INTEREST RATE PASS-THROUGH IN THE EURO AREA DURING THE FINANCIAL CRISIS: A MULTIVARIATE REGIME-SWITCHING APPROACH

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Interest Rate Pass-Through in the Euro Area during the Financial Crisis: a Multivariate Regime-Switching Approach

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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. Empirical results, based on monthly data for the period 2003-2011, show that during periods of financial distress bank lending rates to both households and non-financial corporations 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. The condition of stable prices and of low inflation level represents a primary objective of European Central Bank’s (ECB's) monetary policy, while the stability of a financial system ensures an efficient allocation of financial resources (Issing, 2003). Bordo et al. (2000) write that “a monetary regime that produces aggregate price stability will, as a by-product, tend to promote stability of the financial system”. So, these two goals are related each other: price stability is a condition for financial stability, while this latter is important for the effective transmission of monetary policy (Papademos, 2009).

One of the most important channels of monetary policy is the interest rate channel (Borio and Fritz, 1995; Kwapil and Scharler, 2006a). The interest rates set by central banks affect the interbank rates, which are the basis of the process of defining the cost of money lent by banks to their customers, and therefore 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 financial stability (De Bondt, 2005). So, 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 system to raise funds (Blot and Labondance, 2011). The Euro area financial system is characterized by a dominant role played by banks in the financing of the economy, so the transmission process from policy rates to banking rates is of high importance for economic activity (Papademos, 2009).

Even if there are additional market and demand factors that affect the definition of bank rates (i.e. 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 (Borio and Fritz, 1995).

From another point of view, the wholesale bank funding (and the related interest rates) is also affected by the performance of retail funding. In fact, the rising costs that banks are facing 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.

The recent literature on interest rate pass-through has shown that the current global financial crisis has drastically affected the transmission mechanism from money market to retail rates in the Eurozone (Blot and Labondance, 2011; Cihak et al., 2009). Many scholars have questioned the role of monetary policy during periods of financial turbulence, the effectiveness of monetary policy instruments and processes of transmission of monetary policy impulses (Humala, 2005; Papademos, 2009; Giannone et al., 2011; Abbassi and Linzert, 2011).
In this paper we focus on the interest rate channel of monetary policy transmission. Our purpose is not only to verify the effectiveness of the interest rate pass-through from policy rates to bank interest rates, but also to investigate how much the interest rate pass-through is influenced by periods of financial turmoil and whether the banking system adjusts its pricing behaviour to highly volatile market conditions or if it is not affected by them.

Our main research questions can be summarized as follow: 1) How financial turmoils, and in particular the recent financial crisis, affect 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) Do banks show different behaviours in setting rates to 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 the relationships between bank interest rates and the money market rates in the Eurozone for the period 2003-2011, allowing for changes in the degree and speed of pass-through in normal market conditions and during financial turmoil periods. This model assumes that changes in the degree of pass-through happen under certain values of a stochastic regime-switching model. For the analysis of the transmission process of monetary policy impulses through the interest rate channel, to the best of our knowledge, this approach has been used only by Humala (2005) on data from Argentinean banking system, during the period 1993-2000. Compared to most of the empirical literature, the main advantage of a Markov-switching model is that it allows to estimate not only the short and long run interest rate pass-through, but also the different stickiness of the interest rate transmission mechanism during periods characterized by different economic conditions (i.e. high or low volatility, recession or expansion, etc.).

The contribution of the present paper is twofold. First, it analyses the short and long-run relationship between the money market (interbank) rate and different lending rates in a multivariate framework, by measuring the pass-through process between these interest rates in the Euro area banking system. Second, it captures the effects of financial crises over this transmission mechanism.

Our results point out the existence of significant heterogeneities in the degree and speed of pass-through with respect to both different bank retail rates and market conditions. In particular, 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 crisis and in normal market conditions. During financial distress episodes all rates reduce their degree of pass-through, impairing the interest rate channel for the transmission of monetary impulses. However, the higher speed of adjustment to long-term disequilibria in turmoil periods contributes to partially restore the functioning of the monetary transmission mechanism.
The remainder of the paper is organized as follows. Section 2 provides a review on the literature related to the bank interest rate pass-through. Section 3 summarizes and describes the main events relating to the financial crisis of 2007. Section 4 presents the data and Section 5 illustrates the econometric methodology. In Section 6, we present the main empirical results, whereas Section 7 offers some concluding remarks and policy implications.

2. Overview of the literature on interest rate pass-through

The economic literature on the mechanisms of transmission of monetary policy impulses through the bank interest rates is based on different theoretical and methodological approaches. Empirical analyses are applied to single different countries (Cottarelli and Kourelis, 1994; Weth, 2002; Horváth et al., 2004; Coffinet, 2005; Humala, 2005; De Graeve et al., 2007; Gambacorta and Iannotti, 2007; Jobst and Kwapił, 2008; Ozdemir, 2009; Harbo Hansen and Welz, 2011), or to groups of countries, as the Eurozone (De Bondt, 2005; ECB, 2009; Karagiannis et al., 2010; Blot and Labondance, 2011; Antao, 2009; De Bondt, 2002) and focus on different periods of time. 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.

