The Relationship Between Bank and Interbank Interest Rates during the Financial Crisis: Empirical Results for the Euro Area

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Abstract

In this paper we use a Markov-switching vector autoregressive model to analyse the interest rate pass-through between interbank and retail bank interest rates in the Euro area during the financial crisis. Empirical results, based on monthly data for the period 2003(1)-2011(9), show that during periods of financial turmoil all the rates considered show a reduction of their degree of pass-through from the interbank rate. Interest rates on loans to non-financial firms are found to be more affected by changes in the interbank rate than loans to households, both in times of high volatility and in normal market conditions.

Key Words: Interest rate pass-through, financial crisis, interbank interest rate; loans interest rate; Regime-switching vector autoregressive models; Euro area.

JEL Classification: C32, E43, E58, G01, G21.

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1. Introduction

The pass-through process from policy-controlled to retail bank rates is important for monetary policy, both from the point of view of price stability and from the financial stability perspective. Even if there are additional market and demand factors that affect the definition of bank rates, as for example banking competition, size of banks, level of development of financial markets, and even aspects affecting each single customer or credit transaction, interbank interest rates are one of the main drivers of the rates charged by banks on loans.

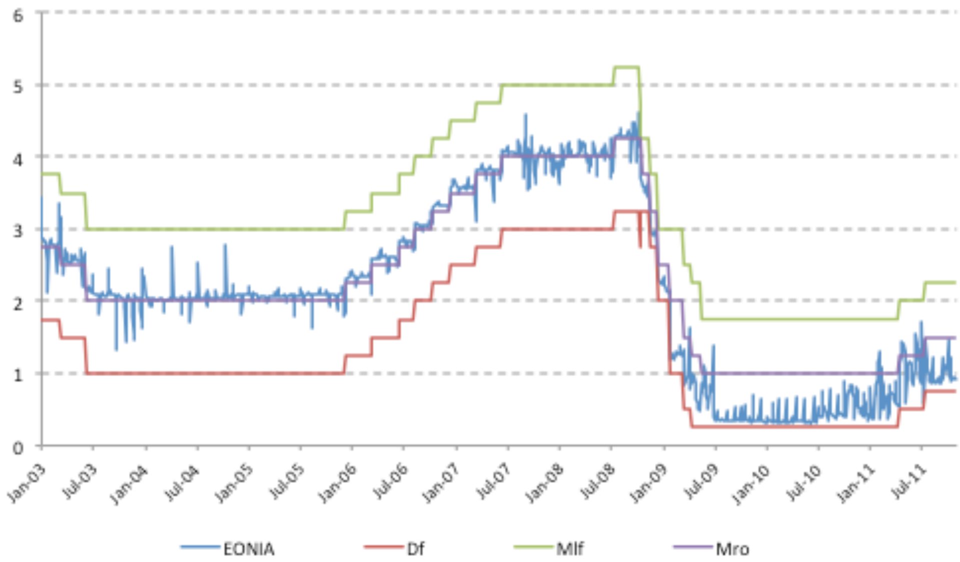
The interest rates set by Central Bank affect the interbank rates, which are the basis of the process of defining the cost of money lent by banks to their customers, therefore they have effects on the behaviour of borrowers and consequently on the real economy. On the other hand, prices set by banks influence their profitability and soundness and thus the financial stability (De Bondt 2005). It is clear that banks play an important role in the transmission of monetary policy, especially in the Euro area, where borrowers rely more heavily on the banking systems to raise funds (Blot and Labondance 2011). Borio and Fritz (1995, p. 3) argue that "bank lending rates are a key, if not the best, indicator of the marginal cost of short-term external funding in an economy".

The interest rate transmission channel has become particularly important in the context of the financial crisis. During the current financial turmoil, monetary authorities have repeatedly cut interest rates charged in order to provide liquidity in the financial system, facilitating the solvency of banks and supporting the confidence of savers. However, the rigidity of interbank rates has slowed the process of transfer of monetary policy impulses to the real economy. In fact, while there has been a substantial reduction in market yields, on the other, at least in the short term, the pricing of bank loans has not been characterized by an equally evident decrease. The presence of strong information asymmetries has created a panic in financial markets and reduced the net financial wealth of the banks and borrowers, reducing the effectiveness of monetary policies. Also expectations influence significantly the effectiveness of all other channels of monetary policy transmission to the extent that central bank policy is anticipated by the market and priced into the yield curve (Gaspar et al., 2001). Several factors, like the degree of central bank credibility, predictability of central bank actions, and commitment by the central bank to vary its instrument consistently, can enhance the role of the expectations channel (Stavrev et al., 2009).

During the period from January 2003 to September 2011, the official rates underwent a considerable fall, gradually followed by interbank rates, which, nevertheless, continued to incorporate the manifested distrust among intermediaries.

Figure 1 presents the pattern of the key Central Bank interest rates, together with the Euro Over Night rate (EONIA)[2]. The Figure shows that the interest rate on *main refinancing operations*[3] has reached historic lows, surpassing even the minimum of 2% reached in 2003: this fact demonstrates the will of the Central Bank to provide liquidity at exceptionally low costs, in order to support the banks and the process of financing of the real economy.

Figure 1 - Euro Over Night rate (EONIA) and Key ECB interest rates (January 2003-September 2011)



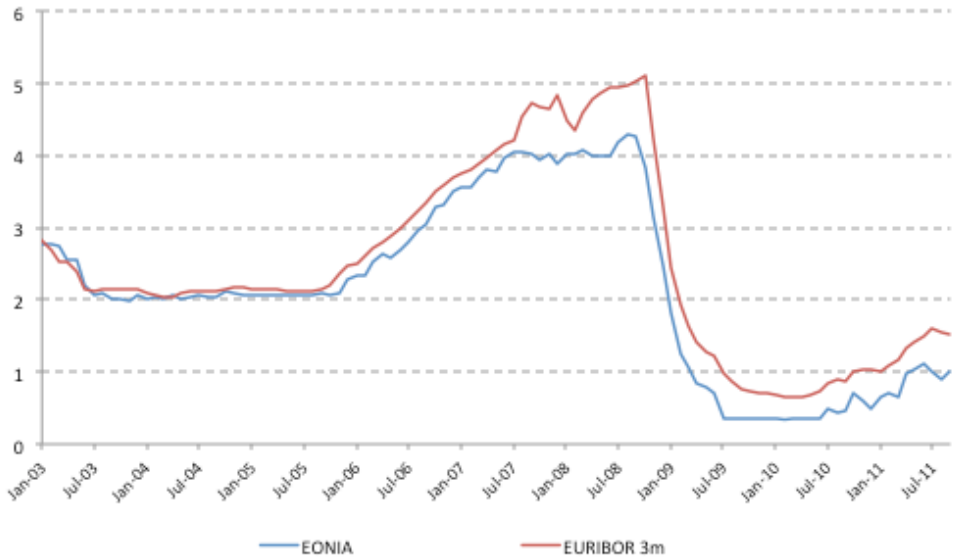
Notes: EONIA= Euro Over Night interest rate; DF = Deposit Facilities; Mlf = Marginal lending facility; Mro = Main refinancing operations.
Data Source: European Central Bank

The increase in the cost of borrowing among banks, measured by EURIBOR[4] (Figure 2), throughout 2007 and much of 2008, led the European intermediaries to demand increasing levels of liquidity to the Central Bank, while the decrease in interbank interest rate, suffered during the last months of 2008, has reduced the use of the operations with ECB (Figure 3) for the first six months of 2009. The *deposit facilities* and *main refinancing operations*[5] began to grow again in the summer of 2009 and, after a short process of reduction, even in the month of June 2010 and October 2011,

[2] The EONIA is the benchmark interbank reference value and is derived by the European Central Bank on the basis of interest rates applied to the overnight transactions in Euros between banks. Usually it ranges in the corridor between the rate on marginal lending facility and the interest rate on deposits facilities.
[3] The European Central Bank, on its own initiative, aims to provide liquidity to the banking system by means of the *main refinancing operations* (MRO). The interest rate applied to such operations is therefore the main instrument to transfer impulses of monetary policy to the financial system.
[4] The EURIBOR is calculated daily for interbank deposits with a maturity of one week and one to 12 months as the average of the daily offer rates of a representative panel of prime banks, rounded to three decimal places.
[5] The operations of *marginal lending facilities* (MLF) and of *deposit facilities* (DF) are two standing facilities: the first to obtain overnight liquidity from the central bank, against the presentation of sufficient eligible assets; the second to make overnight deposits with the central bank. The interest rates paid on these operations feel the effects of the MRO rate, placing below and above this respectively.

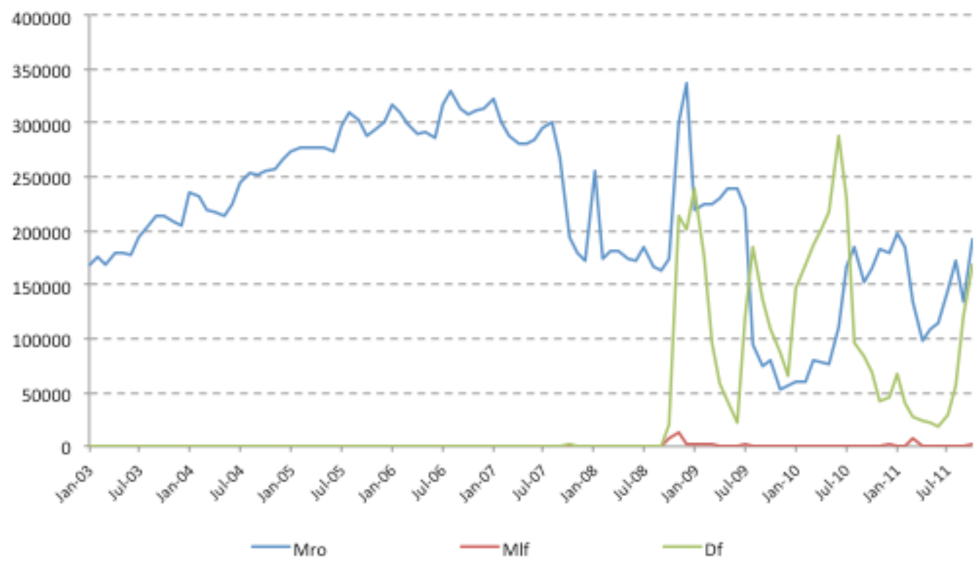
in correspondence of economic and political tensions that some countries (Greece, Ireland, Italy) experienced at these times and also in correspondence of the crisis of some financial intermediaries (for example Dexia, MF Global). These processes confirm the status of mistrust among the intermediaries and the perpetuation of the conditions of financial crisis.

