Unconventional Monetary Policies and the Bank Lending Channel

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Abstract

This paper deals with changes in the monetary policy transmission mechanism from appealling to 'unconventional' measures. Focusing on the bank lending channel and credit supply, we study the creation of lending facilities to recapitalize banks' balance sheets and the implementation of swap programs to exchange banks' toxic assets for government bonds. Our theoretical model shows the outperformance of the first program in decreasing the credit interest rate and the adverse effect the existence of a rate rewarding excess reserves has on the effectiveness of both programs. We also uncover the existence of a limit on these reserves beyond which these programs are counterproductive. The pass-through from the official rate to the credit interest rate also depends on the type of program and the level of excess reserves. An empirical analysis with macroeconomic data for the Euro area and the United States provides evidence of significant differences in the effects of each program on the bank lending channel.

Keywords: Equilibrium model, 'Unconventional' monetary policies, Transmission mechanisms, Structural change, VECM.

JEL codes: C32, E32, E41, E51.

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1 Introduction

The role of monetary aggregates for conducting monetary policy is controversial. Thus, whereas Woodford (2008) does not find a compelling reason to assign a prominent role to monetary aggregates, McCallum (2000, 2008) considers that narrow monetary instruments such as the money base may be superior to interest rates. Bernanke (2006) and Reynard (2007) exhibit similar arguments in favor of the use of monetary aggregates and state that policy rules based on a monetary base instrument can be more effective from a macroeconomic point of view and provide qualitative and quantitative information on subsequent economic developments. Similarly, McCallum and Nelson (2011) suggest that studies of inflation and monetary policy behavior can benefit from including both interest rates and money in the empirical analysis. In this line, and without challenging interest rates as the main policy instrument, money has been introduced in New Keynesian models with sticky prices (Nelson, 2002; Beck and Wieland, 2007; Andrés et al., 2009), the standard workhorse for monetary policy analysis both by central banks and academic economists.

The 'conventional' monetary policy approach achieved low and stable inflation, but did not prevent asset bubbles from occurring. For that reason, central banks add financial stability and economic recovery to their goals after the commence of the last financial crisis in 2007. Moreover, since then there has been a renewed interest for monitoring both monetary and credit developments and for exploring other 'unconventional' monetary policies (UMPs, hereafter). These alternative measures have been adopted for two main reasons. First, nominal short-term interest rates in many countries reached the lower bound during this period, losing their ability to stimulate the economy (Reifschneider and Williams, 2000). In this context, alternative monetary policy instruments are the monetary base (Krugman, 1998), long-term interest rates (McGough et al., 2005) or the exchange rate (Svensson, 2001). Second, disruptions in the financial system generated large losses and affected the liquidity and solvency of both banks and borrowers.

Earlier mechanisms for the transmission of monetary policy discussed in the literature were based on neoclassical theories. Within this class of models, Boivin et al. (2011) highlight the importance of investment-based channels such as the Tobin's q, consumption-based channels given by wealth and intertemporal substitution effects or international-trade channels determined by the exchange rate. Nevertheless, the bank lending channel has a prominent role on the transmission of monetary policy. In this non-neoclassical view, the transmission of monetary policy takes place as the pass-through from the official interest rate to the credit interest rate on banks' loans. In this respect, a expansionary monetary policy, which increases bank reserves and bank deposits, increases the quantity of bank loans to finance economic activities.

In order to stimulate the economy and, hence, recover the effectiveness of 'conventional' monetary policies, central banks have tried to affect interest rates other than the official rates using the size and the structure of their balance sheets, see Durré and Pill (2012) and Joyce et al. (2012) for a description of the transmission channels at work[1]. Most of these measures have been interpreted as 'unconventional' forms of conducting monetary policy. One remarkable example is the 'Operation Twist' carried out by the Federal Reserve (FED) and consisting of sterilized operations by buying longer-term Treasuries and, simultaneously, selling some of the shorter-dated issues. The FED also followed a large-scale asset purchase (LSAP) program of mortgage-backed securities with the aim of increasing market liquidity and reducing mortgage interest rates ('credit easing'). The most popular LSAP across monetary authorities in the recent crisis has been the creation of money to buy assets ('quantitative easing', QE hereafter). While the FED bought Treasury, agency debt and agency-backed mortgage securities, the Bank of England purchased government bonds from the non-bank private sector. Although in these two cases the main objective was to affect yields on assets, the European Central Bank (ECB) used QE to mitigate liquidity problems within the banking system. Specifically, the ECB carried out repurchase agreements providing long-term loans in exchange for bank loans and non-government bonds as collateral.

[1] Other useful related references are Borio and Disyatat (2010), Lenza et al. (2010) and Krishnamurthy and Vissing-Jorgesen (2011).

The aim of this paper is to analyze the existence of changes in the monetary policy transmission mechanism due to the implementation of UMPs. To do this we focus on the non-neoclassical credit view of monetary policy transmission. According to it, banks play a special role in the financial system because they are well suited to solve asymmetric information problems in credit markets. The main contributions of this article are twofold. First, we propose a theoretical model that studies equilibrium in the credit market as the result of banks' profit maximization subject to a balance sheet identity restriction. The model is extended to study credit market equilibrium under the implementation of UMPs, broadly identified with two different measures carried out by monetary authorities: the creation of lending facilities to recapitalize banks balance sheets and the implementation of swap programmes to exchange banks' 'toxic' assets for government bonds. Both programs rely on increasing the monetary base by creating central bank excess reserves and their impact on the equilibrium is through the supply side of the credit market. More specifically, banks' profit function is modified to accommodate disruptions on variable costs produced by the occurrence of the credit crunch. This is done by replacing the fixed costs of banks' troubled assets by loans from the central bank or government bonds, depending on the LSAP program under scrutiny.

The theoretical model predicts a complete pass-through from the official rate to the credit interest rate for economies with a very competitive banking sector. Otherwise, the transmission of monetary policy through interest rates is more efficient under QE measures consisting of repurchase agreements providing long-term loans in exchange for bank loans than under measures focused on exchanging Treasury bonds for 'toxic' assets. We assess the success of a monetary policy by its ability to decrease the credit interest rate in distress periods. In this sense, our theoretical framework predicts a better performance of central bank lending programs than of swap programs. Key factors in determining these differences are the extent of excess reserves held by banks on the central banks derived from increments on the monetary base and the interest rate paid on them.

The model also predicts the existence of a limit on the amount of excess reserves beyond which the implementation of QE measures can be counterproductive in the monetary transmission mechanism by leading to increases in the credit interest rate and reductions in the money stock. This unintended effect of QE programs has the potential to explain the absence of inflationary pressures on the real economy and the relative failure of these measures in restoring the credit channel from banks to the private sector during the financial crisis. Moreover, the existence of excess reserves beyond this limit and the corresponding contractionary effects on the money stock can also explain drops observed in the money multiplier during the last years.

Our second contribution is to empirically assess changes in the credit channel monetary transmission mechanism derived from the implementation of UMPs. We do this by the modelization and estimation of a Vector Error Correction Model (VECM) for the long-run equilibrium relationship between interest rates and monetary aggregates for the Euro area and the United States (U.S.) during a 'normal' period spanning from 2000 until the collapse of Lehman Brothers and the subsequent 'distress' episode running up to September 2012. We formalize the existence of these two regimes by statistically testing for the presence of a structural break in the residuals of the VECM. The empirical analysis suggests that monetary policy is mainly conducted through operating with the official rate in the Euro area. In contrast, the long-run dynamics between the variables highlight the importance of the government bond interest rate as a driving force for conducting monetary policy in the U.S. and, hence, provide indirect evidence on the importance of swap programs to exchange Treasury assets for 'toxic' assets.

The rest of the article is structured as follows. Section 2 presents the theoretical model and derives implications in terms of optimal monetary policy under 'unconventional' measures. Section 3 presents the empirical study assessing changes in the relationship between the official interest rate, credit interest rate, government bond yields, money stock, monetary base and real income, before and after the collapse of Lehman Brothers. The analysis focuses on interpreting long-run cointegration relationships between these variables in terms of the UMPs discussed above. This is done with data for the Euro area and the U.S. economy. Section 4 concludes. Tables and figures are collected in the Appendix.

2 Economic Model

The money supply process deals with the interface between the central bank and the commercial banks. Central banks or, more generally, monetary authorities are monopolistic suppliers of the monetary base. The creation of the money stock is determined by the interplay between the central bank, commercial banks and the non-bank sector. For simplicity, we assume in what follows that the supply of money is the supply of loans[2], neglecting the role of monetary authority interventions on the foreign sector as a means of creating monetary base.

Each bank's balance sheet satisfies the following identity:

$$Q_{B/NB} + R = Q_{CB/B} + D \tag{1}$$

$Q_{B/NB}$ is the quantity of loans vis-a-vis non-banks and $Q_{CB/B}$ is the quantity of credits from the central bank to the banking sector. R is the level of reserves held by a bank on the central bank, such that $R_{min} = rD$. $0 < r < 1$ is the minimum reserve ratio and D are the deposits made by customers.