The adjustment of retail rates to changes in money market rates is not instantaneous, but the transmission mechanism needs some time to be effective. In the short run, lending rates are sticky and the degree of pass-through is less than one, while in the long run the degree of pass-through is higher and, in some cases, complete (Cottarelli and Kourelis, 1994; Borio and Fritz, 1995; Kleimeier and Sander, 2000 and 2002; Donnay and Degryse, 2001; Kwapił and Scharler, 2006a; Toolsema et al., 2001; Gambacorta, 2008). 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 transmission of monetary policy is influenced by macroeconomic factors, as well as by the distinct features of legal and financial structures and by cultural differences (Cottarelli and Kourelis, 1994; Sander and Kleimeier, 2004).

Heterogeneities in the degree of pass-through are also related to banks’ characteristics (Weth, 2002; Affinito and Farabullini, 2006), to the size of banks and their liability structure (Cottarelli et al., 1995; Bistricanau, 2009).

The health of banks is one of these characteristics 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, banks 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.

Gambacorta (2008) shows that heterogeneity in the banking rates pass-through depends on liquidity, capitalization and relationship lending. Heterogeneity in adjustments is also found to be linked to menu costs and key financial ratios under managerial control (Fuertes and Heffernan, 2009).

Differences in the degree of pass-through are also related to the presence of structural breaks and discrete economic events (Hofmann and Mizen, 2004; Sander and Kleimeier, 2004; Hofmann, 2006; Vajanee, 2007; Marotta, 2009; Blot and Labondance, 2011). The presence of several episodes of financial crises alters speed and degree of response to shocks in the interbank rate (Humala, 2005; Cihak et al., 2009; Blot and Labondance, 2011; Panagopoulos and Spiliotis, 2011). Blot and Labondance (2011) demonstrate that the heterogeneity between Eurozone countries in the degree of interest rate pass-through has increased after the financial crisis.

Ritz (2010) shows that increased funding uncertainty can explain a more intense competition for retail deposits, 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.

Cihak et al. (2009) analyse the European Central Bank’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 rates to market rates has continued to operate, but at a decreased efficiency. Besides they also find some evidence that the ECB’s non-standard measures reduced money market term spreads, facilitating the pass-through from policy to market rates.

One of the consequences of the widespread financial crisis is the interruption in the correct functioning of money market. The bank lending transmission channels is weakened by financial turmoil. This clearly emerges from the increased spread between official rates and money market rates and between the official rates and the retail rates: the bank interest rates to the retail market (households and firms) declined much less than the policy rate (Cihak et al., 2009; Karagiannis et al. 2010). In these cases non-standard monetary policy measures are needed to help stabilizing the financial system and broader economy (Lenza et al., 2010). For example, during the current financial crisis, the European Central Bank have adopted non-standard policy measures, like the introduction of some changes to the eligible collateral list, a major lengthening of the maturity of ECB’s refinancing operations, the liquidity provision in foreign currency (Lenza et al., 2010; Moutot, 2011).
The behaviour of interest rates on bank loans recorded during the financial crisis is connected not only to changes in official interest rates, but also to the losses suffered by 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 paper contributes to the empirical literature on the interest rate pass-through, analysing a period of time ranging from 2003 to 2011, during which several episodes of turbulence, in particular the financial crisis of 2007-2008, have played a important role in the transmission process of monetary policy impulses. Through the use of Markov-switching vector autoregressive model, we analyse the relationships between bank interest rates and the money market rates in the Eurozone, and we study the different stickiness of the interest rate transmission mechanism during periods characterized by different economic conditions. This approach allows us to test whether the transmission process from money market interest rates to retail rates significantly differs in periods of normal economic conditions and in periods of financial turbulence, like the current global financial crisis.

3. Monetary policy and interest rates in the Eurozone during the financial crisis

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. The presence of strong information asymmetries has created a panic in financial markets and has reduced the net financial wealth of banks, weakening the effectiveness of monetary policies. Monetary authorities have repeatedly cut interest rates (Lenza et al., 2010) in order to provide liquidity in the financial system, facilitating the solvency of banks and supporting the confidence of savers. Furthermore they have introduced a package of non-standard monetary policy measures, defined enhanced credit support, with the aim to ensure that their policies may have effects on the real economy (Giannone et al., 2011).
In mid 2007, the U.S. Sub-prime mortgage crisis started to involve the European financial system. As a consequence, banks became more reluctant to lend money to other banks in the interbank market. This loss of confidence leads to a shortage of liquidity in the money market and to an increased demand for liquidity from the European Central Bank. The growth of the longer-term money market rates demonstrates the increasing uncertainty about the reliability of bank counterparties.

The ECB responded by increasing the frequency and the liquidity allotted in its long-term refinancing operations. Besides, it provided dollar liquidity, through Term Auction Facility operations, to support the increased demand for liquidity in foreign currency (Abbassi and Linzert, 2011; Cecioni et al., 2011). These last operations were made in the context of the coordinated measures between the Federal Reserve and the major foreign central banks, also defined Reciprocal Currency Agreements.

After the collapse of Lehman Brothers, the ECB cut repeatedly official rates and increased non-standard measures. In fact, during October 2008, the ECB performed all its refinancing operations with fixed rate full allotment tenders and it enlarged the list of eligible collateral in its refinancing operations. Moreover, the ECB continued to provide liquidity in foreign currency and, during the spring 2010, it put in practice the Securities Markets Programme. It consists in a program of purchases of Euro area private and public securities, with the aim to improve the functioning of some government bond markets seriously affected by increased public deficit in some European countries.