Figure 2 - EURIBOR 3 months and EONIA rate (January 2003-September 2011)



Data Source: European Central Bank

Figure 3 - Open market operations (Mro) and Standing facilities
(millions of Euros, January 2003-September 2011)



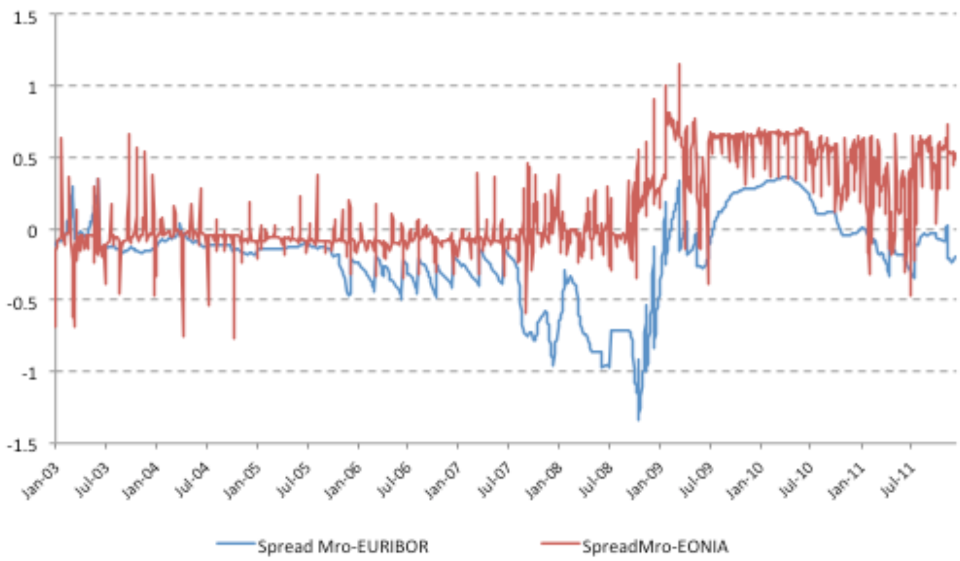
Data Source: European Central Bank

In September 2008, the bankruptcy of the U.S. investment bank Lehman Brothers has triggered a growing loss of confidence among the operators, which produced a significant rise in yields on the interbank money market, demonstrating the increased credit risk in the interbank market.

Figure 2 shows that the 3 months EURIBOR has reached its maximum (5.393%) in October 2008, while the EONIA has scored the highest value (4.469%) a few days after the failure of Lehman Brothers.

The higher cost of money on the interbank market has triggered a liquidity crisis and an increasing risk of failure for a number of intermediaries. Immediately, many governments have tried to avoid that the situation of distrust among depositors could evolve in a systemic crisis, by offering guarantees to depositors and nationalizing, in some cases, the banks most exposed to the risk of failure. Because of these choices, in early 2009, the difference between ECB rates and interbank rates has attenuated; these spreads have started to grow during the last year, driven by a new phase of the financial crisis, which now begins to affect the sovereign states in UE (Figure 4).

Figure 4 - Spreads Mro-EONIA and Mro-EURIBOR (January 2003-September 2011)



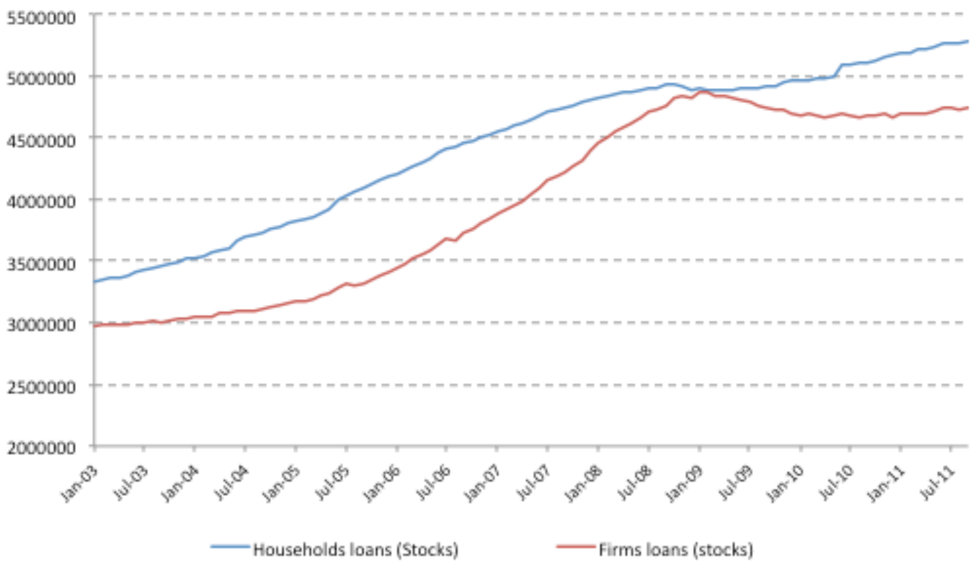
Data Source: http://marketratesonline.com

The financial crisis has highlighted the importance of the inter-bank market for wholesale funding, which saw a decline in the volume of lending and an increase in spreads over the implied official rates at comparable maturities. This shows a changing in the nature of bank funding that leads us to formulate questions about the relationship between interest rates in wholesale and retail markets (Banerjee et al., 2010).

In fact, the financial situation has immediate repercussions on the real economy, as it affects granting and pricing of loans to firms and households. The price of bank loans is a key factor in determining final demand and consequently inflation in an economy (Kwapil and Scharler, 2006, 2010). Figure 5 attests a distinct change in the amount of (new business) loans since the last quarter of 2008. While the official rates decreased, the cost of financing the real economy continued to rise, at least until January 2009. These costs have fallen steadily over the following months, until the autumn of 2009, most significantly for the operations of shorter duration, and slowly began to rise again since the mid-2010.

So we can se that there has been, and it is still occurring, an impediment or a slowdown in the transmission process of monetary policies, which must be identified and controlled in order not to frustrate the attempts of monetary authorities.

Figure 5 - Households loans and Non financial corporations loans
(stocks in millions of Euros, January 2003-September 2011)



Data Source: European Central Bank

The aim of this paper is to study how the financial crisis has affected the interest rate transmission mechanism for the Eurozone between market rates and bank interest rates and to trace the features related to the current financial crisis.

The main results of this investigation are that interest rates on loans to non-financial firms are more affected by changes in the interbank rate, than loans to households, both in times of crisis and in normal market conditions, even the speed of adjustment in long-term is greater in turmoil periods. Moreover, during the crisis all rates reduce their responsiveness to the interbank rate.

The remainder of the paper is organized as follows. Section 2 provides a short review on the literature related to the bank interest pass-through. Section 3 presents the data and Section 4 illustrates the econometric methodology. In Section 5 we present the main empirical results, whereas Section 6 offers some concluding remarks.

2. Overview of the literature and research questions

The economic literature on the mechanisms of transmission of monetary policy impulses through the bank interest rates in the Eurozone is based on different theoretical and methodological approaches. It is applied to single different countries (Harbo et al., 2011; Ozdemir, 2009; Jobst and Kwapil, 2008; Gambacorta and Iannotti, 2007; Coffinet, 2005; Humala, 2005; De Graeve et al., 2004; Horváth et al., 2004; Weth, 2002; Cottarelli and Kourelis, 1994), or to the Eurozone as a whole (De Bondt, 2005; ECB, 2009; Blot and Labondance, 2011; Antao, 2009; De Bondt, 2002) and focuses on different periods of time. For the aims of our analysis, we are particularly interested in studies that dwell on the effects of financial crisis (Blot, Labondance, 2011; Harbo et al., 2011; Karagiannis et al., 2010; Jobst and Kwapil 2008). Moreover, several econometric approaches are used to analyse interest rate pass-through[6]:

- *Univariate and Vector Autoregressive (VAR) models* (De Bondt, 2002 and 2005; Sander and Kleimeier, 2004);
- *Error Correction Models* (univariate ECM or Vector Error correction model – VECM) (see for example: Horváth et al., 2004; De Graeve et al., 2004; De Bondt, 2005; Marotta, 2009);
- *Panel Seemingly Unrelated Regression*, SUR-ECM (see for example: Sorensen and Werner, 2006; Blot and Labondance, 2011);
- Univariate and multivariate non-linear models (i.e. regime switching), used to account for the presence of important discrete economic events, that would distort econometric inference if it not capture in model (Dahlquist and Gray, 2000; Humala, 2005; Hendricks and Kempa, 2008).

All these different elements do not allow to reach a clear conclusion on the degree of pass-through, but it is always possible to find points of common reflection. In the short run, lending rates are sticky and so the degree of pass-through is less than one; in the long run the degree of pass-through is higher and, in some cases it may be complete (Cottarelli and Kourelis, 1994; Borio and Fritz, 1995; Kleimeier and Sander, 2000 and 2002; Donnay and Degryse, 2001; Toolsema et al., 2001; Gambacorta, 2008). The adjustment of retail rates to changes in money market rates does need some time and does not occur instantaneously, as the immediate pass-through is smaller than the long-term pass-through (Kwapil and Scharler, 2006).

[6] A complete description of these different econometric techniques is given in Section 4.

The heterogeneities in the degree of pass-through are related to the legal and financial structures (Cottarelli and Kourelis 1994; Cechetti, 1999; Mojon, 2001; Lago-González and Salas-Fumás 2005) or to the legal and cultural differences (Sander and Kleimeier, 2004).

The transmission of monetary policy is also influenced by banks' characteristics (Weth, 2002; Affinito and Fabullini, 2006), by the size of banks and their liability structure (Cottarelli et al., 1995; Weth 2002, Bistriceanu 2009). The health of banks is one of these characteristic according to Van den Heuvel (2002), who demonstrates that the effect of monetary policy may be smaller when banks are constrained by regulatory requirements; even if monetary policy is eased, bank cannot expand credits since they can hardly raise new equity. The author, by examining how bank capital and its regulation affect the role of bank lending in the transmission of monetary policy, argued that an expansionary monetary policy would alleviate the capital constraint by improving bank profits. The size and the dynamics of the effect are highly dependent on the initial level and distribution of capital among banks. Intuitively, the reason is that the capital requirement affects bank behaviour more when bank equity is low. Gambacorta (2008) showed that heterogeneity in the banking rates pass-through depends on liquidity, capitalization and relationship lending, but it exists only in the short run.

Adapting to changes in official interest rates may be delayed due to the presence of agency costs and customer switching costs (Fried and Howitt, 1980; Stiglitz and Weiss, 1981; Berger and Udell, 1992; Klemperer, 1987; Calem et al., 2006)

The heterogeneities in the degree of pass-through are related to the presence of structural breaks and discrete economic events (Hofmann, 2006; Sander and Kleimeier, 2004; Vajanne, 2007; Marotta, 2009; Blot and Labondance, 2011). Heterogeneity in adjustments is also found to be linked to menu costs and key financial ratios under managerial control (Fuertes and Heffernan, 2009).

The presence of several episodes of financial crises alters the speed and degree of response to shocks in the interbank rate (Humala, 2005; Stavrev et al., 2009; Blot and Labondance, 2011; Panagopoulos and Spiliotis, 2011). This last aspect is of particular interest for the purposes of our analysis: it shows that under normal financial conditions short-run stickiness is higher for those rates on loans with higher credit risk. But when there is a high-volatility scenario, the pass-through increases considerably for all interest rates (Humala, 2005). Blot and Labondance (2011), in a panel cointegration analysis, demonstrate that the heterogeneity between the Eurozone countries in the degree of interest rate pass-through has increased after the financial crisis. Kato et al. (1999) have shown monetary policy becomes less effective as borrowers' net worth decreases: they find that the effectiveness of expansionary monetary policy in the 1990s in Japan has been weakened by the deterioration of borrowers' balance sheets, contributing to the long stagnation of the Japanese economy during the period. Ritz (2010) shows that increased funding uncertainty: can explain a more intense competition for retail deposits (including deposits turning into a “loss leader”), and typically dampens the rate of pass-through from changes in the central bank’s policy rate to market interest rates. These results may help in explaining some elements of commercial banks’ behaviour and the reduced effectiveness of monetary policy during the 2007-2009 financial crisis. This analysis also may help explaining why banks with a strong deposit base appear to have done better throughout the recent financial crisis.

