Transmission of monetary policy in the United States and the Eurozone in times of expansion and crisis.

Fructuoso Borrallo Egea
European Central Bank
Luis Ángel Hierro
Universidad de Sevilla

ABSTRACT

In this work, the effectiveness of monetary policy and its transmission channels are analysed before and after the 2007 economic crisis in the United States and the Eurozone by using a VAR model. We find that, in the United States, conventional monetary policy before the crisis and unconventional monetary policy after have been effective, with special emphasis on the "risk channel". In the Eurozone, monetary policy was also effective before the crisis but with a preponderance of the "credit channel". Once the crisis erupted, the transmission mechanisms changed in the Eurozone and unconventional monetary policy remained effective only at the start of the crisis; the risk channel then became the effective transmission mechanism.

1. Introduction

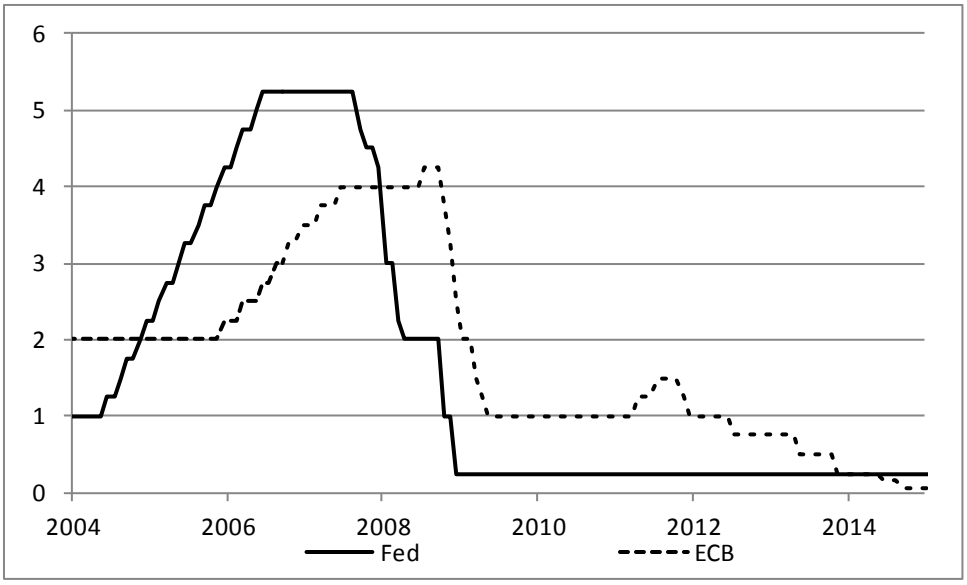
Following the suspension of three investment funds in August 2007 by BNP Paribas, the financial markets suffered from acute strain that reached its peak with the collapse of Lehman Brothers in September 2008. Central banks, including the Federal Reserve (Fed) and the European Central Bank (ECB), were forced to act, initially injecting huge amounts of liquidity into the banking system and later reducing the interest rates to historical lows (Figure 1). When interest rates hit the zero lower bound, central banks initiated a considerable monetary expansion.

Figure 2 shows how the monetary base was affected by those expansive measures and Figure 3 displays the total assets of the balance sheet of the Fed and of the ECB relative to GDP in order to appreciate the size of the expansion by relating it to the real economy. Before the crisis, the monetary base in USA changed slowly, however, after the eruption of the crisis, the Fed systematically increased the size of its balance sheet by introducing liquidity programs and quantitative easing, which involved the purchase of agency bonds, Mortgage-Backed Securities, and long-term Treasury bonds. As a result, the balance sheet of the Fed increased from 6% to nearly 30% of GDP.

The rate of expansion of the balance sheet of the ECB has been less constant than that of the Fed. After the introduction of the new procedure for auctions, the *Fixed Rate Full Allotment*, an increase of the size of the ECB balance sheet to GDP could be observed and was then held approximately constant. However, at the end of 2011 and the beginning of 2012, the most important change in the monetary base and in the total assets took place through the auctions of the Long-Term Refinancing Operations (LTRO) maturing in 3 years. Those operations vastly increased the liquidity and the size of the balance sheet, which amounted to more than 30% of GDP. It was a temporary increase however; after 2013, the balance sheet started to diminish due to the repayment of these loans by the financial entities, and finally it returned to 20% of GDP.

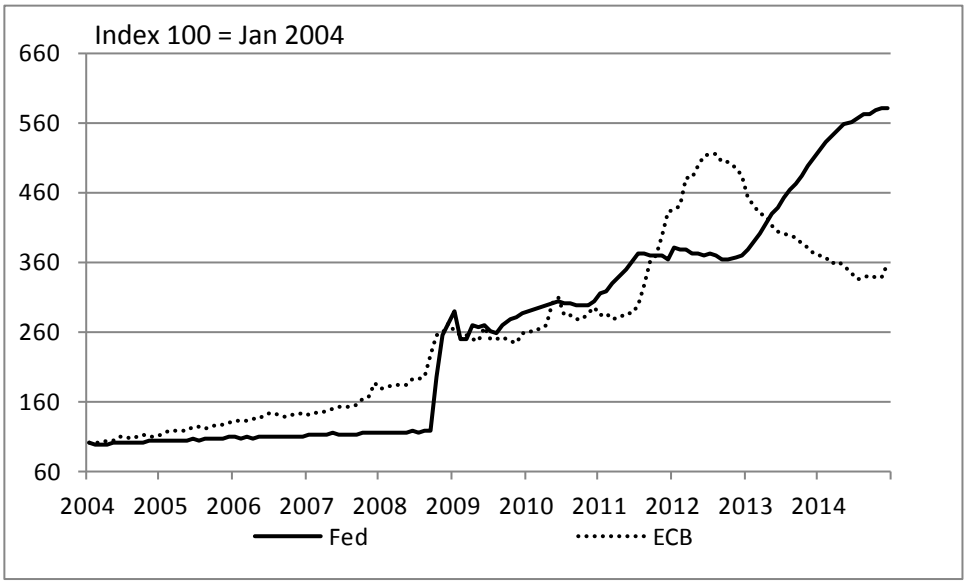
In effect, the increase of the balance sheet of the ECB was temporary and dependent on the decisions regarding the repayment of the loans made by banks, whereas the increase of the balance sheet of the Fed was permanent or at least remained until there was an explicit change in monetary policy. This particular way of expanding the monetary base forced banks to lend to families and firms with a smaller maturity than the financing received through the ECB, and could therefore have led to a reduced effectiveness of the monetary expansion on the real economy.

