Unconventional monetary policies and the credit market

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Abstract

This paper analyzes the ability of unconventional monetary policies to reduce the spread between the credit and the short-term policy interest rates. We provide a theoretical framework based on the bank-lending channel that incorporates an interbank money market. The proposed model shows that the implementation of swap programmes to exchange government bonds for troubled assets is more successful in reducing the credit spread than the creation of central bank lending facilities. Key determinants for policy effectiveness are the market value of the collateral on defaulted loans, the risk premium on the interbank money market, the composition of banks' balance sheet liabilities and the degree of banking competition. The quantitative assessment of the model with real data confirms the appropriate response of the Federal Reserve in recent crisis episodes but sheds some doubts on the European Central Bank intervention. Finally, a sensitivity analysis illustrates the sets of parameters describing the market conditions under which these unconventional measures result in unfavourable outcomes.

Keywords: Bank profit maximization, credit interest rate, optimal credit supply, unconventional monetary policy.

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1 Introduction

In the face of severe dislocations in financial markets and profound declines in economic activity, monetary authorities have taken extraordinary measures beyond lowering short-term policy rates using the size and structure of their balance sheets (Borio and Disyatat, 2010; Durré and Pill, 2012). These alternative measures have been adopted for two main reasons. First, nominal short-term interest rates reached the lower bound during this period in many countries, losing their ability to stimulate the economy (Reifschneider and Williams, 2000). Second, disruptions in the financial system generated large losses and affected the liquidity and solvency of both banks and borrowers.

One noteworthy example of an unconventional monetary policy (UMP, hereafter) is the Maturity Extension Program carried out by the Federal Reserve (FED) and consisting of sterilized operations, buying long-term Treasuries and, simultaneously, selling some of the short-term issues. The FED also followed a large-scale asset purchase (LSAP) programme of mortgage-backed securities with the aim of increasing market liquidity and reducing mortgage interest rates (credit easing). Nevertheless, the most popular LSAP across monetary authorities in the recent crisis has been the so-called quantitative easing (QE), based on the creation of money to buy assets. While the FED bought Treasuries, agency debt and agency-backed mortgage securities, the Bank of England purchased government bonds from the non-bank private sector. Although the main objective, in both cases, was to affect yields on assets, the European Central Bank (ECB) used QE to mitigate liquidity problems within the banking system. More specifically, it carried out repurchase agreements providing long-term loans in exchange for bank loans and non-government bonds.

The effectiveness of these UMPs, which aim to restore the functioning of the financial system, has been an object of debate since their inception (Joyce et al., 2012). Nevertheless, their influence on credit markets and the real economy are not well understood yet. Lenza et al. (2010) argue that QE mainly affected interest rates - in particular, money market spreads - rather than only generating quantitative effects in the money supply. These authors also discuss alternative channels through which UMPs can be transmitted into the economy. In this respect, non-standard measures can influence bank lending through the expansion of the monetary base, the level of the overnight interest rate determining the access to liquidity in the money market or the expectations about the path of future policy decisions that affect the slope of the money market yield curve. It is worth noting that, despite the success of these measures in restoring stability to the financial sector and the flow of credit to financial markets through the above-mentioned mechanisms, borrowing costs have not fallen to levels commensurate with the magnitude of the measures implemented by the monetary authorities. Cukierman (2013) also notes the importance of this anomaly and suggests that it is yet to be determined whether the transmission of monetary policy to commercial banks' lending rates differs between normal times and periods of distress.

[**Insert Figure 1 here**]

Figure 1 illustrates that central bank cuts of the short-term policy rate to levels close to the zero lower bound - and subsequent increases of the monetary base - have not meant a similar reduction of the credit interest rates that determine borrowing costs for the non-financial sector. The dynamics of the official and the credit interest rates have been plotted for the United States (US) and the euro area (EA). The spreads between these interest rates in each economy are also shown. These graphs reflect two stylized facts of interest rate dynamics: first, credit interest rates follow the upward and downward movements of the official interest rate; and second, there is a spread between the two time series that is usually interpreted as evidence of credit risk in financial institutions. It is, however, surprising that the dynamics of the spreads for the US and the EA show different patterns in the wake of the 2007-2008 financial turmoil. Whereas the US credit spread decreases after the crisis to 3% and remains constant afterwards, the credit spread corresponding to the EA displays a significant increase in the aftermath of the crisis and follows an upward trend from 2010 onwards. This contrast in the dynamics of the interest rate spreads may be due to the differences in the implementation of UMPs across the two economic areas considered. Whereas the US mainly embarked on exchange programmes to swap troubled assets for government bonds and other risk-free assets, the rescue packages of the EA mainly consisted of creating lending facilities that provided unlimited access to credit from the ECB to financial institutions.

This paper proposes a theoretical model that can offer some insights into the nature of the borrowing spreads in credit markets and, in particular, into the structural variables that determine the credit interest rate in equilibrium. These insights are further explored to assess the implications of the implementation of these two different UMPs - lending facilities and swap programmes - on the credit interest rate. We compare the success of these measures in reducing both the credit interest rate and its spread with the short-term policy rate. To do this, we deploy a framework based on the bank-lending channel that relates the optimal supply of credit by commercial banks with the interest rate that should be observed in equilibrium in the credit market. The transmission of monetary policy takes place as the pass-through from the policy rate to the interest rate on bank loans and, hence, alters both their cost and the amount of credit firms and households have access to. In the proposed model, the pass-through is a function of the fraction of the total amount of loans by commercial banks that is borrowed from the central bank. A complete pass-through is, theoretically, achieved if commercial banks solely rely on the central bank to provide lending to the non-financial sector and if there is perfect competition in the banking sector. Otherwise, variables such as the interbank money market interest rate, the value of assets held as collateral on defaulted loans and the default rate play a key role in determining the credit interest rate in equilibrium.

The comparison of the interest rates for credit in three scenarios - a baseline characterized by the inaction of the central bank, the creation of lending facilities and the implementation of swap programmes - is carried out using a counterfactual analysis. The main predictions of our theoretical model are that lending facilities are appropriate measures for reducing the credit interest rate when the assets held by banks as collateral lose their value and when the risk premium on the interbank money market is high. Otherwise, this unconventional measure may raise borrowing costs for the non-financial sector more than in the baseline case. Similarly, the model predicts the relative success of swap programmes in reducing the credit interest rate with respect to the baseline if the return on government bonds is higher than that provided by the assets held as collateral for defaulted loans.

Our analysis also provides some insights into the relative performance of the above-mentioned UMPs. Lending facilities outperform swap programmes when the risk premium on the interbank money market is sizeable and the yield on government bonds is low. The fraction of aggregate bank lending that is obtained from the central bank also has an important role in determining the efficacy of these programmes. The proposed model shows that the greater the reliance of the banking sector on central bank lending during normal periods, the more difficult it is for lending facilities to reduce the credit interest rate and, hence, to restore access to credit for the non-financial sector. Swap programmes also perform better than lending facilities in these cases. A similar outcome is observed for the fraction of aggregate bank lending that is held as remunerated excess reserves in the central bank because it is more difficult for lending facilities to reduce the credit interest rate as the quantity of excess reserves grows. In contrast, a higher loan default rate favours the implementation of lending facilities compared to swap programmes and the inaction represented by the baseline.