Stavrev et al., (2009) analyse the European Central Bank's (ECB's) response to the global financial crisis. Their results suggest that even during the crisis, the core part of ECB's monetary policy transmission -from policy to market rates- has continued to operate, but at a decreased efficiency.

The increase in interest rates on bank loans recorded during the financial crisis (Demyanyk and Van Hemert, 2011) is connected not only to interest rate changes, but also to the losses suffered by many banks. In this respect, Santos (2011) writes that banks that have experienced the greatest losses during the crisis are the same ones that had the greatest difficulty in raising funds on the interbank markets, and that suffer the most pressure from the market for improving their performance. Gambacorta and Marques-Ibanez (2011) demonstrate how the 2007-2010 financial crisis highlighted the central role of financial intermediaries’ stability in reinforcing a smooth transmission of credit to borrowers. They show that bank-specific characteristics can have a large impact on the provision of credit: factors, such as changes in banks’ business models and market funding patterns, modify the monetary transmission mechanism. Banks with weaker core capital positions, greater dependence on market funding and on non-interest sources of income restricted the loan supply more strongly during the crisis period.

Our main research questions are therefore: *1) How the financial crisis has affected the transmission process of monetary policy impulses to the real economy through the bank lending channel?; 2) Do differences occur in the adjustment of bank rates to changes in interbank rates in the short and long term?*; *3) Have banks shown different behaviours in setting rates of households and firms? Or in setting rates on loans of different amount?*

To these aims, we use a Markov-switching vector autoregressive model to analyse interest the relationships between bank interest rates and the money market rate (proxied by the three-month EURIBOR) in the Eurozone for the period 2003(1)-2011(9), allowing for changes in the degree and speed of pass-through in normal market conditions and during financial turmoil periods.

3. Data

Interest rates[7] for new loans on a monthly basis have been selected from the European Central Bank database. The period considered is from January 2003 to September 2011 and the geographic area taken into account is the Euro area (changing composition). The banks' counterpart sectors and the types of bank loans are:

- *Households and non-profit institutions serving households*
    1. Loans for consumption (excluding revolving loans and overdrafts, convenience and extended credit card debt); maturity: over 1 and up to 5 years; average of monthly observations, in per cent per annum.
    2. Lending for house purchase (excluding revolving loans and overdrafts, convenience and extended credit card debt); original maturity: total; average of monthly observations, in per cent per annum.
- *Non-Financial corporations*
    1. Loans other than revolving loans and overdrafts, convenience and extended credit card debt, Up to and including EUR 1 million; original maturity: total.
    2. Loans other than revolving loans and overdrafts, convenience and extended credit card debt, over EUR 1 million; original maturity: total.

The selection of the loans described above was performed to take into account the credit granted to "Households" and "Non-financial Companies" sectors, which are likely to suffer exogenous changes in interbank rates in a different manner, because of different bargaining power in dealing with banks. The subdivision of loans to households in the two categories "Consumer credit, with duration between 1 and 5 years" and "Credit for house purchase "(without further distinctions in maturity) has been done with the aim of combining the need to account for a minimum subdivisions of loans in this sector, both in terms of maturity and of purpose, with the need not to overcomplicate the econometric analysis. In addition, the distribution of loans to non-financial corporations was made solely on the basis of the size of the credit granted, to telling loans to small and medium-sized firms apart from loans to larger firms.

We use the three-month EURIBOR as a proxy for the policy-controlled rate: the official interest rate cannot be used directly because of the ECB interest rate on the main refinancing operations

[7] Interest rate data types are either the Annualized agreed rate (AAR) or the Narrowly defined effective rate (NDER). The annualized agreed rate (AAR) is an interest rate for a deposit or loan calculated on an annual basis and quoted as an annual percentage. The narrowly defined effective rate (NDER) reflects the annual costs of a loan in terms of the size of the loan, possible disagios, maturity and interest settlements. This makes it possible to compare the costs of loans with identical periods of interest rate fixation. No other costs related to the loan are taken into account. The NDER is the interest rate which, on an annual basis, equalizes the present value of all commitments (deposits or loans, payments or repayments, interest payments), future or existing, agreed between the bank and the household or non-financial corporation.

changes only infrequently (De Bondt, 2005; Kwapil and Scharler, 2006; Blot and Labondance, 2011). In the literature some empirical studies support the choice of using the EURIBOR as a proxy for the official rate, while others studies use the EONIA. De Bondt (2005) demonstrates that *EONIA* reflects relatively well official interest rate decisions and closely fluctuates around the ECB main refinancing rate, so it may be considered as the best indicator of monetary policy, because it is more related to changes in the expectation of official interest rates and less to liquidity issues. On the other hand, Bernoth and Von Hagen (2004) find that the three-month EURIBOR is a good indicator of monetary policy.

Our choice to use the EURIBOR rate instead of the EONIA rate derives from some considerations that we try to summarize below.

Starting from the definition, the Euro overnight index average (EONIA) is a measure of the effective interest rate prevailing in the Euro interbank overnight market, while the Euro interbank offered rate (EURIBOR) is the rate at which a prime bank is willing to lend funds in Euros to another prime bank. The first is a real interest rate, while the second is an offered rate. The EONIA is therefore more sensitive to expectations about the ECB's official interest rates, while the EURIBOR is the cost of interbank funding and depends on the expectations on banks' solvency. In normal times, EONIA and EURIBOR rates move fairly together but with the financial market turbulences, this relationship has been impaired (Blot and Labondance, 2011) (in this regard, see Figure 2). Spread between EONIA and EURIBOR is driven by perceived credit and liquidity risk.

The three-month EURIBOR is the rate applied to most of the floating rate bank loans and so also the principal element to which the cost of money for the real economy is related. In making our assessments, we are also aware of the instability that characterizes the evolution of the EURIBOR rate in recent months. It is due, among other things, to new fears of bank failures and to the decline in the number of transactions in the interbank market (see Figure 2), which reduces the predictive power of the rate.

From another point of view, the wholesale bank funding is also affected by the performance of retail funding: the rising costs that banks are enduring for the short term funding (current accounts, deposit accounts), but also for the long-term one (bond issues), affect the use of wholesale markets, in the attempt to obtain the resources needed to manage liquidity.

What we are experiencing is definitely a very special time for making predictions on bank lending rates: the EURIBOR is heavily influenced by the climate of mistrust among financial intermediaries and, in turn, bank loan interest rates are also affected by numerous factors, including a set of managerial determinants that cannot be ignored without risk of being considered superficial.

In this work we analyse the mechanism of pass-through from money market interest rate on bank lending interest rate, investigating how banks adjust their rates in relation to external impulses. It is not our intention, however, to analyse all the other factors that may exert an influence on the determination of bank and interbank rates, which may be subject to further investigation. In any case, the following factors can be considered particularly important for price-setting: the cost of retail funding, which affects the use of the interbank market for wholesale funding; the level of banks' capitalization, which allows the most capitalized banks to be considered more reliable and enables them to raise funds at lower costs, both in the retail and wholesale market; the liquidity situation of bank, which affects its solvency and also the conditions for access to credit.

These aspects may affect the use of the interbank market and the formation of interbank interest rates, limiting and, in some cases, blocking the effects of monetary policies. Such situations, in which conventional monetary policies become constrained or ineffective despite the need for further monetary easing, were described as liquidity traps by Keynes (1936).

Graphical analysis of time series shows a similar trend for all interest rates, except that of the consumer credit, which has a more stable pattern over time and appears to be less influenced by changes in the EURIBOR.

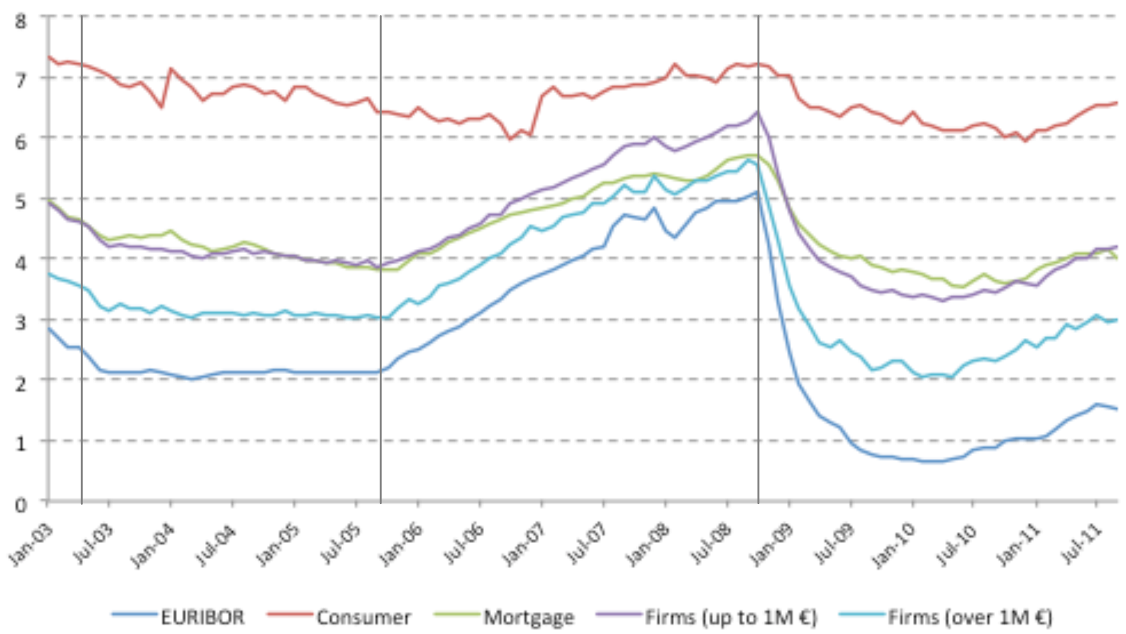
We may notice at least three critical points in the trend of these time series. The first, during the first half of 2003, when the European Central Bank has cut official interest rates by 0.25 points on March and by another 0.5 on June. As a result of these cuts the minimum bid rate on main refinancing operations is placed at the 2.0%. The decisions were taken in a macroeconomic environment characterized by a reduction in inflationary pressures, by the stagnation of the productivity and progressively more uncertain prospects for recovery, in connection with the rising international political tensions due to the war in Iraq and terrorist acts in Europe and the Middle East.

The second critical point is at the end of 2005 and early 2006, where, after a period of substantial stability, interest rates go up again. In fact, European Central Bank has kept official interest rates unchanged, in a context of uncertainty about the strength of economic recovery in the Euro area and stability of inflation expectations. Since autumn 2005 there were signs of growth prospects and the higher oil price was reflected in an acceleration in prices and an increase in expectations of inflation over the medium term. As a result of this, ECB raised its official interest rates by a quarter percentage point in December and the same rate in March 2006. The two following years were characterized by continuous increases in official interest rates and consequently in interbank rates.

The last critical point is at the end of 2008, when the current financial crisis has forced Central Bank to cut repeatedly interest rates. The wide spread uncertainty about possible defaults of counterparties, after the collapse of the investment bank Lehman Brothers, has sent haywire wholesale markets on which banks do fundraising. Central banks have made up for the block of national interbank markets with liquidity injections with exceptional high amounts. On 8 October 2008, the ECB, the Federal Reserve, the Bank of England, the Bank of Canada, the Bank of Sweden and the Swiss National Bank, with the support of the Bank of Japan, have carried out a coordinated reduction in interest rates: an event never before happened. Further cuts also occurred in the following months, when it became clear that the Euro area is in recession[8].