FIGURE 1. Evolution of the interest rates in the United States and the Eurozone



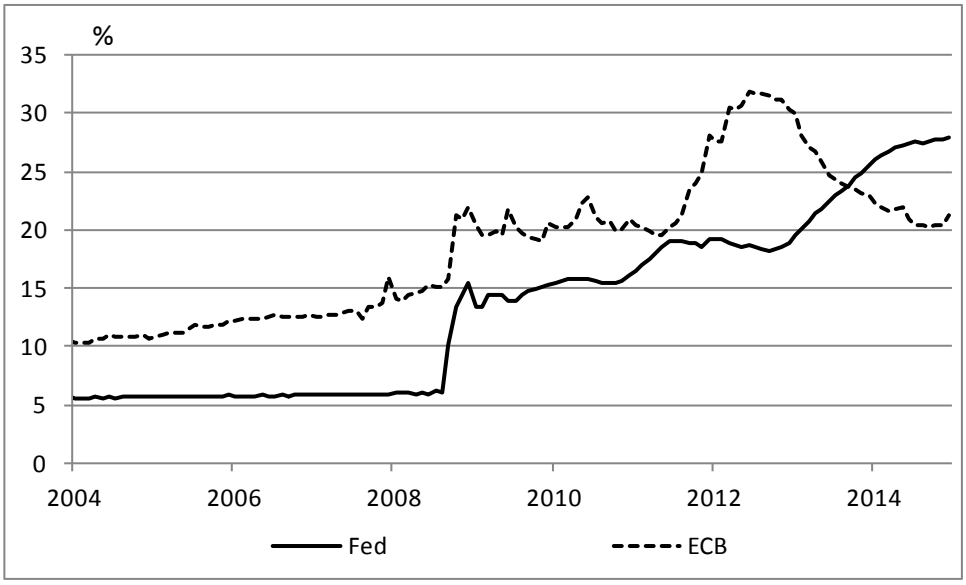
Source: Authors' own based on data from the Federal Reserve and the European Central Bank

FIGURE 2. Evolution of the monetary base in the United States and the Eurozone



Source: Authors' own based on data from the Federal Reserve and the European Central Bank

FIGURE 3. Evolution of the size of the balance sheet of the Federal Reserve and of the European Central Bank with respect to the GDP of each area of currency



Source: Authors' own based on data from the Federal Reserve and the European Central Bank

During the crisis, in the US, research has focused on studying the very short-term effects of the Federal Reserve monetary policy measures on financial indicators (Krishnamurthy and Vissing-Jorgensen, 2011; Gagnon, Raskin, Remache and Sack, 2011; and Wright, 2012, among others), while in the Eurozone, researchers have sought to determine whether the ECB measures increased the volume of loans (Lenza, Pill and Reichlin, 2010; and Peersman, 2011, among others). However, no study in the literature compares the effectiveness of the transmission channels before and after the start of the crisis.

This work studies the transmission of monetary policy in the United States and the Eurozone in order to discover whether the transmission channels have changed with the arrival of the financial crisis and with the application of unconventional measures by its monetary authorities. In the first place, we study the relative importance of the various transmission channels for the conventional monetary policy during the period previous to the financial crisis and for the unconventional policy after the latter had begun, both for a permanent expansion of the balance sheet, as in the case of the Fed, and for a transitory expansion, as in the case of the ECB.

A great number of monetary policy transmission channels have been identified (Boivin, Kiley and Mishkin, 2010), of which we focus on two: the risk-taking channel or simply the *risk channel*, that is, expansive monetary policy provides an incentive for risk-taking of the agents (Altunbas, Gambacorta and Marques-Ibanez, 2014), whose study has grown in importance after the crisis began, and the *credit channel*, which indicates the special role of the banks in lending to families and firms (Bernanke and Getler, 1995; Jiménez, Ongena, Peydró and Saurina, 2012).

By using a VAR model, we conclude that both conventional and unconventional monetary policy in the United States stimulated economic growth, with the risk channel as the most important factor. In the Eurozone, conventional monetary policy was effective and was transmitted fundamentally through the credit channel, but the expansion of the balance sheet after the start of the crisis was only effective at the beginning of the crisis. Moreover, it was transmitted paradoxically through the risk channel, despite the fact that the mechanism employed for said expansion was in terms of the injection of liquidity into the banking system and not via the purchase of assets in the financial markets destined to reduce the spread of risk.

This work is structured as follows. The following section shows a sample of the empirical literature regarding the effects of monetary policy. The third section contains the methodology. In the fourth section, the results are presented, and in the fifth, the corresponding implications of economic policy are extracted and conclusions are drawn.

2. Related literature

The controversy surrounding the effects of monetary policy is traditional in economic thinking. There are several empirical studies that find a decrease in economic activity after an exogenous monetary contraction (Christiano, Eichenbaum and Evans, 1999; Gambetti, 1999; Bernanke and Blinder, 1992; Canova and Nicolo, 2002; Roberts, 1993; Faust, 1998 for the United States; and Boivin, Giannoni and Mojon, 2009, and Weber, Gerke and Worms, 2011, for the Eurozone), although there are others (Leeper, Sims and Zha, 1996; Kim, 1999; Uhlig, 2005) who conclude that this effect is small and even insignificant.

The study of the effectiveness of monetary policy is unarguably associated to the analysis of its transmission channels. Boivin, Kiley and Mishkin (2010) divide these channels into two groups: those associated to the neoclassical cost of capital, and the *credit view.*

The first group of channels is then subdivided into the investment channel, consumption channel, and external trade channel. According to empirical evidence, the investment channel is the most important due to the effect of the interest rate on capital cost and on Tobin's *q.* Those effects have been modelled by Reifschneider, Tetlow and Williams (1999) and Fagan, Henry and Mestre (2005) in the first case, and by Edge, Kiley and Laforte (2007) and Christoffel, Coenen, Warne (2008) in the second. Endut, Morley and Tien (2015) state that this channel was the main transmission mechanism during the Great Moderation in the United States.

The consumption channel, composed of the wealth effect and the intertemporal substitution effect, is not found to be significant as a monetary policy transmission channel in previous work

(Catte, Girourard, Price and Andre, 2004; Smets, 1995; Hall, 1988). Moreover, the external trade channel, or the exchange rate channel, is only important in small and open economies, except if the uncovered interest parity condition is imposed (Taylor, 1993; Smets, 1995; Bryant, Hooper and Mann, 1993).

The banking sector is considered to be of major importance in the transmission of monetary policy by the second group of transmission mechanisms. The most significant mechanism here is the credit channel: banks extend loans to borrowers otherwise unable to obtain funds in the financial markets due to problems of asymmetric information against which the banks are specialized. Banks are specialized in managing the transaction costs that emanate from this asymmetry. Studies by Bernanke and Blinder (1992), Gertler and Gilchrist (1993, 1994), Kasyhap and Stein (1995), and Peek and Rosengren (1997) find evidence pointing to the relevance of this channel, whereas Romer and Romer (1990), Ramsey (1993), and Carpenter and Demilrap (2010) dispute these findings.

Other non-neoclassical channels include: the bank capital channel, which considers that the capital-to-assets ratio may influence the concession of financing; and the borrower balance sheet channel, according to which monetary policy affects the value of collateral on loans and therefore the amount of the loans. These channels have been studied in previous work, such as that by Kishan and Opiela (2006) and by Curdia and Woodford (2010).

There are numerous other topics related to the transmission of monetary policy. Certain authors have proposed the role of the long-term interest rate, although, according to the evidence available, it cannot be considered to be a transmission channel (Bagliano and Favero, 1998). The denominated liquidity effect, which establishes that the creation of new money would increase liquidity through an increase in the supply of loanable funds and would reduce the interest rate, has also been considered. There is favourable evidence for the existence of this effect in Leeper and Gordon (1992), Strongin (1995), and Hamilton (1996), and unfavourable evidence in Eichenbaum (1992).