Furthermore, a quantitative assessment of the proposed model has been carried out with real data from the US and the EA. In both cases, the simulated equilibrium outcomes provide ample support for the implementation of swap programmes to reduce the credit interest rate with respect to the baseline scenario. Nonetheless, this simulation exercise raises some doubts about the success of lending facilities. In fact, we observe that, in market conditions such as those in the EA, lending facilities would only be able to reduce the credit interest rate beyond that in the baseline if the spread on the interbank money market is sufficiently large to offset the negative effects of the return on the collateral assets, the reward on excess reserves and the amount of credit borrowed from the central bank.

The reason is that the European banking sector is characterized by a stronger presence of central bank loans within the commercial banks' balance sheet liabilities than in the US and by a solid portfolio of secured bank loans.

The present paper is related to the contribution made by Brei et al. (2013) who analyze whether the rescue measures adopted by the monetary authorities during the global financial crisis of 2008-2009 helped to sustain bank lending supply. Using a novel dataset covering large international banks, these authors conclude that bank recapitalisations may not translate into greater credit supply until commercial banks' balance sheets are sufficiently strengthened. Christiano and Ikeda (2011) also focus on the bank-lending channel to assess the impact of UMPs on economic conditions, in order to determine which asset market program, and at what scale, should be undertaken. By studying moral hazard and adverse selection models of financial frictions, these authors explore different channels by which the effects of UMPs might have occured. Related studies considering the effects of government asset purchases are those by Moore (2009) and Kiyotaki and Moore (2012). We also provide insights on how competition in the banking sector influences the bank-lending channel corroborating the empirical findings of Fungáková et al. (2014), according to which the transmission of monetary policy is less pronounced for banks with extensive market power. Finally, our work is related to that of Cukierman (2014) who compares the policies implemented by the ECB and the FED during the global financial crisis as well as the behavior of EA and US banks.

The rest of the article is structured as follows. Section 2 introduces a partial equilibrium model for the credit market that takes into account the balance sheet structure of commercial banks, the probability of loan default and the existence of an interbank money market. Building on this model, Section 3 analyzes the effects of the implementation of UMPs on the credit interest rate in equilibrium and determines the influence of excess reserves on it. Section 4 presents a simulation exercise that illustrates the functioning of the model in different scenarios. Section 5 provides an assessment of how sensitive our findings are to the introduction of risk aversion and the consideration of alternative specifications for the default rate and the share of deposits held as excess reserves in the central bank. Section 6 concludes.

2 A model for the credit market

In this section, a theoretical framework that builds on the balance sheets of commercial banks is proposed to describe the bank-lending channel of monetary policy. The model considers a banking sector comprised of N banks that differ in the level of deposits held by their customers. Following traditional reserve management models such as Orr and Mellon (1961), Niehans (1978) and Baltensperger (1980), these deposits are exogenous and depend on stochastic flows. Commercial banks borrow funds from the central bank at the official interest rate and trade in an interbank money market where funds from banks with an excess of deposits from customers are channelled to banks with a shortage.

The competition faced by commercial banks is reflected in the assumption that they are price takers. This entails that the interest rate on banks' deposits i_d and the interest rate on the interbank money market i_m are determined exogenously. In addition, and following the empirical evidence, the equilibrium interest rate of the interbank money market is assumed to be higher than the official interest rate i_r. The latter and the interest rate on reserves $\tilde{\imath}_r$ held in the central bank in excess of the minimum reserve maintenance ratio $0 < r < 1$ are set by the central bank, who is the monopolistic supplier of the monetary base.

Our framework is characterized by a representative commercial bank that solves a static profit maximization problem with a single creditor type. This choice is considered for two reasons: first, for the sake of simplicity and clarity in the derivation of optimality conditions; and second, in the belief that the model is able to reflect the main features of the bank-lending channel and the effect of UMPs on commercial banks' balance sheets. This theoretical framework could easily be generalized to accommodate an infinite number of time periods in the objective function and different creditor types with distinct default rates. These features would add flexibility to the model through dynamics in the variables involved and the relevant interest rates but at the expense of more convoluted and difficult to interpret equilibrium conditions.

The result of this optimizing behavior is the supply of loans by a commercial bank whose balance sheet satisfies that

$$Q_{B/NB} + R_{min} + ER = Q_{CB/B} + Q_{B/B} + D. \tag{1}$$

The asset side is made up of the quantity of funds lent by the bank, $Q_{B/NB}$, and the level of minimum reserves $R_{min} = rD$, with D the level of deposits made by customers. ER denotes the deposits by the commercial bank beyond R_{min} held in the central bank as excess reserves. The liability side is given by the credit obtained from the central bank $Q_{CB/B}$, the amount of lending financed through the interbank money market $Q_{B/B}$ and customer deposits.

The balance sheet (1) provides banks a profit that is determined by the difference between the returns on the assets and the interest rates paid on the liabilities. Furthermore, the asset side of the balance sheet is affected by the occurrence of defaults of a fraction of the total supply of loans. The default rate is defined as $p(Q_{B/NB}) = \int_0^{Q_{B/NB}} f(z)dq$, with $0 < f(z) < 1$ the probability of default on an infinitesimal loan. The latter corresponds to an individual within a continuum of borrowers in the bank's credit portfolio. The probability of default is assumed to depend on a set of factors (z) that are idiosyncratic to the individual but exogenous to the bank's optimization problem. Thus,

$$p(Q_{B/NB}) = f(z)Q_{B/NB}. \tag{2}$$

The bank's profit function is

$$\begin{aligned} \Pi &= i_c\left[1 - p(Q_{B/NB})\right]Q_{B/NB} + \widetilde{i}_c p(Q_{B/NB})Q_{B/NB} + i_r R_{min} + \widetilde{i}_r ER \\ &\quad - i_r Q_{CB/B} - i_m Q_{B/B} - i_d D, \end{aligned} \tag{3}$$

where i_c denotes the interest rate on loans to the non-financial sector and $\widetilde{i}_c$ is the net return on the assets held as collateral for defaulted loans, such that $0 \leq \widetilde{i}_c < i_c$; the case of uncollateralized debt corresponds to $\widetilde{i}_c = 0$.

The profit function (3) can be rearranged in terms of $Q_{B/NB}$. To do this, we assume that the amount of funds borrowed from the central bank is a fraction of total lending: $Q_{CB/B} = \lambda Q_{B/NB}$, with $0 < \lambda \leq 1$. A value of this parameter smaller than one also reflects constraints on the monetary base provided by the central bank. This is the case, for example, when the aggregate demand for credit by commercial banks is much higher than the monetary base targeted by the central bank, implying that each bank is only allocated a fraction of its total demand. Similarly, the level of excess reserves held by the commercial bank is assumed to be a fixed proportion of its total lending implying that $ER = \tau Q_{B/NB}$, with $0 \leq \tau < 1$. The robustness of the results to this assumption is discussed in Section 5.