Figure 1 presents the pattern of the key Central Bank interest rates, together with two money-market rates: the Euro Over Night rate (EONIA) and the Euro Interbank Offered Rate on three months (3m EURIBOR). The Figure shows that the interest rate on main refinancing operations 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 in the process of financing of the real economy and to allow them to “by-pass” money market tensions (Giannone et al. 2011). The 3m 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 (Lenza et al., 2010). The increase in the cost of borrowing among banks, measured by the 3m EURIBOR, 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

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1 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 Euro between banks. Usually it ranges in the corridor between the rate on marginal lending facility and the interest rate on deposits facilities.

2 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.

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.
last months of 2008, has reduced the use of the operations with ECB for the first six months of 2009 (Figure 1). The deposit facilities 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. In fact, 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), banks prefer to deposit their surplus of liquidity in the Central Bank, even with lower returns, rather than use it in the interbank markets.

Figure 1 – EONIA, 3m EURIBOR Key ECB interest rates and the use of deposit facility (daily data, 1 January 2003 – 30 September 2011)

Notes: 3m EURIBOR = 3-month Euro interbank offered rate; EONIA = Euro Overnight interest rate; DF = Deposit Facilities; MLF = Marginal lending facility; MRO = Main refinancing operations.
Data Source: European Central Bank

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. 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 (Figure 2). These spreads have started to grow during the last year, driven by a new phase of the financial crisis, which has begun to affect the sovereign states in the European Union. The analysis of the Figure also suggests that the
The financial situation has repercussions on the real economy, as it affects granting and pricing of loans to firms and households. Figure 3 shows a distinct change in the amount of (new business) loans since the last quarter of 2008. All loans have suffered a considerable decline. Loans to the households sector were the first to undergo the consequences of the credit crisis and they decline for a longer period. Moreover, the drop in the growth rate of loans to non-financial companies was more marked, becoming even negative starting from the second half of 2009. Loans for house purchases have started to grow again during the first months of 2010, while loans to enterprises recovered approximately one a year later. Consumer credit continues to have much lower amounts than the pre-crisis period. These trends show a substantial reduction of the credit granted that, on the one hand, may be due to declining demand, while on the other may be the result of a credit crunch by banks (Ivashina and Scharfstein, 2010).
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).

Next sections are dedicated to the analysis of the interest rates on loans in retail market and are focused on the transmission mechanism between changes in market interest rates and bank rates.

4. Data

Data on interest rates for new loans on a monthly basis have been selected from the European Central Bank database\textsuperscript{4}. The period considered is from January 2003 to September

\textsuperscript{4} 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 that, 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.
2011 and the geographic area taken into account is the Euro area (changing composition)\textsuperscript{5}. The banks' counterpart sectors and the types of bank loans considered are:

- **Households and non-profit institutions serving households**
  1. Loans for consumption, excluding revolving loans and overdrafts, convenience and extended credit card debt, with 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, all maturities (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, all maturities (average of monthly observations, in per cent per annum);
  2. Loans other than revolving loans and overdrafts, convenience and extended credit card debt, over EUR 1 million, all maturities (average of monthly observations, in per cent per annum).

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 be affected by 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 accounting for a minimum subdivision of loans in this sector, both in terms of maturity and of purpose. The distribution of loans to non-financial corporations was made only 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 3m 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 changes only infrequently (De Bondt, 2005; Kwapil and Scharler, 2006b; Blot and Labondance, 2011). The 3m EURIBOR is the rate applied to most of the floating rate bank loans and so it is also the principal element to which the cost of money for the real economy is related. Moreover, the EURIBOR is an offered rate that appropriately measures the cost of interbank funding and depends on the expectations on banks' solvency.

\textsuperscript{5} The area encompassing the EU Member States whose currency is the Euro and in which a single monetary policy is conducted under the responsibility of the Governing Council of the ECB. In particular, data refer to the changing composition of the Euro area, i.e. they cover the EU member States that had adopted the Euro at the time to which the statistics relate. In our opinion, for the aims of this analysis, it is important to consider the Euro area in its changing composition because the formation of interest rates within the interbank market may have been affected by the presence of banks belonging to different banking systems and with different levels of creditworthiness.
In the literature some empirical studies support the choice of using the EURIBOR as a proxy for the official rate, while other 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, as 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 3m EURIBOR is a good indicator of monetary policy. Besides, Abbassi and Linzert (2011) affirm that the EURIBOR influences the function of the transmission mechanism in the Euro area, incorporating the expectations on the future short-term interest rates. In fact, the instability that has characterized the evolution of the EURIBOR in recent months, due, among other things, to new fears of bank failures and to the decline in the number of transactions in the interbank market, has interfered with the transmission mechanism of monetary policy.

Figure 4 shows the evolution of 3m EURIBOR and of bank retail rates from January 2003 to September 2011. Graphical analysis illustrates a similar trend for all interest rates that we consider in our empirical analysis, except that of the consumer credit, which has a more stable pattern over time and appears to be less influenced by changes in the 3m EURIBOR.

Figure 4 – Evolution of 3m EURIBOR and bank retail rates (January 2003-September 2011)
We may notice at least four 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 third point is in correspondence of September 2007. It highlights the diffusion of U.S. Sub-prime mortgage crisis in the European financial system and the beginning of the money market tensions. The European Central Bank starts implementing unconventional monetary policy measures with the aim to allow banks to bypass money market malfunctions, as discussed in the previous Section.