2.1 Equilibrium in 'normal' times

There is a conventional wisdom in monetary economics to assume that the demand for money is a positive function of real income and a negative function of the interest rate, which represents the opportunity cost of holding money. It is standard to do this by means of a linear function, which applies equally to the demand for loans and the demand for money:

$$M^d = Q^d_{B/NB} = \mu + \gamma Y - \alpha i_c, \tag{2}$$

[2] Accordingly, the demand for money is equivalent to the demand for loans.

with Y being real income, i_c the credit interest rate and satisfying that $\mu > 0$ and $\gamma Y - \alpha i_c \geq 0$.

We consider that the banking system is made up of identical banks which act as price takers. That is, each bank takes the loan rate (i_c) and the deposit rate (i_d) as given. In line with Freixas and Rochet (2008), the deposit market and the money market rates will converge to the central bank's official rate due to abitrage opportunities between the deposit and the money markets.The official interest rate i_r and the interest rate paid on excess reserves $\widetilde{i_r}$ are set by the central bank. Although $\widetilde{i_r}$ is exogenous, we acknowledge the potential endogeneity of i_r that, in equilibrium, can respond to shocks in the rest of the economic system. Nevertheless, for simplicity and without loss of generality, we do not impose an equilibrium model for i_r obtained as a result of the maximization of some objective function by the monetary authority (Clarida et al., 1999) or the implementation of some policy rule (Taylor, 1993). Instead, we leave this variable unmodeled but determined in equilibrium by the central bank. Finally, and following traditional reserve management models (Orr and Mellon, 1961; Niechans, 1978; Baltensperger, 1980), we take the level of deposits as given and depending on stochastic flows. This model is also discussed in Bofinger and Debes (2010).

Against this background, the profit function of an individual bank can be written as

$$\Pi = i_c Q^s_{B/NB} - i_r Q_{CB/B} + \widetilde{i_r} R - i_d D - V, \tag{3}$$

with $R = R_{min} + ER$, being ER the level of excess reserves. $Q^s_{B/NB}$ is the supply of loans by the bank and V its variable costs. In 'normal' times the latter depend on the total amount of credit and the default probability of loans, proxied by the overall macroeconomic situation and measured by real income. Following Cosimano (1988), we assume that $V = \beta Q^2_{B/NB}/Y$ with $\beta > 0$ the cost for the bank of failed loans.

Bofinger and Debes (2010) claim that, also in 'normal' conditions, $\widetilde{i_r}$ is unlikely to be different from i_r due to the inability of the central bank to expand the amount of reserves beyond the minimum required without changing its official rate i_r. Thus, the optimal supply of loans in the economy is $M^s = Q^s_{B/NB} = \frac{i_c - i_r}{2\beta} nY$, with n the number of banks operating in the system.

To calculate the equilibrium loan interest rate, we equalize loan supply with loan demand $M^s = M^d$ and obtain that

$$i_c^* = \frac{2\beta(\mu + \gamma Y) + i_r nY}{nY + 2\alpha\beta}. \tag{4}$$

There is a positive nonlinear relationship between interest rates such that

$$\frac{\partial i_c^*}{\partial i_r} = \frac{1}{1 + 2\alpha\beta / nY} > 0 \tag{5}$$

implying a complete pass-through from the official rate to the credit interest rate as n or Y tend to infinity. Nevertheless, for a relatively high concentration of firms in the banking sector (low n) and moderate values of real income the pass-through is driven by (5) tends to one as the cost for the banking sector of the 'toxic' assets (β) tends to zero.

For the equilibrium amount of loans we plug i_c^* into (2):

$$M^* = \frac{\mu + \gamma Y - \alpha i_r}{1 + 2\alpha\beta / nY}. \tag{6}$$

This expression uncovers the existence of a positive equilibrium relationship between real income and nominal money stock, supporting the view that monetary aggregates are related to the real economy. Finally, it can also be observed that increments in the official rate are negatively related to the money stock.

2.2 Equilibrium in 'distress' periods

In this section we identify the occurrence of a structural break with a change in the instruments used by central banks, namely, the official interest rate and the monetary base. A shift in central banks' operating procedures not only can produce a change in the relationship between these variables but also in character of the monetary base that becomes a decision variable (endogenous) for the monetary authority. If this is the case a potential decoupling between the main official interest rate and the monetary base will take place.

Figure 1 shows the relationship between i_r and B for the Euro area and the U.S. over the period 2000 : 07 to 2012 : 10. These graphs show the shift in the linear relationship between these variables after September 2008, when Lehman Brothers collapsed. [**Explain better**]

The decision by central banks to increase the monetary base is motivated by the need to improve credit conditions for the private sector. Using our simple model above we now assume that the increase in B is used by central banks to recapitalize banks' balance sheets. This can be done by lending funds to banks in order to payoff their defaulting debt or by printing money used to purchase government bonds that are swapped with troubled assets held in banks accounts. In the first case β in the variable cost function V is replaced by i_r; in the second case β is replaced by the government bond interest rate (i_g). This interest rate is obtained from equilibrium between the supply and demand of government bonds in the sovereign debt market. Rather than proposing a model for the supply and demand of government bonds, we simply note that in 'normal' times the fluctuations of this interest rate and, hence, of the demand and supply of these bonds have no direct effect over the monetary base. Nevertheless, there is an indirect effect through the increase in money supply due to the purchase of these bonds, potentially funded by loans from banks. In 'distress' periods, however, monetary authorities expand the monetary base and activate government bonds purchase programs that have a direct impact on the government bond market by decreasing i_g. For simplicity, we will assume that i_g does not depend on $Q_{B/NB}$ and is such that $i_r < i_g < \beta$.

Scenario 1: Central bank lending facilities

In this scenario monetary authorities expand the monetary base to recapitalize banks' balance sheets. This is done by means of a loan from the central bank for the quantity V in (3) at a fixed interest rate, that we assume to be equal to the official interest rate i_r. In short, the QE measure consists of replacing the cost β by i_r in the profit function.

The increase in the demand for monetary base can exceed the aggregate requirements by the banking sector consistent with the elimination of 'toxic' assets from their balance sheets. The magnitude of the outstanding excess reserves generated by these programs can make futile the use of fine-tuning operations to sterilize the increase in monetary base. Instead, monetary authorities can recourse to the use of deposit facilities with the aim of withdrawing some of the excess liquidity from the system. The bank profit function is

$$\Pi = i_c Q^s_{B/NB} - i_r Q_{CB/B} + \widetilde{i}_r (R_{min} + ER) - i_d D - i_r \frac{(Q^s_{B/NB})^2}{Y}. \tag{7}$$

This model makes allowance for the possibility that banks borrow funds beyond those necessary to recapitalize their balance sheets. In parallel to the relationship between deposits and minimum reserves we assume that $ER = \tau V$ **[Shouldn't this be** $ER = \tau \frac{(Q^s_{B/NB})^2}{Y}$**?]**, with $0 \leq \tau \leq 1$ a constant denoting the proportion of the total loan reinvested on the central bank account as excess reserves. In this case, the optimal supply of loans in the economy is

$$M^s = Q^s_{B/NB} = \frac{i_c - i_r}{2\delta} nY, \tag{8}$$

with $\delta = i_r + \tau(i_r - \widetilde{i}_r)$. The equilibrium loan interest rate is

$$i^*_c = \frac{2\delta(\mu + \gamma Y) + i_r nY}{nY + 2\alpha\delta}. \tag{9}$$

This expression reveals the nonlinear influence in equilibrium of Y, i_r and $\widetilde{i}_r$. As the number of banks operating in the system grows to infinity the credit interest rate in equilibrium satisfies a complete pass-through from i_r to i^*_c. For the equilibrium loan amount we plug i^*_c into the loan demand:

$$M^* = Q^*_{B/NB} = \frac{\mu + \gamma Y - \alpha i_r}{1 + 2\alpha\delta/nY}. \tag{10}$$

One of the main issues on monetary policy, particularly under financial turmoil, is to assess the impact of policy decisions on the credit interest rate. The comparison of (4) and

(9) shows that for

$$\tau < \frac{\beta - i_r}{i_r - \widetilde{i}_r} \quad \Leftrightarrow \quad \beta > \delta \tag{11}$$

the equilibrium credit interest rate is lower under the implementation of the UMPs. This result also shows that if these monetary measures are accompanied by an excess of remunerated reserves given by values of τ failing to satisfy (11) the resulting equilibrium credit interest rate is even higher than before the implementation of these exceptional measures. The creation of excess reserves also has an effect on the optimal money stock in equilibrium. Thus, the comparison of (6) and (10) reveals that an excess of reserves beyond that permitted by (11) leads to a decrease in the stock of money in equilibrium rather than to an increase, as expected by monetary theory. [**Discuss this paragraph**]

Scenario 2: Government bonds purchase

The second scenario that we contemplate considers the existence of swap programs between government bonds and the 'toxic' assets held by banks. More specifically, central banks increase the monetary base to purchase government bonds that exchange for V from the bank. The banks' profit function is analogous to (3) **with the only difference given by the marginal variable costs** that are equal to i_g instead of β. That is, $V = i_g \frac{Q^2_{B/NB}}{Y}$ The equilibrium conditions for the money stock and the credit interest rate are slightly modified to incorporate this change. Let δ_g takes on the role of δ with $\delta_g = i_g + \tau(i_r - \widetilde{i}_r)$. Thus, in equilibrium,

$$i_c^* = \frac{2\delta_g(\mu + \gamma Y) + i_r nY}{nY + 2\alpha\delta_g}. \tag{12}$$

In this scenario the credit interest rate responds to movements in i_g and i_r. The interest rate pass-through consists of assessing variations of i_c^* for marginal increments of i_r and i_g. The relevant condition determining the success of this UMP in reducing the credit interest rate is

$$\tau < \frac{\beta - i_g}{i_r - \widetilde{i}_r}. \tag{13}$$

This condition further limits the extent of the accumulation of excess reserves held by banks. Finally, we compare the equilibrium credit interest rates (9) and (12). Condition $i_r < i_g$ is sufficient to have a lower i_c^* in the first model specification compared to the second one characterized by the swap bonds program. The optimal money stock is

$$M^* = Q^*_{B/NB} = \frac{\mu + \gamma Y - \alpha i_r}{1 + 2\alpha\delta_g/nY}. \tag{14}$$

As before, if excess reserves are too large the optimal money stock is smaller than under normal conditions.