In this context, the optimal supply of loans by a commercial bank is the solution to

$$\max_{Q_{B/NB}} \left\{ [(i_c - i_m) + (i_m - i_r)\lambda + \widetilde{i}_r \tau] Q_{B/NB} - \widetilde{D} - (i_c - \widetilde{i}_c) f(z) Q_{B/NB}^2 \right\}, \tag{4}$$

where $\widetilde{D} = [(i_d - i_m) - (i_r - i_m)r]D$, that yields

$$Q_{B/NB}^s = \frac{(i_c - i_m) + (i_m - i_r)\lambda + \widetilde{i}_r \tau}{2f(z)(i_c - \widetilde{i}_c)}. \tag{5}$$

An aggregate demand for credit is required in order to determine the equilibrium interest rate for the non-financial sector. For simplicity, we consider this demand to be perfectly inelastic with respect to the credit interest rate[1]:

$$Q_{B/NB}^D = \alpha Y. \tag{6}$$

[1] A similar assumption fixing loan demand is imposed by Dell'Ariccia et al. (2014) to analyze the case of a monopolist facing an inelastic demand function.

Therefore, the credit interest rate in equilibrium is

$$i_c^* = \frac{\lambda i_r + (1-\lambda) i_m - \widetilde{i}_r \tau - 2\widetilde{i}_c \alpha Y f(z)/N}{1 - 2\alpha Y f(z)/N}. \tag{7}$$

This expression establishes that the loan market interest rate depends on the structure of the liability side of commercial banks' balance sheets. In particular, the share of loans borrowed from the central bank determines the extent of the pass-through from the interbank and short-term policy rates to the credit interest rate. The model also predicts an increase in the interest rate for credits when the net return on the assets held as collateral on secured loans falls. Similarly, expression (7) is a positive function of individual loans' probability of default. The existence of a reward for excess reserves held in the central bank decreases the equilibrium interest rate due to the reduction of aggregate credit supply to the non-financial sector. The degree of competition in the banking sector also influences the credit interest rate. An increase in the number of banks reduces this interest rate at the expense of nullifying the role of the collateral. Expression (7) also shows that, in a perfectly competitive banking sector ($N \to \infty$) without excess reserves and in the absence of a risk premium on the interbank money market, the credit interest rate in equilibrium is equal to the official interest rate.

Rearranging expression (7) we can obtain the credit interest rate spread over the short-term policy rate as a function of the corresponding spreads in the interbank money market and of the collateral:

$$i_c^* - i_r = \frac{(1-\lambda)(i_m - i_r) - \widetilde{i}_r \tau - 2(\widetilde{i}_c - i_r)\alpha Y f(z)/N}{1 - 2\alpha Y f(z)/N}. \tag{8}$$

The following section derives the optimal supply of loans by commercial banks and the equilibrium interest rate when implementing UMPs that shift the focus of attention from the official interest rate to the monetary base.

3 Optimal credit supply under the implementation of UMPs

With the implementation of UMPs, central banks increase the monetary base with the aim of invigorating commercial banks' balance sheets and, as a consequence, restoring the flow of credit to the non-financial sector. In the present paper, we focus on two measures widely implemented by monetary authorities: (i) the creation of lending facilities, and (ii) the acquisition of government bonds that are swapped for the collateral held by commercial banks in their portfolio of defaulted loans.

3.1 Central bank lending facilities

Central bank lending facilities have a threefold objective. First, to provide credit to the non-financial sector; second, to restore the profitability of defaulted loans in commercial banks' balance sheets; and third, to raise funds that can be reinvested as excess reserves in the central bank. By implementing this UMP, the identity of the balance sheet (1) is modified to reflect that the total amount of funds borrowed from the central bank is $Q_{CB/B} = \lambda Q_{B/NB} + L^*$, with L^* denoting the loan used to restore the profitability of troubled assets. Therefore, L^* is the counterpart of the amount of defaulted loans $p(Q_{B/NB})Q_{B/NB}$ on the liability side. Without loss of generality, we assume that lending facilities only apply to defaulted loans and ignore their effects on other assets on the bank's balance sheet such as common stocks or commercial papers.

Therefore, the access to lending facilities expands the asset side of the bank's balance sheet by a quantity equal to the amount of defaulted loans, satisfying that

$$Q_{B/NB} + p(Q_{B/NB})Q_{B/NB} + R_{min} + ER = \lambda Q_{B/NB} + L^* + Q_{B/B} + D. \tag{9}$$

The bank's profit maximization problem is equal to (4), but replacing $(i_c - \widetilde{i_c})$ by i_r. The reason is that commercial banks use the funds lent by the monetary authority to restore the profitability of defaulted loans, implying three effects on the objective function: first, the term $(i_c - \widetilde{i_c})p(Q_{B/NB})Q_{B/NB}$ is nullified; second, the additional assets obtained from the loan provide a return i_c; and third, the loan L^* used to restore the value of these assets is paid at an interest i_r.

Under these conditions, the optimal loan supply schedule of a commercial bank is

$$Q^{s1}_{B/NB} = \frac{(i_c - i_m) + (i_m - i_r)\lambda + \widetilde{i}_r\tau}{2i_r f(z)}. \tag{10}$$

Proceeding as in (7), the equilibrium credit interest rate is

$$i_c^{rep} = \lambda i_r + (1-\lambda)i_m - \widetilde{i}_r\tau + 2i_r f(z)\frac{\alpha Y}{N}, \tag{11}$$

its spread with respect to the short-term policy rate being:

$$i_c^{rep} - i_r = (1-\lambda)(i_m - i_r) - \widetilde{i}_r\tau + 2i_r f(z)\frac{\alpha Y}{N}. \tag{12}$$

The success of lending facilities in reducing this spread can be assessed through a comparison between the equilibrium credit interest rate in (11) and that obtained from inaction of the central bank, characterized by the baseline in (7). In doing so, we implicitly assume that the values of market variables such as the risk premium on the interbank money market, the parameter λ and the default rate $f(z)$ are exogenously determined and remain the same across expressions[2]. This comparison reveals that the implementation of lending facilities reduces the credit spread below that in the baseline scenario discussed in the previous section if

$$\widetilde{i}_c < (1-\lambda)(i_m - i_r) - \widetilde{i}_r\tau + 2i_r f(z)\frac{\alpha Y}{N}. \tag{13}$$

This condition reflects the adequacy of lending facilities for reducing borrowing costs if the value of the collateral on defaulted loans is low and the risk premium on the interbank money market is high. Interestingly, expression (13) is likely not to be satisfied when the

[2] An alternative modelling strategy would be to consider that these variables respond to the stimulus induced by the UMP. We should note that, in this case, the comparison of the credit interest rates under the creation of lending facilities and the baseline scenario is not straightforward because the interbank money market rate and the default rate are endogenously determined.

interbank money market exhibits borrowing costs similar to the short-term policy interest rate.

[Insert Figure 2 here]

Figure 2 shows, for reasonable values of the parameters (see Section 4), the effects of increases in the model parameters on the relative effectiveness of lending facilities with respect to the baseline scenario. The plotted lines represent the pairs of values of the net return on the collateral and the amount of excess reserves for which expression (13) holds with equality. The coloured areas below these lines correspond to those parameter combinations for which the equilibrium credit interest rate under the implementation of lending facilities is lower than in the baseline model.

Figure 2(a) illustrates how the ability of lending facilities in reducing the credit spread changes as the risk premium on the interbank money market increases. This is reflected in parallel shifts of the equivalence lines away from the origin. Figure 2(b) shows how the region characterizing the outperformance of lending facilities shrinks as the interest rate on excess reserves rises. Figure 2(c) analyzes the sensitivity of condition (13) to changes in the amount of credit from the central bank. It implies that the higher its amount the lower the number of parameter combinations for which the UMP is able to decrease the credit interest rate with respect to the baseline. Finally, Figure 2(d) illustrates the impact of concentration in the banking sector, showing that an increase in the number of banks reduces the region of lending facilities' relative outperformance.