The last critical point is at the end of 2008, when the current financial crisis has forced the ECB to cut repeatedly interest rates. The widespread uncertainty about possible defaults of counterparties, after the collapse of the investment bank Lehman Brothers, has impaired the correct functioning of 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. Further cuts also occurred in the following months, when it became clear that the Euro area was in recession\(^6\).

Graphical analysis of Figure 4 helps in anticipating some 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.

\(^6\) See Bank of Italy (2003-2009).
5. Econometric methods: a regime-switching approach to model interest rate pass-through

Empirical studies on interest rate pass-through have provided a wide range of approaches to model monetary transmission mechanisms (see Blot and Labondance (2011) for a survey on recent analyses). The literature on bank interest rate pass-through has dealt with two issues: i) the analysis of monetary policy transmission channels, by focusing on the measurement of the pass-through 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 conditions of the banking system.

Focusing on the transmission mechanism between changes in market interest rates and bank rates, these two approaches base banks’ price-setting behaviour on the following marginal cost pricing model equation (De Bondt, 2002):

\[ br = \beta_0 + \beta Mr \]  \hspace{1cm} (1)

where \( br \) is the price set by banks, \( \beta_0 \) is a constant mark-up and \( Mr \) is the marginal cost price proxied by a comparable market interest rate and \( \beta_1 \) measures the degree of pass-through. The coefficient \( \beta_1 \) 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. On the one hand, 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). On the other hand, 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-through process has been analysed by means of a simple single equation Autoregressive Distributed Lag (ARDL) model of bank interest rates (Cottarelli and Kourelis, 1994):

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

where \( br \) and \( mr \) are bank and market rates, respectively, and \( j^* \) and \( k^* \) indicates optimal lag lengths. The intercept is represented by \( \nu \) and \( \gamma_0 \) measures the degree of short-run pass-through: a value of less than 1 for \( \gamma_0 \) indicates a sluggish adjustment (i.e. bank rate stickiness). The coefficients \( \phi_j \) and \( \phi_k \) can be used to compute the long-run multiplier as:

\[ \beta = \sum_{k=0}^{k^*} \gamma_k / (1 - \sum_{j=1}^{j^*} \phi_j) \] \hspace{1cm} (3)

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 to avoid spurious regression problems. However, first-difference models lead to a loss of information about long-run relationships when interest rates are \( I(1) \) and cointegrated and can be augmented by a lagged error correction term to obtain the following error correction (ECM) model:

\[
\Delta br_t = \sum_{j=1}^k \phi_j \Delta br_{t-j} + \sum_{k=0}^\infty \gamma_k \Delta mr_{t-k} + \alpha ECT_{t-1} + \varepsilon_t
\]  

(4)

where \( ECT_{t-1} \) measures the deviation from long-run equilibrium and can be obtained from the estimated error of the cointegration regression:

\[
br_t = \beta_0 + \beta mr_t + u_t
\]  

(5)

\( ECT_{t-1} \) enters model (5) with its coefficient \( \alpha \) reflecting the speed of adjustment to the long-run equilibrium. The long-run multiplier can be estimated from the cointegration vector (5).

Interest rate pass-through can be also analysed in a multi-equation framework. By simultaneously estimating multivariate autoregressive (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, 2012). 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 Bondt, 2002; Sander and Kleimeier, 2004 and 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:

\[
y_t = v + \sum_{i=0}^{p} \Pi_i y_{t-i} + u_t
\]  

(6)

where \( y_t \) is a two-dimensional vector of market and bank interest rates time series, \( y_t = [mr_t, br_t] \), \( \Pi_i \) are \( 2 \times 2 \) 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 \( \Sigma \), \( u_t \sim NID(0, \Sigma_u) \).

When the two interest series in \( y_t \) are non-stationary in levels, but first-difference stationary (i.e. \( y_t \) are \( I(1) \)) 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 a stationary stochastic process (Engle and Granger, 1987). If the two series are indeed cointegrated, the VAR implies the following vector error correction model (VECM):

\[
\Delta y_t = v + \sum_{i=1}^{p} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + u_t
\]  

(7)
where $\Gamma_i = -\sum_{j=i+1}^{p} \Pi_j$ are $2 \times 2$ 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, $\Pi$ can be partitioned into the $2 \times 1$
vector $\beta$ of the long-coefficients of the cointegration vector and a $2 \times 1$ vector $\alpha$ containing
the equilibrium correction coefficients: $\Pi = \alpha \beta^T$. In the case of no cointegration between the series
considered, the VECM in (7) 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, 2012) 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 (Dahlquist and Gray, 2000; 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:

\[
p_{ij} = \Pr(s_{t+1} = j | s_t = i), \quad \sum_{j=1}^{M} p_{ij} = 1 \quad \forall i, j \in \{1, ..., M\} \tag{8}
\]

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 (6) 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:

\[
y_t = v(s_t) + \sum_{i=1}^{p} \Pi_i(s_t)y_{t-i} + \epsilon_t \tag{9}
\]

where \( v(s_t) \) is the intercept term and \( \Pi_i(s_t) \) are autoregressive parameter matrices, all assumed to be regime-dependent, and \( \epsilon_t \) is the error term with variance allowed to change across states (i.e. \( \epsilon_t | s_t \sim NID(0, \Sigma(\epsilon_t)) \)). 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 (9) 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\((p)\))\(^7\).