Graphical analysis shows many of the aspects that will be highlighted later in this work: the greater rigidity of the rate on consumer credit; the largest spreads charged on loans to firms of smaller amount; the considerable increase in the spread of all rates, but particularly those on loans to households and small and medium-sized enterprises.

Figure 6 – Evolution of EURIBOR and bank retail rates (January 2003-September 2011)



Data Source: European Central Bank

4. Econometric methods: a regime-switching approach to model interest rate pass-through

As discussed in the previous Section, empirical studies on interest rate pass-through have provided a wide range of theoretical and methodological approaches to model monetary transmission mechanisms (see Blot and Labondance (2011) for a survey on recent analyses). In particular, the literature on bank interest rate pass-though has dealt with two issues: i) the analysis of monetary policy transmission channels, by focusing on the measurement of the pass-through

[8] See Bank of Italy (2003-2009).

degree from policy-controlled to short-term money market interest rates (first stage of the pass-through process) and then to retail bank loans and deposits rates (second stage); ii) the analysis of banks' price-setting behaviour, mainly concerned with the market condition of the banking system.

Focusing on the transmission mechanism between changes in market interest rates and bank rates, these two approaches appear to be highly related as they both base banks price setting behaviour on the following marginal cost pricing model equation (de Bondt, 2002):

$$br = \beta_0 + \beta_1 mr \quad (1)$$

where br is the price set by banks, β_0 is a constant markup and mr is the marginal cost price proxied by a comparable market interest rate and β_1 measures the degree of pass-through. The coefficient β_1 will be less than one if banks have some degree of market power and demand elasticity of bank products, with respect to retail rates, is inelastic, resulting from the existence of switching costs and asymmetric information costs. The choice of the market interest rate depends on the approach adopted: studies focusing on banks' price-setting behaviour and competition issues use market rates at different maturities, with the aim of a better matching between rates (*cost-of-funds approach*), while short-term money market rates (like interbank rates) are chosen as a driving rate when the focus is on the transmission of monetary policy, since they are strongly related with policy-controlled rates (*monetary policy approach*).

Based on the simple theoretical framework defined in (1), alternative specifications have been proposed in the empirical literature. Traditionally, the pass-trough process has been analysed by means of a simple single equation Autoregressive Distributed Lag (ARDL) model of bank interest rates (Cottarelli and Kourelis, 1994):

$$br_t = \nu + \sum_{j=1}^{j^*} \phi_j br_{t-j} + \sum_{k=0}^{k^*} \gamma_k mr_{t-k} + \varepsilon_t \quad (2)$$

where br and mr are bank and market rates, respectively, and j^* and k^* indicates optimal lag lengths. The intercept is represented by ν and γ_0 measures the degree of short-run pass-through: a value of less than 1 for γ_0 indicates a sluggish adjustment (i.e. bank rate stickiness). The coefficients ϕ_j and ϕ_k can be used to compute the long-run multiplier as:

$$\beta = \sum_{k=0}^{k^*} \gamma_k / (1 - \sum_{j=1}^{j^*} \phi_j) \quad (3)$$

so that the long-run equation can be written as $br_t = \beta_0 + \beta mr_t$, where β_0 is a constant term and with full pass-through in the long run given by $\beta_0 = 1$.

The basic model (1) is only valid if interest rate time series are stationary. When interest rates series are integrated of degree 1, the model has to be estimated in first differences:

$$\Delta br_t = \sum_{j=1}^{j*} \phi_j \Delta br_{t-j} + \sum_{k=0}^{k*} \gamma_k \Delta mr_{t-k} + \varepsilon_t \tag{4}$$

This specification avoids spurious regression problems, but leads to a loss of information about long-run relationships and is appropriate when *br* and *mr* are $I(1)$, but not cointegrated. When interest rates are $I(1)$ and cointegrated, model (4) can be augmented by a lagged error correction term ECT_{t-1}, so that the following error correction (ECM) model can be formulated:

$$\Delta br_t = \sum_{j=1}^{j*} \phi_j \Delta br_{t-j} + \sum_{k=0}^{k*} \gamma_k \Delta mr_{t-k} + \alpha ECT_{t-1} + \varepsilon_t \tag{5}$$

where ECT measures the deviation from long-run equilibrium and can be obtained from the estimated error of the cointegration regression:

$$br_t = \beta_0 + \beta mr_t + u_t \tag{6}$$

ECT_{t-1} enters model (5) with its coefficient α reflecting the speed of adjustment to the long-run equilibrium. The long-run multiplier either estimated from the cointegration vector (6) or can be obtained as in (3), based on the coefficients of equations (2) or (4).

Interest rate pass-through can be also analysed in a multi-equation framework. By simultaneously estimating multivariate autoregression (VAR) models, it is possible to allow for endogeneity of both interest rates. In fact, the interbank rates, despite being closely influenced by monetary policy interventions, could also be assumed as endogenous to the extent that central banks' actions are influenced by market forces, including the banking sector (Rocha, 2011). In the single equation approach, as pointed out by Humala (2005), the presence of any possible feedback into the market rate is completely disregarded and valuable information for the estimation of the interest rate pass-through model can be lost. For these reason, several authors (de Bond, 2002; Sander and Kleimer, 2004, 2006) have proposed multivariate generalization of the autoregressive models so far considered. In particular, focusing on the bivariate extension of the stable model (2), a stationary VAR of order *p* model can be formalized as:

$$y_t = v + \sum_{i=1}^{p} \Pi_i y_{t-i} + u_t \tag{7}$$

where y_t is a two-dimensional vector of market and bank interest rates time series, $y_t = [mr_t, br_t]$, Π_i are 2×2 matrices of parameters and $u_t = [u_{mr_t}, u_{br_t}]'$ is a two-dimensional vector of Gaussian white-noise processes with covariance matrix Σ, $u_t \sim NID(0, \Sigma_u)$.

When the two interest series in y_t are non-stationary in levels, but first-difference stationary (i.e. y_t is $I(1)$) there may be up to one linearly independent cointegrating relationship, which represents the long-run equilibrium of the system, with the deviation from the long-run equilibrium (the equilibrium term) measured by the stationary stochastic process $h_t = \beta' y_t$ (Engle and Granger, 1987). If the two series are indeed cointegrated, the VAR implies the following vector error correction model (VECM):

$$\Delta y_t = v + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + u_t \tag{8}$$

where $\Gamma_i = -\sum_{j=i+1}^{p} \Pi_j$ are 2×2 autoregressive parameters matrices and $\Pi = \sum_{i=1}^{p} \Pi_i - I$ (where I is the identity matrix) is the long-run impact matrix, whose rank r determines the number of cointegrating vectors (Johansen, 1995). In the bivariate case, Π can be partitioned into the 2×1 vector β of the long-coefficients of the cointegration vector and a 2×1 vector α containing the equilibrium correction coefficients: $\Pi = \alpha\beta'$. In the case of no cointegration between the series considered, the VECM in (8) simplifies into a first-difference stationary VAR (DVAR).

All the interest rate pass-through models so far considered assume that the relationships between bank and market rates are symmetric and linear. Several studies (Kleimeier and Sander, 2006; Payne and Waters, 2008; Wang and Thi, 2010; Rocha, 2011) have focused attention on the existence of asymmetric adjustments of retail rates in response to deviations from equilibrium. Such asymmetric adjustment patterns are modelled with threshold autoregressive models (Tong, 1983; Enders and Syklos, 2001), where the equilibrium term is split either into its positive and negative elements or into values above or below a certain non-zero threshold. These studies have provided evidence supporting the hypothesis that the degree of interest-rate pass-through is associated with an asymmetric price adjustment of retail bank products.

Despite the relatively broad empirical literature on asymmetric effects, only few studies have explicitly dealt with the issue of stochastic regime shifts and non-linearities in pass-through models. Interest rates time series, like many other economic and financial series, are characterized by occasional jumps or structural changes in their levels or volatility, which are more frequent and severe in periods of financial turmoil like the current global crisis. The presence of important discrete economic events induces substantial nonlinearities in the stochastic process and distorts inference if it is not appropriately modelled. All these concerns have led to considerable interest on econometric models that can adequately capture nonlinearities arising from regime switches. In the interest rate pass-through literature there are few studies attempting to deal with regime shifts in the relationship between bank and market rates. Almost all these analyses adopt a deterministic approach which consists in identifying (exogenously or endogenously) single or multiple structural breaks in the series (Sander and Kleimeier, 2004; Marotta, 2009) and then modelling these shifts by augmenting the empirical model with an appropriate set of dummy variables or by conducting split sample analyses. This is the case, for example, of the recent studies by Blot and Labondance (2011) and Panagopoulos and Spiliotis (2011), which analyse the effect of the current financial crises on interest rate pass-through in the Eurozone by separately estimating error correction models for the periods before and during the crisis, assuming that the turmoil period starts in the last months of 2007 and the beginning of 2008, respectively. However, when the regime shifts are stochastic rather than deterministic both previous approaches can lead to biased, or at least inefficient, results (Krolzig et al., 2002; Clarida *et al*., 2006). In these cases, a multivariate generalization of the univariate Markov-switching (MS) model originally proposed by Hamilton (1989) represents a viable alternative to allow behavioural changes by introducing the possibility of stochastic changes of regime. In the interest rate pass-through literature, the study by Humala (2005) represents, to the best of our knowledge, the only analysis employing multivariate Markov-switching models to assess the effects of financial crises on the transmission mechanism.

The basic idea behind the class of MS models is that the parameters depend upon a stochastic, unobservable regime indicator variable $s_t \in \{1,...,M\}$, which generating process is an ergodic *M*-state Markov chain governed by the transition probability:

$$p_{ij} = \Pr(s_{t+1} = j \mid s_t = 1), \ \sum_{j=1}^{M} p_{ij} = 1 \quad \forall i, j \in \{1,...,M\} \tag{9}$$

The regime indicator s_t is a variable that the researcher does not observe and has to be inferred conditional on available information, together with the parameter estimates.

Extending the bivariate VAR(*p*) model (7) in order to allow the variance–covariance matrix of the errors, the intercept term of the multivariate process and the autoregressive coefficients to switch endogenously between possible regimes, we obtain the following *M*-regime *p*th-order Markov-switching autoregressive (MS(*M*)-VAR(*p*)) model:

$$y_t = v(s_t) + \sum_{i=1}^{p} \Pi_i(s_t) y_{t-i} + \varepsilon_t \tag{10}$$

where $v(s_t)$ is the intercept term and $\Pi_i(s_t)$ are autoregressive parameter matrices, all assumed to be regime-dependent, and ε_t is the error term with variance allowed to change across states (i.e. $\varepsilon_t \mid s_t \sim NID(0, \Sigma_\varepsilon(s_t))$). Following Krolzig (1997), MS-VAR allows for a variety of specifications and it can be considered as generalizations of the basic finite order VAR model. In particular, model (10) represents the most general specification, as it allows all the parameters and the variance to vary between each state s_t of the Markov chain, and can be referred to as Markov-switching Intercept Autoregressive Heteroskedastic VAR (MSIAH(*M*)-VAR(*p*))[9].

[9] Less flexible nested specifications allows only the intercept (MSI-VAR) or the intercept and the variance (MSIH-VAR) to be regime-dependent.