The excess demand for government bonds increases their price and decreases the corresponding interest rate i_g. Therefore, the creation of these swap programs results in a negative relationship between B and i_g, where the former responds to changes both in i_g and i_r. The marginal importance of each interest rate will depend on the magnitude of the swap program and the existence and success of the standing facilities available to the private sector for obtaining funding from the central bank. This relationship can be modeled using the following linear specification: [**Is this really needed?**]

$$B = \alpha_0 - \alpha_1 i_r - \alpha_2 i_g. \tag{15}$$

Robustness check

The existence of a limit on the amount of excess reserves held by the banking system on the central bank is robust to their specification in (7). This statement is shown considering that excess reserves are of a smaller magnitude than the variable costs. That is, $ER = \tau Q^s_{B/NB}$ with $0 \leq \tau \leq 1$ on the profit function (7). Under this specification, excess reserves are a fixed proportion of the bank's credit supply and not of the variable costs.

In these cases the optimal money supply is given by

$$M^s = nY\frac{i_c - \delta}{2g} \tag{16}$$

where $g = i_r$ for Scenario 1 and $g = i_g$ for Scenario 2 [$\mathbf{i_p}$ **instead of g?**], while the corresponding equilibrium credit interest rate is

$$i_c^* = \frac{2g\mu + 2g\gamma Y + \delta nY}{nY + 2\alpha g}. \tag{17}$$

Simple algebra shows that for both scenarios the resulting equilibrium interest rate for the credit market is lower than (4) if

$$\tau < \left(\frac{\beta - g}{i_r - \widetilde{i}_r}\right) \frac{2(\mu + \gamma Y - \alpha i_r)}{nY} \tag{18}$$

In equilibrium, this condition is equal to (11) and (13) up to a constant. In this case, the constraint on the level of excess reserves is more binding than before because of the extra term on the right hand side of the equation. Interestingly, for large values of real income the condition can be restated as $\tau < \frac{\beta - g}{i_r - \widetilde{i}_r} \frac{2\gamma}{n}$. This shows the importance of the concentration of the banking sector on the success of UMPs and the sensitivity of the money stock to variations in real income. Correspondingly, the equilibrium money stock is

$$M^* = Q^*_{B/NB} = \frac{\mu + \gamma Y - \alpha\delta}{1 + 2\alpha g/nY}. \tag{19}$$

As before, if condition (18) is violated the quantity of money stock in equilibrium is smaller than in the normal period implying no quantitative effect of the 'unconventional' policy.

3 Empirical Application

The aim of this section is to empirically assess the theoretical relationships between the variables described in Section 2 and provide evidence regarding the existence of a structural break around the collapse of Lehman Brothers. This new regime is identified with the implementation of UMPs.

In particular, the econometric specification used for modeling the long-run relationships between the variables is the VECM representation of a multivariate vector autoregression

(VAR) for $Z_t = (ln\ M_t, i_{c,t}, ln\ B_t, i_{g,t}, i_{r,t}, ln\ Y_t)$, assuming they are $I(1)$ variables that have a common stochastic trend.

$$\Delta Z_t = \mu + AZ_{t-1} + \sum_{j=1}^{p} C_j \Delta Z_{t-p} + u_t \qquad (20)$$

u_t is a $6x1$ unobservable error term, assumed to be a zero-mean independent white noise process with time invariant, positive definite covariance matrix $E(u_t u_t^{'}) = \Sigma_u$. A can be written as the product of two $(6xr)$ matrices $A = ab'$, being $r = rank(A)$ the number of cointegration relationships among the components of Z_t contained in $b'Z_{t-1}$. a and b are referred to as the loading and cointegration matrix, respectively. The former contains the weights attached to the cointegration relationships in the individual equations of the VECM.

The model is estimated for two different subperiods determined by the occurrence of a structural break in the aftermath of Lehman Brothers' collapse in September 2008. This shift is statistically assessed by implementing Chow type tests and recursive estimation of the parameters in the loading matrix for checking the stability along the whole sample.

3.1 Description of the data

The data for the Euro area has been extracted from the ECB Statistical Data Warehouse. It has monthly frequency, covers the period 2004:09-2012:09 and includes base money, working day and seasonally adjusted M2 as the monetary aggregate and the official interest rate for main refinancing operations. The interest rate for bank loans refers to the business sector and a maturity of up to one year. Accordingly, nominal the interest rate for government bonds has been obtained from a Svensson model with continuous compounding and error minimisation for the same maturity. Market prices GDP has been converted to real terms using its corresponding deflator, both series are also working day and seasonally adjusted and have quarterly frequency. For that reason, linear interpolation was required in order to be converted to a monthly frequency.

The source of information for the U.S. is the FRED economic data of the St. Louis FED. The monetary base refers to that monitored by the Board of Governors and is not adjusted for changes in reserve requirements. The monetary aggregate is seasonally adjusted M2 and the official interest rate is the effective one for Federal Funds. Bank prime loans rate, used to price short-term loans, proxies the credit interest rate and the 1-year Treasury constant maturity rate has been used as the interest rate for government debt. Real GDP is seasonally adjusted and has also been converted from a quarterly to a monthly frequency using linear interpolation. The sample period is 2000:12-2012:09.

3.2 Empirical analysis for the Euro area

The cointegrated VECM model relies on the unit root character of the set of variables Z_t. In order to confirm this graphical impression in Figure 2 for the different univariate series considered, we have applied the efficient $DF - GLS$ test proposed by Elliot et al. (1996), choosing the optimal number of lags by the application of the sequential procedure and the modification to the Akaike information criterion (MAIC) in Ng and Perron (2001). Resulting test statistics for two different specifications of the deterministic component are those reported in the two first set of columns in Table 1. The confirm our initial suspicion on the memory of the time series.

In order to estimate the VECM, the Hannan-Quinn and Bayesian information criteria suggest to use one endogenous lag ($p = 1$). Moreover, and in light of the results reported in the two first columns of Table 2, Johansen (1991, 1995)'s trace test establish that the number of cointegration relationships is three ($r = 3$). Against this background, the estimated cointegration relationships are shown in Table 3[3]. As it will be further discussed in the impulse-response functions analysis, the relationships for (the log of) the money stock, the credit interest rate and (the log of) the monetary base have been chosen for identification purposes. They correspond to the long-run equilibria in the credit, interest rate and money markets, respectively. The results obtained from the full sample period are roughly consis-

[3] Results regarding the stationary lags are not reported for sake of space.

tent with the theoretical model, with the exceptions of the positive relationship between the money stock and the official interest rate. Nevertheless, Portmanteau's no autocorrelation test gives us evidence of the presence of some misspecification. For that reason, we have further explored the possibility of the presence of a structural break using the sample-split version of the Chow test. The p-values for its bootstrap version (Candelon and Lütkepohl, 2001) and the period 2007:01-2011:09 are those in Figure 3. It can be observed that the null hypothesis of no break is systematically rejected at the 5% significance level after May 2008. Nevertheless, we will consider February 2009 as the break date in what follows because it is when the value of the test statistic reaches its maximum.

Further evidence of the presence of a structural break is provided in Figure 4, where a recursive estimation of the coefficients in the loading matrix is plotted for the period 2007:09-2012:10. It can be observed that the estimated parameters change around the collapse of Lehman Brothers in October 2008 as information referred to the end of the sample is included in the estimation. These changes mainly affect the cointegration relationship in the credit and money markets and changes in the interest rates. These results lead us to carry out the same analysis for two subperiods covering January 2004 to January 2009 and February 2009 to September 2012, respectively.

Proceeding in that way we observe that, in most cases, the signs of the different equilibrium relationships are consistent with the predictions of our model. After the break the money stock and real income move in opposite directions, suggesting that during this period money supply did not increase as a result of an increase in real income. This change between subsamples is also observed for the relationship between the monetary base and real income. These findings reflect that the stock of money and the monetary base increased to stimulate output markets and not as a result of an increase in economic activity.

