should last to restore a normal functioning of the loan market. We build a DSGE model where financial intermediaries and non financial agents face balance sheet constraints. Our results are two. First, we find that a credit policy has an intertemporal effect as it smoothes the negative shock along a greater number of periods. It dampens the initial negative consequences of financial shocks at the expense of a higher length of the unconventional period. Second, accounting for the joint effect of shocks on the length of the saturated period and on the fluctuation of activity in the transitory period back to the steady state situation, we find that the positive effect of this policy requires some qualification. For the benchmark calibration, conducting such a policy affects activity positively. However, for a high value of firm's leverage we find that unconventional monetary policy can be counterproductive. Ignoring credit policy will generate higher short run losses in activity but the transition to the steady state would be quicker, implying lower short run activity losses than those encountered with a credit policy where the transition to the steady state would last longer.

**JEL classification:** E31; E32; E52; E58

**Keywords:** Monetary Policy; Financial Frictions; Financial Accelerator; DSGE model;

## 1 Introduction

The 2007-2008 crisis has deeply affected the conduct of monetary policies in industrialized countries. The initial financial disruption that affected the loan market and the sharp decrease of the official rate down to the zero lower bound, led most central bank to adopt unconventional monetary policy practices based on their balance sheets beyond the use of short term official interest rates<sup>1</sup>

This paper focuses more particularly on the link between unconventional policy decisions and financial intermediation disruption. In the wake of the crisis, many commercial banks were affected by a sharp deterioration of their balance sheets and restricted the supply of loans, being concerned about their ability to refinance themselves. Fears that commercial banks were keeping funds to improve their liquidity rather than lending to the private sector, led central banks to intervene with the direct provision of credit to restore the functioning of the loan market.

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<sup>1</sup>Unconventional policy tools can broadly be divided into three categories: quantitative easing (QE), targeted asset purchases (TAP), and forward guidance. QE involves an expansion of the central bank's balance sheet. TAP involves a change in the mix of central bank assets—keeping the balance sheet scale and supply of reserves unchanged—in order to alter the relative prices of different assets. Forward guidance is a form of communication by the central bank about its future policy rate path.

There is a growing literature that concentrates on the efficacy of this bank funding channel, where policy operates in conditions of stressed bank funding. The analysis of Gertler and Karadi (2011) provides a natural point of departure for our paper. Gertler and Karadi (2011) develop a model where financial intermediaries may be subject to endogenously determined balance sheet constraints coming from an agency problem. This feature creates a shortage in the provision of loans and causes a sharp rise in various key credit spreads in troubled times. In their paper, an increase in central bank credit intermediation improves the availability of bank credit for non financial agents and moderates the decline in activity.

Our paper contributes to this literature, by analysing the state dependent nature of this policy based on the banking funding channel. Beneath the effect of this policy on activity, we analyse how long such measures should last to restore a normal functioning of the loan market and the implementation of conventional policy measures based on the use of short term official interest rates. This aspect has not yet been covered in the literature, although such policy measures are meant to be transitory to the stressed lending situation. Our objective is twofold. First, we provide a compact approach to describe how negative financial and real shocks can generate an endogenous transitory loan market stress with a shortened provision of loans to the economy and how they determine the length of the stressed situation. Second, we evaluate the effect of credit policies aimed at restoring a normal functioning of the financial sector in providing loans to the economy, accounting for an endogenous length of the stressed situation.

Our results are two. First, in line with the existing literature, we find that unconventional monetary policy significantly reduces the negative consequences of a financial crisis on the main aggregates of the economy. However adopting such measures may generate a longer period of stress on the loan market with respect to a situation with no intervention. A credit policy has an intertemporal effect as it smooths the negative shock along a greater number of periods. The lower increase in market loan interest rate following a credit policy tends to increase the total amount of loan demand more than proportionally, which, in turn, increases the length of the saturation period. Second, accounting for the joint effect of shocks on the length of the saturated period and on the fluctuation of activity in the transitory period back to the steady state situation, we assess the interest of conducting credit policy measures. We find that the positive effect of this policy requires some qualification. For the benchmark calibration, conducting such a policy affects activity positively. However, for a high value of firm's leverage we find that unconventional monetary policy can be counterproductive. Ignoring

credit policy will generate higher short run losses in activity but the transition to the steady state would be quicker, implying lower transitory activity losses than those encountered with a credit policy where the transition to the steady state would last longer.

The rest of the paper is organized as follows. Section 2 presents the loan market and the origin of loan shortages. Section 3 presents the real part of the model. Section 4 presents the calibration of the model and the effect of endogenous quantitative lending shortage on the dynamics of the aggregates. Section 5 evaluates the consequences of a credit policy implemented according to a state dimension. Section 6 concludes.

## 2 A model with borrowing and lending accelerators

This section introduces the main contribution of the analysis regarding the demand and supply of loans and the setting of loan interest rates. We more particularly focus on the behavior of entrepreneurs and financial intermediaries. Entrepreneurs finance investment projects decided by firms with their wealth and loans. Financial intermediaries collect savings from households and provide loans to entrepreneurs. Entrepreneurs and financial intermediaries are affected by balance sheet constraints. This feature limits the ability of non-financial firms to obtain investment funds and the ability of financial intermediaries to issue loans. This, in turn creates two acceleration phenomena that affects the transmission of shocks in the economy.

In this section, we contrast normal and abnormal times. In normal times, banks are able to finance all investment projects in the economy while in abnormal times, the quantity of loans issued by the financial system does not meet the "notional" loan demand (i.e., the entire loan demand coming from entrepreneurs to finance all viable investment projects).

### 2.1 Entrepreneurs and the demand for loans

Loan demand emanates from entrepreneurs. The number of entrepreneurs is normalized to 1. As in Poutineau and Vermandel (2015 a and b), the representative entrepreneur  $e \in [0, 1]$  finances the capital renting of intermediate firms. In period  $t$ , this entrepreneur conducts a great number of heterogeneous projects with total value  $Q_t K_{t+1}(e)$ , where  $Q_t$  is the price of capital and  $K_{t+1}(e)$  is the amount of capital financed. These projects are financed by his net wealth ( $N_t^E(e)$ ) and by loans contracted from the banking system ( $L_t^D(e)$ ). The balance sheet of the representative entrepreneur is determined by,

$Q_t K_{t+1}(e) = N_t^E(e) + L_t^D(e)$ , so that, the value of capital he finances is proportional to his net wealth,

$$Q_t K_{t+1}(e) = \phi_t^E(e) N_t^E(e), \quad (1)$$

where  $\phi_t^E(e) > 1$  is the financial accelerator, while the entrepreneur's loan demand is defined as,

$$L_t^D(e) = (\phi_t^E(e) - 1) N_t^E(e).$$

Here, the higher his net wealth, the greater is the quantity of loans he may obtain. Both the quantity of loans subscribed and the amount of capital financed by the entrepreneur depend on the expected profitability of investment projects through the variable  $\phi_t^E(e)$ .

The investment projects undertaken by the entrepreneur are risky and differ with respect to their individual returns and allow entrepreneurs to default on its loans for its least profitable projects. To model individual riskiness, we follow Poutineau and Vermandel (2015 a and b) by assuming that each project has an individual return equal to  $\omega(1 + R_t^k)$ , *i.e.* that the aggregate return of investment projects in the economy  $1 + R_t^k$  is multiplied by a random value  $\omega$  (drawn from a Pareto distribution).<sup>2</sup> We define the value for a profitable project by  $\bar{\omega}_t = E(\omega | \omega \geq \omega_t^C)$  (where  $\omega_t^C$  is the critical value of  $\omega$  that distinguishes profitable and non-profitable projects), and the probability of success for an individual project by  $\eta_t^E = \Pr(\omega \geq \omega_t^C)$ . To introduce a financial accelerator mechanism, we assume that entrepreneurs' forecasts regarding the aggregate profitability of a given project  $\bar{\omega}_t$  are optimistic (*i.e.*, their expectation is biased upwards). The perceived *ex ante* value of profitable projects is defined by the CES function,

$$g(\bar{\omega}_{t+1}, \varepsilon_t^Q) = \gamma (\bar{\omega}_{t+1})^{\frac{\varkappa^E}{(\varkappa^E - 1)}} (e^{\varepsilon_t^{opt}})^{\frac{1}{(\varkappa^E - 1)}},$$

where  $\varepsilon_t^{opt}$  is an  $AR(1)$  process,<sup>3</sup>  $\varkappa^E$  is the elasticity of the external finance premium and  $\gamma$  is a scale parameter.<sup>4</sup> In this expression, the exogenous shock is affected by exponent  $1/(\varkappa^E - 1)$  to normalize to unity the impact of the financial shock  $\varepsilon_t^{opt}$  in the log deviation form of the model.

Thus, *ex-ante* the entrepreneur chooses a capital amount  $K_{t+1}(e)$  that maximizes its expected

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<sup>2</sup>With respect to the standard framework standardly used in the literature, we assume that the heterogeneity in the return of investment project undertaken by firms is modeled using a Pareto distribution as in Poutineau and Vermandel (2015a), Poutineau and Vermandel (2015b). This device commonly used in other branches of the economic literature provides a series of interesting features in the analysis and allows an easier estimation of the financial amplification effect.

<sup>3</sup>This shock affects the expected profitability of financial projects by rising in exogeneously the risk premium implying an increase in the cost of capital and hence a reduction in investment.