The majority of studies on the effectiveness of monetary policy have focused on the study of conventional monetary policy. However, following the financial turmoil in 2007 and the introduction of unconventional measures, the effects of this new kind of policy have become the object of study[1]. Baumeister and Benati (2013), Chung, Laforte, Reifschneider and Williams (2011), Chen, Curdiá and Ferrero (2012), and Engen, Laubach and Reifschneider (2015) find that the monetary policy applied by the Fed has contributed towards economic growth, although there is no consensus on its quantification. A similar conclusion is reached in the work of Peersman (2011), Ciccarelli, Maddaloni and Peydró (2013), and Darracq-Paries and De Santis (2015) for the Eurozone: the monetary policy

[1] A survey on the effectiveness of unconventional monetary policy can be found in Borrallo and Hierro (2015).

of the ECB has increased the GDP. The same conclusion is reached by Gambacorta, Hofmann and Peersman (2015), who study the effects of unconventional monetary policy in advanced economies, including the United States and the Eurozone, and conclude that it has stimulated the economic activity with similar effects across those countries.

However, the proliferation of studies on the effectiveness of unconventional monetary policy has not been followed by abundant literature on its transmission mechanisms. Despite the evidence of structural changes in monetary policy transmission in the United States and the Eurozone (Gambacorta and Marques-Ibanez, 2011), any explicit study of the channels after the start of the crisis has been scarce. In fact, the literature has focused on analysing the impact of monetary policy on financial indicators and not on economic activity (Krishnamurthy and Vissing-Jorgensen, 2011; Gagnon, Raskin, Remache and Sack, 2011; Wright, 2012; De Pooter, Martin and Pruitt, 2012; Beirne, 2011).

Nevertheless, there is work focused on the study of the credit channel in the Eurozone. Lenza et al. (2010) find a positive effect of the ECB measures on credit after the start of the crisis, and, according to Peersman (2011), the increase of the balance sheet of the ECB has increased the amount of loans. Later on in the crisis, Ciccarelli, Maddaloni and Peydró (2013) and Paries and De Santis (2013) find that the 3-year LTRO eased credit conditions. Finally, Ciccarelli et al. (2013) conclude that without the credit channel, the effects of monetary policy would have been considerably smaller.

The *risk-taking channel* has also been studied more in recent times. According to this channel, a monetary contraction increases risk aversion and therefore the agents disinvest in risky assets. Altunbas, Gambacorta and Marques-Ibanez (2014) and Jiménez, Ongena and Saurina (2009) find evidence of this effect.

In addition to the scarcity and limits of the research, one of the main problems from which the majority of the studies suffer is that they incorporate observations previous to the financial crisis and thus they do not separate between pre-crisis and post-crisis periods. This procedure can distort the results when the coefficients change between periods[2]. Moreover, there is no research that compares the monetary policy effectiveness and its transmission mechanisms between the United States and the Eurozone specifically during the period of unconventional monetary policy, despite the fact that the two monetary authorities have employed different instruments.

The main objective of our paper is to cover those gaps in the literature.

[2] One exception is the work of Gambacorta et al. (2015), although its estimation starts in January 2008 and structural changes after the bankruptcy of Lehman Brothers are not taken into account.

3. Methodology

Our analysis is performed by using an Autoregressive Vector Model (VAR), introduced previously by Sims (1980), and employed widely for the analysis of monetary policy (Bernanke and Blinder, 1988; Christiano, Eichenbaum and Evans, 1996; Kim, 1999; Lenza, Pill and Reichlin, 2010; Bridges and Thomas, 2012).

Specifically, we propose a Structural VAR (SVAR):

$$A_o Y_t = A(L) Y_{t-1} + \varepsilon_t \quad (1)$$

where Y_t is a vector of endogenous variables, A_o and $A(L)$ are matrices of coefficients and ε_t is a vector of structural innovations, that is supposed to be white noise with variance-covariance matrix $E(\varepsilon_t \varepsilon_t') = I$.

The reduced form of (1) is:

$$Y_t = A_o^{-1} A(L) Y_{t-1} + A_o^{-1} \varepsilon_t = B(L) Y_{t-1} + v_t \quad (2)$$

The model is estimated in two different periods. For the United States, the first period covers from January 1995 to July 2007, and the second period covers from August 2007 to December 2014. The two periods are thus separated by the initial financial turbulences that would lead to the Great Recession. Moreover, in order to know how the effectiveness and transmission of monetary policy were changing with the worsening of the crisis, we estimate the second period recursively, and eliminate one observation at the start of the period in every iteration and calculate the corresponding impulse response functions[3]. In the Eurozone, the same criteria is followed as was applied in the United States, but the first period now covers from June 1999 to July 2007 and, therefore, the estimation is started after the introduction of the single monetary policy.

Our analysis deliberately omits recent measures such as the new asset purchase programmes of the ECB, since the new quantitative expansion is similar to that previously applied by the Fed and therefore our work would otherwise lose its main focus: the study of the different expansive policies applied by those central banks.

The vector Y_t includes, for the pre-crisis period: the logarithm of real GDP; the logarithm of the consumer price index; the overnight interest rate in the interbank market, as proxy for monetary policy (the federal funds rate for the United States and the Eonia for the Eurozone); the interest rate spread between high-yield bonds and the 10-year Government bond (composite in the case of the Eurozone), which we call 'interest rate spread' or 'risk channel'; and the logarithm of the banking loans, or 'credit channel'.

[3] This kind of analysis was previously applied, although with a moving window, in Blanchard and Galí (2010).

The decomposition of the variance-covariance matrix is arbitrary if the identification of the impulse response functions is performed through sign restrictions and, in consequence, the order of the variables does not affect our results.

We obtain the variance-covariance matrix of v_t, which we call Σ:

$$E(v_t v_t') = \Sigma = A_o^{-1} E(\varepsilon_t \varepsilon_t') A_o^{-1'} = A_o^{-1} A_o^{-1'} = PP' \quad (3)$$

The matrix Σ does not enable the matrix P to be identified, which is necessary for the recuperation of the innovations ε_t, because the matrix P has k^2 free elements whereas the matrix Σ has only $k(k+1)/2$. At least $k(k-1)/2$ restrictions must be imposed on P in order to identify this matrix.

Those restrictions are usually imposed by supposing that P is upper triangular, and hence the expression (3) would be reduced to a Cholesky decomposition of the variance-covariance matrix Σ. This method implies a certain order of the variables in that the first variable is not affected contemporarily by the rest; the second variable is only affected contemporarily by the first variable, and so on. Alternatively, we can fix the signs of the impulse response functions for certain variables in a predetermined horizon without imposing *ex ante* the parameters of the coefficient matrix $A(L)$ nor those of matrix P.

To employ this method, we follow Uhlig (2005) and define the impulse vector, α, in accordance with the following expression[4]:

$$\alpha = Pa \quad (4)$$

where P is an arbitrary decomposition of the variance-covariance matrix of the residuals, Σ, and a is a vector kx1 of modulus one. For a specific matrix P, we would have infinite impulse vectors depending on the values of a. Every value of the impulse vector can be understood as the sum of the responses of a variable to itself and of the other variables multiplied by a component of a. We study the distribution of those impulse vectors that generate impulse response functions consistent with the imposed signs. The components of the vector a are obtained from independent standard normal distributions and the resulting vector is then divided by its modulus.

Sign and zero restrictions are imposed on the impulse response functions. Specifically, we establish that, on impact, monetary policy does not affect GDP and that the effect on prices of a monetary contraction cannot be positive. Moreover, we establish that the monetary policy shock increases both the overnight interest rate and the interest rate spread.