It is also interesting to note the lack of statistical significance of the interest rate on government bonds in the credit market equilibrium relationship after the break. Nevertheless, this interest rate has the expected sign for the money market in equilibrium suggesting that a boost in the demand for sovereign bonds is corresponded by an increase in monetary base or, alternatively, that an exogenous increase in monetary base to purchase government bonds is corresponded by a decrease in their yield.

The pass-through from the interest rate of government bonds to that of credir is incomplete and has a negative sign, suggesting some positive correlation between the return on sovereign bonds and the existence of favourable credit conditions. After the break, the relation between these interest rates is positive but the pass-through from is low (0.26). On the contrary, the official rate exhibits an almost one-to-one relationship with the credit interest rate. This equilibrium relationship shows that even after the break the interest rate transmission mechanism works well.

[**Impulse response functions**]

To sum up, the equilibrium dynamics in the credit and monetary markets do not suffer strong changes after the break. The monetary stimulus by the ECB is through the exogenous official rate that exhibits a one-to-one relationship with the credit interest rate. The monetary base reacts to disequilibriums between interest rates and responds to drops in economic activity. The credit interest rate also responds to disequilibriums between interest rates such that positive shocks to the long-run equilibrium imply negative variations. Therefore, the creation of excess reserves does not seem to be a burden for the success of monetary policies focused on the official rate.

3.3 Empirical analysis for the U.S.

The unit root character of the variables referred to the U.S. economy is confirmed both by the time series displayed in Figure 5 and the test statistics in the last two set of columns in Table 1. Also in line with the results for the Euro area, information criteria suggest to include one endogenous lag in the specification of the VECM and Johansen's trace test establishes that there are three cointegration relationships. Moreover, the sample-split Chow test and the recursive estimation of the loading matrix give evidence regarding the presence of a structural break[4]. More interestingly, in this case the supremum of the sample-split

[4] Although these results are not reported in order to save space, they are available from the authors upon request.

Chow test is obtained for September 2008.

The results of the estimation of (20) for the full sample period and the two subsamples are reported in Table 4. The estimated cointegration relationships link the monetary base and the stock of money with real income. More specifically, increases in real income and monetary variables go hand-in-hand. During the whole period the money stock is exogenous but responds to disequilibriums in the money market after the break. Furthermore, shocks to the money market have an impact on the credit market. [**I cannot find these results...**]

The money market equilibrium relationship also differs across periods as the official rate and real income are not statistically significant after the break. This cointegrating relationship reveals that the monetary base only responds to movements in the sovereign interest rate in the second subsample. Alternatively, it can be stated that the interest rate of government bonds responds to movements in the monetary base. The analysis of the coefficients in the loading matrix reported in Table 5 confirms these findings and shows that, during this period, both variables respond only to disequilibriums in the money market.

The equilibrium dynamics of the credit interest rate are somehow surprising. Before the break there is a one-to-one relationship between the official and the credit interest rates, being the latter the driver of disequilibriums in the money market. Nonetheless, the relationship between the interest rate for credit and the rest of variables is very weak after the break. More specifically, the pass-through from the official and the government bonds rates to the interest rate of credit is almost null. However, the statistical significance of the loading coefficients suggest that the credit interest rate responds to disequilibriums in the three markets.

These empirical findings suggest that monetary authorities operated in the economy after the break through movements in the government interest rate and the monetary base that are transmitted into real income through the occurrence of shocks in both the credit market and the money market. Surprisingly, these shocks to the money market have a negative effect on the credit market as stated by the negative signs of the loading factors corresponding to the change in the money stock. This phenomenon can explain the fall in the money multiplier observed during this period, see Figure 8. The equilibrium credit interest rate hardly responds to stimulus in interest rates. However, variations in the credit interest rate can be predicted by shocks to the three equilibrium relationships. The positive sign of the loading coefficients suggest that interest rates increase after positive shocks to the money supply and monetary base. These results provide indirect empirical evidence of the existence of accumulation of excess reserves by banks after the occurrence of monetary stimulus driven for this economy by decreases of the government interest rate and, thus, interpreted with the existence of swap programmes as discussed in Section 2.

4 Conclusions

In the face of severe dislocations in financial markets and profound declines in economic activity, several central banks have taken extraordinary monetary measures beyond lowering short-term policy rates. The effectiveness of these 'unconventional' measures as monetary stimulus has been object of debate since their inception with the aim of restoring the well functioning of the financial system. In this article we have presented a simple model that studies the relationship between the money stock and the credit interest rate in equilibrium. This model is refined to incorporate the effect of 'unconventional' monetary policies in the profit function of banks and their balance sheets. The theoretical analysis shows that the issuance of lending facilities by central banks is more successful in reducing the credit interest rate than programs based on swapping 'toxic' assets for sovereign bonds. The relative success of these measures depends on the equilibrium relationship between the official rate and the interest rate on the government bond. We also note the existence of a limit in the accumulation of excess reserves by the private sector beyond which these 'unconventional' measures are counterproductive, that is, they lead to rises in the credit interest rate. Nevertheless, these rises in interest rates are accompanied by decreases in the money stock and hence are expected not to be inflationary.

The empirical study supports the existence of a ‘normal’ period and a ‘distress’ regime that commences around the collapse of Lehman Brothers. The estimation of a VECM for studying the long-run equilibrium dynamics between monetary variables, interest rates and real GDP confirms the theoretical relationships derived in the equilibrium model. More specifically, the empirical results for the Euro area and the U.S. suggest that the former economy is more responsive to manipulation of the official interest rate while the latter to manipulation of the government interest rate. These differences can be identified with ‘conventional’ measures for the Euro area and ‘unconventional’ measures for the U.S. In fact, the statistical analysis suggests that the latter are in line with the creation of swap programmes between government bonds and ‘toxic’ assets. We also obtain indirect evidence of the importance excess reserves holdings by banks for the U.S. economy but not for the Euro area.

References

[1] Andrés, J., D. López-Salido and E. Nelson, 2009. Money and the natural rate of interest: structural estimates for the United States and the euro area. Journal of Economic Dynamics and Control 33(3), 758-776.

[2] Baltensperger, E., 1980. Alternative approaches to the theory of the banking firm. Journal of Monetary Economics 6(1), 1-37.

[3] Beck, G. and V. Wieland, 2007. Money in monetary policy design: a formal characterization of ECB style cross checking. Journal of the European Economic Association 5(2-3), 524-533.

[4] Bernanke, B., 2006. Monetary aggregates and monetary policy at the Federal Reserve: a historical perspective. Speech delivered at the Fourth ECB Central Banking Conference on the role of Money.

[5] Boivin, J., M. T. Kiley and F. S. Mishkin, 2011. How has the monetary transmission mechanism evolved over time? In: Handbook of Monetary Economics, Vol. 3A (B. M. Friedman and M. Woodford, eds.). Chapter 8, 369-422.

[6] Bofinger, P. and S. Debes, 2010. A primer on unconventional monetary policy. CEPR Discussion Paper No. 7755.

[7] Borio, C. and P. Disyatat, 2010. Unconventional monetary policies: an appraisal. Manchester School 78(s1), 53-89.

[8] Candelon, B. and H. Lütkepohl, 2001. On the reliability of Chow-type tests for parameter constancy in multivariate dynamic models. Economics Letters 73(2), 155-160.

[9] Clarida, R., J. Galí and M. Gertler, 1999. The science of monetary policy: a New Keynesian perspective. Journal of Economic Literature 37(4), 1661-1707.

[10] Cosimano, T., 1988. The banking industry under uncertain monetary policy. Journal of Banking and Finance 12(1), 117-139.

[11] Durré, A. and H. Pill, 2012. Central bank balance sheets as policy tools. BIS Paper No. 66m.

[12] Elliott, G., T. J. Rothenberg and J. H. Stock, 1996. Efficient tests for an autoregressive unit root. Econometrica 64(4), 813-836.

[13] Freixas, X. and J. C. Rochet, 2008. Microeconomics of Banking. MIT Press.

[14] Johansen, S., 1991. Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregression models. Econometrica 59(6), 1551-1580.

[15] Johansen, S., 1995. Likelihood-based inference in cointegrated vector autoregressive models. Oxford University Press.

[16] Joyce, M., D. Miles, A. Scott and D. Vayans, 2012. Quantitative easing and unconventional monetary policy - An introduction. Economic Journal 122, F271-F288.

[17] Krishnamurthy, A. and A. Vissing-Jorgensen, 2011. The effects of quantitative easing on interest rates. Brookings Papers on Economic Activity 43(1), 215-287.

[18] Krugman, P. R., 1998. It's baaack: Japan's slump and the return of the liquidity trap. Brookings Papers on Economic Activity 49(2), 137-206.

[19] Lenza, M., H. Pill and L. Reichlin, 2010. Monetary policy in exceptional times. Economic Policy 25(4), 297-339.