It is worth noting that condition (13) can be expressed in terms of the percentage of credit from the monetary authority as

$$\lambda < 1 - \frac{\widetilde{i}_c + \widetilde{i}_r \tau}{i_m - i_r} + \frac{2 i_r f(z)}{i_m - i_r} \frac{\alpha Y}{N}, \tag{14}$$

establishing the amount of borrowing from the central bank that is compatible with the superiority of lending facilities for different combinations of the model parameters.

3.2 Government bonds purchases

The second UMP under scrutiny in the present paper is the implementation of swap programmes characterized by the creation of monetary base by central banks to purchase government bonds that are exchanged for commercial banks' troubled assets. As in the previous scenario, we identify 'toxic' assets with defaulted loans and ignore the effects of swap programmes on other assets on the bank's balance sheet. Under this scheme, commercial banks obtain a net return i_g - instead of $\widetilde{i}_c$ - on their share of defaulted loans $p(Q_{B/NB})Q_{B/NB}$. Therefore, the balance sheet identity (1) becomes

$$(1 - p(Q_{B/NB}))Q_{B/NB} + G + R_{min} + ER = Q_{CB/B} + Q_{B/B} + D, \tag{15}$$

where $G = p(Q_{B/NB})Q_{B/NB}$ denotes the amount of government bonds swapped by the commercial bank in return for its portfolio of defaulted loans; $Q_{CB/B} = \lambda Q_{B/NB}$, as in the baseline scenario.

The banks' profit maximization problem (4) is modified to

$$\max_{\{Q_{B/NB}\}} \left\{ [(i_c - i_m) + (i_m - i_r)\lambda + \widetilde{i}_r\tau]Q_{B/NB} - \widetilde{D} - (i_c - i_g)f(z)Q^2_{B/NB} \right\}. \tag{16}$$

Its solution leads to the optimal loan supply to the non-financial sector when implementing this UMP:

$$Q^{s2}_{B/NB} = \frac{(i_c - i_m) + (i_m - i_r)\lambda + \widetilde{i}_r\tau}{2f(z)(i_c - i_g)}. \tag{17}$$

Aggregating for all commercial banks, and considering the aggregate demand for credit (6), the equilibrium interest rate is given by

$$i^{swp}_c = \frac{\lambda i_r + (1 - \lambda)i_m - \widetilde{i}_r\tau - 2f(z)i_g\frac{\alpha Y}{N}}{1 - 2f(z)\frac{\alpha Y}{N}}, \tag{18}$$

and its spread over the short-term policy rate can be expressed as

$$i_c^{swp} - i_r = \frac{(1-\lambda)(i_m - i_r) - \widetilde{i}_r\tau - 2f(z)(i_g - i_r)\frac{\alpha Y}{N}}{1 - 2f(z)\frac{\alpha Y}{N}}. \tag{19}$$

Using the same type of counterfactual analysis as in the previous subsection, the success of this policy with respect to the baseline and the lending facilities scenarios can be established. The comparison of (7) and (18) shows that swap programmes are successful in reducing borrowing costs when the return on government bonds is higher than that on the collateral on defaulted loans. Meanwhile, the comparison of (11) and (18) reveals that the creation of lending facilities reduces the credit spread with respect to that under swap programmes if

$$i_g < (1-\lambda)(i_m - i_r) - \widetilde{i}_r\tau + 2i_r f(z)\frac{\alpha Y}{N}. \tag{20}$$

This condition is similar to (13) and highlights the importance of the interbank market risk premium for credit conditions and the negative influence that rewarding excess reserves may have on borrowing costs. It is worth mentioning that the same analysis to that carried out for lending facilities in Figure 2 also applies here, but considering the government bond interest rate instead of the net return on the collateral. In addition, expression (20) can be expressed in terms of the percentage of credit borrowed from the central bank as

$$\lambda < 1 - \frac{i_g + \widetilde{i}_r\tau}{i_m - i_r} + \frac{2i_r f(z)}{i_m - i_r}\frac{\alpha Y}{N}, \tag{21}$$

determining the values of λ for which lending facilities outperform swap programmes for different combinations of the other model parameters.

4 Quantitative model assessment

A simulation exercise that illustrates the predictions of our theoretical framework is carried out in this section. The main goal is to analyze the supply of credit by commercial banks under the three scenarios described in the preceding sections. In particular, we study how the conditions that characterize the relative performance across measures change with the relevant model parameters.

[Insert Tables 1 and 2 here]

The values for the parameters have been chosen to suit data observed in the US and the EA during the period 2006-2012. With this aim, aggregate monetary and financial information for these economic areas have been extracted from the FRED database (St. Louis FED) and the ECB Statistical Data Warehouse. The description of the variables in our theoretical model and their simulation counterparts is reported in Tables 1 and 2 for the US and the EA, respectively. As can be observed in Table 1, the selected value for the short-term policy interest rate is 2% in the US, where excess reserves are considered to be rewarded at a rate equal to 0.25%. Banks face a common loan default rate of 4% and the net return on the assets held as collateral is 2%. While the fraction of total lending held as excess reserves in the FED is 2%, the corresponding fraction borrowed by commercial banks from it is 3%. Finally, we have chosen an interest rate in the interbank money market of 5% and a return on government bonds of 4%.

[Insert Figure 3 here]

Figure 3 compares the credit supply schedule in the baseline scenario (5) to those obtained when implementing UMPs (10) and (17). The sensitivity analysis considers the displacements of the optimal loan supply derived from increases in the interbank money market ($i_m = 0.05$, 0.06, 0.07; left panel) and in the fraction of total lending that is borrowed from the central bank ($\lambda = 0.03$, 0.13, 0.23; right panel). The results show the outperformance of both UMPs with respect to the baseline in easing access to credit. More specifically, the graphs in the left panel of Figure 3 confirm the success of lending facilities and swap programmes in reducing the credit spread for different values of the interbank money market rate. It can also be observed that the latter plays a significant role in assessing which measure is more appropriate. The graph at the bottom reinforces the findings in Figure 2(a) regarding the outperformance of lending facilities over swap programmes as the interbank money market rate increases. However, it is worth mentioning that, for the initial values fitting US data (solid lines) swap programmes display a marginally better performance.

The sensitivity of the results to the composition of the liability side of commercial banks' balance sheets is depicted in the right panel of Figure 3. The simulation exercise reflects that increases in the amount of borrowing from the monetary authority should reduce borrowing costs to the non-financial sector. The graph at the bottom also shows the outperformance of swap programmes over lending facilities. Interestingly, the convexity of the loan supply schedule for swap programmes suggests a more rapid increase of the credit interest rate with respect to the lending facilities scenario, implying a better performance of the latter for large values of the credit stock.

[Insert Figure 4 here]

Figure 4 presents the results obtained from a similar analysis for the EA. As reported in Table 2, the initial values that characterize the baseline model in this case are a short-term policy rate of 3% and a reward for reserves held in excess of 0.2%. The common loan default rate is equal to 4% and the net return on the collateral for these non-performing assets is 2%. The fraction of total lending held as excess reserves by commercial banks is 1%, the interbank money market rate is 5% and the return on government bonds is equal to 4%. Finally, the percentage of the total amount of loans that is borrowed from the ECB is 7%.