Analogously, the bivariate cointegrated pass-through model (8) can be extended to be regime-dependent, obtaining a Markov-switching VECM of the form:

$$\Delta y_t = v(s_t) + \sum_{i=1}^{p-1} \Gamma_i(s_t)\Delta y_{t-i} + \alpha(s_t)\beta' y_{t-1} + \varepsilon_t \tag{11}$$

where, $\Gamma_i(s_t)$ are autoregressive parameter matrices and $\alpha(s_t)$ is a matrix of adjustment parameters, all assumed to be state dependent, β is the vector of long-run parameters, and ε_t is again the error term assumed to change across regimes.

The MS-VECM can be estimated by means of a limited information approach, using a two-stage maximum likelihood procedure (Krolzig, 1997). In the first stage, the cointegration properties of the model can be analysed by applying Johansen's (1995) maximum likelihood procedure to test for the presence of cointegration in the system and to estimate the cointegrating parameters β. The use of the conventional Johansen procedure in the first stage, by adopting a finite-order VAR approximation of the underlying data generating process, is legitimate without modelling the Markovian regime shifts explicitly (Clarida et al., 2006). In the second stage, conditional on the estimated cointegration vector, the remaining parameters of the model can be estimated by implementing the Expectation-Maximization (EM) algorithm discussed in Hamilton (1990).

Within this setting, the relationships between bank and money market (interbank) interest rates would shift stochastically between regimes, associated with periods characterized by different economic conditions (i.e. high or low volatility, recession or expansion, etc.). In this respect, the Markov-switching framework significantly differs from the threshold (asymmetric) approach to interest rate pass-through: the former accounts for the existence of switching regimes, governed by a stochastic process, which modify the transmission mechanism between market and retail interest rates, while the latter assumes that changes in the degree of pass-through happen under certain values of a deterministic model of regime switching[10]. In particular, such studies model non-linear and asymmetric adjustments depending on the size and sign of deviations of bank rates from their equilibrium relationship with respect to the interbank rate, with regime-shifts occurring once deviations exceed a predetermined threshold. For the aim of the present study, which mainly focuses on testing for the presence of heterogeneities in the degree of interest rate pass-through caused by financial distress episodes and increases in rates' volatility, a Markov switching autoregressive model seems to be more appropriate as it exhibits non-linearity over time and endogenously separates regimes arising from the probabilistic process of an unobservable state variable.

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[10] Clarida et al. (2006) attempt to integrate the two approaches by proposing an asymmetric MS-VECM of interest rates term structure, which allows for both endogenous regime switching and threshold asymmetries. Their model, however, allows only intercept and variance to be regime dependent and does not fully capture parameters heterogeneity between regimes.

5. Empirical results

In this Section we apply a Markov-switching vector autoregressive model to analyse interest rate pass-through between alternative retail interest rates and money market interest rate (proxied by the three-month EURIBOR rate) in the Euro zone, using monthly data for the period 2003(1)-2011(9). Firstly, we investigate the univariate properties of the interest rates series by testing for the presence of unit roots. Secondly, we investigate the cointegration properties of the system. In both the analyses we explicitly deal with the sensitiveness of unit root and cointegration tests in the presence of structural breaks. Finally, the results of the bivariate MS-VECM with two regimes are presented and discussed.

5.1 Unit roots tests

As a starting point of our empirical strategy, we test for evidence of non-stationary behaviour of each interest rate time series considered by employing alternative testing procedures. In particular, we analyse the behaviour of series in levels and first differences by means of the Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979) and the Dickey-Fuller-Generalized Least Squares (DF-GLS) (Elliott et al., 1996) unit root tests and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity test (Kwiatkowski et al., 1992). The range of unit root tests is completed by the Clemente-Montañés-Reyes (CMR) (Clemente et al., 1998) unit-root test that allow for a structural break in the series. A well known problem in the unit root literature is, in fact, its potential confusion of structural breaks as evidence of non-stationarity and the resulting possibility for a series which exhibits structural shifts to fail in rejecting the unit root null. In the present application, in order to account for the dramatic shift in all the interest series analysed at the end of 2008, we allow for the presence of a single breakpoint in the series, identified by means of a grid-search technique, assuming a gradual adjustment of the series following the break (innovational outlier, IO, model).

Results of the battery of tests considered are presented in Table 1. As it can be noticed, all the unit root tests considered lead to an unambiguous acceptance of the null hypothesis of unit root for all the series in levels and a rejection for the series in first-differences, providing evidence of an I(1) (difference stationarity) behaviour. The results of the CMR unit root test with one structural break (identified for all the five series in September 2008) support the non-stationarity in levels of the interest rates series even after controlling for the structural shift. Finally, the KPSS test further confirms the order of integration of the series, excluding the possibility of fractional integration.

Table 1 – Unit root tests

	EURIBOR		Consumer		Mortgage		Firms (up to 1M€)		Firms (over 1M€)	
	Levels	First diff.	Levels	First diff.	Levels	First diff.	Levels	First diff.	Levels	First diff.
a) Unit root tests										
ADF	-1.720	-4.183*	-2.305	-11.422*	-1.628	-4.679*	-1.868	-4.274*	-1.405	-5.791*
	(0.418)	(0.001)	(0.173)	(0.000)	(0.465)	(0.000)	(0.346)	(0.001)	(0.577)	(0.000)
DF-GLS	-1.688	-3.754*	-1.142	-8.868*	-1.208	-3.393*	-1.753	-3.154*	-1.365	-5.528*
	(0.084)	(0.000)	(0.256)	(0.000)	(0.230)	(0.001)	(0.083)	(0.001)	(0.175)	(0.000) *
CMR (ρ-1)	-0.049	-0.280*	-0.113	-1.430*	-0.035	-0.448*	-0.041	-0.343*	-0.049	-0.603*
b) Stationarity test										
KPSS	1.097*	0.263	1.431*	0.112	0.762*	0.250	0.787*	0.240	0.907*	0.237

Notes: asymptotic critical values for the KPSS test are -2.587, -1.944 and -1.615 at the 1, 5 and 10% levels, respectively. Clemente-Montañés-Reyes unit-root test with single mean shift, IO model. Optimal breakpoints are in 2008M09 for all the 5 series.
* denotes rejection of the null hypothesis at the 5% significance level.

5.2 Cointegration analysis

Once the nonstationary behaviour of the series has been identified, we test for pairwise cointegration between EURIBOR rate and each of the different bank rate considered. Following the two-stage procedure proposed by Krolzig (1997), we study the cointegration properties of the bivariate systems within a linear autoregressive representation, using maximum likelihood techniques.

As cointegration analysis is sensitive to the lag order of the VAR model, we firstly applied different lag selection criteria to determine the optimal number of lags to include in the bivariate systems. Results are presented in Table 2. As it can be noted, assuming a maximum order of p=5, the sequential modified LR test (LR) and the Hannan-Quinn (HQ) and Schwarz (SC) information criteria estimate an optimal order of p=2 for VAR specifications in levels of all the bivariate models. The Akaike information criterion (AIC), on the other hand, is not consistent with the other criteria and supports a larger specification with p=3 for the pass-through models of house mortgage and loans to firms over 1 million of Euros. Despite the results of the AIC criterion, we choose a VAR(2) specification in levels to perform the cointegration analysis for all the four bivariate models.

As in the univariate stationarity analysis, standard cointegration tests too often incorrectly fail to reject the null of no cointegration when there is a break in the cointegrating vectors. Johansen et al. (2000) generalised the Johansen's maximum likelihood cointegration test in order to allow for up to two known structural breaks in the deterministic part of the model. In particular, they assume that the data generating process of y_t can be described by a standard VAR model extended with appropriate dummy variables to account for structural shifts in the deterministic components. Under the hypothesis of cointegration, they propose different likelihood ratio cointegration tests, corresponding to alternative sub-models for the stochastic process y_t generated by placing restrictions on the deterministic terms, and they derive the corresponding asymptotic distributions.

Table 2 – VAR lag order selection

a) EURIBOR-Consumer

Lag	LogL	LR	AIC	SC	HQ
0	-178.62	NA	3.61	3.66	3.63
1	89.95	521.03	-1.68	-1.52	-1.62
2	121.67	60.27*	-2.23*	-1.97*	-2.13*
3	123.80	3.96	-2.20	-1.83	-2.05
4	125.56	3.20	-2.15	-1.68	-1.96
5	127.26	3.02	-2.11	-1.53	-1.87

b) EURIBOR-Mortgage

Lag	LogL	LR	AIC	SC	HQ
0	-157.46	NA	3.19	3.24	3.21
1	170.68	636.59	-3.29	-3.14	-3.23
2	207.67	70.27*	-3.95	-3.69*	-3.85*
3	212.01	8.07	-3.96*	-3.60	-3.81
4	212.31	0.55	-3.89	-3.42	-3.70
5	213.82	2.69	-3.84	-3.26	-3.60

c) EURIBOR-Firms (up to 1M €)

Lag	LogL	LR	AIC	SC	HQ
0	-150.29	NA	3.05	3.10	3.07
1	203.26	685.89	-3.95	-3.79	-3.88
2	244.01	77.42*	-4.68*	-4.42*	-4.57
3	247.60	6.68	-4.67	-4.31	-4.52
4	251.35	6.83	-4.67	-4.20	-4.48
5	252.26	1.62	-4.61	-4.03	-4.37

d) EURIBOR-Firms (over 1M €)

Lag	LogL	LR	AIC	SC	HQ
0	-106.24	NA	2.16	2.22	2.19
1	144.09	485.64	-2.76	-2.61	-2.70
2	182.64	73.25*	-3.45	-3.19*	-3.35*
3	187.70	9.40	-3.47*	-3.11	-3.33
4	190.52	5.13	-3.45	-2.98	-3.26
5	193.70	5.66	-3.43	-2.86	-3.20

Notes: * indicates lag order selected by the criterion.

Based on the empirical evidence obtained in the univariate time series analysis, we thus refer to the Johansen-Mosconi-Nielsen (JMN) test to carry out cointegration analysis in the presence of one known structural break in the deterministic intercept[11]. The break has been defined as occurring in September 2008, an observation which has been identified as the optimal breakpoint for all the series considered in the CMR unit root test. Table 3 presents the results of the JMN cointegration test. The null of no cointegration is clearly rejected at the 1% significance level in favour of the alternative hypothesis of one cointegrating relationship with a structural break occurring in September 2008 in all the four bivariate models. On the other hand, linear cointegration (Johansen, 1995) tests, presented in Table A1 in the Appendix, fail in rejecting the null hypothesis of no cointegration between bank and interbank interest rates, further confirming the necessity of appropriately modelling structural shifts in the deterministic components for the assessment of the cointegration properties of the systems.

The estimated long-run cointegration relationships between bank and interbank rates assumes the following form:

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[11] In particular, we refer to the model with a broken constant level in Johansen et al. (2000, page 225):

$$\Delta y_t = (\Pi, \mu)\begin{pmatrix} y_{t-1} \\ E_t \end{pmatrix} + \sum_{i=1}^{p-1}\Gamma_i \Delta y_{t-i} + \sum_{i=1}^{p}\sum_{j=2}^{q}\kappa_{j,i} D_{j,t-i} + u_t$$

where $E_t = (E_{1t}, E_{1t}, \ldots, E_{qt})'$ is a matrix of q dummy variables, where $E_{j,t}$=1 if observation t belongs to the jth period and 0 otherwise, $D_{j,t-i}$ is an impulse dummy that equals 1 if observation t is the ith observation of the jth period. The hypothesis of reduced cointegration rank $H_c(r)$: rank $(\Pi, \mu) \leq r$ can be then tested by means of a LR test statistics.

$$\beta' y_{t-1}^{consumer} = br_{t-1}^{consumer} - \underset{(0.0603)}{0.1757}\, mr_{t-1}$$
$$\beta' y_{t-1}^{mortgage} = br_{t-1}^{mortgage} - \underset{(0.0485)}{0.4321}\, mr_{t-1}$$
$$\beta' y_{t-1}^{firm\_up1M} = br_{t-1}^{firm\_up1M} - \underset{(0.0547)}{0.4957}\, mr_{t-1} \quad (12)$$
$$\beta' y_{t-1}^{firm\_ov1M} = br_{t-1}^{firm\_ov1M} - \underset{(0.0415)}{0.7292}\, mr_{t-1}$$

where we have normalized the cointegration vectors so that the coefficient of br_{t-1} in each model equals 1 and the constant has been suppressed.