[20] McCallum, B. T., 2000. Alternative monetary policy rules: a comparison with historical settings for the United States, United Kingdom and Japan. Federal Reserve Bank of Richmond Economic Quarterly 86(1), 49-79.

[21] McCallum, B. T., 2008. How important is money in the conduct of monetary policy? A comment. Journal of Money, Credit and Banking 40(8), 1783-1790.

[22] McCallum, B. T. and E. Nelson, 2011. Money and inflation: some critical issues. In: Handbook of Monetary Economics, Vol. 3A (B. M. Friedman and M. Woodford, eds.). Chapter 3, 97-153.

[23] McGough, B., G. D. Rudebusch and J. C. Williams, 2005. Using a long-term interest rate as the monetary policy instrument. Journal of Monetary Economics 52(5), 855-879.

[24] Nelson, E., 2002. Direct effects of base money on aggregate demand: theory and evidence. Journal of Monetary Economics 49(4), 687-708.

[25] Ng, S. and P. Perron, 2001. Lag length selection and the construction of unit root tests with good size and power. Econometrica 69(6), 1519-1554.

[26] Niehans, J., 1978. The Theory of Money. The John Hopkins University Press.

[27] Orr, D. and W. G. Mellon, 1961. Stochastic reserve losses and expansion of bank credit. American Economic Review 51(4), 614-623.

[28] Reifschneider, D. and J. C. Williams, 2000. Three lessons for monetary policy in a low inflation era. Journal of Money, Credit and Banking 32(4), 936-966.

[29] Reynard, S., 2007. Maintaining low inflation: Money, interest rates, and policy stance. Journal of Monetary Economics 54(5), 1441–1471.

[30] Svensson, L. E. O., 2001. The zero bound in an open-economy: a foolproof way of scaping from a liquidity trap. Monetary and Economic Studies 19(S-1), 277-312.

[31] Taylor, J.B., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Series on Public Policy 39(1), 195-214.

[32] Woodford, M., 2008. How important is money in the conduct of monetary policy? Journal of Money, Credit and Banking 40(8), 1561-1598.

Appendix. Tables and Figures

Table 1: Unit root testing for the univariate time series.

	Euro area				United States			
	Constant		Trend		Constant		Trend	
	lags	DF-GLS	lags	DF-GLS	lags	DF-GLS	lags	DF-GLS
B	6	1.75	8	−3.20**	4	0.66	9	−1.42
$M2$	0	−0.01	6	−1.54	9	1.82	4	−1.92
Y	1	−1.06	1	−2.16	1	0.53	1	−1.98
i_r	2	−1.34	2	−1.64	8	−1.29	8	−3.45**
i_c	8	−1.91*	8	−2.19	5	−0.58	8	−2.98*
i_g	6	−1.47	6	−1.76	8	−0.66	8	−2.19

Note: DF-GLS is the unit root test proposed by Elliot et al. (1996). The lag length is determined using the modification of Ng and Perron (2001) to the Akaike information criterion (MAIC). * and ** denote rejection of the unit root null at the 10 and 5% level of significance, respectively. Sample period is 2004:09-2012:09 for the Euro area and 2000:12-2012:09 for the U.S.

Table 2: Cointegration rank testing for the multivariate system.

	Euro area (lags=1)		United States (lags=2)	
Null hypothesis	LR	p-value	LR	p-value
r=0	401.85	0.00	232.42	0.00
r=1	225.01	0.00	134.39	0.00
r=2	85.96	0.00	75.12	0.00
r=3	30.08	0.16	27.42	0.27
r=4	11.92	0.46	13.88	0.30
r=5	2.81	0.62	4.54	0.35

Note: LR is the trace test proposed by Johansen (1995). The deterministic term is an intercept. The number of lags is determined by the Bayesian information criterion (BIC). Sample period is 2004:09-2012:09 for the Euro area and 2000:12--2012:09 for the U.S.

Table 3: Estimated long-run market equilibrium (cointegration) relationships for the Euro area.

	All sample (2004:09-2012:09)			Subsample 1 (2004:09-2009:01)			Subsample 2 (2009:02-2012:09)		
	Credit	Rates	Money	Credit	Rates	Money	Credit	Rates	Money
$M2$	1.00	–	–	1.00	–	–	1.00	–	–
i_c	–	1.00	–	–	1.00	–	–	1.00	–
B	–	–	1.00	–	–	1.00	–	–	1.00
i_g	0.30***	−0.12*	1.49***	0.03***	0.67***	−0.13***	0.02	−0.26**	0.60***
	(0.04)	(0.07)	(0.34)	(0.01)	(0.09)	(0.02)	(0.01)	(0.13)	(0.16)
i_r	−0.09**	−0.51***	−0.24	0.07***	−1.12***	0.24***	0.14***	−1.28***	1.10***
	(0.04)	(0.07)	(0.32)	(0.01)	(0.12)	(0.02)	(0.03)	(0.27)	(0.34)
Y	−5.74***	−2.89**	−15.74*	−5.80***	−6.94***	−6.98***	1.25**	−32.54***	16.80***
	(0.75)	(1.15)	(5.63)	(0.26)	(2.64)	(0.56)	(0.57)	(5.05)	(6.40)
Portmanteau test (12)		428.63			363.45			362.21	
p-value		0.04			0.69			0.71	
Portmanteau test (6)		247.66			183.96			190.11	
p-value		0.00			0.11			0.06	

Note: Estimation results from a VECM with an intercept as the deterministic component, 3 cointegration relationships and 1 endogenous lag. Standard errors in parentheses. *, ** and *** denote statistical significance at the 10, 5 and 1% level, respectively.

Table 4: Estimated long-run market equilibrium (cointegration) relationships for the United States.

	All sample (2000:12-2012:09)			Subsample 1 (2000:12-2008:12)			Subsample 2 (2009:01-2012:09)		
	Credit	Rates	Money	Credit	Rates	Money	Credit	Rates	Money
$M2$	1.00	–	–	1.00	–	–	1.00	–	–
i_c	–	1.00	–	–	1.00	–	–	1.00	–
B	–	–	1.00	–	–	1.00	–	–	1.00
i_g	1.99***	1.21***	10.69***	0.27***	0.08***	0.15***	−1.67***	0.01	2.98***
	(0.25)	(0.16)	(1.34)	(0.04)	(0.02)	(0.02)	(0.30)	(0.05)	(0.62)
i_r	−1.81***	−2.11***	−9.76***	−0.24***	−1.08***	−0.13***	0.88**	0.08*	1.11
	(0.23)	(0.15)	(1.24)	(0.04)	(0.02)	(0.02)	(0.42)	(0.07)	(0.86)
Y	3.12***	3.22***	27.03***	−1.51***	0.22*	−1.43***	−8.34***	−0.04	3.43
	(1.10)	(0.00)	(5.91)	(0.22)	(0.12)	(0.13)	(1.49)	(0.26)	(3.05)
Portmanteau test (12)		481.60			398.72			359.05	
p-value		0.00			0.22			0.75	
Portmanteau test (6)		242.83			428.51			194.29	
p-value		0.00			0.04			0.04	

Note: Estimation results from a VECM with an intercept as the deterministic component, 3 cointegration relationships and 1 endogenous lag. Standard errors in parentheses. *, ** and *** denote statistical significance at the 10, 5 and 1% level, respectively.

Table 5: Estimation of the VECM loading matrix for the United States.

	All sample (2000:12-2012:09)			Subsample 1 (2000:12-2008:12)			Subsample 2 (2009:01-2012:09)		
	Credit	Rates	Money	Credit	Rates	Money	Credit	Rates	Money
$\Delta M2$	-0.07^{***}	0.02^{*}	0.01^{***}	-0.02	-0.01	0.02	-0.04^{*}	0.03	-0.02^{**}
	(0.02)	(0.01)	$(4{\cdot}E-03)$	(0.02)	(0.01)	(0.03)	(0.02)	(0.02)	(0.01)
Δi_c	-0.33	-0.78^{***}	0.18^{**}	0.10	-1.75^{***}	2.45	0.30^{***}	-0.70^{***}	0.15^{***}
	(0.46)	(0.19)	(0.09)	(0.54)	(0.40)	(0.80)	(0.06)	(0.06)	(0.02)
B	0.12	0.01	-0.02	0.15^{***}	-0.07^{**}	-0.21^{***}	-0.20	0.28^{**}	-0.13^{**}
	(0.12)	(0.05)	(0.02)	(0.04)	(0.03)	(0.06)	(0.13)	(0.13)	(0.06)
Δi_g	-0.36	-0.21	0.10	0.32	-0.61	0.43	-0.26	-0.20	-0.21^{***}
	(0.81)	(0.33)	(0.16)	(1.02)	(0.75)	(1.51)	(0.16)	(0.16)	(0.07)
Δi_r	-0.71	-0.16	0.18	-0.61	-0.62	3.05^{***}	-0.40^{***}	-0.33^{***}	-0.15^{***}
	(0.57)	(0.23)	(0.11)	(0.59)	(0.43)	(0.88)	(0.00)	(0.11)	(0.04)
ΔY	$5{\cdot}E-03$	$5{\cdot}E-03^{**}$	$1{\cdot}E-03$	-0.01	$-5{\cdot}E-03$	0.02^{**}	0.01^{***}	-0.01^{*}	$5{\cdot}E-03^{***}$
	$(6{\cdot}E-03)$	$(2{\cdot}E-03)$	$(1{\cdot}E-03)$	(0.01)	$(4{\cdot}E-03)$	(0.01)	$(4{\cdot}E-03)$	$(4{\cdot}E-03)$	$(2{\cdot}E-03)$

Note: Estimation results from a VECM with an intercept as the deterministic component, 3 cointegration relationships and 1 endogenous lag. Standard errors in parentheses. *, ** and *** denote statistical significance at the 10, 5 and 1% level, respectively.