<sup>4</sup>This parameter is needed to make the steady state independent of  $\varkappa^E$ , such that  $\gamma = \bar{\omega}^{1/(1-\varkappa^E)}$ .

profit defined as,

$$\max_{\{K_{t+1}(e)\}} \mathbb{E}_t \left\{ \eta_{t+1}^E \left[ g \left( \bar{\omega}_{t+1}, \varepsilon_t^Q \right) (1 + R_{t+1}^k) Q_t K_{t+1}(e) - (1 + R_t^L) L_{t+1}^D(e) \right] \right\}. \quad (2)$$

Using the characteristics of the Pareto distribution, the expected spread required by the representative entrepreneur  $e$  to undertake the decision to finance firms' investment is:

$$S_t(e) = \frac{\mathbb{E}_t(1 + R_{t+1}^k)}{1 + R_t^L} = \gamma^{\varkappa^E - 1} \left[ \frac{\kappa}{\kappa - 1} \left( 1 - \frac{N_{t+1}^E(e)}{Q_t K_{t+1}(e)} \right) \right]^{\varkappa^E} e^{\varepsilon_t^{opt}}. \quad (3)$$

The size of the accelerator is determined by the elasticity of the external finance premium  $\varkappa^E$ . For  $\varkappa^E > 0$ , the external finance premium is a positive function of the leverage ratio,  $Q_t K_{t+1}(e) / N_{t+1}^E(e)$ , so that an increase in net wealth induces a reduction of the external finance premium. This phenomenon disappears if  $\varkappa^E = 0$ . Concerning the exogenous movements of the external finance premium, a positive realization of  $\varepsilon_t^{opt}$  means that entrepreneurs require a higher expected profitability of capital  $E_t[R_{t+1}^k]$  to finance investment for a given level of lending conditions  $R_t^L$ . Furthermore, a shock that hits the entrepreneur net wealth  $N_{t+1}^E(e)$  will also affect the return of physical capital in the economy. As the rentability of capital is a cost for the intermediate sector, a variation in the net wealth will have aggregate consequences on goods supply through the channel of the capital market.

Combining (1) and (3) we can thus define,

$$\phi_t^E(e) \equiv \left[ 1 - \frac{\kappa - 1}{\kappa} \left( \frac{E_t(1 + R_{t+1}^k)}{1 + R_t^L} \frac{\gamma^{1 - \varkappa^E}}{e^{\varepsilon_t^{opt}}} \right)^{\frac{1}{\varkappa^E}} \right]^{-1},$$

Finally, the net wealth of the entrepreneur in the next period is equal to:

$$N_{t+1}^E(e) = (1 - \tau^E) \frac{\Pi_t^E(e)}{e^{\varepsilon_t^{NE}}}, \quad (4)$$

where  $\varepsilon_t^{NE}$  is an exogenous process of net wealth destruction,  $\tau^E$  is a proportional tax on the profits and  $\Pi_t^E(e) = \eta_t^E [\bar{\omega}_t(e) (1 + R_t^k) Q_{t-1} K_t(e) - (1 + R_{t-1}^L) L_{t-1}^D(e)]$ .

## 2.2 Financial intermediaries and the supply of loans

The provision of loans to entrepreneur is operated by financial intermediaries. Financial intermediaries lend funds obtained from households to entrepreneurs.<sup>5</sup> The total number of banks is normalized to 1.

The representative bank  $b \in [0, 1]$  operates in a regime of monopolistic competition to provide deposit and credit services to households and firms. Each period, the bank collects deposits  $B_t(b)$  from households remunerated at the risk free interest rate  $R_t$ , and supplies loans  $L_t^S(b)$  to entrepreneurs whose rate is  $R_t^L(b)$ . As in Gertler and Karadi (2011) each period a constant fraction  $(1 - \theta)$  of banks exit the market and is replaced by the same number of new banks.<sup>6</sup> At the end of its life, the bank gives back the amount of wealth it has accumulated through its activity to its landlord. The representative bank  $b$  thus maximizes its expected terminal wealth,

$$V_t(b) = \max E_t \sum_{\tau=0}^{\infty} (1 - \theta) \theta^\tau \beta^{\tau+1} \Lambda_{t,t+1+\tau} (N_{t+1+\tau}^B(b)), \quad (5)$$

where the discount rate  $((1 - \theta) \theta^\tau \beta^{\tau+1} \Lambda_{t,t+1+\tau})$  accounts for the survival rate of the bank and the marginal rate of intertemporal substitution between  $t$  and  $t + 1 + \tau$  ( $\beta \Lambda_{t,t+1+\tau}$ ), so as its surplus can be expressed in terms of marginal utility of consumption.

In providing resources to the banking system, households are faced with a problem of moral hazard. As in Gertler and Karadi (2011), banks may decide to divert a fraction  $\lambda_t$  of deposits and transfer this back to the household of which it is a member. The depositors can force the intermediary into bankruptcy and recover the remaining fraction  $(1 - \lambda_t)$  of assets. We assume that  $\lambda_t = \lambda e^{\varepsilon_t^\lambda}$ , with  $\varepsilon_t^\lambda \sim AR(1)$ . In what follows this shock will be interpreted as the perception of bank risk. This moral hazard problem may lead depositors to shrink the quantity of resources needed by the banking system. This, in turn, induces quantitative restriction in the provision of loans to entrepreneurs. For lenders to be willing to supply funds to the banker, the following incentive constraint must be satisfied,

$$V_t(b) \geq \lambda_t L_t^S(b),$$

where  $L_t^S(b)$  is the total amount of loans intermediated by the bank, owing deposits  $(B_{t+1}(b))$  and its

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<sup>5</sup>As in the original setting of Gertler and Karadi, banks are owned by households (see the next section) and the landlord of the bank cannot put deposits in his bank.

<sup>6</sup>This assumption is required to avoid an infinite expansion of bank assets, that would allow financial intermediaries to issue loans without the need of deposits.

equity capital ( $N_t^B(b)$ ), namely  $N_t^B(b) + B_{t+1}(b) = L_t^S(b)$ . When this incentive constraint is checked, the total amount of loans intermediated by the banking system depends on the quantity of loans demanded by entrepreneurs. In this situation, defining  $L_t^D$  as the total amount of loans demanded in the economy (namely,  $L_t^D = Q_t K_{t+1} - N_t^E$ ), the quantity of loans supplied by the representative bank is  $L_t^S = L_t^D$ . In normal times,

$$L_t^S = (\phi_t^E - 1)N_t^E.$$

As presented above  $\phi_t^E$  takes into account the interest rate set on loans. The setting of loan interest rate in normal times is intended to maximize the expected profit of the bank. The bank maximizes its expected profit that takes into account the possibility of entrepreneurs to go bankrupt, it is defined as,

$$\begin{aligned}\Pi_{t+1}^B(b) &= E_t [\eta_{t+1}^E] R_t^L(b) L_t^S(b) - R_t B_{t+1}(b) \\ &= (E_t [\eta_{t+1}^E] R_t^L(b) - R_t) L_t^S(b) + R_t N_t^B(b).\end{aligned}$$

Finally, the value of bank assets is determined by its profit, as,

$$N_{t+1}^B(b) = \frac{(\eta_t^E R_{t-1}^L(b) - R_{t-1}) L_{t-1}^S(b) + R_{t-1} N_{t-1}^B(b)}{e^{\varepsilon_t^{N^B}}}, \quad (6)$$

with  $\varepsilon_t^{N^B} \sim N(0, \sigma_{\varepsilon^{N^B}})$ , represents an exogenous shock on bank wealth.

Individually, the determination of interest rate on loans is as follows: the representative bank  $b$  maximizes expected profit from Equation 27 with respect to  $L_t^S(b)$  to obtain the expression of the marginal cost of producing new loans:

$$R_t^L(b) = \frac{\epsilon^B}{\epsilon^B - 1} MC_t^B(b) = \frac{\epsilon^B}{\epsilon^B - 1} \frac{R_t}{E_t [\eta_{t+1}^E]}, \quad (7)$$

where  $\epsilon^B$  is the elasticity of substitution between different types of loans. If the incentive constraint is binding, the constraint determines the maximal amount of loans ( $L_t^S(b)^{\max}$ ) the bank can provide to the economy,

$$L_t^S(b)^{\max} \equiv \frac{V_t(b)}{\lambda_t}.$$

The total amount of loans intermediated in the economy is limited to  $L_t^{S \max}$  and depends on its



expected terminal wealth  $V_t(b)$  that can be expressed as,

$$V_t(b) = \nu_t(b)L_t^S(b) + \eta_t(b)N_t^B(b), \quad (8)$$

with,

$$\nu_t(b) = E_t(1 - \theta)\beta\Lambda_{t,t+1}(\eta_{t+1}^E R_t^L(b) - R_t) + \Lambda_{t,t+1}\theta\beta\frac{L_{t+1}^S(b)}{L_t^S(b)}\nu_{t+1}(b),$$

$$\eta_t(b) = E_t\left[(1 - \theta)\beta\Lambda_{t,t+1}R_{t+1} + \Lambda_{t,t+1}\theta\beta\frac{N_{t+1}^B(b)}{N_t^B(b)}\eta_{t+1}(b)\right].$$

Finally, collecting terms, the amount of loans provided by the banks depends on its net wealth corrected by the leverage ration,

$$L_t^S(b) = \phi_t^B(b)N_t^B(b),$$

where,

$$\phi_t^B(b) \equiv \frac{\eta_t(b)}{\lambda_t - \nu_t(b)},$$

is the leverage ratio. In this situation, the interest rate on loans becomes a jump variable determined at the market level to force demand to equalize loan supply.

### 2.3 Loan market tightness

In this model, the equilibrium on the loan market takes into account normal situations (where the quantity of loans issued by the banking system meets the quantity demanded, given loan interest rates) and abnormal times (where the quantity of loans obtained by entrepreneurs is less than their notional demand).

In normal times, the constraint does not bite. In this situation, the banking system determines the interest on loans according to,

$$R_t^L = (1 - \tau^B) \frac{\epsilon^B}{\epsilon^B - 1} MC_t^B = (1 - \tau^B) \frac{\epsilon^B}{\epsilon^B - 1} \frac{R_t}{E_t[\eta_{t+1}^E]},$$

where  $\tau^B$  is a tax on the marginal cost from the bank, and the quantity of loans that is issued corresponds to the loan demand of entrepreneurs given this interest rate,

$$L_t = (\phi_t^E - 1)N_t^E,$$

where the interest rate affects the value of  $\phi_t^E$ .