The long-run multipliers in (12), as discussed in Section 4, measure the degree of pass-through and a coefficient equal to 1 implies that all the changes in the policy-vehicle rate are transmitted to retail rates. The long-run pass-through from interbank to all the bank rates considered is found to be incomplete: despite being statically significant, all the impact multipliers are lower than 1. Our results are in line with those of Blot and Labondance (2011) and suggest that the transmission mechanism becomes more effective in both household and firm markets as the maturity and the amount of the loans increases.

Table 3 – Johansen-Mosconi-Nielsen cointegration test with one break in the intercept

			Critical Values*:		
H_0: *rank* = *r*	LR Statistic	p-value	90%	95%	99%
a) EURIBOR-Consumer					
$r = 0$	43.11*	0.0000	22.66	24.73	28.94
$r \leq 1$	9.31	0.1779	10.93	12.74	16.62
b) EURIBOR-Mortgage					
$r = 0$	32.44*	0.0022	22.66	24.73	28.94
$r \leq 1$	8.35	0.2442	10.93	12.74	16.62
c) EURIBOR-Firms (up to 1M €)					
$r = 0$	35.07*	0.0007	22.66	24.73	28.94
$r \leq 1$	3.39	0.8265	10.93	12.74	16.62
d) EURIBOR-Firms (over 1M €)					
$r = 0$	42.75*	0.0000	22.66	24.73	28.94
$r \leq 1$	6.21	0.4592	10.93	12.74	16.62

Notes: * indicates rejection of the null hypotesis at the 5% level. Critical values are derived from the estimated distribution for the model *Hc*(*r*) presented in Johansen et al. (2000).

The pass-through between money market and consumer loans rate is found to be particularly weak, revealing that these interest rates are less impacted by monetary conditions than the others considered and suggesting the existence of higher market power of banks in setting retail prices for short term consumption loans. The degree of pass-through is found to be higher for lending rates for house purchase (0.4321) and for loans to non-financial corporations up to 1 million Euros (0.4957). Finally, the highest degree of pass-through is estimated for loans over 1 million Euros, which may generally granted to bigger and more firms than the loans up to 1 million. For such loans, the higher competition between banks and markets, as pointed out by Blot and Labondance (2011), reduce banks' market power, thus increasing the long-term equilibrium pass-through.

5.3 MS-VECM results

The cointegration results from the previous sub-section are used in the second stage of our interest rate pass-through analysis. We specify a Markov-switching VECM with 2 regimes and 1 lag in the first-differences of the variables[12], with regime shifts in the intercept, the autoregressive parameters and the error variance (MSIAH(2)-VECM(1)). The estimates of the MS-VECM, obtained by using the *MSVAR* package by Krolzig (2004) for the Ox programming language (Doornik, 2007), are presented in Table 4 and Figure 7.

In analysing the results, we first verify for the appropriateness of the non-linear representation of the data, by testing the Markov-switching VECMs against their linear counterparts by means of likelihood ratio tests[13]. Results show a clear rejection of the hypothesis of linearity at the 1% significance level for all the bivariate models, providing strong support to the necessity of including a Markov-switching mechanism to correctly representing the dynamic relationship between interbank and each retail bank interest rate and to capture the different degrees of interest rate pass-through in normal market conditions and in a high-volatility context. Moreover, LR tests for nested Markov-switching specifications (namely, MSI and MSIH) unambiguously suggest a rejection of the null hypothesis, indicating that a MSIAH-VECM allowing for shifts in the intercept, the variance-covariance matrix and the autoregressive structure is the most appropriate specification for all the bivariate models of interest rate pass-through considered. Figure A2 in the Appendix shows the statistical properties of the normalized residuals of the bivariate models. The residuals appear to be non-autocorrelated, homoskedastic and normally distributed and thus provide support for our interest rate pass-through models to be based on a congruent econometric specification.

Turning to the analysis of the characteristics of the two regimes, for all the four models it is possible to note that Regime 2 contains most of the observations, has the longest duration and highest probability, and can be therefore assumed as the "Normal" regime. Regime 1, on the other hand, contains 15% to 20% of the observations and has an average duration over 5 months only for

[12] Given the optimal lag order of the VECM, defined in the linear analysis, AIC and log-likelihood criteria were used to determine the number of regimes.
[13] Similar results are obtained for the non-linear MSI-VECM and MSIH-VECM. All the LR tests, not presented here but available from the authors, lead to reject the null hypothesis of linearity.

the pass-through model of loans to firm up to 1 million Euros, while for the remaining models the duration of this regime is below 3 months. Regime 1 is also characterized by a significantly higher volatility of the EURIBOR rate and a general decreasing tendency of all the interest rates (as it can be noted from the graphs in Figure A.1 in the Appendix), which turns into a higher estimated variance especially for the interbank rate equation with respect to the normal regime in almost all the bivariate models. Regime 1 can therefore defined as a "High-volatility" state.

Moreover, the transition matrices defining the Markov switching regimes show that there is a higher probability to remain in a "Normal" state if that was the current state of the economy in the previous period: the normal regime is therefore highly persistent, with more than a 90% probability of staying in this regime for all the models (with the mortgage and loans to firms up to 1 million Euros rates displaying the highest persistence). Conversely, the probability of changing from one regime to another is higher in periods of financial turmoil (with transition probabilities around 30%, with a maximum of 46% for consumer rates), suggesting an overall instability of the high-volatility state.

In Figure 7, we represent the estimated filtered and smoothed regime probabilities for the two-regimes bivariate pass-through models. The filtered probability is the probability of being in a given regime at time *t* conditional on the information set observed up to date *t*, while the smoothed probability represents the conditional probability based on the information available throughout the whole sample of *T* observations. The probability of being in a "High-volatility" (Regime 1) state is represented on the *y*-axis, while the corresponding date on the *x*-axis. The analysis of the graphs allows to reconstruct the time-path of regimes and offers additional support to the usefulness of the approach adopted in this application[14]. Looking at the regime probabilities patterns, we observe similar regime properties for all the models. Moreover, our modelling approach is able to undoubtedly identify those periods of financial turmoil already discussed in the descriptive analysis of Section 3. In particular, from the onset of the subprime crises at the end of 2007, the frequency of the high-volatility regime significantly increases in all the models, highlighting the necessity of separately modelling interest rate pass-through in this period of global crisis. Focusing on the crisis period, the models show some heterogeneity in the dynamics of interest rates. The evident structural break in the last months of 2008 and in the firsts of 2009 as well as the marked variability of interest rates at the end of 2007 are correctly captured in all the specifications. The pass-through models for consumer loans and for non-financial corporations loans over 1 million of Euros rates show frequent regime changes with the presence of several short periods of high variability in 2010

[14] The smoothed regime probabilities are used to assigning observations to each regime. In the two-regimes case, the classification rule simplifies so that an observation is assigned to the first regime if $\Pr(s_t = 1 \mid y_T) > 0.5$ and to the second if $\Pr(s_t = 1 \mid y_T) < 0.5$.

and in 2011. On the other hand, the pass-through to interest rates for loans to firms up to 1 million Euros is characterized by a highly volatile state, which lasts for 11 months from October 2008 to September 2009, revealing the remarkable impact of the spread of global financial crisis on the transmission mechanism of changes in interbank rate to this type of retail bank rate.

Turning to the analysis of the estimated parameters in Table 4, and focusing on the short-run multipliers and on the speed of adjustment coefficients, the MSIAH-VECM models show significantly different behaviours for the retail bank lending rates under the two different regimes. A common feature of all the models is the lower degree of pass-through in the short-run and the higher speed of adjustment to disequilibria during periods of high-volatility: the effects of financial turmoil periods seem to weaken the short-run transmission between the money market and retail bank rates, but they strongly increase the responsiveness of loan rates from deviations to long-run equilibrium. This empirical evidence is in line with the findings of Blot and Labondance (2011), based on a split-sample analysis of pass-through in the Euro area before and during the current financial crisis.

Analysing the degree of pass-through for each retail rate, we find that the rates for loans to households to finance both consumption and house purchase are stickier and characterized by a more sluggish adjustment than the loan rates to non-financial corporations. In particular, consumer loans display the lowest short-run pass through in both the regimes (0.1526 and 0.1713 in Regime 1 and 2, respectively) and also the speed of adjustment is lower than that of the other rates, despite it increases in the high-volatility state. A similar picture emerges for the loan rates for house purchase, for which the pass-through is slightly more effective in the normal market regime (0.2610), but it is not significantly different from zero in periods of high-volatility, while the increase in the speed of adjustment is more marked (from 0.0278 to 0.2491, shifting from regime 2 to regime 1). Turning to the analysis of the pass-through to interest rates for loans to non-financial corporations, we note that the short-term relationships with the interbank rate are more important and effective than those found for the household segment. More precisely, the degree of pass-through is significantly higher and quite stable between in the two regimes for loans up to 1 million Euros (0.5341 and 0.5596, respectively), and it is almost complete in the case of loans over 1 million Euros in the normal market state, being equal to 0.9119, and remains high also in financial turmoil periods (0.7490). The speeds of pass-through are also much more pronounced, particularly for interest rates on loans over 1 million Euros, which are characterized by the highest responsiveness in the adjustment to long-run disequilibria especially in high-volatility periods (0.5904). This evidence confirms the existence of significant heterogeneity in banks' pricing behaviour and reveals the lower market power of banks in setting retail rates for loans granted to larger firms.