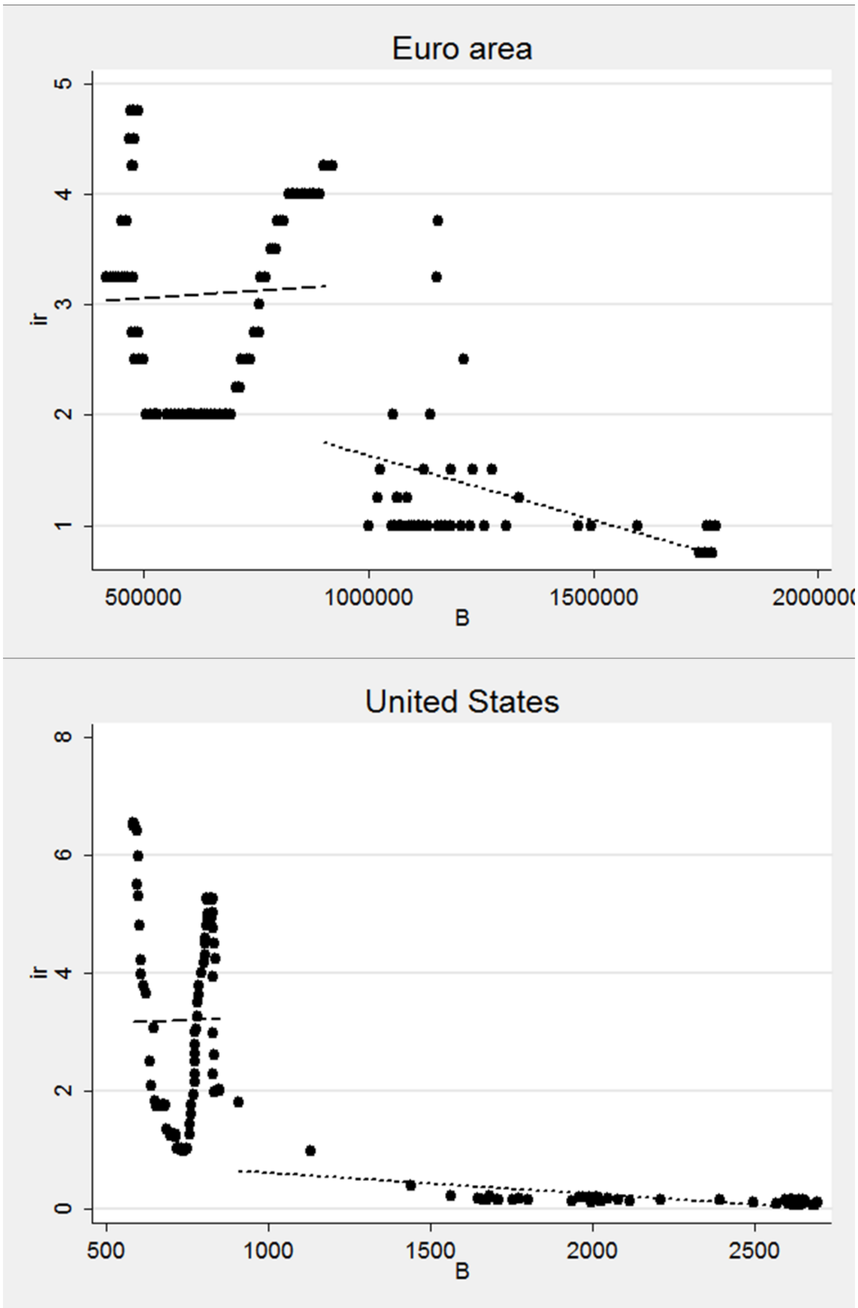

Figure 1: Relationship between the nominal monetary base and the official interest rate, 2000:07-2012:10. Fitted lines refer to the periods before (dashed) and after (dotted) the collapse of Lehman Brothers.

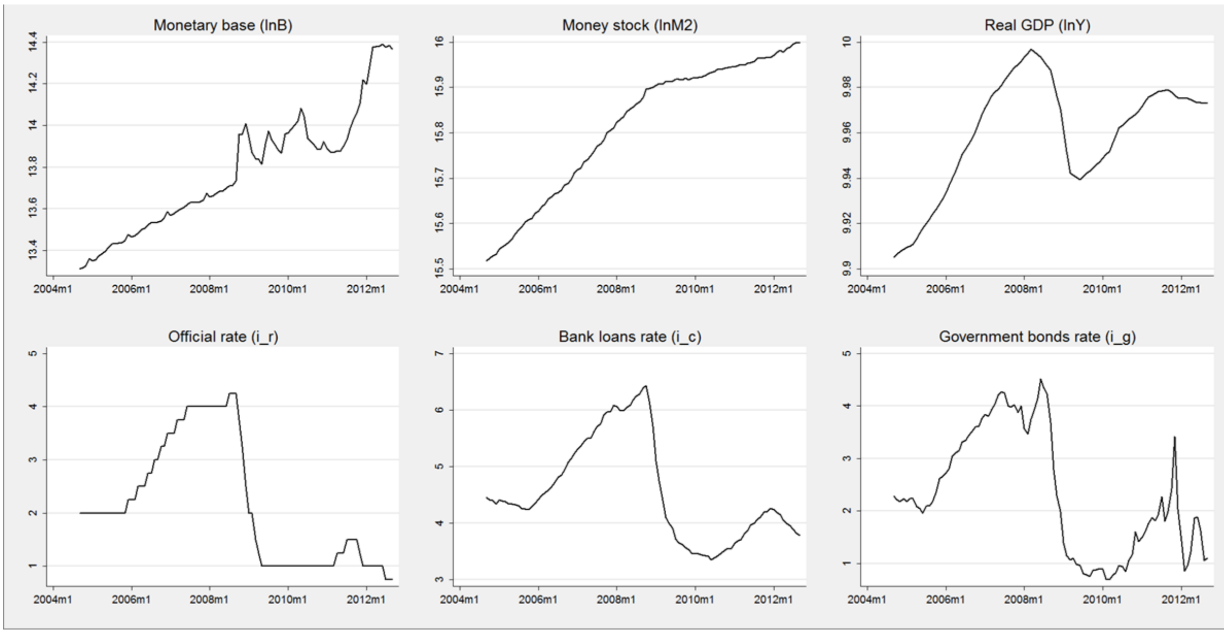

Figure 2: Macroeconomic and monetary variables for the Euro area, 2004:09-2012:09.

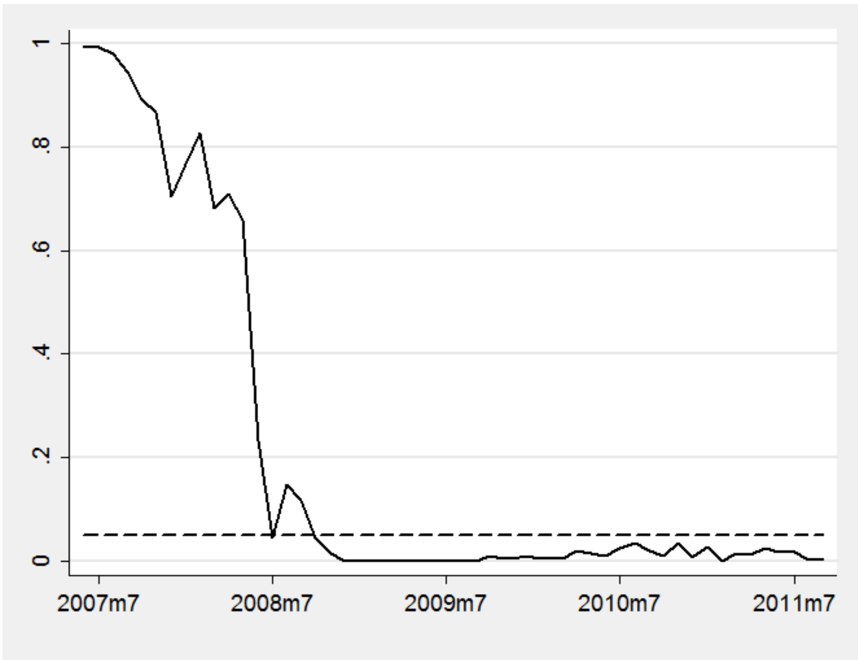

Figure 3: Bootstrap p-values (500 replications) for the sample-split Chow test. Euro-area, 2007:01-2011:09.