The simulation exercise with European data yields similar results to those for the US. The important difference in the amount of money borrowed from the central bank in these two economic areas is reflected in the graphs at the bottom of Figure 4 where the outperformance of swap programmes is more apparent. The creation of lending facilities only displays a better performance for increases in the interbank money market rate or for large values of the credit supply. These findings highlight the close connection between the composition of the liability side of commercial banks' balance sheets, the credit stock and the optimal choice of the UMP to be implemented.

[**Insert Figure 5 here**]

The graphs at the top of Figure 5 illustrate the relevance of condition (14) for the US and EA banking sectors, while the graphs at the bottom reflect the implications of condition (21). In both cases, the term reflecting credit demand ($\alpha Y/N$) has been replaced by its supply ($Q_{B/NB}$). The upper graphs analyze the sensitivity of (14) to an increase in the net return on the collateral from 2% (black solid line) to 3% (black dashed line). In addition, the lower graphs show the sensitivity of (21) to a decrease in the return on government bonds from 4% (black solid line) to 3% (black dashed line). The red solid lines correspond to the observed fraction of borrowing from the central bank in the US (3%) and the EA (7%), respectively.

The results reported in Figure 5 provide further support to lending facilities as measure that is potentially able to reduce the credit interest rate in the US. The solid lines corresponding to condition (14) determine the values of λ that are compatible with the success of lending facilities. These values increase with credit supply with a slope that depends positively on the short-term policy rate and the default rate, and negatively on the risk premium on the interbank money market. The results shown reflect earlier findings according to which higher values of the collateral reduce the success of lending facilities in decreasing the credit spread. In fact, for the US example, a 1% increase in the net return on the collateral assets implies a failure of this UMP in easing credit conditions. A similar analysis concerning condition (21) has been carried out, reflecting the outperformance of swap programmes over lending facilities for the observed value of λ in the US, regardless the amount of credit supplied to the market. These results confirm the adequacy of swap programmes implemented by the FED during the recent financial crisis in reducing borrowing costs to the non-financial sector.

The simulation exercise with European data suggests a poor performance of lending facilities in reducing borrowing costs. In particular, condition (14) is violated for low values of credit supply if the return on the collateral is 2%. A higher value of this parameter (3%) results in stronger rejections of this UMP as a valid instrument for easing access to credit. Similarly, the graph at the bottom right of Figure 5 provides overwhelming evidence of the outperformance of swap programmes over lending facilities raising some doubts about the suitability of the lending facilities created by the ECB during recent crisis episodes.

5 Robustness analysis

In the preceding sections, we have investigated the equilibrium credit interest rate considering that banks are risk neutral and specific functions for excess reserves holdings and the default rate on the portfolio of banks' loans. The robustness of our findings to these three assumptions is analyzed in the present section.

This is done by the introduction of risk aversion into banks' optimal behavior assuming that they maximize a power utility function of profits reflecting constant relative risk aversion (CRRA). Furthermore, as a second robustness exercise, the functional form $p(Q_{B/NB}) = f(z)Q_{B/NB}$ is replaced by a more general function reflecting the existence of comovements between the default rate and the amount of credit to the non-financial sector[3]. After these modifications, the profit function for the baseline scenario (3) changes to

$$\Pi(Q_{B/NB}) = f(i, \lambda, p(Q_{B/NB}))Q_{B/NB} - \widetilde{D}, \tag{22}$$

with $f(i, \lambda, p(Q_{B/NB})) = [(i_c - i_m) - (i_r - i_m)\lambda - (i_c - \widetilde{i}_c)p(Q_{B/NB})]$. The corresponding

[3] As some authors have pointed out (Benes et al., 2014), this default rate can also be modelled as a function of non-performing loans, loss-given default, and risk of default which could potentially be dependent on collateral asset prices.

optimization problem (4) becomes

$$\max_{\{Q_{B/NB}\}} u\left(\Pi(Q_{B/NB})\right) \tag{23}$$

with

$$u(x) = \begin{cases} \frac{x^{1-\gamma}}{1-\gamma} & \text{for} \quad \gamma > 0 \text{ and } \gamma \neq 1; \\ \ln(x) & \text{for} \quad \gamma = 1. \end{cases} \tag{24}$$

For expositional convenience, we first analyze the logarithmic function. In this case, the relevant optimization problem is

$$\ln \widetilde{D} + \max_{\{Q_{B/NB}\}} \ln\left(\frac{f(i, \lambda, p(Q_{B/NB}))Q_{B/NB}}{\widetilde{D}} - 1\right) \tag{25}$$

and its first order condition

$$\frac{\partial f(i, \lambda, p(Q_{B/NB}))}{\partial Q_{B/NB}} Q_{B/NB} + f(i, \lambda, p(Q_{B/NB})) = 0. \tag{26}$$

The solution to this equation can be expressed as

$$Q^s_{B/NB} = \frac{(i_c - i_m) - (i_r - i_m)\lambda - (i_c - \widetilde{i}_c)p(Q_{B/NB})}{(i_c - \widetilde{i}_c)\ \partial p(Q_{B/NB})/\partial Q_{B/NB}}. \tag{27}$$

The same optimality condition is obtained if the logarithmic utility function is replaced by a function reflecting risk aversion and characterized by $\gamma \neq 1$ in the above representation of $u(x)$. This finding reveals the robustness of our results to the specification of the commercial banks' objective function within the CRRA family. It should also be noted that the optimal credit supply in (27) is consistent with the specification of the default rate $p(Q_{B/NB})$ in previous sections. This expression does not provide, however, a meaningful result if the default rate is constant because, in this case, the maximization problem (25) does not have an interior solution. This result illustrates the importance of the specification of the default rate in determining the existence of an optimal supply of credit. In fact, this variable is the only factor reflecting banks' risk aversion in our theoretical framework.

The last of the robustness checks that has been carried out consists of assessing the impact of changes in the specification of excess reserves holdings. We take a more general view on the function considered before and assume that $ER = h(Q_{B/NB})Q_{B/NB}$, with $h(Q_{B/NB})$ a positive and potentially increasing function of credit supply. In this case, and under the scenario deployed for the study of central bank lending facilities[4], the relevant profit function becomes

$$\Pi(Q_{B/NB}) = \widetilde{f}(i, \lambda, p(Q_{B/NB}), h(Q_{B/NB}))Q_{B/NB} - \widetilde{D}, \tag{28}$$

with $\widetilde{f}(i, \lambda, p(Q_{B/NB}), h(Q_{B/NB})) = [(i_c - i_m) - (i_r - i_m)\lambda - (i_r - i_m)p(Q_{B/NB}) + (\widetilde{i}_r - i_r)h(Q_{B/NB})]$.

The optimal credit supply obtained by solving the corresponding maximization problem is

$$Q^s_{B/NB} = \frac{(i_c - i_m) - (i_r - i_m)\left[\lambda + p(Q_{B/NB})\right] + (\widetilde{i}_r - i_r)h(Q_{B/NB})}{(i_r - i_m)\partial p(Q_{B/NB})/\partial Q_{B/NB} + (i_r - \widetilde{i}_r)\ \partial h(Q_{B/NB})/\partial Q_{B/NB}}. \tag{29}$$

This expression highlights the inverse relationship between banks' optimal credit supply and the level of deposits they maintain in the central bank as excess reserves. Moreover, it suggests that the equilibrium credit interest rate - obtained from equating $M^s = NQ^s_{B/NB}$ with $M^d = \alpha Y$ - increases with $h(Q^s_{B/NB})$.