In the estimation of the period under unconventional monetary policy, we maintain the zero restriction and suppose that the monetary shock increases the monetary base and prices, and diminishes the interest rate spread.

[4] This method and the method that uses Givens matrices, which is more common in the literature, are equivalent (Canova and Niccolo, 2002).

Sign restrictions are maintained in the impact month and in the two following months. The described restrictions are summarised in Table 1 below.

Table 1. Zero and sign restrictions

	GDP	Prices	Overnight interbank interest rate / Monetary base	Interest rate spread	Loans
Period previous to the crisis	0	\<=0	>/=0	>/=0	-
Period once the crisis had started	0	>/=0	>/=0	\<=0	-

Source: Authors' own

We estimate (2) by using Bayesian techniques, with a normal-inverse-Wishart distribution, and *P* is obtained through a Cholesky decomposition. Ten thousand extractions are retained of the impulse vectors consistent with the restrictions. A graph of the median and 16^{th} and 84^{th} percentiles of the resulting distribution is then drawn.

In accordance with Sims (1992), a commodity price index is included in order to avoid the so-called 'Price puzzle': a price increase following an interest rate hike. Commodity prices are a common factor to the latter two variables, since they affect inflation and are closely monitored by the central banks. Furthermore, we add the 3-month US interbank interest rate in the Eurozone estimation to control for global liquidity.

We include 3 and 2 lags for the first and second periods, respectively, in the estimation for the United States, and 2 lags for the Eurozone in both periods, as suggested by the Akaike Information Criteria.

For the second period, the same endogenous variables are maintained but the overnight interest rate is substituted with the logarithm of the monetary base as a proxy for unconventional monetary policy. In the Eurozone, we also introduce the logarithm of the US monetary base as an exogenous variable.

Table 2 shows the variables included, their transformations, and their sources.

Table 2. Definition and sources of the variables used in our study

Variable	Definition	Source	Transformation
Real GDP	United States: real quarterly GDP, seasonally adjusted, annualized	United States: Federal Reserve Economic Data (FRED)	Logarithm, lineally interpolated
	Eurozone: real quarterly GDP, seasonally adjusted, annualized	Eurozone: OCDE Economic Outlook	Logarithm, lineally interpolated
Consumer Price Index	United States: standardized general CPI, seasonally adjusted	United States: Federal Reserve Economic Data (FRED)	Logarithm
	Eurozone: general CPI, seasonally adjusted	Eurozone: ECB Statistical Data Warehouse	Logarithm
Overnight interbank interest rate	United States: overnight federal funds rate	United States: Federal Reserve	Levels
	Eurozone: eonia	Eurozone: ECB Statistical Data Warehouse	Levels
Interest rate spread*	United States: interest rate on high-yield bonds minus the 10-year Treasury rate	United States: Barclays and Federal Reserve Economic Data (FRED)	Levels
	Eurozone: interest rate on high yield bonds minus the composite 10-year government bond	Eurozone: Bank of America, ECB Statistical Data Warehouse	Levels
Loans to the private sector	United States: Loans and leasings by commercial banks	United States: Federal Reserve Economic Data (FRED)	Logarithm
	Eurozone: Loans to other euro area residents	Eurozone: ECB Statistical Data Warehouse	Logarithm
Monetary base	United States: Monetary base	United States: Federal Reserve Economic Data (FRED)	Logarithm
	Eurozone: Monetary base	Eurozone: ECB Statistical Data Warehouse	Logarithm
Industrial production	United States: Total Industrial Production, seasonally adjusted	United States: Federal Reserve Economic Data (FRED)	Logarithm
	Eurozone: Industrial Production, excluding construction, seasonally adjusted	Eurozone: Eurostat	Logarithm
Commodity Price Index, excluding energy	United States: Commodity Price Index, excluding energy, in dollars	United States: International Monetary Fund	Logarithm
	Eurozone: Commodity Price Index, excluding energy, in euros, import-weighted	Eurozone: ECB Statistical Data Warehouse	Logarithm
Three-month interbank interest rate in the United States	-	United States: -	-
	-	Eurozone: Thomson Reuters, Datastream	Levels

*Additionally, as explained in the text, we include an alternate definition of this variable by including corporate bonds in the robustness tests, which are also used as one of the definitions of the interest-rate channel in those tests. For the United States, we use the yields on BAA bonds from Moody's; for the Eurozone, the source is Bank of America.

Source: Authors' own

To study the importance of the channels in the transmission of monetary policy, we resort to the shutting-down methodology, applied previously in Sims and Zha (2006), Kilian and Lewis (2011), Bachmann and Sims (2012), and Ciccarelli et al. (2013). This methodology allows us to compare the impulse response function of a monetary policy shock on production with the hypothetical response that would be triggered if one of the transmission channels did not react to the impulse variable. This would be called a 'closed' channel. This is equivalent to imposing a null value on the dynamic responses of this transmission channel over the entire prediction period.

To accomplish this exercise, the transmission channel that is being closed is given null values in the corresponding coefficients of the VAR and in the decomposition of the variance-covariance residual matrix. For example, contractive monetary policy would make funding through financial markets and through private loans more expensive. Closing one of those channels is equivalent to cancelling the effect of the monetary policy and, consequently, such policy would have a lesser effect on production. By comparing the response of an unimpeded monetary shock with that

resulting from closing every channel separately, we are evaluating the role of those channels in the estimated period.

4. Results and robustness

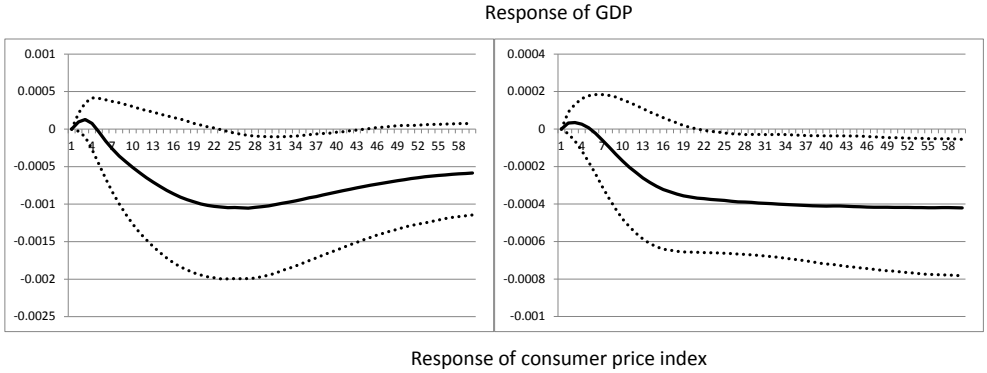
4.1 Pre-crisis period

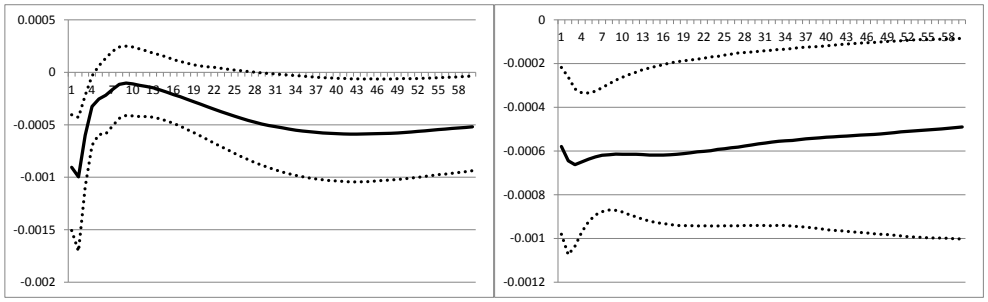
Figure 3 shows the responses to a contractive monetary policy shock for the United States (left-hand side) and for the Eurozone (right-hand side) in the first period over the 60-month prediction period.