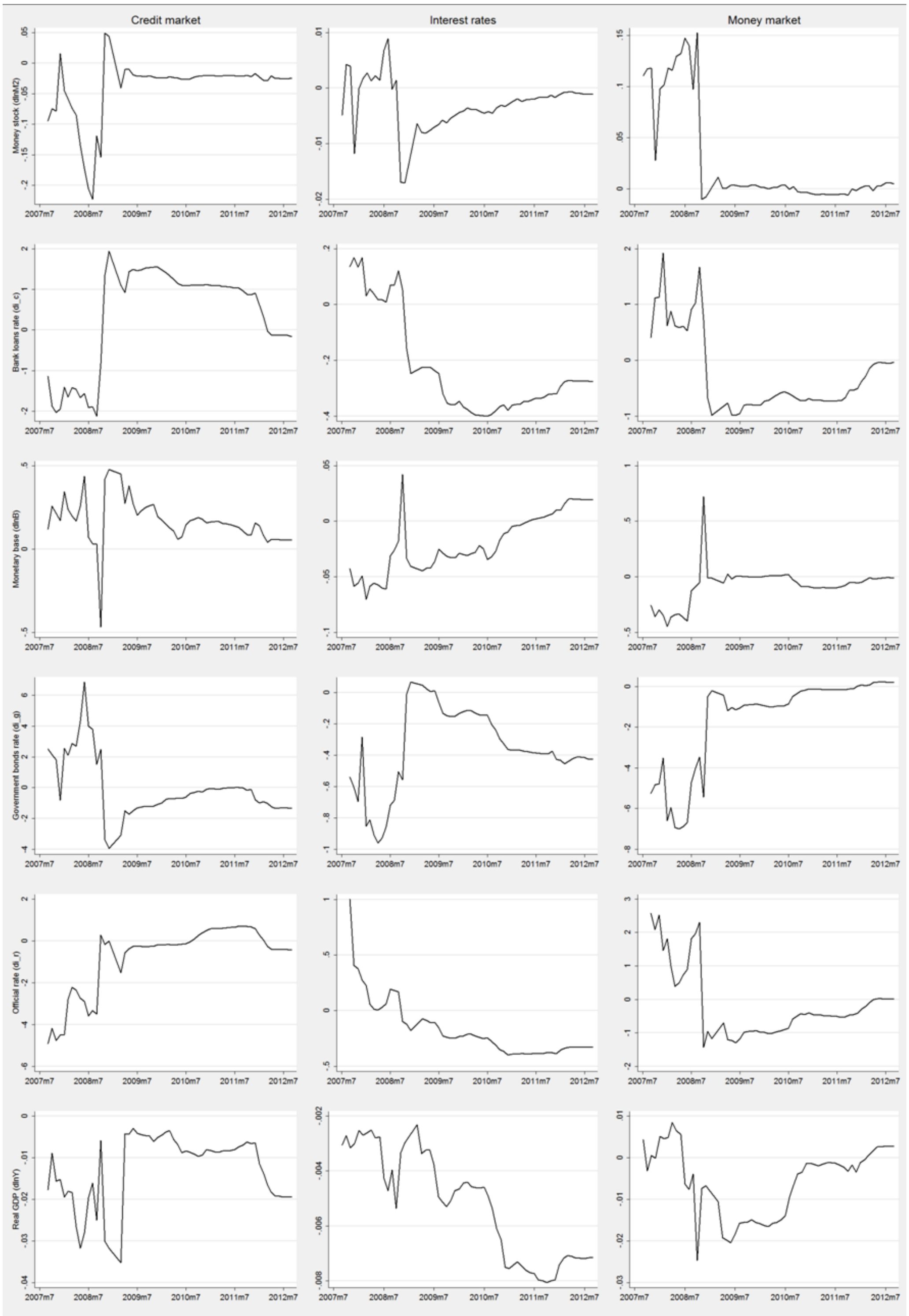

Figure 4: Recursive estimation of the loading coefficients for the Euro zone, 2007:09-2012:10.

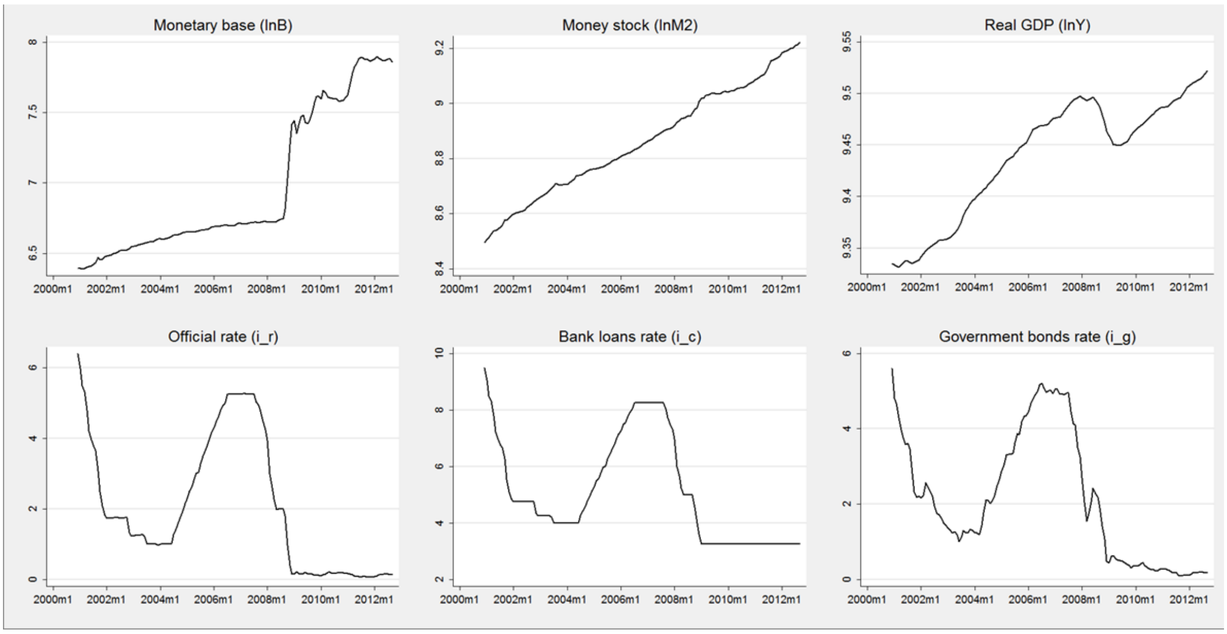

Figure 5: Macroeconomic and monetary variables for the U.S., 2000:12-2012:09.