In abnormal times, the loan constraint bites, and the equilibrium is obtained by a sharp increase of the market interest rate to balance demand and the shortage in loan supply. In this situation, the quantity of loans depends on the maximum amount of resources of the banking system and is equal to,

$$L_t = \phi_t^B N_t^B,$$

with,  $N_t^B = N_t^{EB} + N_t^{NB}$ . Here,  $N_t^{EB}$  is bank net wealth at the end of t-1 and  $N_t^{NB}$  is new entering bank net wealth given the demography of financial intermediaries.<sup>7</sup> Under this regime, the interest rate on loans is a jump variable that is determined so as to adjust loan demand to the maximum amount of loans provided by the banking system. Thus value of  $R_t^{L,S}$  solves,

$$\phi_t^B N_t^B = (\phi_t^E - 1) N_t^E.$$

with,

$$\phi_t^B \equiv \frac{\eta_t}{\lambda_t - \nu_t},$$

$$N_t^B = \theta [(\eta_t^E R_{t-1}^L - R_{t-1}) L_{t-1}^S + R_{t-1} N_{t-1}^B] / e^{\varepsilon_t^{NB}} + \omega L_{t-1}^S, \quad (9)$$

$$\phi_{t+1}^E \equiv \left[ 1 - \frac{\kappa - 1}{\kappa} \left( \frac{1 + E_t [R_{t+1}^k]}{1 + R_t^L} \frac{\gamma^{1-\chi^E}}{e^{\varepsilon_t^{opt}}} \right)^{\frac{1}{\chi^E}} \right]^{-1},$$

$$N_{t+1}^E = (1 - \tau^E) \frac{\Pi_t^E}{e^{\varepsilon_t^N}}. \quad (10)$$

We can measure the loan market tightness as follows: the interest rate that balances the loans market can be written as  $R_t^{L,S}$  where,

$$R_t^{L,S} = \frac{R_t + \zeta_t}{E_t [\eta_{t+1}^E]},$$

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<sup>7</sup>First, the value of  $N_t^{EB}$  is obtained by aggregating over all the banks (using the expression of  $N_t^B(b)$  defined above) given the survival rate  $\theta$ , we get  $N_t^{EB} = \theta [(\eta_t^E R_{t-1}^L - R_{t-1}) L_{t-1}^S + R_{t-1} N_{t-1}^B] / e^{\varepsilon_t^{NB}}$ . In the meanwhile new bankers get from household an initial transfer equal to  $\omega/(1-\theta)$  of all assets intermediated by the banking system. Since in each period a fraction  $(1-\theta)$  of households become bankers, we get  $N_t^{NB} = (1-\theta)\omega/(1-\theta)L_{t-1}^S = \omega L_{t-1}^S$ . Thus,  $N_t^B = \theta [(\eta_t^E R_{t-1}^L - R_{t-1}) L_{t-1}^S + R_{t-1} N_{t-1}^B] / e^{\varepsilon_t^{NB}} + \omega L_{t-1}^S$ .

with  $\zeta_t > 0$  measures the tightness of the loan market. It is computed as follows,

$$\begin{aligned} R_t^{L,S} - R_t^L &= \frac{R_t + \zeta_t}{E_t[\eta_{t+1}^E]} - \frac{R_t}{E_t[\eta_{t+1}^E]}, \\ \zeta_t &= E_t[\eta_{t+1}^E] (R_t^{L,S} - R_t^L). \end{aligned}$$

In normal times,  $\zeta_t = 0$ , as the interest rate that balances the loan market corresponds to the interest rate set by the banking system (i.e.,  $R_t^{L,S} = R_t^L$ ). In abnormal times, the tightness of the loan market combines the expected rate of default (an increase of this rate increases the tightness of the market, as less projects are profitable and less loans are issued by the banking system) and the interest rate spread between the interest rate on loans that balances loan supply and demand and the interest that would be set by the banking system without the quantitative constraint. This variable will be used as an indicator to characterize the situation of the loan market and the policy to be adopted (either conventional for  $\zeta_t = 0$  or combining conventional and unconventional measures for  $\zeta_t > 0$ ). It will be used to compute the amount of the credit policy required in stressed times.

### 3 The rest of the model

The rest of the model is standard to the DSGE literature: The economy is populated by households, intermediate and final firms and capital suppliers. As in Gertler and Karadi (2011), households are made of workers and bankers (workers supply labor to firms, consume and save, while bankers manage financial intermediaries), firms are made of intermediate and final sectors (the intermediate sector produces intermediate goods using capital and labor, while final firms produce final goods by combining intermediate goods and set sticky prices for these goods that are consumed by households), capital is provided to intermediate firms by capital suppliers.

#### 3.1 Households

The number of household is normalized to 1. The representative household  $j \in [0, 1]$  is made of two parts: a fraction  $(1 - f)$  of the household consumes, offers labor and saves, while a fraction  $f$  acts as a banker. Each period a fraction  $(1 - \theta)$  of bankers (thus  $(1 - \theta)f$  individuals) become workers while an equivalent number of workers become bankers, to maintain a constant proportion between the two components. New bankers are endowed with an initial amount of wealth. This assumption is needed

to avoid the fact that bankers may accumulate enough revenue so as to be able to finance all financial projects without the need of depositors. Defining  $C_t(j)$  as the aggregate consumption of the household in period  $t$  and  $H_t(j)$  the supply of labour, we can write the welfare of the representative household as,

$$\max_{\{C_{t+\tau}(j), H_{t+\tau}(j), B_{t+1+\tau}(j)\}} \sum_{\tau=0}^{+\infty} \beta^\tau \left[ e^{\varepsilon_{t+\tau}^C} \ln(C_{t+\tau}(j) - hC_{t+\tau-1}(j)) - \chi^C \frac{1}{1+\varphi} H_{t+\tau}(j)^{1+\varphi} \right]. \quad (11)$$

He maximizes its welfare subject to a budget constraint,

$$P_t^C C_t(j) + B_{t+1}(j) = W_t^h(j) H_t(j) + T_t + R_t B_t(j), \quad (12)$$

where  $B_{t+1}(j)$  is the amount of savings at the end of period  $t$ ,  $W_t^h(j)$  the nominal wage,  $P_t^C$  the consumption price index,  $R_t$  the riskless interest rate,  $T_t$  the total amount of net transfers received in period  $t$ . Here,  $\varepsilon_t^C \sim AR(1)$  is a preference shock. The FOC can be combined as follows,

$$\beta E_t[\Lambda_{t,t+1}(j) R_{t+1}] = 1, \quad (13)$$

$$\varrho_t(j) W_t^h(j) = \chi^C H_t(j)^\varphi, \quad (14)$$

with,

$$\varrho_t(j) = \frac{1}{P_t^C} \left[ \frac{e^{\varepsilon_t^C}}{C_t(j) - hC_{t-1}(j)} - \frac{\beta h e^{\varepsilon_{t+1}^C}}{E_t[C_{t+1}(j)] - hC_t(j)} \right],$$

$$\Lambda_{t,t+1}(j) = \frac{\varrho_{t+1}(j)}{\varrho_t(j)}.$$

where  $\varrho_t(j)$  is the marginal utility of consumption. Households provide differentiated labor types, sold by labor unions to perfectly competitive labor packers who assemble them in a CES aggregator and sell the homogenous labor to intermediate firms. Each representative union is related to an household  $j \in [0; 1]$ . Each household provides a differentiated type of labor  $H_t(j)$ . The aggregated amount of labor in the economy  $H_t$  is defined as,

$$H_t = \left[ \int_0^1 H_t(j)^{(\varepsilon^W - 1)/\varepsilon^W} dj \right]^{\varepsilon^W / (\varepsilon^W - 1)},$$

where  $\varepsilon^W$  is the elasticity of substitution. The demand for an individual type of labor is defined as,

$$H_t(j) = \left( \frac{W_t^h(j)}{W_t} \right)^{-\varepsilon^W} H_t,$$

with  $W_t^h(j)$  is the wage for labor of type  $j$  and,

$$W_t = \left[ \int_0^1 W_t^h(j)^{1-\varepsilon^W} dj \right]^{1/(1-\varepsilon^W)}.$$

Households provide differentiated labor types, sold by labor unions to perfectly competitive labor packers who assemble them in a CES aggregator and sell the homogenous labor to intermediate firms. Assuming that the trade union is able to modify its wage with a probability  $1 - \theta^W$ , it chooses the optimal wage  $W_t^*(j)$  to maximize its expected sum of profits: Wage stickiness arises from the fact that each trade union cannot adjust immediately nominal wages. We assume that each trade union is able to choose an optimal wage  $W_t^{h*}(j)$  with probability  $(1 - \theta^W)$  while the remaining of workers have their wage indexed on the previous period  $\left( \Pi_t = \frac{P_t^C}{P_{t-1}^C} \right)$ . The trade union thus maximizes,

$$\max_{\{W_t^*(j)\}} E_t \sum_{\tau=0}^{+\infty} (\theta^W)^\tau \beta^\tau \Lambda_{t,t+\tau}(j) \left[ \frac{W_t^{h*}(j)}{W_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pw}} - W_t^h(j) \right] H_{t+\tau}(j), \quad (15)$$

subject to,  $H_{t+\tau}(j) = \left( \frac{W_t^{h*}(j)}{W_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pw}} \right)^{-\varepsilon^W}$ , with  $\gamma^{pw}$  featuring the indexation parameter.

The FOC that governs the dynamics of the nominal wage is,

$$E_t \sum_{\tau=0}^{+\infty} (\theta^W)^\tau \beta^\tau \Lambda_{t,t+\tau}(j) \left[ \frac{W_t^{h*}(j)}{W_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pw}} - \frac{\varepsilon^W}{\varepsilon^W - 1} W_t^h(j) \right] H_{t+\tau}(j) = 0, \quad (16)$$

with  $\frac{\varepsilon^W}{\varepsilon^W - 1}$  is the mark up on the labor market.

### 3.2 Firms and capital suppliers

The productive sector combines intermediate firms, final firms and capital suppliers. Intermediate firms produce differentiated goods  $i$ , choose labor and capital inputs, and set prices according to the Calvo model. Final goods producers act as a consumption bundler by combining national intermediate

goods to produce the homogenous final good<sup>8</sup>. Capital suppliers rent and refurbish the capital stock used by intermediate firms and financed by the entrepreneurs on a competitive market.