Our results are coincident with those obtained in previous work. In the first place, a contractive monetary policy shock significantly reduces GDP. In the Eurozone, we find a higher persistence of the response, whereas in the United States the peak of the response is reached two years after the monetary contraction. In both cases, the reduction on GDP is only significant after approximately 6 months.

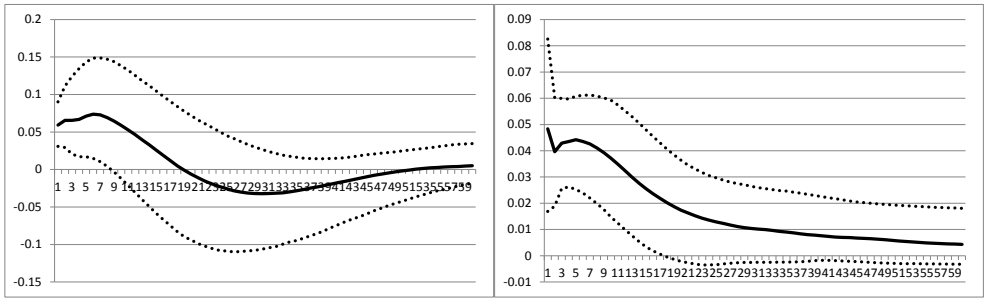
The consumer price index diminishes after the shock, as established in the sign restrictions. The federal funds rate, the Eonia and the interest rate spread increase as a consequence of contractive monetary policy, whereas the volume of loans diminishes. Moreover, the response of the transmission channels to monetary policy is smaller in the United States than in the Eurozone, both in terms of the size of the responses and of the significance.

FIGURE 3. Impulse response functions of a contractive monetary policy shock in the United States (left-hand side) and Eurozone (right-hand side) as the result of estimating (2) in the first period

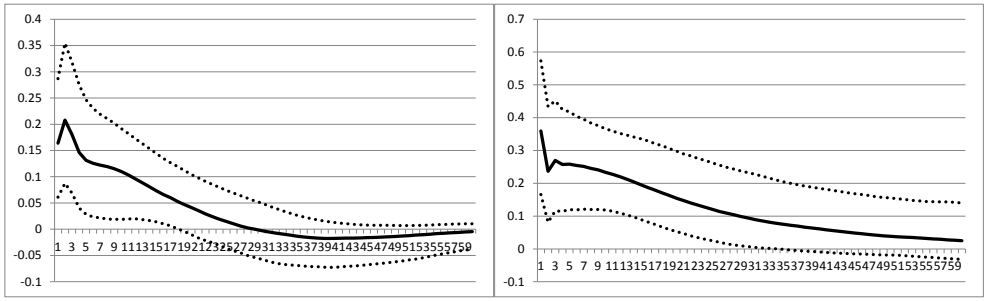




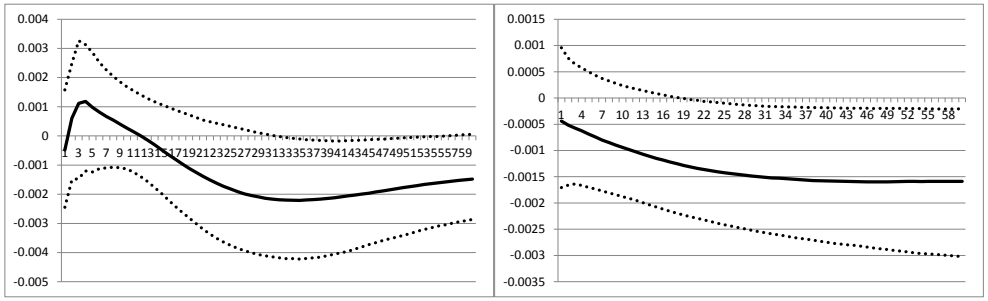
Response of the federal funds rate/Eonia



Response of the interest rate spread



Response of the amount of loans



Source: Authors' own

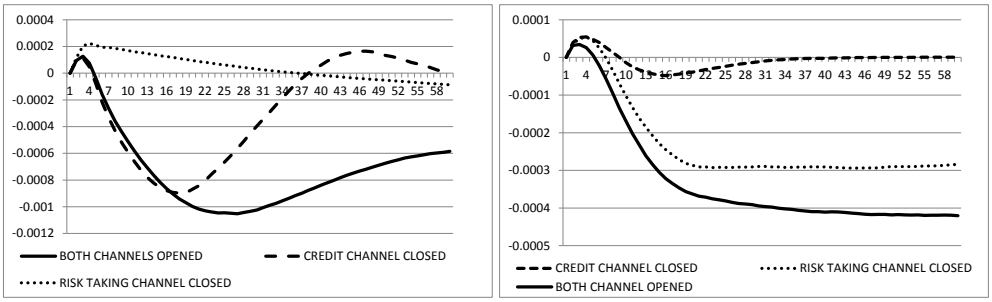
Figure 4 compares, for the two areas, the median of the effect of a contractive monetary policy shock on GDP with the hypothetical effect if each of the considered channels were closed.

When the risk channel is closed in the United States, the sign of the response of GDP is the opposite to that which one should expect after a monetary contraction, whereas if the credit channel is closed, then monetary policy transmission remains unaffected until more than 18 months after the shock. The importance of loans then grows until the sign of the response changes in the third year after the shock. It can therefore be concluded that the risk channel is the one that

transmits monetary policy the fastest and with the biggest effect during the greatest part of the horizon period.

In the Eurozone, monetary policy transmission is produced in a significantly different way. Despite its ever-growing importance, the risk channel has a considerably smaller influence than that of the credit channel. If the latter is closed, then the effect of monetary policy is null after two years.

FIGURE 4. Median of the effect of a contractive monetary shock on GDP in the United States (left-hand side) and the Eurozone (right-hand side) with open channels and separately closed channels



Source: Authors' own

4.2 Results of the estimations after the financial crisis had started

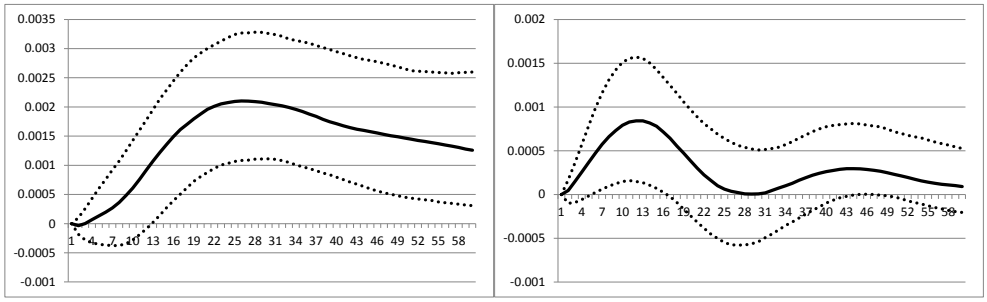
The left-hand-side column in Figure 5 shows the impulse response functions to an increase in the monetary base in the United States, which are obtained by estimating Equation 2 for the period from August 2007 to December 2014, whereas those results for the Eurozone are shown in the right-hand-side column in Figure 5.