Table 4 – Markov-Switching VECM estimates

	a) Consumer		*b) Mortgage*		*c) Firms (up to 1M €)*		*d) Firms (over 1M €)*	
Model:	MSIAH(2)-VECM(1)		MSIAH(2)-VECM(1)		MSIAH(2)-VECM(1)		MSIAH(2)-VECM(1)	
	Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}
Regime 1								
Intercept								
v_1	-0.1279	0.0255†	0.0264	0.0163	-0.0948‡	-0.0656‡	-0.0165	0.0078
	(-1.55)	(1.93)	(0.24)	(1.13)	(-2.87)	(-5.14)	(-0.27)	(0.16)
Autoregressive coefficients								
Δmr_{t-1}	0.5379‡	0.1526‡	-0.0126	0.0063	0.4364	0.5341‡	0.7928	0.7490†
	(2.21)	(4.08)	(-0.03)	(0.11)	(1.57)	(4.43)	(1.48)	(1.81)
Δbr_{t-1}	1.3802	-0.8030‡	0.5843	0.3669‡	-0.4676	-0.4612‡	-0.1940	-0.3864
	(1.35)	(-5.30)	(0.48)	(2.38)	(-1.15)	(-2.66)	(-0.26)	(-0.67)
Adjustment coefficient								
α_1	0.0010	0.1351‡	0.6007	0.2491‡	0.4739‡	0.2242‡	0.4957	0.5904‡
	(0.02)	(4.46)	(1.46)	(4.67)	(8.77)	(10.15)	(1.34)	(2.01)
Standard Error								
σ_1	0.2826	0.0417	0.2847	0.0339	0.0754	0.0356	0.2505	0.1900
Regime 2								
Intercept								
v_2	0.0152‡	-0.0112	0.0133‡	0.0015	0.0340‡	0.0213‡	0.0148‡	0.0075
	(3.84)	(-0.70)	(3.04)	(0.23)	(3.63)	(2.78)	(3.92)	(0.81)
Autoregressive coefficients								
Δmr_{t-1}	0.5883‡	0.1713†	0.6064‡	0.2610‡	0.5177‡	0.5596‡	0.6478‡	0.9119‡
	(21.65)	(1.68)	(11.25)	(3.31)	(3.86)	(4.99)	(11.13)	(6.86)
Δbr_{t-1}	0.0037	-0.1905†	-0.0171	0.1867†	-0.1330	-0.2150	0.0060	-0.4450‡
	(0.15)	(-1.77)	(-0.25)	(1.84)	(-0.74)	(-1.53)	(0.10)	(-3.33)
Adjustment coefficient								
α_2	0.0076‡	0.0209‡	0.0177†	0.0278†	-0.0237	-0.0254‡	-0.0228	0.0518†
	(3.03)	(1.97)	(1.68)	(1.78)	(-1.47)	(-1.99)	(-1.33)	(1.77)
Standard Error								
σ_2	0.0336	0.1447	0.0393	0.0582	0.0653	0.0518	0.0302	0.0754
Log Likelihood	209.20		291.34		310.33		266.31	
LR tests:								
linearity test	179.8 (11) [0.000]		158.0 (11) [0.000]		110.2 (11) [0.000]		159.3 (11) [0.000]	
MSIAH vs MSI	169.1 (9) [0.000]		139.1 (9) [0.000]		90.6 (9) [0.000]		126.2 (9) [0.000]	
MSIAH vs MSIH	17.6 (6) [0.007]		19.9 (6) [0.003]		20.7 (6) [0.002]		19.5 (6) [0.003]	

Characteristics of the regimes:

Persistence of regimes

	Erg.Prob	Duration	Erg.Prob	Duration	Erg.Prob	Duration	Erg.Prob	Duration
Regime 1	0.1588	2.15	0.1487	3.31	0.1987	5.08	0.2346	3.06
Regime 2	0.8412	11.37	0.8513	18.94	0.8013	20.47	0.7654	9.98

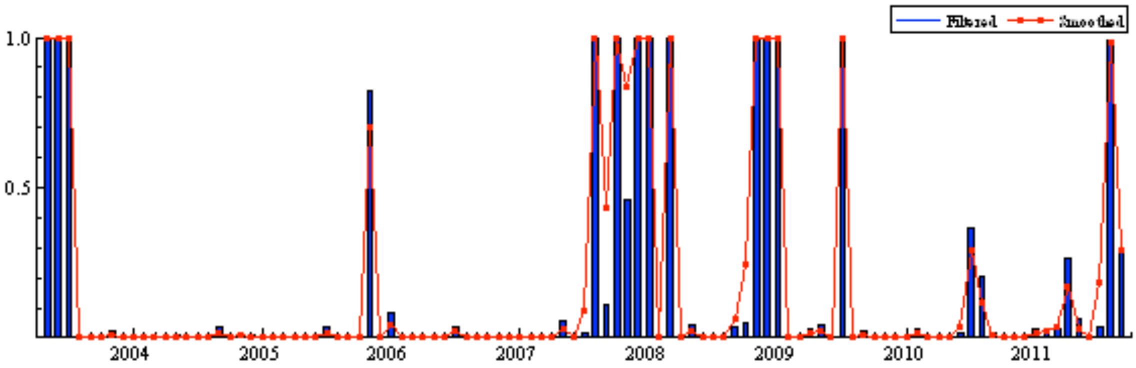
Transition probabilities

	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Regime 1	0.5343	0.4657	0.6977	0.3023	0.8031	0.1969	0.6729	0.3271
Regime 2	0.0879	0.9121	0.0528	0.9472	0.0488	0.9512	0.1002	0.8998

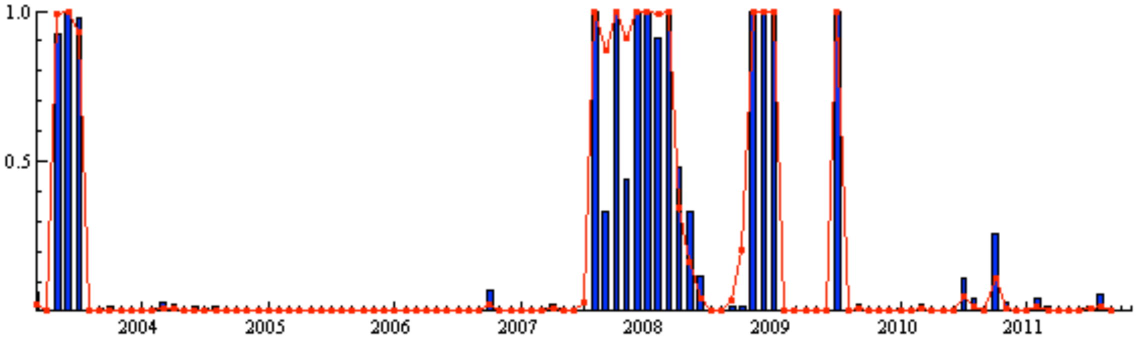
Notes: *t*-statistics in parentheses. Daggers ‡ and † denote significance at the 5% and 10% levels, respectively. For the LR tests we report the degrees of freedom of the chi-square statistics in parentheses and the corresponding *p*-value in brackets.

Figure 7 – “High-volatility” regime probabilities of the MS-VECM

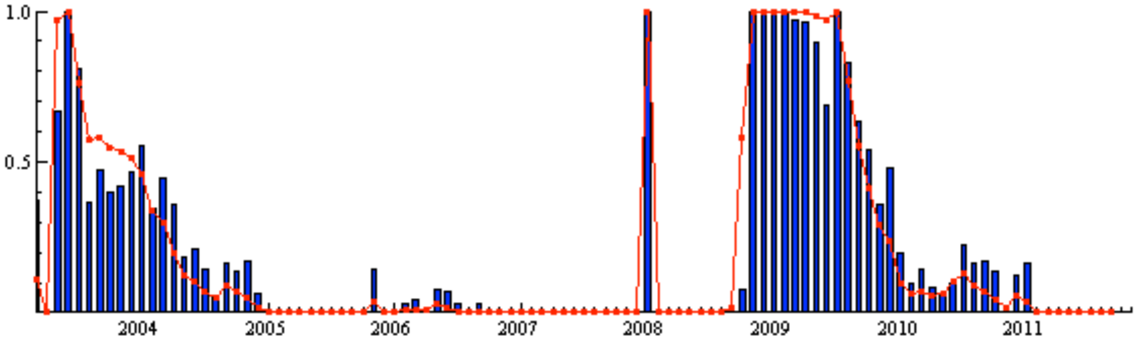
a) EURIBOR-Consumer



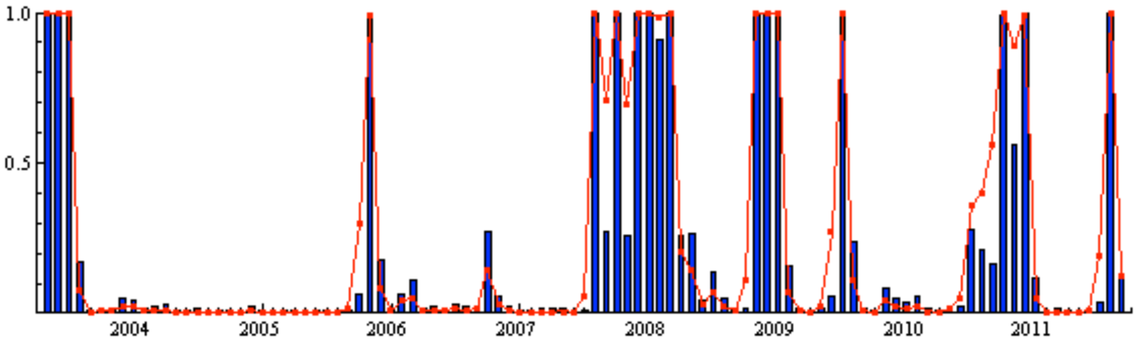
b) EURIBOR-Mortgage



c) EURIBOR-Firms (up to 1M €)



d) EURIBOR-Firms (over 1M €)



Finally, significant insights on the relationships between interbank and retail bank rates can be drawn from the analysis of the contemporaneous correlations in Table 5. In the MSIAH-VECM also the contemporaneous covariance matrices of the residuals is allowed to be regime switching, and substantial differences across regimes in the instantaneous correlations between interest rates, conditional on the past, emerge (Krolzig et al., 2002; Humala, 2005). In particular, although the correlations coefficients are positive in all the regimes, the high volatility regime is characterized by higher contemporaneous correlations between EURIBOR and all the bank interest rates, with the exception of the interest rate on loans to firms up to 1 million Euros. This result reflects that interest rates tend to move together, reacting simultaneously to policy interventions and to the arrival of relevant new information, and this relationship is stronger in periods of financial distress than in normal market conditions. This result does not contradict the evidence of a decreasing degree of short-run pass-through during periods of turbulence, but is instead related to the significantly higher speed of adjustment to disequilibria of both equations of each bivariate system in the high-volatility state.

Table 5 – Contemporaneous correlations

a) EURIBOR-Consumer					*b) EURIBOR-Mortgage*				
Regime 1			Regime 2		Regime 1			Regime 2	
	Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}		Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}
Δmr_{t-1}	1.000	0.2982	1.000	0.2147	Δmr_{t-1}	1.000	0.5419	1.000	0.1377
Δbr_{t-1}	0.2982	1.000	0.2147	1.000	Δbr_{t-1}	0.5419	1.000	0.1377	1.000
c) EURIBOR-Firms (up to 1M €)					*d) EURIBOR-Firms (over 1M €)*				
Regime 1			Regime 2		Regime 1			Regime 2	
	Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}		Δmr_{t-1}	Δbr_{t-1}	Δmr_{t-1}	Δbr_{t-1}
Δmr_{t-1}	1.000	0.5634	1.000	0.6604	Δmr_{t-1}	1.000	0.9305	1.000	0.5719
Δbr_{t-1}	0.5634	1.000	0.6604	1.000	Δbr_{t-1}	0.9305	1.000	0.5719	1.000

Also from the analysis of contemporaneous correlations, the interest rate for loans to firms up to 1 million Euros emerges as the retail rate that follows more closely the dynamics of the EURIBOR rate (with contemporaneous correlations of 0.9305 and 0.5719 in high-volatility and normal regimes, respectively), which therefore mostly determines its evolution over time. All the other rates, especially those on household loans, are less correlated to the interbank rate in both regimes, showing that, not only the past dynamics of the rates, but also other factors significantly contribute in determining the contemporaneous relationship particularly in normal market conditions.

6. Conclusions

In this paper we analyse the transmission mechanism of monetary policy impulses, through the interbank market, to the real economy, in the Euro area and during the period 2003(1)-2011(9). In particular, one of the main research question was to measure to what extent the current financial crisis has affected the transmission process of monetary policy impulses to the real economy through the bank lending channel.

Our investigations, based on Markov-switching vector autoregressive model, show that the effects of financial turmoil periods seem to weaken the short-run transmission between the money market and retail bank rates, but they strongly increase the responsiveness of loan rates to deviations from the long-run equilibrium.