Analogously, the bivariate cointegrated pass-through model (7) can be extended to be regime-dependent, obtaining a Markov-switching VECM of the form:

\[
\Delta y_t = v(s_t) + \sum_{i=1}^{p-1} \Gamma_i(s_t)\Delta y_{t-i} + \alpha(s_t)\beta'y_{t-1} + \epsilon_t \tag{10}
\]

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, \( \beta \) is the vector of long-run parameters, and \( \epsilon_t \) 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

\(^7\) Less flexible nested specifications allows only the intercept (MSI-VAR) or the intercept and the variance (MSIH-VAR) to be regime-dependent.
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 $\beta$. 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. 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.

6. Empirical results

In this Section we apply a non-linear vector autoregressive model to analyse interest rate pass-through between alternative retail interest rates and money market interest 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 and analyse the cointegration properties of the system. In both the analyses we explicitly deal with the sensitiveness of unit root and cointegration tests to the presence of structural breaks. Finally, the results of the bivariate MS-VECMs with two regimes are presented and discussed.

---

8 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.
6.1 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. 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 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.

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 $I(1)$ 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

<table>
<thead>
<tr>
<th></th>
<th>EURIBOR Levels</th>
<th>Consumer First diff. Levels</th>
<th>Mortgage First diff. Levels</th>
<th>Firms (up to 1M€) First diff. Levels</th>
<th>Firms (over 1M€) First diff. Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a) Unit root tests</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADF</td>
<td>-1.720</td>
<td>-4.183*</td>
<td>-2.305</td>
<td>-11.422*</td>
<td>-1.628</td>
</tr>
<tr>
<td></td>
<td>(0.418)</td>
<td>(0.001)</td>
<td>(0.173)</td>
<td>(0.000)</td>
<td>(0.465)</td>
</tr>
<tr>
<td>DF-GLS</td>
<td>-1.688</td>
<td>-3.754*</td>
<td>-1.142</td>
<td>-8.868*</td>
<td>-1.208</td>
</tr>
<tr>
<td></td>
<td>(0.084)</td>
<td>(0.000)</td>
<td>(0.256)</td>
<td>(0.000)</td>
<td>(0.230)</td>
</tr>
<tr>
<td>CMR ($p=1$)</td>
<td>-0.049</td>
<td>-0.280*</td>
<td>-0.113</td>
<td>-1.430*</td>
<td>-0.035</td>
</tr>
<tr>
<td><strong>b) Stationarity test</strong></td>
<td>1.097*</td>
<td>0.263</td>
<td>1.431*</td>
<td>0.112</td>
<td>0.762*</td>
</tr>
</tbody>
</table>

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, innovational outlier (IO) model. Optimal breakpoints are in 2008M09 for all the 5 series. * denotes rejection of the null hypothesis at the 5% significance level.
6.2 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 rates 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 A.1 in the Appendix. 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 Euro. 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 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. 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 and derive the corresponding asymptotic distributions (see Johansen et al., 2000).

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\(^9\). 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 2 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 series.

\(^9\) In particular, we refer to the model with a broken constant level in Johansen et al. (2000, page 225):

\[
\Delta y_j = (\Pi, \mu) \begin{bmatrix} y_{j,1} \\ E_j \end{bmatrix} + \sum_{i=1}^{\gamma} \Gamma_i \Delta y_{j,i} + \sum_{i=1}^{\rho} \sum_{j=2}^{s} \kappa_{ij} D_{j,i} + u_i
\]

where \( E_j=(E_{j,1}, E_{j,2}, \ldots, E_{j,q}) \) is a matrix of \( q \) dummy variables, where \( E_{j,i}=1 \) if observation \( t \) belongs to the \( i \)th period and 0 otherwise; \( D_{j,i} \) is an impulse dummy that equals 1 if observation \( t \) is the \( i \)th observation of the \( j \)th period. The hypothesis of reduced cointegration rank \( H_0(r): \text{rank} (\Pi, \mu) \leq r \) can be then tested by means of a LR test statistics.
bivariate models. It is worth remarking that linear cointegration (Johansen, 1995) tests, not reported here but available from the authors, fail in rejecting the null hypothesis of no cointegration between bank and interbank interest rates in some of the bivariate models, further confirming the necessity of appropriately modelling structural shifts in the deterministic components for the assessment of the cointegration properties of the systems.

Table 2 – Johansen-Mosconi-Nielsen cointegration test with one break in the intercept