The representative intermediate firm  $i \in [0, 1]$ , produces,

$$Y_t^s(i) = e^{\varepsilon_t^A} (U_t(i) K_t(i))^\alpha H_t(i)^{1-\alpha}, \quad (17)$$

where  $Y_t(i)$  is the production function of the intermediate good that combines capital  $K_t(i)$ , labor  $H_t(i)$  and technology  $e^{\varepsilon_t^A}$  (an  $AR(1)$  productivity shock). Intermediate goods producers solve a two-stages problem. In the first stage, taken the real input prices  $W_t$  and  $Z_t$  as given, firms rent inputs  $H_t(i)$  and  $K_t(i)$  in a perfectly competitive factor markets in order to minimize costs subject to the production constraint. They pay a cost  $\Phi(U_t)$  for using capital that is affected to entrepreneurs through the  $R_t^k$ . In equilibrium this marginal cost of using capital ( $\Phi'(U_t)$ ) is equal to the marginal rentability of capital denoted  $Z_t^k$ <sup>9</sup>. The marginal cost of production is thus,

$$MC_t^E(i) = \alpha^{-\alpha} (1 - \alpha)^{\alpha-1} (Z_t^k)^\alpha W_t^{1-\alpha} \left( e^{\varepsilon_t^A} \right)^{-1}. \quad (18)$$

The average rate of capital profitability is,

$$R_{t+1}^k = \frac{[CM_{t+1}^E \alpha \frac{Y_{t+1}^s}{K_{t+1}} + (1 - \delta_c) Q_{t+1} - \Phi(U_t)]}{Q_t}, \quad (19)$$

with  $\delta_c$  is the depreciation parameter.

Final firms produce final goods according to a CES technology,

$$Y_t^d = \left[ \int_0^1 Y_t^s(k)^{(\varepsilon^E - 1)/\varepsilon^E} dk \right]^{\varepsilon^E / (\varepsilon^E - 1)},$$

with  $Y_t(k)$  is the quantity of intermediate good bought by the final firm  $k \in [0, 1]$ ,  $Y_t^d$  is the total amount of final goods available in the economy and  $\varepsilon^E$  is the price elasticity of the individual demand

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<sup>8</sup>Final good producers are perfectly competitive and maximize profits,  $P_t Y_t^d - \int_0^1 P_t(i) Y_t(i) di$ , subject to the production function  $Y_t^d = (\int_0^1 Y_t(i)^{(\varepsilon^E - 1)/\varepsilon^E} di)^{\varepsilon^E / (\varepsilon^E - 1)}$ . We find the intermediate demand functions associated with this problem are,  $Y_t(i) = (P_t(i)/P_t)^{-\varepsilon^E} Y_t^d$ ,  $\forall i$  where  $Y_t^d$  is the aggregate demand.

<sup>9</sup>Suivant Poutineau et Vermandel (2013), on pose  $\Phi(U_t) = \frac{1-\Psi}{\Psi} \bar{Z} [e^{\frac{\Psi}{1-\Psi}(U_t-1)} - 1]$ . On a donc  $Z_t^k = \Phi'(U_t) = \bar{Z} e^{\frac{\Psi}{1-\Psi}(U_t-1)}$ .

of good. The demand addressed to a given final firm is,

$$Y_t^s(k) = \left( \frac{P_t^C(k)}{P_t^C} \right)^{-\varepsilon^E} Y_t^d. \quad (20)$$

Each firm  $k$  fixes sets the price of  $Y_t^s(k)$  according to a Calvo mechanism. Each period firm  $k$  is not allowed to re optimize its price with probability  $\theta^E$ . Thus, only a fraction  $(1 - \theta^E)$  of final firms is able to set the optimal price  $P_t^{C*}(k)$ , other prices being partially indexed on the inflation rate. The optimization program of the representative final firm is thus,

$$\max_{\{P_t^{C*}(k)\}} E_t \sum_{\tau=0}^{\infty} (\theta^E)^\tau \beta^\tau \Lambda_{t,t+\tau} \left[ \frac{P_t^{C*}(k)}{P_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pe}} - MC_{t+\tau}(k) \right] Y_{t+\tau}^s(k), \quad (21)$$

with  $\gamma^{pe} < 1$  is the indexation parameter. The First order condition is given by,

$$\sum_{\tau=0}^{\infty} (\theta^E)^\tau \beta^\tau \Lambda_{t,t+\tau} \left[ \frac{P_t^{C*}(k)}{P_{t+\tau}} \prod_{k=1}^{\tau} (\Pi_{t+k-1})^{\gamma^{pe}} - \frac{\varepsilon^E}{\varepsilon^E - 1} CM_{t+\tau}(k) \right] Y_{t+\tau}^s(k) = 0. \quad (22)$$

Capital suppliers are homogeneous and distributed over a continuum normalized to one. The representative capital supplier  $q \in [0, 1]$  acts competitively to supply a quantity  $K_{t+1}(q)$  of capital. Investment is costly, *i.e.* the capital supplier pays an adjustment cost function  $AC_t^I(q) = \frac{\eta^I}{2} \left( \frac{I_t(q)}{I_{t-1}(q)} - 1 \right)^2$  on investment. They provide a capital amount of  $Q_t K_{t+1}(q)$  by buying the non depreciated capital to entrepreneurs  $(1 - \delta_c) K_{t+1}(q)$  and investing  $I_t(q)$ . The representative capital supplier thus maximizes,

$$\max_{\{I_{t+\tau}\}} E_t \left\{ \sum_{\tau=0}^{\infty} \beta^\tau \Lambda_{t,t+1+\tau} [Q_{t+\tau} (1 - AC_{t+\tau}^I(q)) - 1] I_{t+\tau}(q) \right\}. \quad (23)$$

The first order condition associated to this program defines the renting price of capital,

$$Q_t = 1 + Q_t \frac{d(I_t(q) AC_t^I(q))}{dI_t(q)} + \beta E_t \left[ \Lambda_{t,t+1} Q_{t+1} \frac{d(I_{t+1}(q) AC_{t+1}^I(q))}{dI_t(q)} \right]. \quad (24)$$

Thus, the real return from holding one unit of capital from  $t$  to  $t + 1$  is determined by:

$$\mathbb{E}_t R_{t+1}^k = \mathbb{E}_t \left[ \frac{Z_{t+1} - \Phi(U_t) + (1 - \delta) Q_{t+1}}{Q_t} \right]. \quad (25)$$

### 3.3 Macroeconomic policies and general equilibrium

Fiscal policy is assumed exogenous in our setting, i.e.  $G_t = Ge^{\varepsilon_t^g}$  with,  $G$  is the steady state level and  $\varepsilon_t^g \sim AR(1)$  represents public spendings in period  $t$ , and it affects the resource constraint of the economy,

$$Y_t^d = C_t + (1 + AC_t^I)I_t + G_t + \tau Q_t K_{t+1}. \quad (26)$$

As in Gertler and Karadi (2011),  $\tau Q_t K_{t+1}$  measures inefficiencies related to the cost of implementing a credit policy (assumed less efficient than loan creation by financial intermediaries, with  $\tau$  is an inefficiency parameter if the central bank intermediates funds directly. Capital accumulation is defined according to,

$$K_t = (1 - \delta_c)K_{t-1} + I_t. \quad (27)$$

In normal times, the central bank follows a standard Taylor rule policy,

$$R_t = \frac{1}{\beta} (\Pi_t)^{\phi_\pi} \left( \frac{1/CM_t^E}{\varepsilon^E/(\varepsilon^E - 1)} \right)^{\phi_{CM}} e^{\varepsilon_t^i},$$

where,  $\varepsilon_t^i \sim N(0, 1)$ , as we consider that in a crisis situation the central bank does react in a flexible way to the economic conditions it faces. Accounting for the possibility of a ZLB the nominal interest rate set by the central bank,  $i_t$  is defined as:

$$i_t = \max \left\{ \frac{1}{\beta} (\Pi_t)^{\phi_\pi} \left( \frac{1/CM_t^E}{\varepsilon^E/(\varepsilon^E - 1)} \right)^{\phi_{CM}} e^{\varepsilon_t^i}, ZLB \right\}. \quad (28)$$

In the model, we have 8 AR(1) shocks such that  $\varepsilon_t^s = \rho^s \varepsilon_t^s + \eta_t^s$ , for  $s \in \{N^B, N^E, a, opt, g, C, i, \lambda\}$ , where  $\rho^s$  is the autoregressive parameter and  $\eta_t^s$  is normally distributed. The general equilibrium combines a sequence of quantities  $\{Q_t\}_{t=0}^\infty$  and a sequence of prices  $\{P_t\}_{t=0}^\infty$ , such that, for a given sequence of shocks  $\{S_t\}_{t=0}^\infty$  and conditional on the monetary policy: (i) For a given sequence of prices  $\{P_t\}_{t=0}^\infty$ , the sequence  $\{Q_t\}_{t=0}^\infty$  satisfies first-order conditions of households, entrepreneurs, firms, capital producers and financial intermediaries; (ii) For a given sequence of quantities  $\{Q_t\}_{t=0}^\infty$ , the sequence  $\{P_t\}_{t=0}^\infty$ , guarantees the equilibrium on all markets.



## 4 The effect of quantitative lending constraints on macroeconomic dynamics

In this section, we calibrate the model and we evaluate the macroeconomic effects of a transitory shortage in bank lending. Our aim is mainly to appreciate the determinants of the length of the shortage period and the working of the model with accelerators on the lending and borrowing side of the loan market.

### 4.1 Calibration and steady state

The calibration of the model is summarized in Table 1. The value chosen for the model's parameter should meet two requirements: First, the steady state of the model should correspond to normal times (i.e., it should lie in the non saturated lending region that corresponds to a normal working of the loan market); Second, this steady state should be close enough to a loan shortage situation thus allowing for the possibility of a transitory lending shortage at the outcome of admissible values for financial and real shocks. This feature is important to generate abnormal times in the economy so as to provide the pre requisite for unconventional policy measures.