6 Concluding remarks

This paper has proposed a simple theoretical framework to evaluate the success of the most important UMPs implemented by central banks during the recent crisis episodes. The spread between the credit interest rate and the short-term policy rate is determined by the risk premium in the interbank money market, the composition of commercial banks' balance sheets, the value of the assets held as collateral for defaulted loans and the default rate on

[4]The analysis of the effect of excess reserves holdings under government swap programmes follows similarly.

the portfolio of loans. The degree of competition in the banking sector and the amount of excess reserves maintained in the central bank also play a key role in determining the credit interest rate in equilibrium.

We conclude that swap programmes are superior to the inaction that characterizes our baseline scenario and to the creation of lending facilities if the government bond used for the exchange of assets with the central bank provides high returns and the value of the collateral assets on defaulted loans is low. This situation is reversed, lending facilities becoming more sucsessful in easing credit conditions, if the risk premium on the interbank money market is sufficiently high to offset the yields of the government bond and the net return obtained by the collateral. The application of these theoretical insights to real data from the US and the EA provides further support for the policies implemented by the FED while it raises some doubts about the choice of lending facilities in banking systems that rely more heavily on borrowing from the central bank to sustain the creation of credit.

The theoretical framework proposed in the present paper can be extended to consider that market variables such as the interbank rate, the amount and value of collateral assets and the default rate are endogenous and, hence, also affected by the implementation of UMPs in a similar manner as the credit interest rate. In this case, the counterfactual analysis should also take differences in these variables into account when comparing the credit interest rates between equilibriums. The consideration of the relative success of UMPs in these conditions is left for future research.

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Tables and figures

Table 1. Quantitative model assessment. Selection of the parameter values for the United States.

Model	**FRED database**	**2006**	**2008**	**2012**	**Simulations**
Official interest rate (i_r)	Effective Federal Funds rate	4.96	1.93	0.14	0.02
Interest rate paid on excess reserves ($\tilde{\imath}_r$)	Interest rate paid on excess reserve balances (2-week maintenance period)	0.00	0.00	0.25	2.50E-03
Interbank market rate (i_m)	Interbank rates (3-month/90-day)	1.56	2.97	0.28	0.05
Net return on collateral ($\tilde{\imath}_c$)	Bank prime loan rate*Percentage of value of loans secured by collateral	5.20	3.12	2.33	0.02
Government bonds rate (i_g)	10-year Treasury constant maturity rate	4.80	3.66	1.80	0.04
Fraction of total lending held as excess reserves (τ)	Excess reserves of depository institutions as a percentage of credit (all commercial banks)	0.02	1.53	15.16	0.02
Fraction of total lending borrowed from the central bank (λ)	Credit over total borrowing of depository institutions from the FED	2.94E-03	3.01	0.05	0.03
Loan probability of default ($f(z)$)	Loan delinquency rate (all commercial banks)	1.57	3.67	5.02	0.04

Table 2. Quantitative model assessment. Selection of the parameter values for the euro area.

Model	**ECB Statistical Data Warehouse**	**2006**	**2008**	**2012**	**Simulations**
Official interest rate (i_r)	Interest rate for main refinancing operations	3.00	3.71	0.75	0.03
Interest rate paid on excess reserves ($\tilde{i}_r$)	Interest rate for deposit facility	2.00	2.87	0.00	0.02
Interbank market rate (i_m)	Euribor (3-month)	3.08	4.64	0.57	0.05
Net return on collateral ($\tilde{i}_c$)	Interest rate for loans (<1 year)*Percentage of loand with collateral (Godlewski and Weill, 2011)	4.50	4.91	3.19	0.03
Government bonds rate (i_g)	Spot rate (all ratings), 10-year maturity	3.98	3.92	3.01	0.04
Fraction of total lending held as excess reserves (τ)	Excess reserve maintenance by credit institutions as a percentage of their loans to non-MFIs	0.01	0.01	3.31	0.01
Fraction of total lending borrowed from the central bank (λ)	ECB lending to credit institutions as a percentage of their loans to non-MFIs	4.52	7.16	9.24	0.07
Loan probability of default ($f(z)$)	Percentage of doubtful and non-performing loans	2.93*	2.54	5.32	0.04

Note: * data for the year 2007.

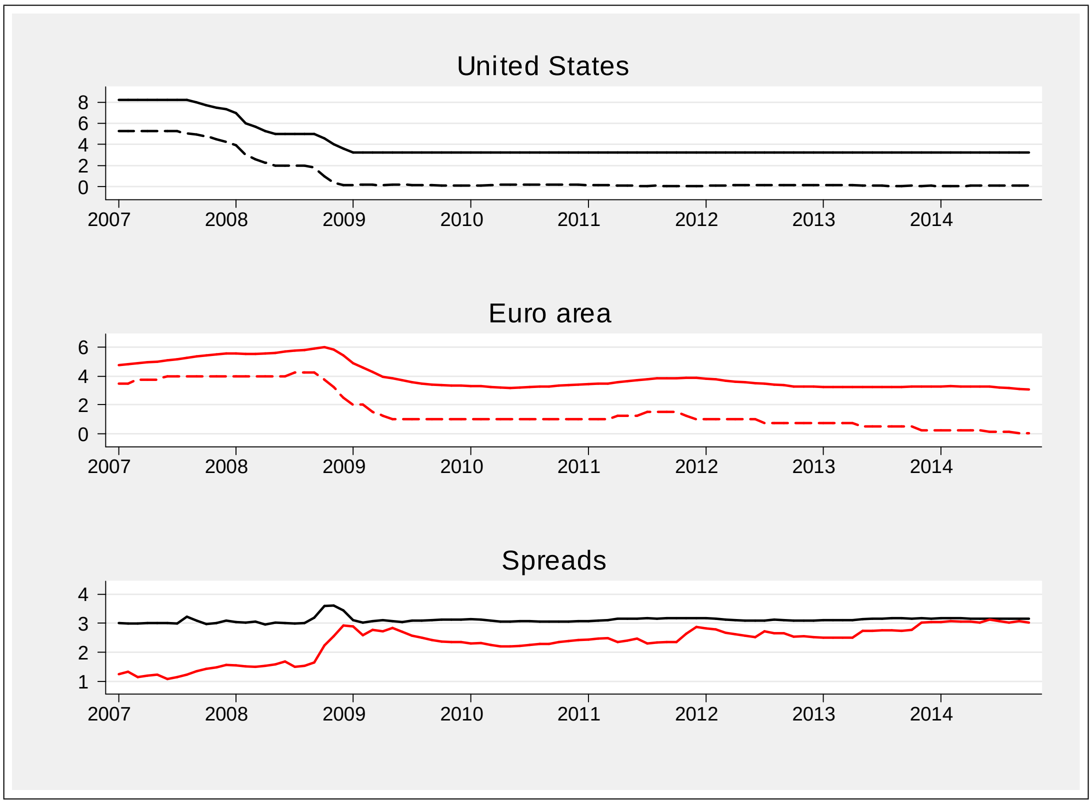

Figure 1: Credit (solid) and short-term policy (dashed) rates, 2007:01-2014:10.