<table>
<thead>
<tr>
<th></th>
<th>Critical Values:</th>
<th></th>
<th>90%</th>
<th>95%</th>
<th>99%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H0: rank = r</td>
<td>LR Stat</td>
<td>p-value</td>
<td>LR Stat</td>
<td>p-value</td>
</tr>
<tr>
<td>a) EURIBOR-Consumer</td>
<td>LR Stat</td>
<td>p-value</td>
<td>90%</td>
<td>95%</td>
<td>99%</td>
</tr>
<tr>
<td>r = 0</td>
<td>43.11*</td>
<td>0.0000</td>
<td>22.66</td>
<td>24.73</td>
<td>28.94</td>
</tr>
<tr>
<td>r ≤ 1</td>
<td>9.31</td>
<td>0.1779</td>
<td>10.93</td>
<td>12.74</td>
<td>16.62</td>
</tr>
<tr>
<td>b) EURIBOR-Mortgage</td>
<td>LR Stat</td>
<td>p-value</td>
<td>90%</td>
<td>95%</td>
<td>99%</td>
</tr>
<tr>
<td>r = 0</td>
<td>32.44*</td>
<td>0.0022</td>
<td>22.66</td>
<td>24.73</td>
<td>28.94</td>
</tr>
<tr>
<td>r ≤ 1</td>
<td>8.35</td>
<td>0.2442</td>
<td>10.93</td>
<td>12.74</td>
<td>16.62</td>
</tr>
<tr>
<td>c) EURIBOR-Firms (up to 1M €)</td>
<td>LR Stat</td>
<td>p-value</td>
<td>90%</td>
<td>95%</td>
<td>99%</td>
</tr>
<tr>
<td>r = 0</td>
<td>35.07*</td>
<td>0.0007</td>
<td>22.66</td>
<td>24.73</td>
<td>28.94</td>
</tr>
<tr>
<td>r ≤ 1</td>
<td>3.39</td>
<td>0.8265</td>
<td>10.93</td>
<td>12.74</td>
<td>16.62</td>
</tr>
<tr>
<td>d) EURIBOR-Firms (over 1M €)</td>
<td>LR Stat</td>
<td>p-value</td>
<td>90%</td>
<td>95%</td>
<td>99%</td>
</tr>
<tr>
<td>r = 0</td>
<td>42.75*</td>
<td>0.0000</td>
<td>22.66</td>
<td>24.73</td>
<td>28.94</td>
</tr>
<tr>
<td>r ≤ 1</td>
<td>6.21</td>
<td>0.4592</td>
<td>10.93</td>
<td>12.74</td>
<td>16.62</td>
</tr>
</tbody>
</table>

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

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

\[
\begin{align*}
\beta'_{y_{\text{consumer}}} y_{t-1} &= b'_{\text{consumer}} r_{t-1} - 0.1757 mr_{t-1} \\
\beta'_{y_{\text{mortgage}}} y_{t-1} &= b'_{\text{mortgage}} r_{t-1} - 0.4321 mr_{t-1} \\
\beta'_{y_{\text{firm up 1M}}} y_{t-1} &= b'_{\text{firm up 1M}} r_{t-1} - 0.4957 mr_{t-1} \\
\beta'_{y_{\text{firm ov 1M}}} y_{t-1} &= b'_{\text{firm ov 1M}} r_{t-1} - 0.7292 mr_{t-1}
\end{align*}
\]

(11)

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 (11), 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.

The long-run pass-through between money market and consumer loans rate is found to be particularly weak, revealing that these interest rates are stickier and 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 lower price elasticity may be due to a higher risk premium for consumer loans. It is related to the higher search cost of information and thus to problems of asymmetric information, to the unavailability of alternative sources of finance, to the small size of the loan that does not justify further investigations on the actual credit risk of the borrower (Rocha, 2012).

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 Euro (0.4957). Finally, the highest degree of pass-through is estimated for loans over 1 million Euro, which are generally granted to larger firms than the loans up to 1 million. For such loans, the higher competition between banks in the credit market, as pointed out by Blot and Labondance (2011), reduce banks’ market power, thus increasing the long-term equilibrium pass-through. Moreover, during the screening of borrowers, the size of the loan requires a careful assessment of credit risk, justifying greater efforts in collecting and processing information and a lower risk premium for the most worthy borrowers.

These results suggest that changes in the interbank rate have different effects on the retail rates applied to the two sectors considered, revealing the presence of significant sectoral heterogeneities in the transmission mechanism of monetary policy impulses.

6.3 MS-VECM results

6.3.1 Testing for non-linearities and regime characteristics

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, 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 Tables 3 and 4 and in Figure 5.

---

10 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.
Table 3 – Markov-Switching VECM estimates