Most parameters are calibrated following Gertler and Karadi (2011). This is the case of the discount factor  $\beta$ , the weight of capital in the production function  $\alpha$ , the elasticity of substitution between goods  $\varepsilon^E$ , the habit parameter on consumption  $h$ , the elasticity of capital depreciation to the capital rate of utilization  $\epsilon$ , The survival rate of bankers  $\theta$ , the parameter of wealth transfers towards new bankers  $\omega$ , the elasticity of labor supply  $\varphi$ , the price rigidity parameter  $\theta^E$ , the indexation parameter on prices  $\gamma^{pe}$ , the parameters of the Taylor rule  $\phi_\pi$  and  $\phi_{CM}$ , the credit policy parameter  $v$ , and the parameter related to authorities inefficiency  $\tau$ . Furthermore, parameters  $\theta^B$  and  $\gamma^{pb}$  are calibrated as  $\theta^E$  and  $\gamma^{pe}$ . To account for an abnormal economic situation, we also follow Gertler and Karadi (2011) by setting the autoregressive parameter on the interest rate  $\rho$  equal to 0, as we consider that in a crisis situation the central bank does react in a flexible way to the economic conditions it faces.

The parameter related to the rigidity of wages  $\theta^W$  is calibrated at a relative lower value (0.3). We fix the steady state value of the leverage ratio ( $LEV = N^E/K$ , equal to the inverse of the shape parameter in the Pareto distribution  $\kappa$ ) to  $2/3$ . In this situation, borrowing affects the steady state, as firms' capital stock correspond to 1.5 times the capital stock they would have chosen on the sole basis of their net wealth. As in Poutineau and Vermandel (2015) we calibrate the labor desutility parameter

$\chi^C$  to get a stock of labor equal at  $H = 1/3$  in the steady state and we fix the bias parameter  $\chi^E = 0.05$  in the entrepreneur expectation function. We calibrate to 10 the elasticity of substitution between the different varieties of loans  $\varepsilon^B$  and between the different varieties of labor  $\varepsilon^W$ , and the probability of reimbursement of firms at the steady state is equal to  $\eta^E = 0.995$ . Finally, the depreciation rate on capital  $\delta_c = 0.025$ , and the ratio of public spending to the GDP ( $G/Y$ ) equal to 0.2.

To meet our requirements regarding the characteristics of the steady state that should correspond to normal times and be close enough to a loan shortage situation, we fix the steady state value of the diversion parameter (i.e., the fraction of available funds that financial intermediaries may choose to divert from the financial project of depositors) equal to  $\lambda = 0.681$ . This value has been chosen so that the credit constraint is not saturated in the steady state but can be saturated for reasonable values of exogenous shocks (namely 5% shocks, as in Gertler and Kiyokati, 2010). The scale parameter on investment  $\eta^I$  is fixed to 0.07. The steady state spread between the interest rate on loans and the policy rate ( $R^L - R$ ) is equal to 0.01. Finally, shock persistency parameters are given as follows:  $\rho_\lambda = 0.95, \rho_a = 0.95, \rho_g = 0.8, \rho_{opt} = 0.9, \rho_C = 0.8$ .

## 4.2 Impulse Response functions

We illustrate the effect of a bidding loan constraint on the transmission of shocks in two steps. The bidding constraint on loan supply operates as a transmission channel of shocks on the dynamics of the economy, we first concentrate on the two financial shocks. We simulate a decrease in the confidence of the banking sector and a decrease in the net wealth of banks (following, for example, a stock exchange collapse). For admissible values, these two financial shocks reduce the resources of financial intermediaries, decrease loan supply and lead to quantitative restrictions on the loan market as the notional demand for loans is not met.

Figure 1 depicts the consequences of a 5% increase in  $\varepsilon_t^\lambda$ . This shock may be understood as a decrease in households' confidence as the banking system has an incentive to divert a further 5% of total deposit if they go bankrupt. This shock directly leads to a shortage of savings in financial intermediaries, decreases the resources required to issue loans and creates a quantitative restriction on loan availability. As reported by the grey area the loan shortage situation lasts for 2 periods, and implies a sharp increase in the interest rate to reduce loan demand in the short run. In this situation, the increase in the interest rate faced by entrepreneurs reflects the scarcity of loans in the economy. As reported in the figure, even if the shortage period lasts for only 2 periods, it has sizable consequences on

$\beta$	0.99	discount factor
$\alpha$	0.33	weight of capital in the production function
$\varepsilon^E$	4.167	elasticity of substitution between goods varieties
$h$	0.815	consumption habit parameter
$\epsilon$	7.2	elasticity of capital depreciation
$\theta$	0.972	survival rate of bankers
$\omega$	0.002	transfer parameter towards new bankers
$\eta^I$	0.07	scale parameter on investment costs
$\varphi$	0.276	labor supply elasticity
$\theta^E$	0.779	price rigidity parameter
$\gamma^{pe}$	0.241	price indexation parameter
$\phi_\pi$	1.5	Taylor coefficient on inflation
$\phi_{CM}$	-0.125	Taylor coefficient on marginal cost
$\tau$	0.001	inefficiency parameter for government XXX
$\theta^W$	0.3	rigidity parameter on wages
$G/Y$	0.2	ratio of government spending on GDP
$\delta_c$	0.025	depreciation rate of capital
$\rho$	0	interest rate persistency
$LEV$	2/3	leverage ratio at the steady state
$H$	1/3	steady state labor supply
$\chi_i$	0.05	bias parameter on entrepreneur expectations
$\varepsilon^B$	10	elasticity of substitution between varieties of loans
$\varepsilon^W$	10	elasticity of substitution between varieties of labor
$\eta^E$	0.995	probability of reimbursement of firms in the steady state
$\lambda$	0.681	share of deposit in the steady state
$\rho_\lambda$	0.95	shock autocorellation (banking risk perception)
$\rho_a$	0.95	shock autocorellation (productivity)
$\rho_g$	0.8	shock autocorellation (fiscal policy)
$\rho_{opt}$	0.9	shock autocorellation (entrepreneur optimism)
$\rho_C$	0.8	shock autocorellation (consumption)
$R^L - R$	0.01	Steady state interest rate spread
$v$	2	credit policy parameter

Table 1: Calibration of parameters

the rest of the analysis: The rise in the interest rate spread decreases investment, activity and inflation. The policy reaction (a decrease in the policy rate) tends to dampen the effect in the following periods so the economy goes back to equilibrium after ten periods. In the same vein, Figure 2 depicts the consequences of a negative realization of 5% on  $\varepsilon_t^{NB}$  that can be interpreted as a sudden depreciation of financial intermediaries assets. This shock leads to the same adjustment profile as it reduces the resources of the banking system to issue loans.

The possibility of a lending shortage affects the transmission of real shocks, as soon as they have a sizable effect on the capacity of entrepreneurs to reimburse contracted loans. We report in figure 3 the consequences of a negative productivity shock (i.e. a 5% decrease of  $\varepsilon_t^a$ ), with and without the possibility of a loan supply shortage. In dotted line the model does not take into account the quantitative shortage of loans and we find standard results. As widely documented in the literature, this shock leads to slump in activity and in the prices. As capital productivity decreases investment decreases. The policy reaction of the authorities leads to an interest rate increase to fight inflation, which affects the interest rate on loans. As reported, the interest rate on loan increases more than the policy rate, as the shock leads also to a decrease in investment profitability, which in turn increases the risk premium correction of banks.

The possibility of a transitory lending constraint (plain line) clearly deteriorates the adjustment of the economy. Even if the quantitative shortage lasts for two periods, it amplifies the negative impact of the shocks and reinforces its persistency on the main aggregates. It takes more time for the economy to recover, as the main effect of the shortage affects the initial five quarters with respect to the standard DSGE model. The negative productivity shock affects the profitability of entrepreneurs projects which, in turn, reduces the net wealth of the banking system, and the resources (and so the bank deposits) of households. As documented above, these two elements create a shortage in the supply of loans that reinforces the initial negative effect of the shock on investment and activity. Following the decrease in loan supply, the interest rate spread needed to balance the loan market increases sharply which lead to a deeper impact of the real shock on both investment and activity. As reported, the further effect on activity and investment due to the loan shortage requires a lower reaction of the central bank. As observed, inflation increases less, while activity loss is higher which dampens the authorities reaction with regard to the standard DSGE model.

### 4.3 The length of the bidding regime

As reported in the irfs, we see that even if bidding is transitory, it clearly affects the time path of macro variables. Here we report for each shock presented above, how some key parameters may affect the length of the constrained regime. The results are summarized in Figure 4 for each of the three shocks. Three parameters have been found to have a significant effect on this phenomenon:  $\kappa$  (the shape ratio of the Pareto distribution, that determines the leverage ratio in the steady state),  $\lambda$  (the share of resources that can be diverted by financial intermediaries in the steady state) and  $\Psi$  (the shape parameter of the marginal cost of using capital). In the different panels of Figure 4, the benchmark value of the parameter selected for the Irf analysis is presented as a vertical line. As observed in these graphs, the transmission of the shock on the net wealth of financial intermediaries is more affected by these parameters than the two other shocks.

The first column reports the sensitivity of the length of the loan shortage period to the value of the  $\kappa$  parameter. As reported, in all cases, an increase in this parameter increases the length of the saturation constraint. An increase in the value of  $\kappa$  increases the leverage ratio in the steady state (namely the ratio between capital and net wealth) which mechanically makes the loan demand consequence of shocks higher and, by so, increases the length of the saturation period (ie, the excess loan demand is reported from period to period).

The second column is devoted to the effect of the value of the  $\lambda$  parameter on the results. A higher value of this parameter means that in the steady state, financial intermediaries have a higher incentive to divert households' savings when leaving the loan market, which in turn decreases the trust of households in the banking system. As a consequence, households put less deposits in financial intermediaries and, by so, reduce the resources of the banking system that are needed to create new loans. This, in turn, makes the economy more sensitive to loan supply shortage situations and, as a consequence, increases the length of the saturation period in the case of financial shocks. Noticeably the length of saturation in the case of a productivity shock is not affected by the diversion parameter.

The third column is devoted to the value of the  $\Psi$  parameter on the results. An increase in the value of this parameter increases the marginal cost of using capital to produce intermediate goods. As a consequence, *ceteris paribus*, production requires more financial resources which translates into more loan demand. In the meanwhile, the increase in the marginal cost of production makes some more financial projects less profitable, which in turn reduces the reimbursement of contracted loans and the resources of the banking system. Both channels lead to an increase in the length of the shortage period for higher values of the  $\Psi$  parameter.