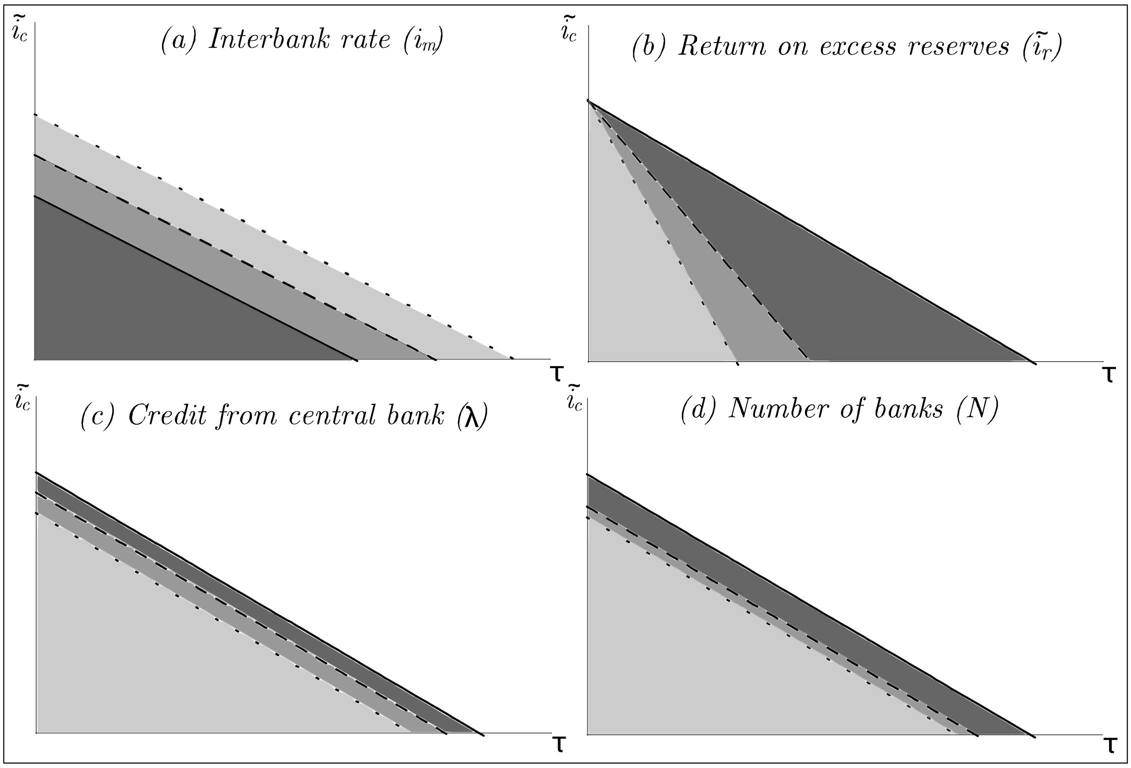

Figure 2: Relative policy effectiveness: Lending facilities vs. baseline. Effects of increases in model parameters (solid to dotted). The coloured areas correspond to a better performance of lending facilities in reducing the credit interest rate.

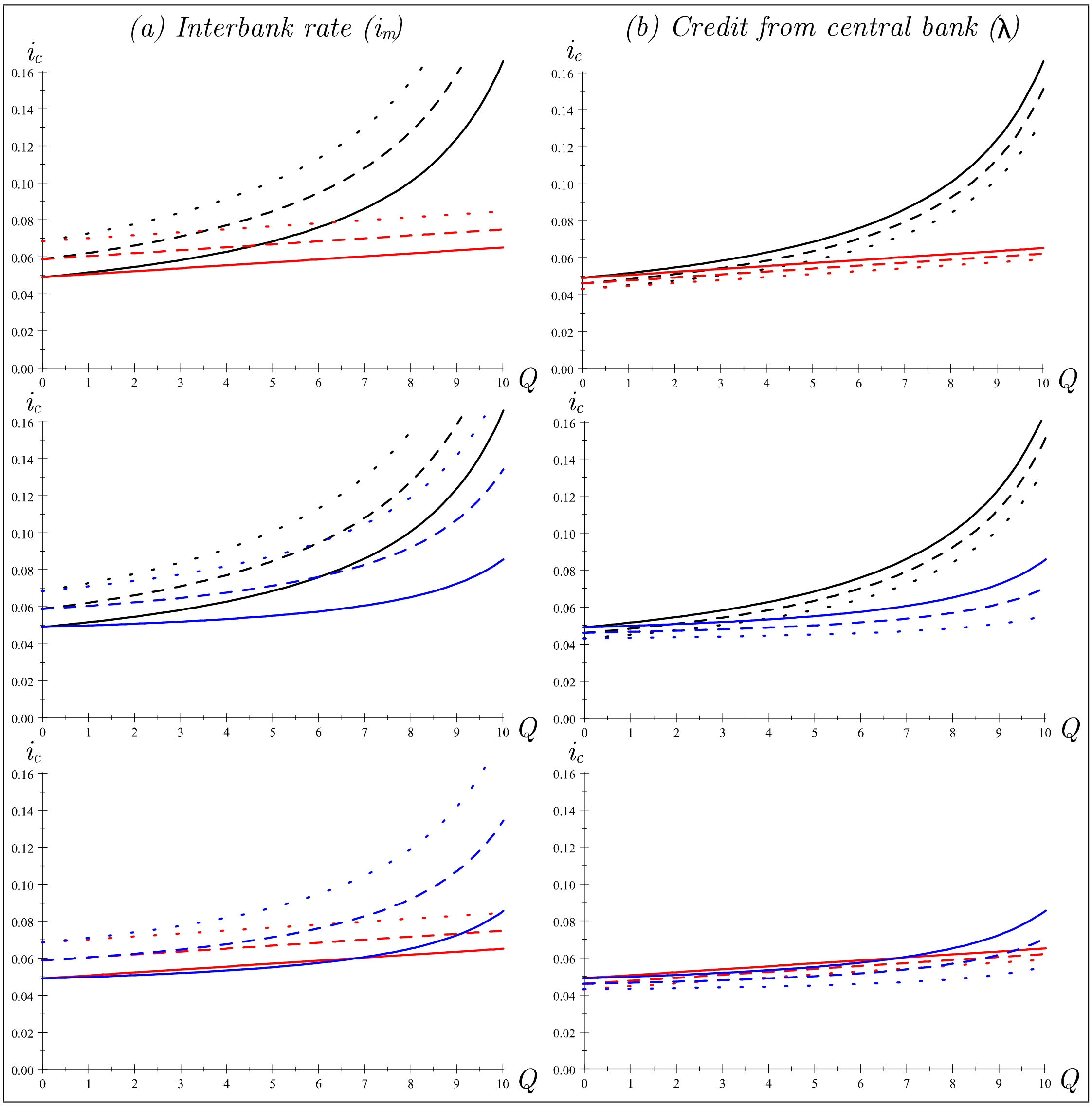

Figure 3: Credit supply curves: Baseline (black), lending facilities (red) and swap programmes (blue) scenarios. Effects of increases in model parameters (solid to dotted) fitting US data (see Table 1).