The figures indicate that a positive shock on the monetary base increases real GDP and prices in the United States. The effect on prices is immediately positive, but on GDP this is only significant after one year. The shock significantly decreases the interest rate spread during the first two years. Finally, the amount of loans also increases after the first year and the effect becomes significant two and a half years after the shock.

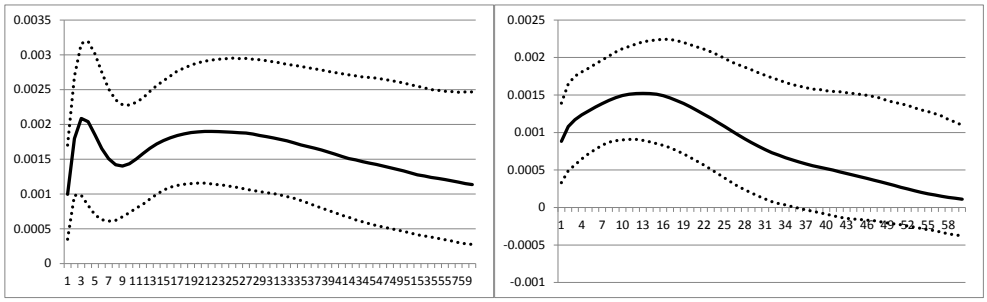
In the Eurozone, however, the expansive monetary policy increases real GDP only during the first year and a half after the shock, and the maximum effect is reached after one year. Prices also increase and the peak is reached 12 months after the shock. The interest rate spread decreases over the first year and no evidence can be found that unconventional monetary policy influenced the amount of loans in the Eurozone.

FIGURE 5. Impulse response functions of an expansive monetary policy shock in the United States (left-hand side) and Eurozone (right-hand side) as results of estimating (2) in the period CHECK PROTOCOL 1 August 2007 to December 2014

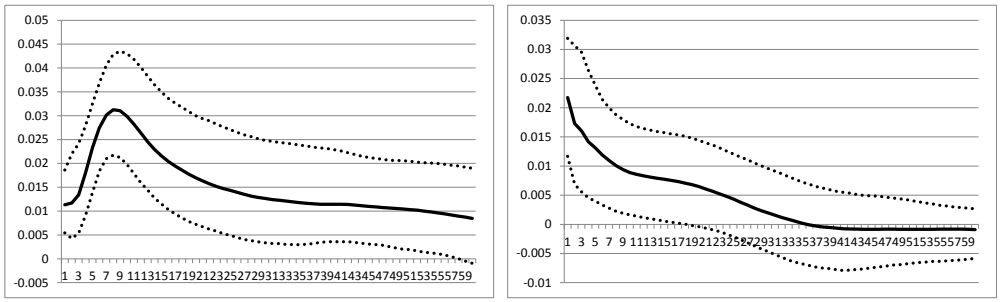
Response of GDP



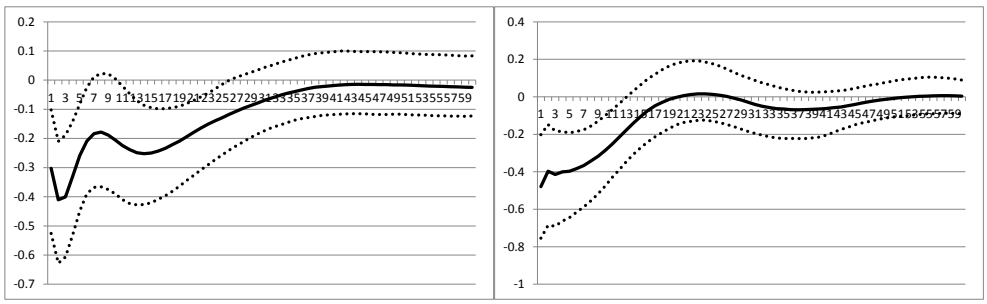
Response of the Consumer Price Index



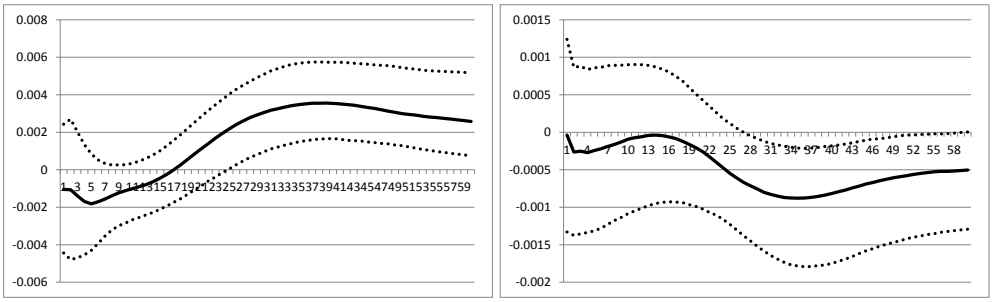
Response of monetary base



Response of the interest rate spread



Response of the amount of loans

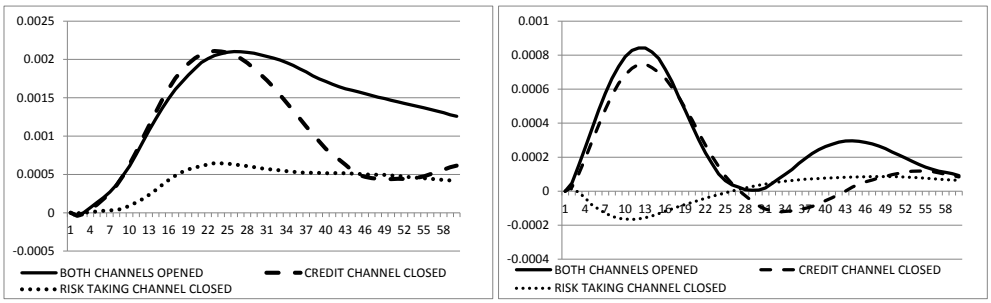


Source: Authors' own

Figure 6 shows the median of the effect of an unconventional monetary shock on GDP and the hypothetical response if each channel had been separately closed. In the United States (left-hand-side chart), the risk channel carries the greatest importance in the monetary policy transmission, although the credit channel becomes equally important starting in the third year after the shock.

In the right-hand-side chart in Figure 6, it can be seen that the closing of the risk channel in the Eurozone leaves monetary policy ineffective, and the credit channel has minor relevance over most of the prediction period. That is, the unconventional monetary policy of the ECB could act through financial markets and eased financing conditions through the reduction of the risks perceived by agents, whereas its influence on GDP through an increase in loans was severely diminished. Thus, monetary policy transmission has changed in the Eurozone when compared to the pre-crisis period.

FIGURE 6. Median of the effect of an expansive unconventional monetary shock on GDP in the United States (left-hand side) and the Eurozone (right-hand side) with open channels and separately closed channels



Source: Authors' own

4.3 Changing response to unconventional monetary policy

As indicated in Section 3, the effectiveness of monetary policy and its transmission could have undergone major changes as a consequence of the crisis. We look into those possible changes by estimating (2) recursively from August 2007 to December 2014, while eliminating one observation in the beginning of the sample in every iteration.