In the short term, interest rates on loans to non-financial firms are more affected by changes in the interbank rate, than loans to households, both in times of turmoil and in the normal regime.

The degree of long-run pass-through is higher for rates on loans to larger firms. The responsiveness of the household sector is confirmed to be lower than the firm sector and, in particular, the transmission mechanism is almost ineffective for the consumer credit rates.

This behaviour confirms the theory that the increased bargaining power enjoyed by financial intermediaries with respect to households and the characteristics of the European credit market, strongly focused on banks, affect the process of price-setting. Interest rates on loans to households are therefore affected by other elements, related to the specific risks arising from the type of relationship established between banks and customers. Note that, although during the crisis all rates reduce their responsiveness to the interbank rate, the interest rate on mortgage has a very low coefficient and if, as usually happens during times of crisis, the official rates and the interbank rates reduce, this means that mortgage rates (at least in the short term) do not benefit from this reduction and, more generally, that there is a slowdown in the transfer of monetary policy impulses.

Consumer credit is the type of loan that is less influenced by movements in the interbank rate: it is usually a loan of small amount, for the provision of which automated procedures (credit scoring) is used for the evaluation of the creditworthiness of borrowers. Normally, banks apply very high spreads in these loans, because the small size of the loan does not justify further investigation on the actual credit risk of the borrower.

Loans to non-financial companies for amounts over 1 million Euros are more sensitive to changes in EURIBOR in both regimes. While for loans up to 1 million the transition from the normal regime to the high volatility/crisis state does not lead to substantial changes in bank price-setting behaviour, for loans of higher amount (i.e. for loans to larger firms) there is a more considerable decrease of the influence exerted by changes in EURIBOR. Thus, the variation of the

EURIBOR rate has a lower effect on bank rate during the financial crisis than during the "normal" period. This demonstrates a further reduction in the bargaining power of banks in setting retail rates for loans to larger firms.

These findings are in line with the recent literature focusing on the current global financial crisis and confirm the existence of heterogeneous behaviours in adapting bank rates to changes in money market rates during high volatility periods and with respect to different types of loans.

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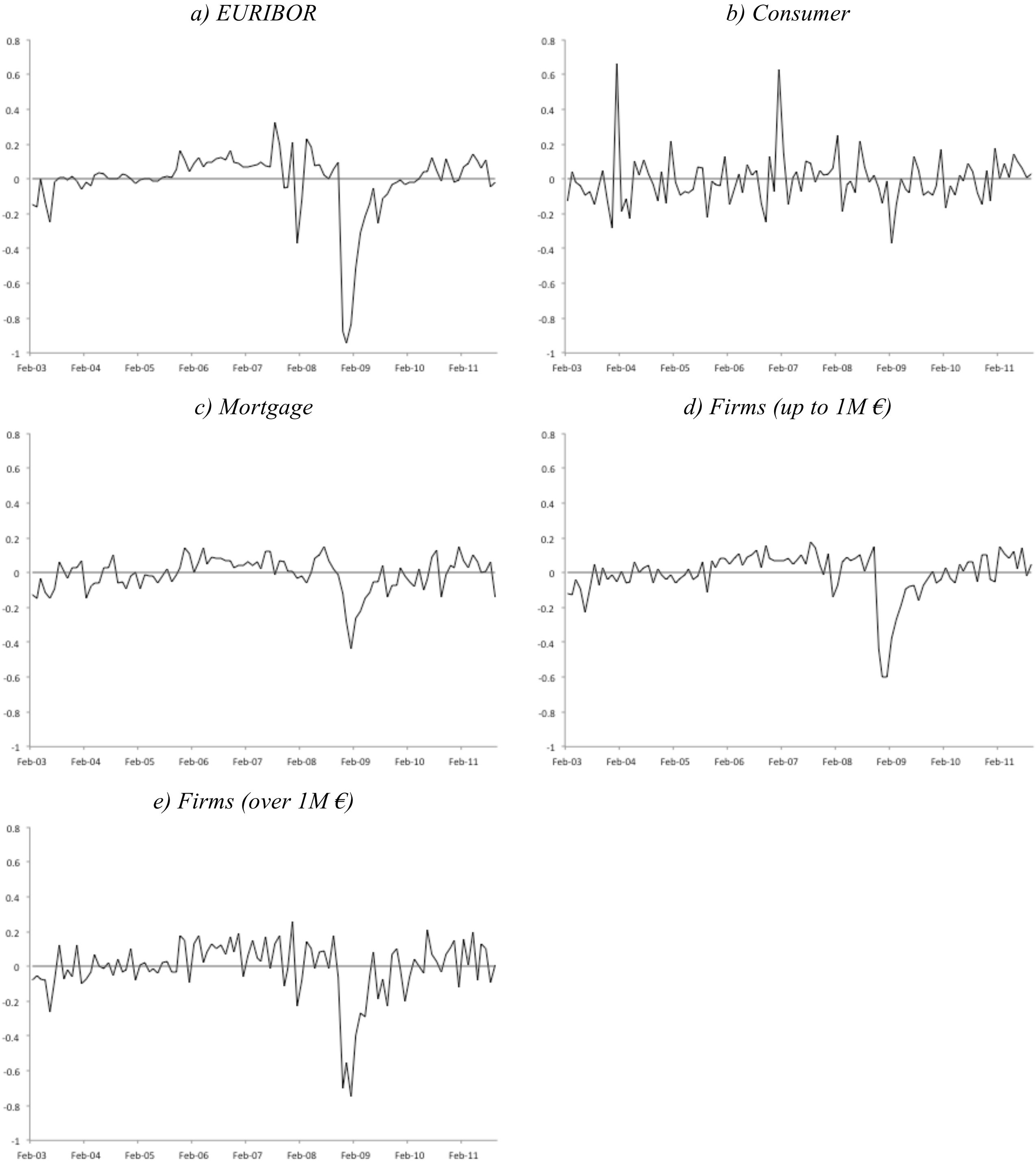
Appendix

Table A1 – Johansen cointegration tests

H_0: *rank* = *r*	Eigenvalue	Trace Stat.	95% CV	p-value*	Max-Eigen Stat.	95% CV	p-value*
a) EURIBOR-Consumer							
$r = 0$	0.0992	14.93	20.26	0.231	10.76	15.89	0.270
$r \leq 1$	0.0397	4.17	9.16	0.388	4.17	9.16	0.388
b) EURIBOR-Mortgage							
$r = 0$	0.0767	13.11	20.26	0.355	8.22	15.89	0.522
$r \leq 1$	0.0464	4.89	9.16	0.295	4.89	9.16	0.295
c) EURIBOR-Firms (up to 1M €)							
$r = 0$	0.1090	13.27	20.26	0.343	11.89	15.89	0.192
$r \leq 1$	0.0133	1.38	9.16	0.895	1.38	9.16	0.895
d) EURIBOR-Firms (over 1M €)							
$r = 0$	0.0508	8.20	20.26	0.808	5.37	15.89	0.854
$r \leq 1$	0.0271	2.83	9.16	0.613	2.83	9.16	0.613

Notes: *MacKinnon-Haug-Michelis (1999) p-values

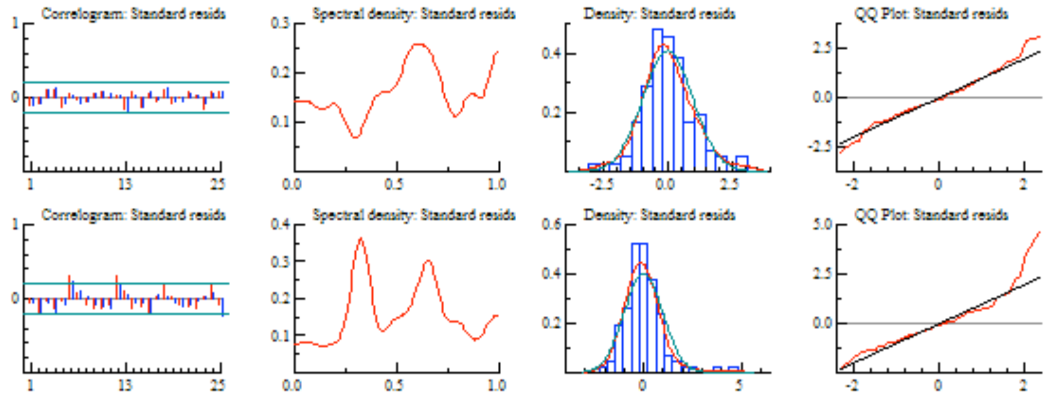
Figure A1 – Monthly changes in EURIBOR and bank retail rates



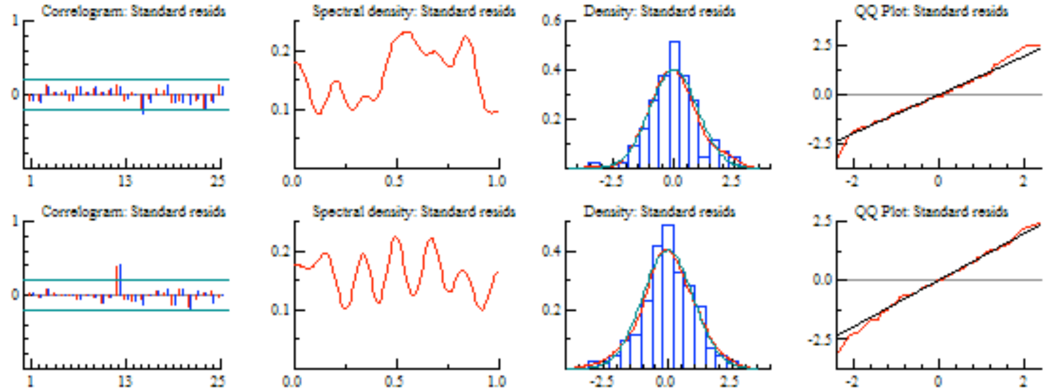
Data Source: European Central Bank

Figure A2 – Statistical properties of the normalized residuals

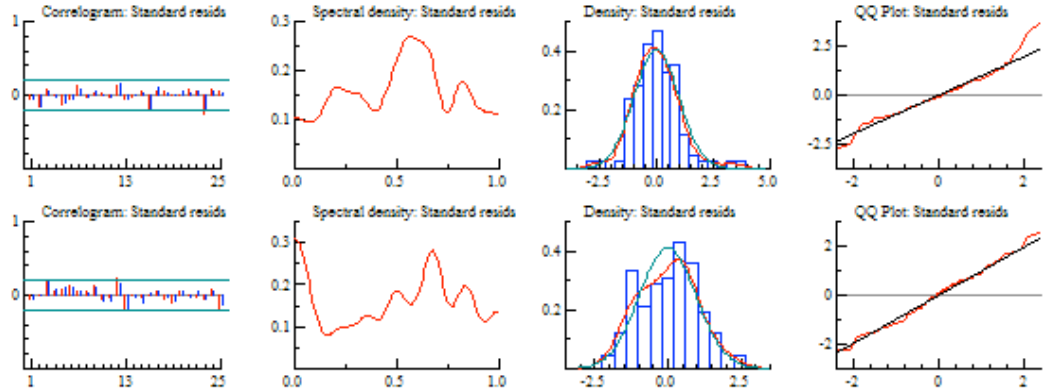
a) EURIBOR-Consumer



b) EURIBOR-Mortgage



c) EURIBOR-Firms (up to 1M €)



c) EURIBOR-Firms (over 1M €)