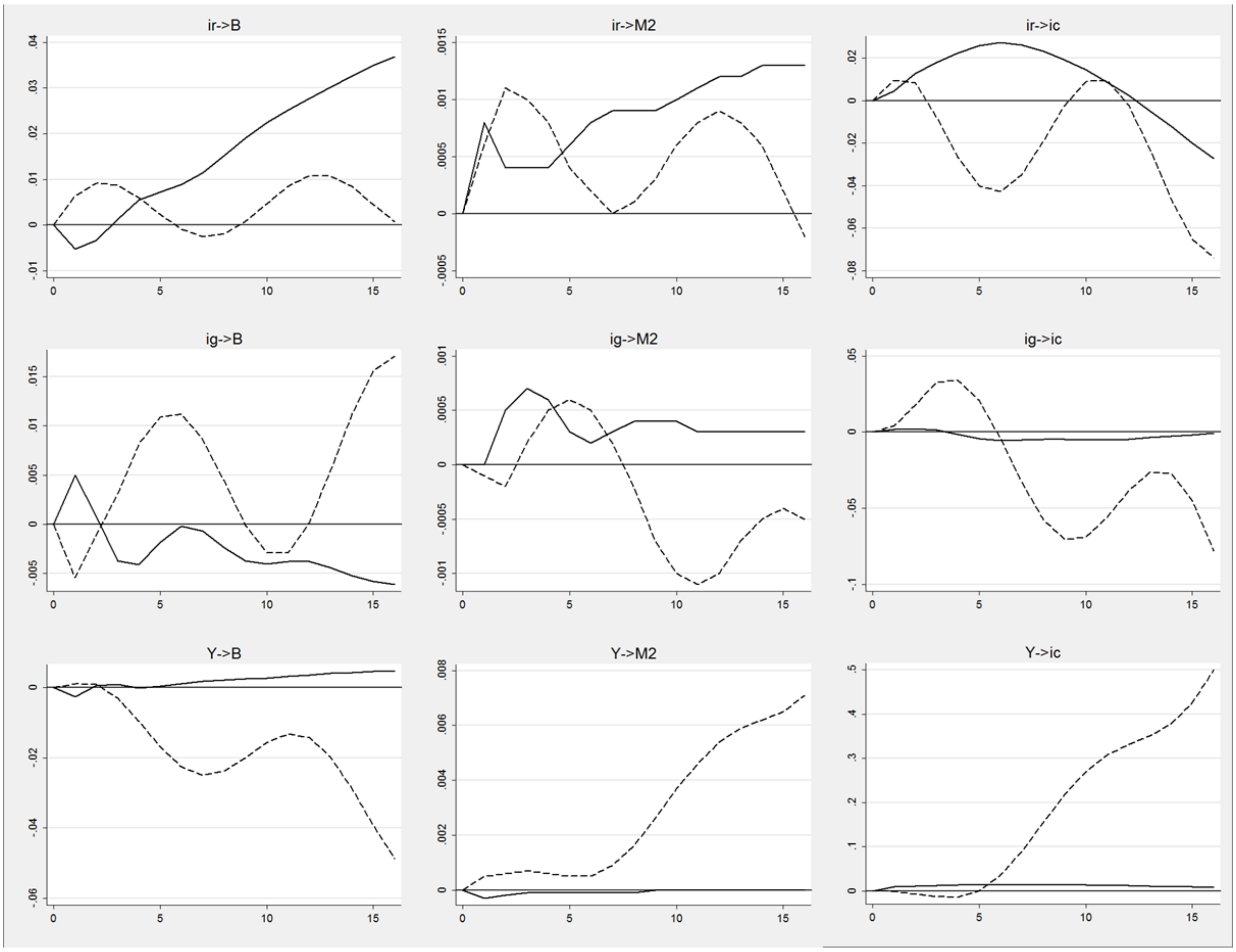

Figure 6: Impulse response functions for the Euro area. Before (dashed) and after (solid) the structural break.

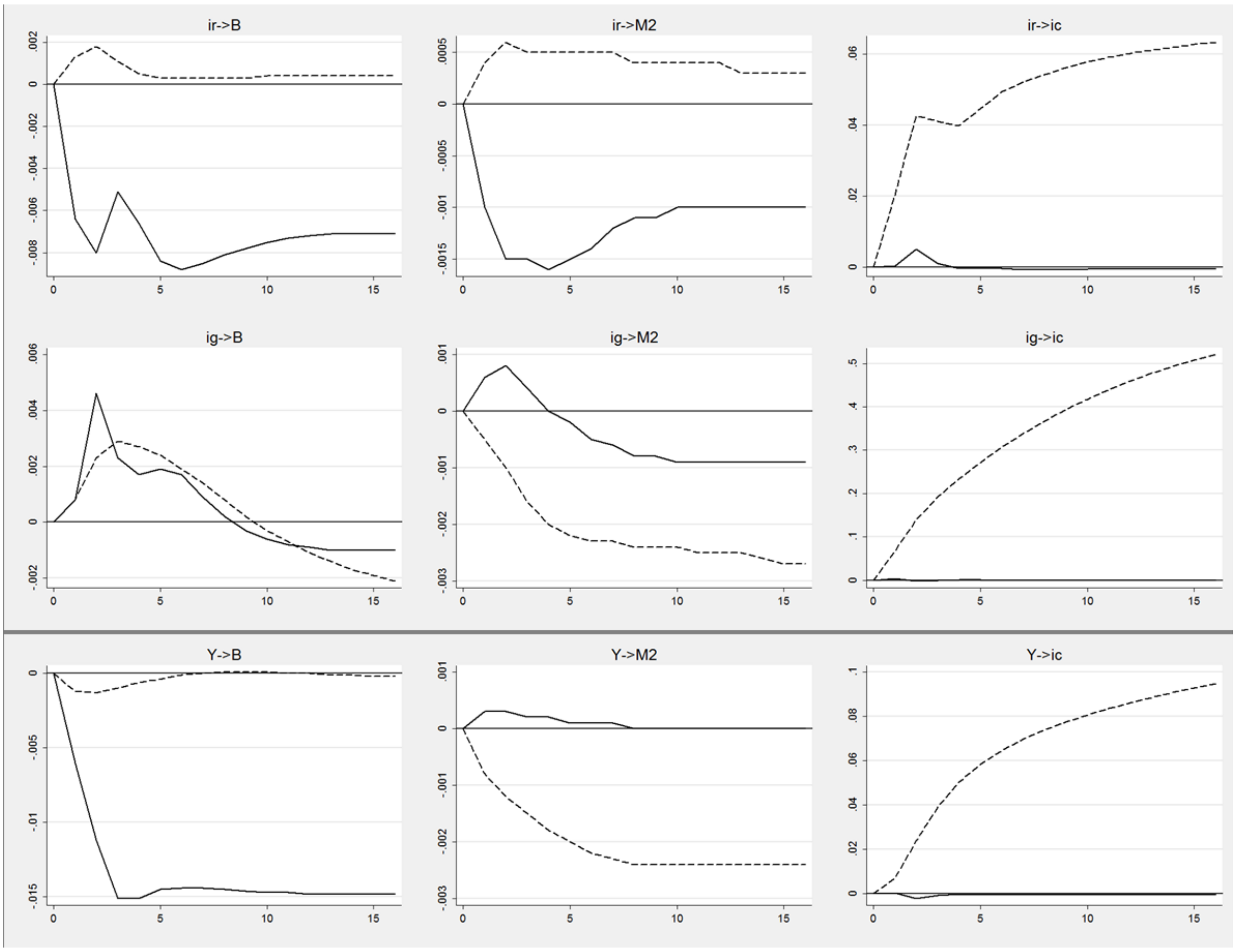

Figure 7: Impulse response functions for the U.S. Before (dashed) and after (solid) the structural break.

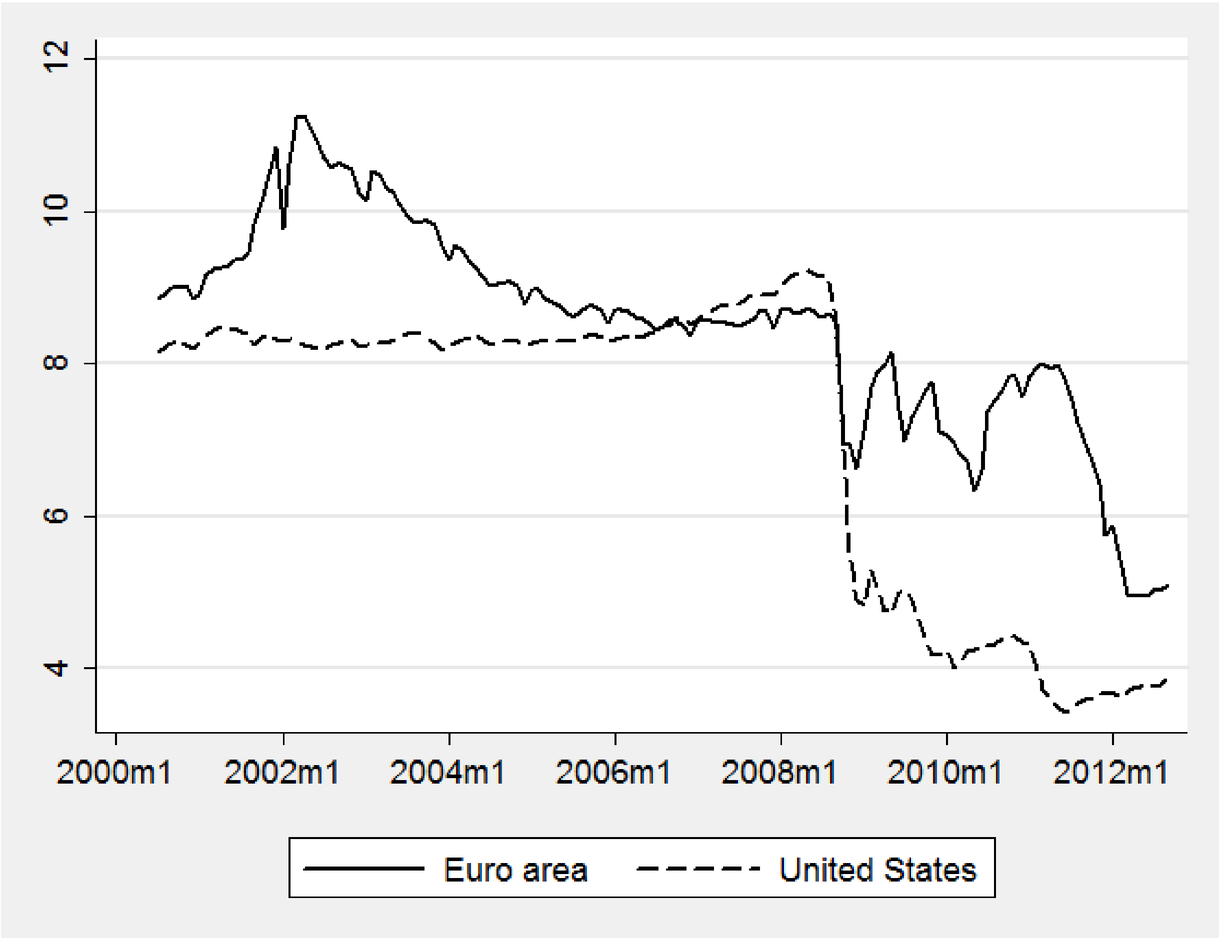

Figure 8: Evolution of the money multiplier, 2000:07-2012:10.