## 5 The consequences of a credit policy

Our model generates a transitory disruption of lending coming from the deterioration in the situation of financial intermediaries. This tightening of credit raises the cost of borrowing and amplifies the transmission of financial and real shocks. The transitory shortage situation may thus justify the adoption of non conventional monetary policy measures to reinforce a loosen conventional policy. In this section, we follow Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) by assuming that the central bank decides to proceed to direct lending measures. As in these papers, we focus on direct lending since this policy is the simplest to present. We evaluate the consequences of such measures according to a state dependent perspective, assuming that they are stoped once the shortage situation ends.

### 5.1 Credit policy

We suppose that at the onset of a crisis, the central bank injects credit in response to movements in credit spreads as a mean to mitigate the impact of the crisis. The total amount of loans available to entrepreneurs thus becomes,

$$L_t^S = L_t^{Sp} + L_t^{Sg},$$

with  $L_t^{Sp} = L_t^{S\max} = \phi_t^B N_t^B$ , is the loan supply of the private sector, and  $L_t^{Sg}$  is the quantity of loans supplied by the central bank. As in Gertler and Karadi (2011), there is no agency problem between the central bank and its creditors because it can commit to always honoring its debt.<sup>10</sup> We assume that the central bank offers loans proportionnaly to the quantity of total assets available in the economy,

$$L_t^{Sg} = \psi_t L_t^S,$$

with  $0 < \psi_t < 1$ , is the credit policy variable. In this situation, the lending accelerator is

$$L_t^S = \frac{\phi_t^B}{1 - \psi_t} N_t^B.$$

As in Gertler and Karadi (2011),  $\phi_{c,t}^B \equiv \frac{\phi_t^B}{1 - \psi_t}$ , so  $\phi_{c,t}^B > \phi_t^B$ , ie, the credit policy reinforces the lending accelerator in the economy. However, in contrast with Gertler and Karadi (2011), we link the imple-

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<sup>10</sup>We refer the reader to the discussion provided in Gertler and Karadi (2011).

mentation of a credit policy to a situation of lending shortage coming from financial intermediaries. We assume that the size of this policy is proportional to the quantity of missing loans in the economy. As we outlined above the rise in the interest rate on loans is symptomatic of the financial distress in the economy and the size of credit shortage can be approached by the value  $\zeta_t = E_t [\eta_{t+1}^\pi] (R_t^{L,S} - R_t^L)$ . We thus link the credit policy parameter to this indicator of market stress, according to,

$$\psi_t = v\zeta_t,$$

with  $v$  is a scale parameter.

## 5.2 The dampening effect of credit policy

We evaluate the macroeconomic impact of a credit policy by contrasting the irfs of the model under this policy with regard to a conventional intervention of the central bank. The result of the exercise are reported in figures 5 to 7, depending on the nature of the shocks. As a general result (in line with the literature), the credit policy moderates the contraction. The prime reason is that central intermediation dampens the rise in the interest rate spread, which in turn dampens the investment decline that follows negative financial or real shocks. Credit policy has a clear dampening effect on all the variables of the model.

First, as reported in figure 5, following a 5% negative shock on  $\varepsilon_t^\lambda$  a credit policy has two consequences on the dynamics of the model: it reduces the negative impact of the shock on the one side but it increases the length of the shortage period on the other side (as reported, the grey area corresponds to two periods without the credit policy and to four periods with the credit policy). This second effect means that with unconventional policy measures, it takes a longer time for the economy to come back to conventional monetary policy mechanisms. Thus, the credit policy acts as a way to smooth intertemporally the negative consequences of the shock over a greater number of periods.

The first effect can be explained as follows: As observed, following the shock, the central bank applies an expansionary loan supply policy ( $\psi_t$  increases), which in turn increases the number of new loan contracts which has a marginally positive impact on investment and activity and limits the increase in the interest rate spread with respect to the value observed under a conventional monetary policy. As a consequence the negative effect of the shock is reduced by the implementation of the credit policy.

The second effect related to the length of the shortage period can be explained as follows: the lower increase in loan interest rate tends to increase the total amount of loan demand more than proportionally with respect to the loan supply. As loan demand that is not met at a given period is reported to the following periods, this explains the increased length of the saturation period observed when authorities implement a credit policy.

The same effects apply for the transmission of the other two shocks. The transmission of a negative shock on the financial intermediaries net wealth is depicted in figure 6 (a negative 5% shock on  $\varepsilon_t^{N^B}$ ). As displayed, the number of contracted loans by entrepreneurs diminishes less than without the credit policy which has a stabilizing effect on the main aggregates and the shortage period clearly increases. Figure 7 depicts the consequences of a negative realization of 5% on  $\varepsilon_t^a$ . As for financial shocks the implementation of credit policy measures dampens the transmission of this negative shock, as entrepreneurs can now borrow more from financial intermediaries and the saturation period is clearly increased.

### 5.3 The arbitrage between the length and the amplitude

We evaluate the extent to which central bank credit interventions moderate the economic downturn by taking into account the joint effect of this policy on both the size of the correction and the length of the adjustment to the steady state. As the credit policy acts as a mechanism that smoothes intertemporally the consequences of real and financial shocks, we question whether the net effect of this policy is positive. We take into account the whole time it takes to go back to the steady state under the two policies. To this aim we proceed to a sensitivity analysis that rely the differential effect of the two policy regimes (accounting for both the amplitude and the length of the adjustment period) computed as,

$$\Delta = \frac{\text{effects without credit policy} - \text{effects with credit policy}}{\text{effects with credit policy}},$$

to the value of the three key parameters of the model. A positive value of the ratio indicates the net dampening effect of a credit policy all along the adjustment path back to the steady state, taking into account the endogenous length of the implementation of unconventional policy measures.

As observed, there is a reversal of regimes for higher values of  $\kappa$ . As underlined previously, an increase in this parameter increases the length of the saturation constraint as it corresponds to both a higher steady state value of the leverage ratio. In this situation, entrepreneurs borrow more from financial intermediaries, which tends to increase the length of the saturated period in both regimes



but also reduces the speed of the return to the steady state under the credit policy regime. Thus, for higher value of  $\kappa$  it seems less interesting to adopt such credit policy measures because of the marginally higher cost of this policy related to the longer period of the saturation of the constraint. Under our calibration, we more particularly find that for values of  $\kappa \geq 1.5$ , credit policy generates a net recession effect to the economy with respect to a situation ignoring this policy.

The second row of figure 9 depicts the difference of effect following an increase in parameter  $\lambda$ . As reported a higher value of the diversion parameter reduces the difference between situations with and without credit policy. A higher value of this parameter means that financial intermediaries have an incentive to divert more deposits in the steady state. In this case, it reduces the resources of the banking sector, thus the quantity of loans issued. As a consequence, the shortage period is longer without a credit policy, which tends to lower the speed of the economy to go back to steady state. For a higher value of the parameter, household put less deposit in the banking sector and reduces the loan leverage ratio in the steady state. Thus the amplifying effect of the lending channel is dampened and the credit policy has less effect on the economy, and by so on the dampening of shocks. As observed, we get an opposite effect for the real shock. Under this shock the loan shortage channel plays only a supplementary role, and credit policy has an increased impact for higher values of this parameter.

Finally, the positive net effect of a credit policy tends to vanish with an increased value of  $\Psi$ . As underlined above, an increase in the value of this parameter increases the marginal cost of using capital to produce intermediate goods. Thus loan demand is less responsive to interest rate decrease that follows the credit policy, as the profitability of project decreases since production is more costly. Thus, credit policy has less impact on investment and activity, and for higher values of this parameter it can even be counterproductive to conduct such actions.

## 6 Conclusion

In this paper we have analysed the consequences of transitory non conventional measures. We provide a simple approach to the decision to begin and end up unconventional policy measures, by specialising this kind of policies to periods with loan supply shortages. Accounting for an endogenous implementation length of this policy we find that it has two main effects. As previously found in the literature, by raising the value of the lending accelerator in a situation of loan scarcity, it dampens the consequences of shocks. As a second effect (new in the literature), it increases the length of the loan saturation period. This second effect can be explained as follows: The lower increase in loan interest rate tends

to increase the total amount of loan demand more than proportionally, which, in turn, increases the length of the saturation period (as loan demand that is not met at a given period is reported to the following periods, which explains the length of the saturation period under this kind of policy). Accounting for these two effects, we find that there can be some reversal effects regarding the interest of conducting such policy measures.

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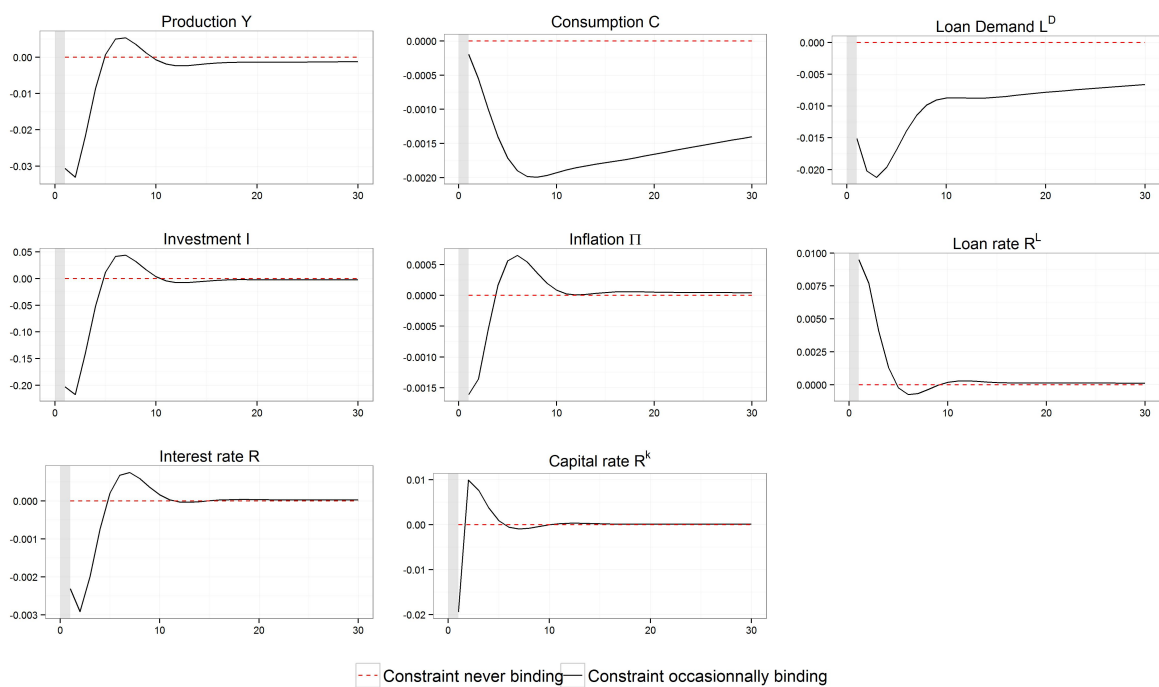