<table>
<thead>
<tr>
<th></th>
<th>a) Consumer</th>
<th>b) Mortgage</th>
<th>c) Firms (up to 1M €)</th>
<th>d) Firms (over 1M €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>MSIAH(2)-VECM(1)</td>
<td>MSIAH(2)-VECM(1)</td>
<td>MSIAH(2)-VECM(1)</td>
<td>MSIAH(2)-VECM(1)</td>
</tr>
<tr>
<td></td>
<td>Δmr_{r,1}</td>
<td>Δbr_{r,1}</td>
<td>Δmr_{r,1}</td>
<td>Δbr_{r,1}</td>
</tr>
<tr>
<td>Regime 1: Normal conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.0152‡</td>
<td>-0.0112</td>
<td>0.0133‡</td>
<td>0.0015</td>
</tr>
<tr>
<td></td>
<td>(3.84)</td>
<td>(-0.70)</td>
<td>(3.04)</td>
<td>(0.23)</td>
</tr>
<tr>
<td>Autoregressive coefficients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δmr_{r,1}</td>
<td>0.5883‡</td>
<td>0.1713†</td>
<td>0.6064‡</td>
<td>0.2610†</td>
</tr>
<tr>
<td></td>
<td>(21.65)</td>
<td>(1.68)</td>
<td>(11.25)</td>
<td>(3.31)</td>
</tr>
<tr>
<td>Δbr_{r,1}</td>
<td>0.0037</td>
<td>-0.1905‡</td>
<td>0.0037</td>
<td>0.1867†</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(-1.77)</td>
<td>(0.25)</td>
<td>(1.84)</td>
</tr>
<tr>
<td>Adjustment coefficient</td>
<td>-0.0076‡</td>
<td>-0.0209‡</td>
<td>-0.0177†</td>
<td>-0.0278†</td>
</tr>
<tr>
<td></td>
<td>(-3.03)</td>
<td>(-1.97)</td>
<td>(-1.68)</td>
<td>(-1.78)</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.0336</td>
<td>0.1447</td>
<td>0.0393</td>
<td>0.0582</td>
</tr>
<tr>
<td>Regime 2: High volatility</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.1279</td>
<td>0.0255†</td>
<td>0.0264</td>
<td>0.0163</td>
</tr>
<tr>
<td></td>
<td>(-1.55)</td>
<td>(1.93)</td>
<td>(0.24)</td>
<td>(1.13)</td>
</tr>
<tr>
<td>Autoregressive coefficients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δmr_{r,1}</td>
<td>0.5379‡</td>
<td>0.1526‡</td>
<td>-0.0126</td>
<td>0.0063</td>
</tr>
<tr>
<td></td>
<td>(2.21)</td>
<td>(4.08)</td>
<td>(-0.03)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Δbr_{r,1}</td>
<td>1.3802</td>
<td>-0.8030‡</td>
<td>0.5843</td>
<td>0.3669‡</td>
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<td></td>
<td>(1.35)</td>
<td>(-5.30)</td>
<td>(0.48)</td>
<td>(2.38)</td>
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<td>Adjustment coefficient</td>
<td>-0.0010</td>
<td>-0.1351‡</td>
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<td>(-0.02)</td>
<td>(-4.46)</td>
<td>(-1.46)</td>
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<td>Standard Error</td>
<td>0.2826</td>
<td>0.0417</td>
<td>0.2847</td>
<td>0.0339</td>
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<td>Log Likelihood</td>
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<td>310.33</td>
<td>266.31</td>
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<td></td>
<td></td>
<td></td>
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<td>linearity test</td>
<td>179.8 (11 [0.000])</td>
<td>158.0 (11 [0.000])</td>
<td>110.2 (11 [0.000])</td>
<td>159.3 (11 [0.000])</td>
</tr>
<tr>
<td>MSIAH vs MSI</td>
<td>169.1 (9 [0.000])</td>
<td>139.1 (9 [0.000])</td>
<td>90.6 (9 [0.000])</td>
<td>126.2 (9 [0.000])</td>
</tr>
<tr>
<td>MSIAH vs MSIH</td>
<td>17.6 (6 [0.007])</td>
<td>19.9 (6 [0.003])</td>
<td>20.7 (6 [0.002])</td>
<td>19.5 (6 [0.003])</td>
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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.

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. Results (Table 3) 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 A1 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 (Table 4), for all the four models it is possible to note that Regime 1 contains most of the observations, has the longest duration and highest probability, and can be therefore assumed as the “Normal Conditions” regime. Regime 2, on the other hand, contains 15% to 20% of the observations and has an average duration over 5 months only for the pass-through model of loans to firms up to 1 million Euro, while for the remaining models the duration of this regime is below 3 months. Regime 2 is also characterized by a significantly higher volatility of the EURIBOR rate and a general decreasing tendency of all the interest rates, 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 2 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 Conditions” 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 Euro 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.

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.
Table 4 – Characteristics of the regimes

<table>
<thead>
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<th>Persistence of regimes</th>
<th>a) Consumer</th>
<th>b) Mortgage</th>
<th>c) Firms (up to 1M €)</th>
<th>d) Firms (over 1M €)</th>
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<tr>
<td>Regime 1</td>
<td>Erg. Prob</td>
<td>Duration</td>
<td>Erg. Prob</td>
<td>Duration</td>
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<td>Regime 1</td>
<td>0.8412</td>
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<td>Regime 2</td>
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<td>Transition probabilities</td>
<td>Regime 1</td>
<td>Regime 2</td>
<td>Regime 1</td>
<td>Regime 2</td>
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<td>Regime 1</td>
<td>0.9121</td>
<td>0.0879</td>
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<tr>
<td>Regime 2</td>
<td>0.4657</td>
<td>0.5343</td>
<td>0.3023</td>
<td>0.6977</td>
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In Figure 5, 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 2) 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\textsuperscript{12}. Looking at the regime probabilities patterns, we observe similar regime properties for all the models. Moreover, our modelling approach is able to identify those periods of financial turmoil already discussed in the descriptive analysis of Section 4. In particular, from the onset of the subprime crisis 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 Euro rates show frequent regime changes with the presence of several short periods of high variability in 2010 and in 2011. On the other hand, the pass-through to interest rates for loans to firms up to 1 million Euro 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.

\textsuperscript{12} 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 $\Pr(s_t = 1 | y_T) > 0.5$ and to the second if $\Pr(s_t = 1 | y_T) < 0.5$. 

25
Figure 5 – “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 €)
6.3.2 Short-run degree of pass through and speed of adjustment

Turning to the analysis of the estimated parameters in Table 3, 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 increase the speed of adjustment of loan rates to deviations from long-run equilibrium. This empirical evidence is in line with the findings of Blot and Labondance (2011) and Panagopoulos and Spiliotis (2011), based on a split-sample analysis of pass-through in the Euro area before and during the current financial crisis. Although interbank interest rates reduce, bank retail rates remain relatively high, incorporating a high risk premium. This is related to the growing risks of deterioration in the creditworthiness of counterparties. Banks are cautious and refrain from adjustments of retail rates, interfering with the functioning of the interest rate channel and thus with the effectiveness of monetary policy in the short-run. As pointed out by Kato et al. (1999), the limited effectiveness of monetary policy during periods of financial distress can be related to capital tightening in banks and borrowers, which are particularly relevant for households and small and medium-sized firms as they strongly depend on borrowing from banks.