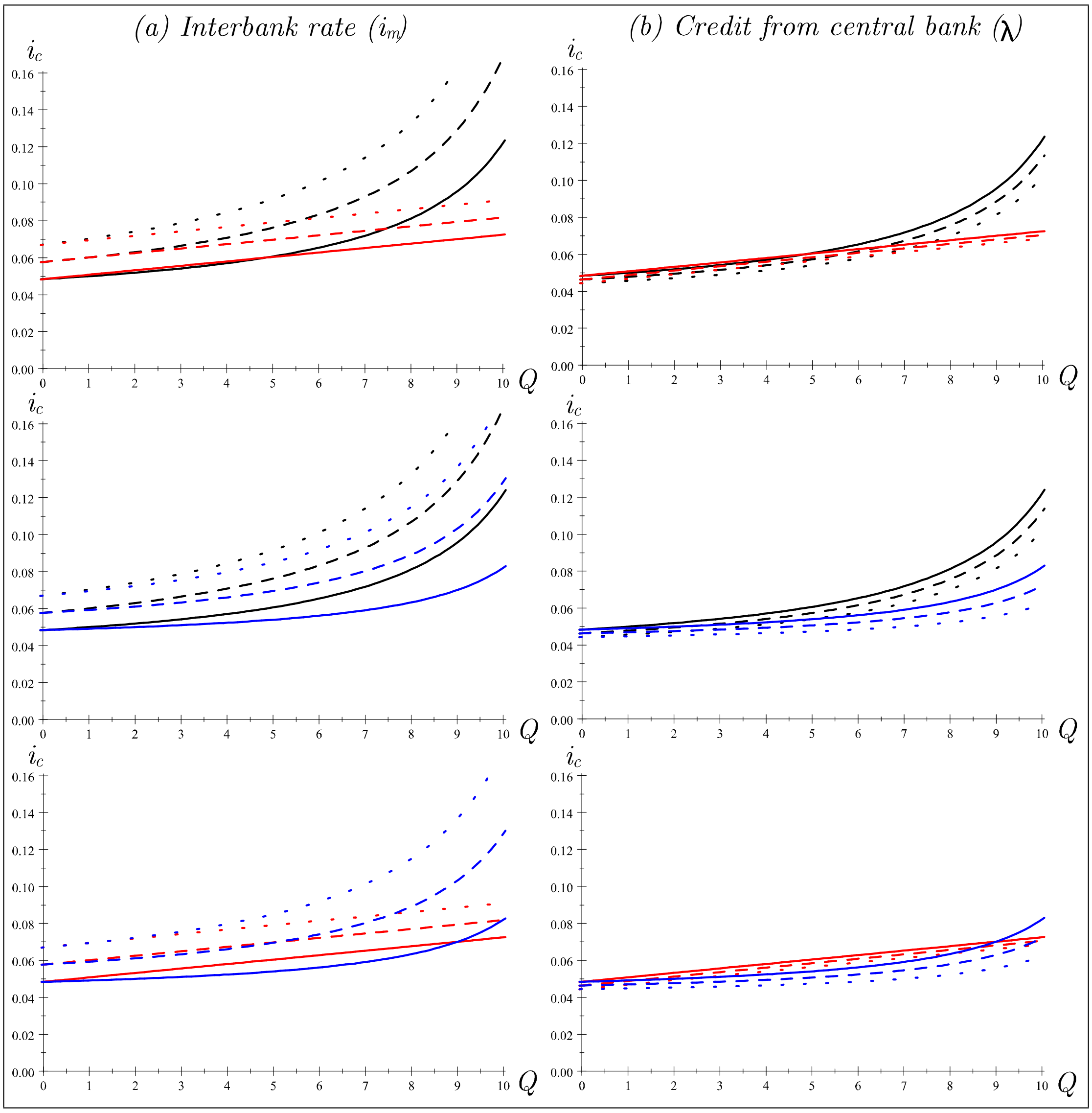

Figure 4: Credit supply curves: Baseline (black), lending facilities (red) and swap programmes (blue) scenarios. Effects of increases in model parameters (solid to dotted) fitting EA data (see Table 2).

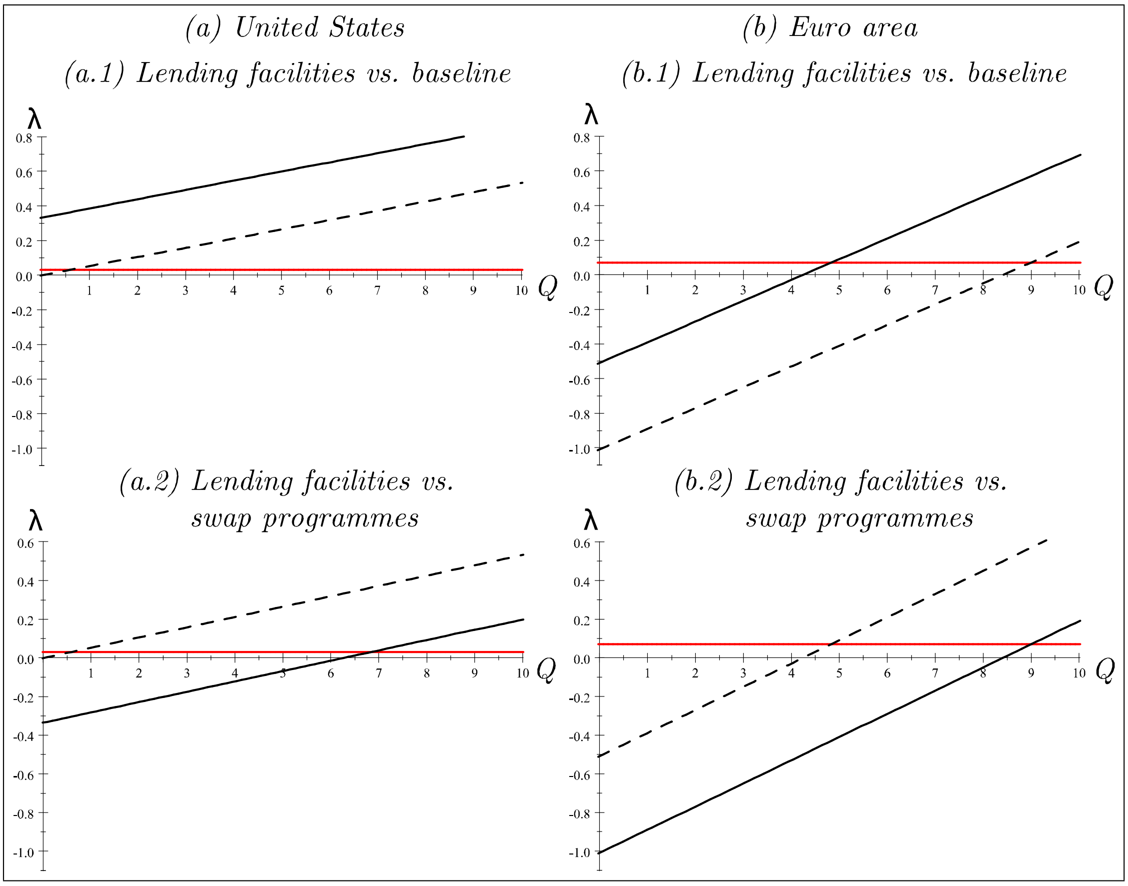

Figure 5: Relative policy effectiveness. The areas below the black lines correspond to a better performance of lending facilities in reducing the credit interest rate. Red horizontal lines are the observed values for the percentage of commercial bank loans that are borrowed from the monetary authority. Dashed lines in the upper (lower) panel reflect an increase (decrease) in the net return on the collateral (government bonds rate).