Figure 1: Shock on  $\lambda$ , response of the model with and without credit constraint

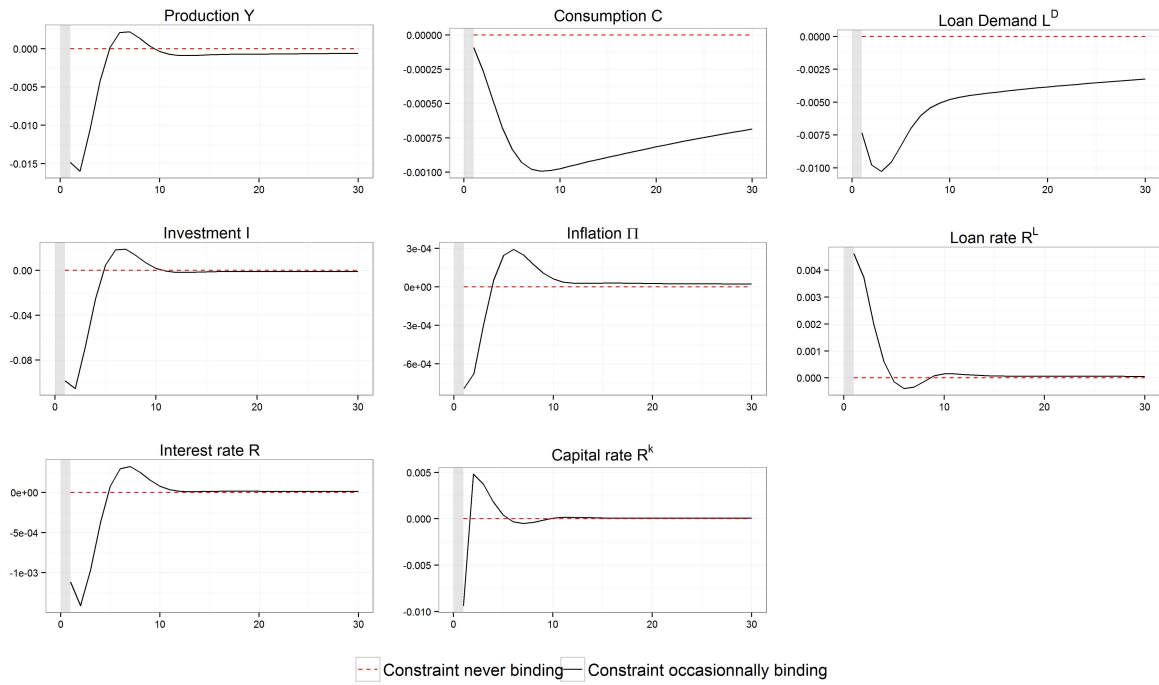


Figure 2: Shock on  $N^B$ , response of the model with and without credit constraint

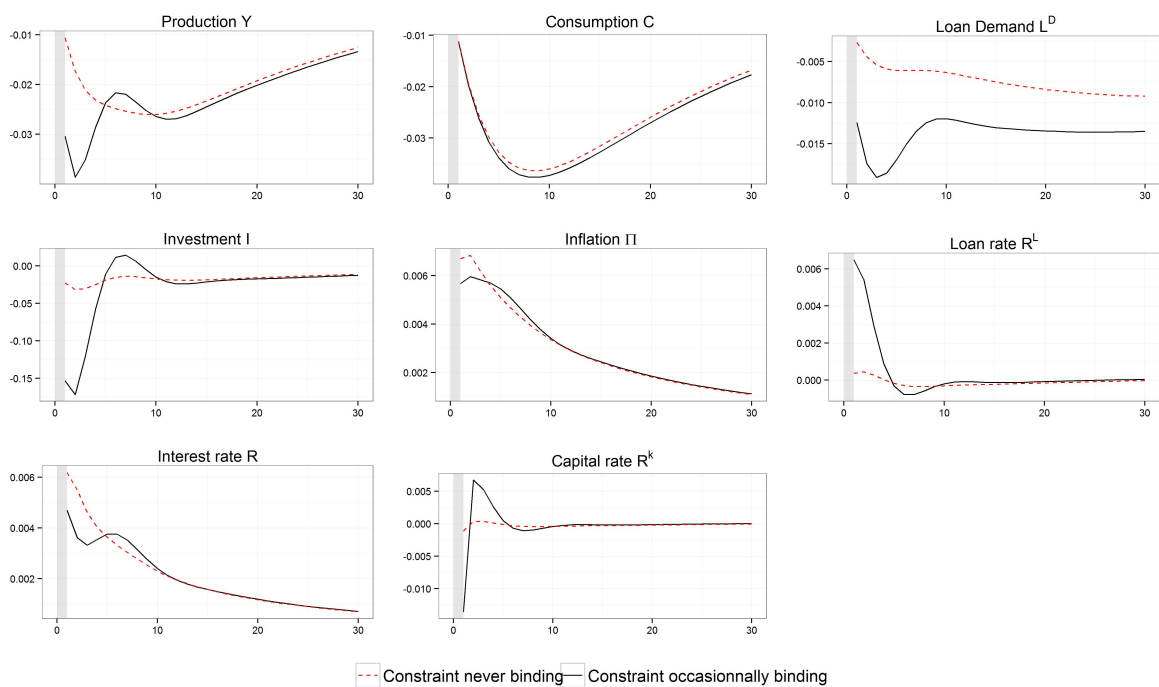


Figure 3: Shock on technology, response of the model with and without credit constraint

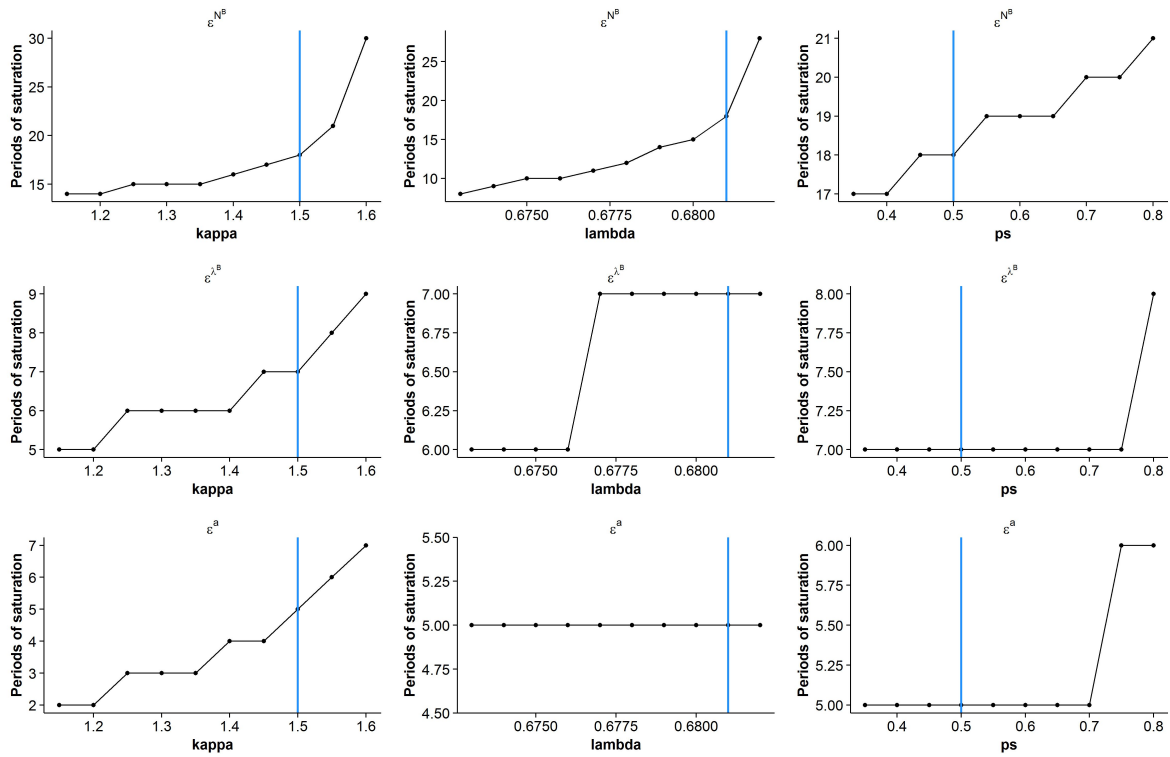


Figure 4: Sensitivity Analysis for the model without credit policy - number of periods of saturation