On the other hand, the speed of adjustment is affected by the expectations of the banking system on future monetary policy impulses (Kleimeier and Sanders, 2006): anticipated changes in policy controlled interest rates make the response of retail interest rates faster. In particular, after the bankruptcy of Lehman Brothers and the first liquidity support measures by central banks, the subsequent actions of the European Central Bank (i.e. cuts in official rates and other unconventional policy measures) have likely been to a large extent anticipated by market participants. The increasing role of signalling during episodes of financial turbulence (Cecioni et al., 2011) thus turns into a faster responsiveness of the banking sector to policy impulses, which helps in restoring the functioning of the monetary transmission mechanism.

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 (0.1713 and 0.1526 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 1 to regime 2). In particular, as pointed out by Rocha (2012), in a situation of decreasing interbank rates and higher levels of risk, the downward adjustment of the rates on loans to the household sector may be slower due to the upward pressure from the increased risk premium. Moreover, although during the crisis all rates reduce their responsiveness to the interbank rate, it is worth noting that 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.

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 Euro (0.5596 and 0.5341, respectively), and it is almost complete in the case of loans over 1 million Euro 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 Euro, 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 of large amounts granted to firms.

7. Conclusions and policy implications

In this paper we analyse the transmission mechanism of monetary policy impulses, through the interbank market, to the real economy, in the Euro area during the period 2003-2011. In particular, one of the main aims of our analysis is to measure to what extent the current financial crisis, and in general episodes of financial distress, has affected the transmission process of monetary policy impulses to the real economy through the bank lending channel. In fact, financial turmoil periods may impair the functioning of money markets and reduce the efficiency of monetary policy transmission, causing a change in the responsiveness of financial intermediaries’ pricing behaviour to policy controlled interest rates. By allowing the reaction of retail rates to policy impulses to differ in periods of normal market conditions and during financial crisis episodes, we aim at providing a better assessment of interest rate pass-through between bank lending and money market rates.

Our investigation, based on a Markov-switching vector autoregressive model, show that the effects of financial turmoil seem to weaken the short-run transmission between the money market and retail bank rates, but they increase the responsiveness of loan rates to deviations from the long-run equilibrium.
The degree of long-run pass-through is higher for rates on loans of larger amounts to non-financial corporations. The responsiveness of the household sector is found to be lower than the firm sector and, in particular, the transmission mechanism is almost ineffective for consumer credit rates. This behaviour confirms the hypothesis 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, and particularly on consumer credit, are mainly affected by other elements related to the specific risks arising from the type of relationship established between banks and customers. Loans to non-financial companies for amounts over 1 million Euro are more sensitive to changes in EURIBOR in both regimes. However, the transition from the normal regime to the high volatility/crisis state lead to a decrease of the influence exerted by money market rates on the pricing of larger loans (i.e. loans granted to larger firms). This demonstrates an increase in the bargaining power of banks in setting retail rates also for larger loans to non-financial corporations.

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.

These results highlight the need for monetary authorities to bring forward a set of coordinated activities in order to improve the effectiveness of monetary policy measures even during periods of financial distress. In these cases monetary policy impulses fail to reach the real economy, so that households and firms do not completely enjoy the effects of monetary easing policies. These coordinated activities should be designed, first of all, to meet the increasing demand for liquidity in interbank markets and then to restore the proper functioning of the monetary transmission channel.

If during periods of financial turbulence the speed of adjustment to long-term disequilibria increases, but the degree of transmission of the variation of money market rates to retail bank reduces, it is necessary to implement actions that will impact on the factors that impede a correct and complete pass-through. As discussed above, authorities should intervene on factors affecting the risk-premium and the level of market competition, and improve the dissemination and sharing of information with the aim of maintaining the correct functioning of the markets. In fact, by reducing information asymmetries, banks are more likely to manage their liquidity needs in the interbank markets and lend money to borrowers. At the same time, policies that affect expectations of financial intermediaries facilitate the speed of response to monetary policy impulses.

To this end, during periods of liquidity stress, monetary authorities should implement clear policies to directly and indirectly support liquidity in interbank markets. In this respect, they can intervene by stimulating interbank operations with longer maturity and by containing the...
excessive use of deposit facility operations. The role of "lender of last resort" of the central bank is, in fact, particularly important to stabilize the markets, but it is equally important to ensure that banks do not excessively rely on the central bank, completely bypassing the interbank market and contributing to make it ineffective.

For this reason, it is necessary to establish relationships of information sharing between central banks, to provide a regular transmission of information to markets and to promote coordinated monetary and fiscal policy activities. Competent authorities should also aim to ensure an appropriate process of selection and monitoring of borrowers and an adequate level of banks’ capitalization. Besides, they should enforce regulatory and supervisory activities to limit excessive risk-taking behaviours in financial and credit operations.

Appendix

Table A1 – VAR lag order selection

<table>
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<th>Lag</th>
<th>LogL</th>
<th>LR</th>
<th>AIC</th>
<th>SC</th>
<th>HQ</th>
<th>Lag</th>
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Notes: * indicates lag order selected by the criterion.
Figure A1 – Statistical properties of the normalized residuals

a) EURIBOR-Consumer

b) EURIBOR-Mortgage

c) EURIBOR-Firms (up to 1M €)

d) EURIBOR-Firms (over 1M €)
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