Figure 7 shows, for the United States, the median of the response of GDP to expansive monetary policy over time. Moreover, a cross-section is added in order to show the evolution of the significance of the responses and the same exercise as that performed in Figure 6 at three different moments in time. The figures are obtained starting the estimation in August 2007, June 2008, and January 2009: the latter being the last impulse response calculated and shown in the upper part of the tri-dimensional Figure 7. Figure 8 is analogous to Figure 7 but is computed for the Eurozone.

As can be seen in Figure 7, the response of GDP to the expansion of the balance sheet of the Fed was positive, independent of the moment at which the estimation was initiated, but it lost persistence with the worsening of the crisis. When the estimation was started in January 2009, the maximum effect was found 12 months after the shock versus a period of 24 months when the estimation was begun in August 2007. On monetary transmission, the risk channel was still the most important, although in the most recent period of estimation, the credit channel was more influential from two years after the shock.

In the Eurozone, the response of GDP to an expansive monetary policy shock was also decreasing over time, both in the size of the response and its significance. On considering the entire estimation period, a positive and significant response of production to the increase in monetary base was found, but if the estimation is started in January 2009, no significant effect of unconventional monetary policy on GDP can be found. On monetary transmission, the main result of Section 4.2 was maintained, and the risk channel was largely responsible for the transmission of monetary policy in the Eurozone, whereas the credit channel lost importance.

FIGURE 7.a. Evolution of the response of GDP to expansive monetary policy in the United States, obtained by estimating (2) starting between August 2007 and January 2009, and always ending in December 2014 (upper graph), and cross-sections in August 2007, June 2008, and January 2009 and the transmission of monetary policy (3 lower graphs)

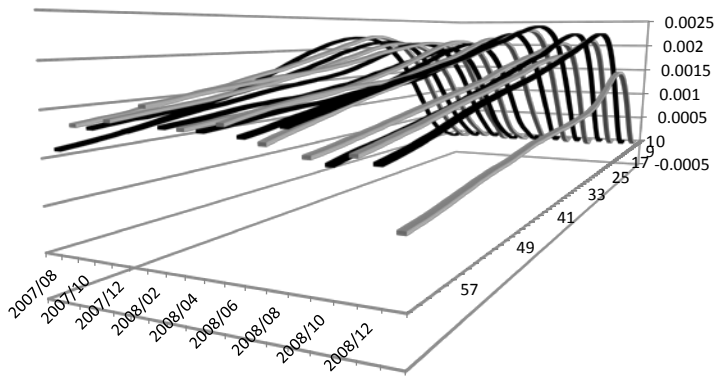
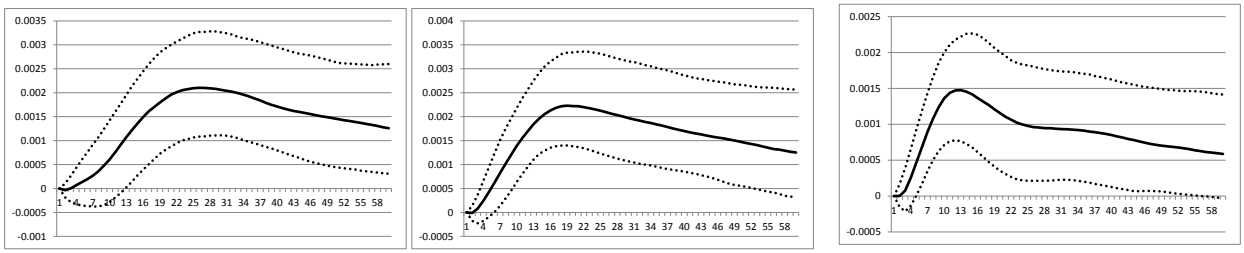
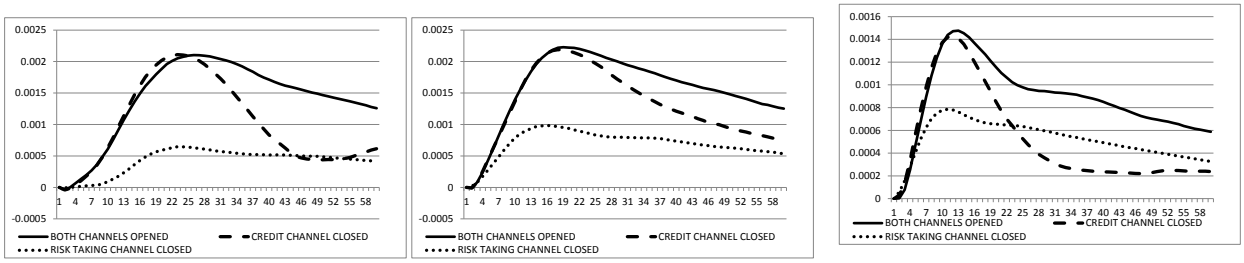


FIGURE 7.b. Cross-section



August 2007 June 2008 January 2009

FIGURE 7.c Closing of the transmission channels



August 2007 June 2008 January2009

Source: Authors' own

FIGURE 8.a. Evolution of the response of GDP to expansive monetary policy in the Eurozone, obtained by estimating (2) starting between August 2007 and January 2009 and always ending in December 2014 (upper graph) and cross-sections in August 2007, June 2008 and January 2009 and the transmission of monetary policy (lower graph)

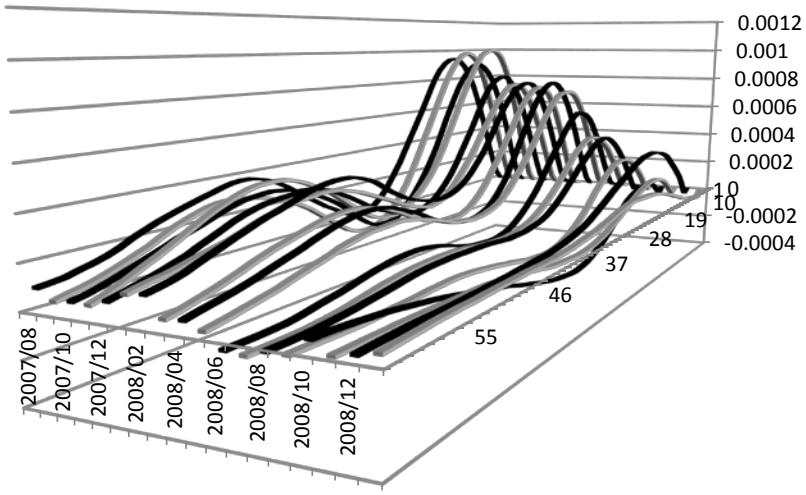
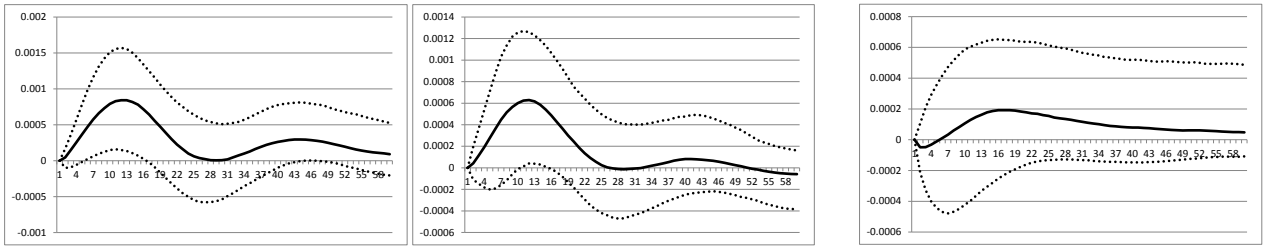
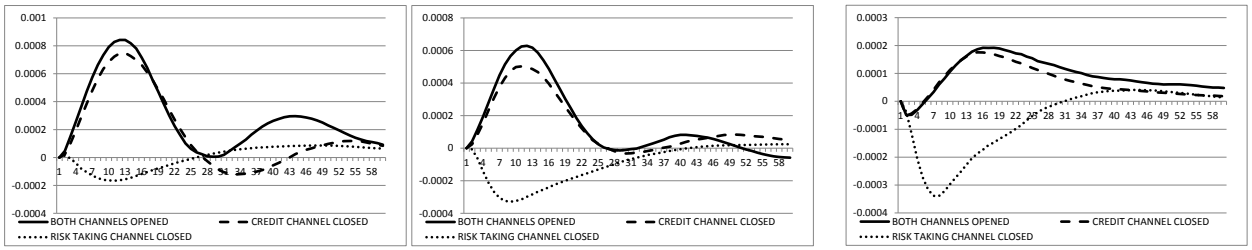