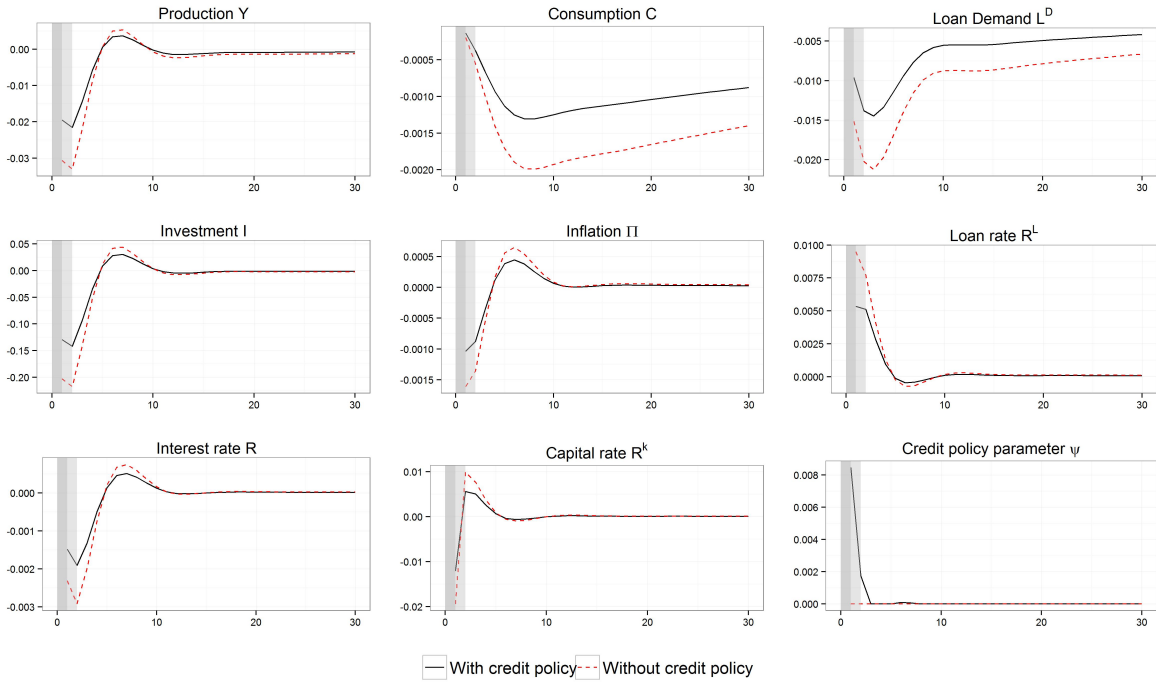


Figure 5: Shock on  $\lambda$ , response of the model with credit constraint, with and without credit policy

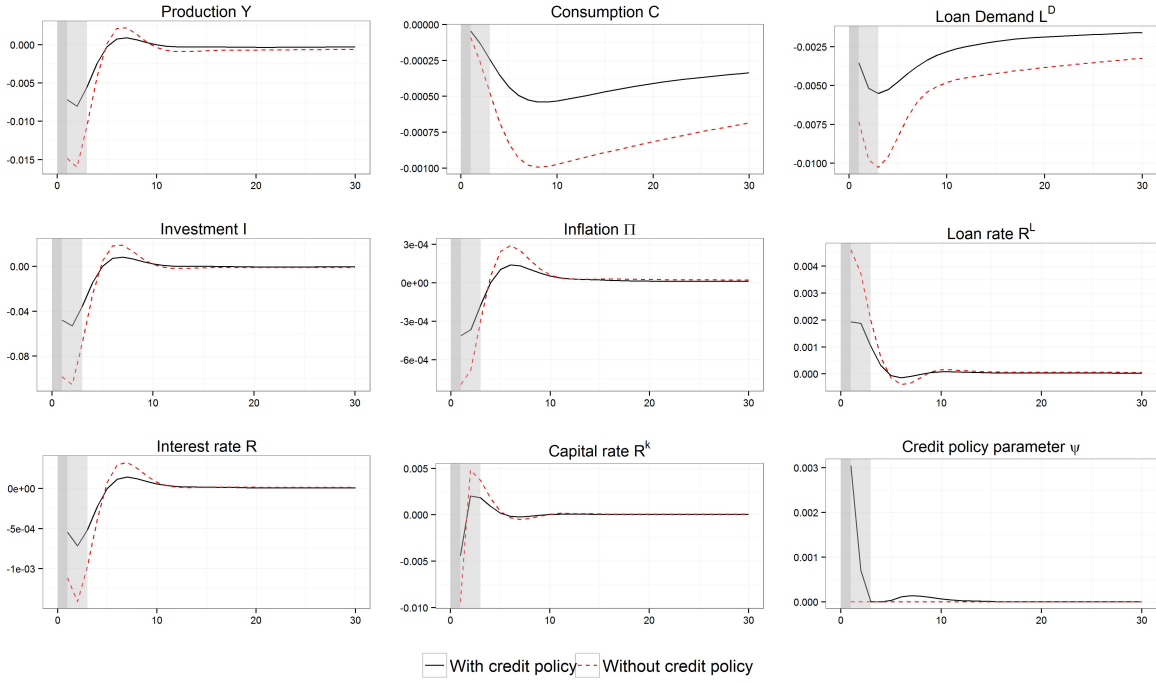


Figure 6: Shock on  $N^B$ , response of the model with credit constraint, with and without credit policy

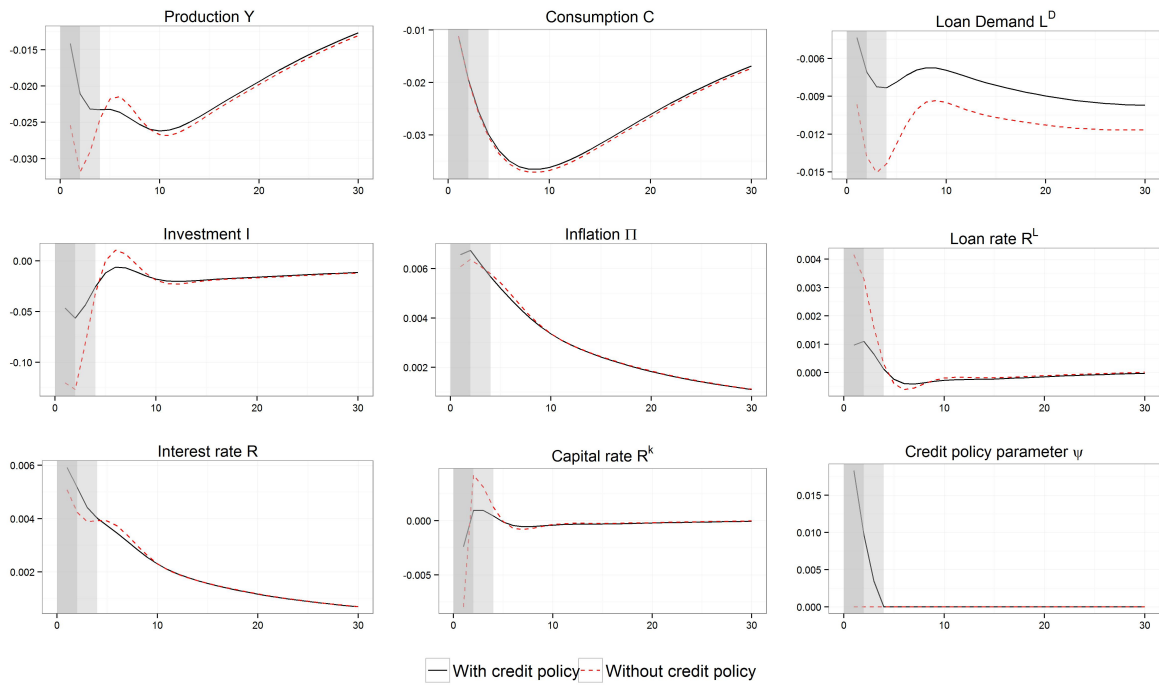


Figure 7: Shock on technology, response of the model with credit constraint, with and without credit policy

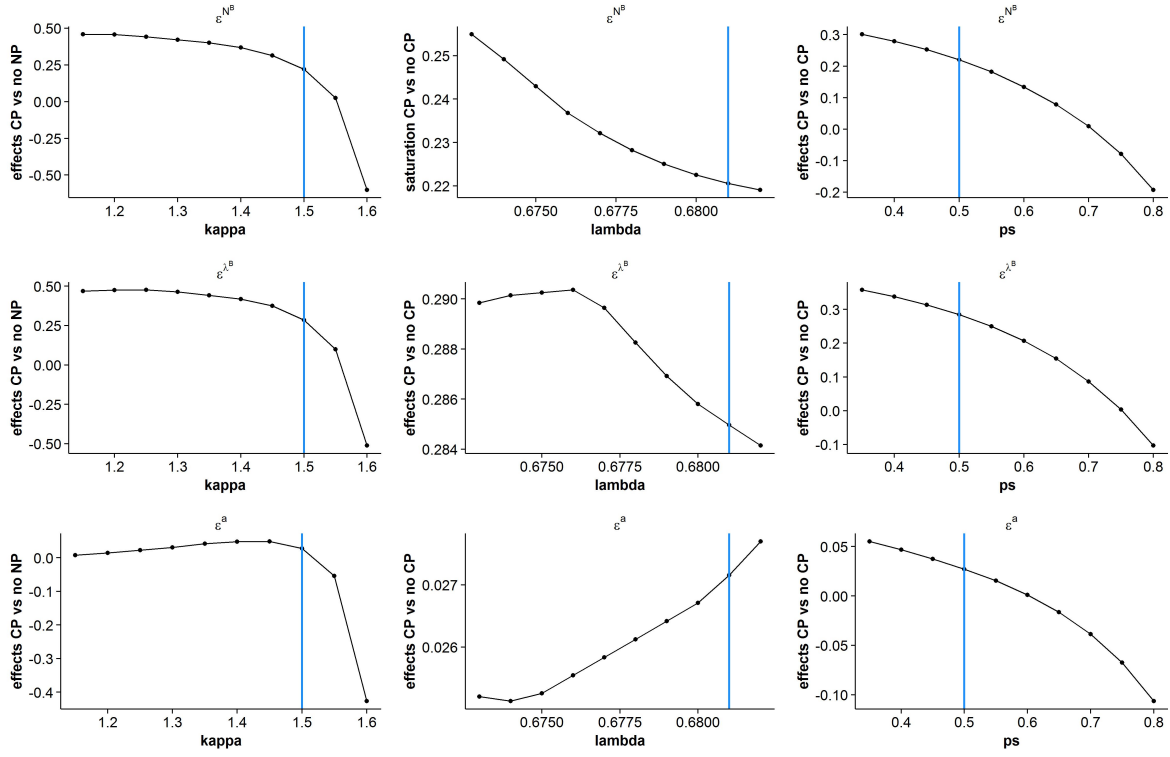


Figure 8: Sensitivity Analysis - comparison between the model with and without credit policy - cumulated size of irfs