FIGURA 8.b. Cross-section



August 2007 June 2008 January 2009

FIGURA 8.c. Closing of the transmission channels



August 2007 June 2008 January 2009

Source: Authors' own

4.4 Robustness

In order to prove the robustness of our results, the following changes are made in the model:

(1) GDP is substituted by industrial production as an alternate measure of economic activity;
(2) For the period starting in August 2007, the logarithm of the monetary base is substituted by the logarithm of total assets of each central bank;
(3) The definition of the interest rate spread is changed by substituting the return on high-yield bonds with the return on corporate bonds;
(4) The risk-taking channel is substituted with the interest rate of corporate bonds as an approximation to the interest-rate channel.

Table 3 presents a summary of the results of every robustness test when compared to those from our baseline model. From these results, it can be deduced that, in general, our results are robust.

Table 3. Results of the robustness tests

	RELEVANT CHANGES RELATIVE TO BASELINE MODEL
GDP is substituted with industrial production	-United States: loans react more significantly to monetary policy in the pre-crisis estimation -Eurozone: the market channel is more important in the pre-crisis estimation than the baseline model suggests
Monetary base is substituted with total assets	-United States: in qualitative terms, conclusions remain the same -Eurozone: in qualitative terms, conclusions remain the same
Interest rate spread definition is changed	-United States: the market channel is less important than the credit channel after two years in the pre-crisis estimation. In qualitative terms, our conclusions remain the same in the post-crisis period -Eurozone: GDP and loans react more significantly whereas the interest rate spread reacts less to a monetary shock in the pre-crisis period. In qualitative terms, our conclusions remain the same in the post-crisis period
Substitution of the interest rate spread with the interest rate on corporate bonds	-United States: qualitatively, conclusions remain the same in the pre-crisis period. Once the crisis began, the response of GDP and loans to the monetary shock was smaller and the latter was less important as a transmission channel than in the baseline model -Eurozone: higher response of GDP and of loans to the shock in the pre-crisis period and the interest rate channel would be more important than the risk channel. After the crisis started, the response of GDP to the monetary expansion was no longer significant

Source: Authors' own.

5. Implications for economic policy and Conclusions

Several relevant implications can be drawn from our study regarding the transmission of monetary policy in the United States and the Eurozone and regarding its design.

In the first place, we have shown that the effect of a monetary shock on GDP, before the onset of the financial crisis, was significant in both currency areas. An increase of the key policy rate would result in a decrease in economic activity. As a side note, we detect a major difference between the two areas regarding the transmission channels of the monetary shock. In effect, in the United States, the transmission took place especially through the reduction of the interest rate spread on private debt, and the amount of loans only influenced the transmission of monetary policy after a considerable lag. In the Eurozone, however, the amount of loans to the private sector was the main transmission channel of monetary policy, while the risk channel played a much less prominent role. This difference is coherent with the greater importance in the United States of funding through financial markets, and the greater importance of funding through loans in the Eurozone.

Once the economic crisis was under way, the effectiveness of monetary policy changed. Initially, the monetary expansion carried out by the Fed and the ECB contributed to a higher level of production, although with a certain lag in the United States. With the worsening of the crisis, the

expansive monetary policy in the US increased GDP for ever-shorter periods. This loss of persistence could explain why the Fed decided to slowly increase the monetary base with periodical purchases. However, in the Eurozone, monetary policy was gradually losing significance over time, and expansive monetary policy failed to stimulate economic activity significantly after the second half of 2008.

This difference could be related to the functioning of the transmission channels. In effect, unlike the previous period, monetary policy was transmitted through the risk channel in both currency areas. In the United States, this risk channel was essential and the amount of loans contributed to the transmission with a considerable lag, although we find evidence that its relative importance increased with respect to the pre-crisis period. However, in the Eurozone, the monetary policy applied by the ECB only increased GDP at the start of the crisis and the great volume of funds at low interest rates granted as loans to the banking entities must have been channelled through the financial markets and not through loans to the private sector.

There are several possible explanations for this result. On the one hand, it is feasible that the situation of the financial entities led to a *credit crunch*, whereby they would have used the funding to maintain the value of their assets, and therefore the traditional transmission in the Eurozone would have been impaired. Another possibility is that the lack of functioning of the credit channel was related to the design of the monetary expansion. In effect, the Fed purchased a huge amount of securities, thereby permanently increasing the monetary base and hence an endogenous monetary decrease was not possible, except with an explicit change in the policy: as can be observed in Figure 2, there was no reduction in the monetary base even after the end of its purchase programs in October 2014. However, the ECB increased its balance sheet through loans to the banking entities with a range of maturities (up to three years) that could also be reduced if those entities decided to return these loans earlier, which in fact happened (Figures 2 and 3). In other words, the ECB designed the increase of the monetary base as a temporary strategy, by limiting the granting of loans to households and firms to very short terms. This probably caused the central bank funding to be channelled through the financial market, thereby reducing the risk spreads, where there is a much higher possibility of recovering the funds in the short-term.

Furthermore, the expansion of the balance of the ECB was distributed asymmetrically. To a large degree, the new funds were obtained by the entities of the peripheral countries at higher costs than those prevailing in the market (Dunne, Fleming and Zholos, 2013). These entities, faced with uncertain growth in their countries and problems of liquidity and capital, would have used the temporary funding to improve their position of liquidity and to acquire government bonds, from

which they would gain profits from the spread of the yield of those bonds over the policy rate (Acharya and Steffen, 2015).

We conclude that:

Conventional monetary policy was effective at stimulating economic activity, and was mainly transmitted through the financial markets in the United States and through banking loans in the Eurozone.

After the crisis had started, central banks increased the size of their balance sheets. In the United States, this policy stimulated the economy but in ever-shorter periods and was transmitted to a greater degree through the risk channel. In the Eurozone, monetary policy stimulated the economy only at the beginning of the crisis, and, in contrast with the pre-crisis period, it was transmitted solely by the risk channel and not through the credit channel. In other words, there was a qualitative change in the effectiveness of the channels. Additionally, there was also a difference in the mechanism: unlike the Fed, the ECB increased the monetary base only temporarily, which could have influenced both the scant effectiveness of the measures and the change in the relative importance of the transmission channels.

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