Reaction of Overnight Rate to Its Determinants Under 'Normal' Situation and During the Financial Turmoil of 2007-2009

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Abstract— We analyze the reaction of the spread between the overnight rate and the target rate to Central Banks' instruments during normal time and the Subprime crisis. By using US, UK and Euro area data, we estimate the dynamic of these spread with an asymmetric EGARCH model. Our results reveal that most of the modifications of these instruments have reduced the volatility of the spreads. In situation marked by liquidity risks, as during the first phase of this crisis, these Banks managed to control the overnight rate. Conversely, in situation marked with credit risks, as after the collapse of Lehman Brothers, the control of this rate was harder even when unconventional measures alleviated the pressure on markets and reduce the volatility of the spreads.

Index Terms— Monetary policy, Overnight rate, Open Market Operations, Standing Facility, Reserve Requirement, Subprime crisis, EGARCH.

I. INTRODUCTION

Overnight interest rate, paid for one day unsecured loans, is the equilibrium outcome of supply and demand for bank reserves. By influencing the supply and the demand with their instruments (reserve requirements, standing facilities and open market operations), central banks try to control the overnight interest rates.¹ By targeting these rates, Central Banks exert a substantial amount of control over very short- and longer-term rates. In a fully liquid interbank reserve market, the underlying supply and demand for funds should not have an impact on the dynamic of overnight interest rates ([1]). Then Central Banks can control more efficiently the overnight rate. Conversely, a low level of market liquidity might increase the level as well as the volatility of these rates as it was observed during the Subprime crisis. Furthermore, in this situation the control of the overnight rate can be more difficult.

Understanding and evaluating the dynamic of overnight rates are important for central banks as well as for financial institutions.² The purpose of this article is to analyze the impact of the major developments in the monetary framework on the dynamic of the overnight interest rates.

In the empirical literature, most of existing studies have concentrated on whether and how the instruments and procedures to implement the monetary policy affect the behavior of overnight rates.

The main used instruments are: reserve requirements, standing facilities and open market operations. Open market operations directly affect the slope of the overnight rate. As

for the standing facilities and the reserve requirement, they influence the variability of these rates. Several empirical studies focused on the behavior of this rate over the reserve maintenance period ([2] [3]; [4]; [5]; [1]; [6]; [7]). These authors found that the volatility of overnight rates is higher on the last days on the reserve maintenance period. This particular behavior of these rates suggests that the martingale hypothesis, past observations should have no predictive content, does not hold. As for [8] and [1], they show the important role of the refinancing operation on the level of overnight rates.

The features of the monetary policy instruments change across countries as well as across time for the same country in the light of changes in the structure and working of financial markets as well as the broader economic and political environment ([4]; [1]). Since the beginning of the 1990s central banks have aimed to reduce the volatility of the money market and mainly overnight rate. For this, these banks have redesigned their monetary policy instruments. The major modifications have been related to reserve requirements and to the REPO operations by central banks (see Table A1). The modifications should have influenced the dynamic of overnight rates. In the empirical literature, authors have taken into account only some of the modifications ([9]; [10], [11]; [12]; [7]). For instance, the recent modifications, which are very important, have been rarely or not analyzed. These modifications concern the reform made by the European Central Bank (ECB) in March 2004, the reform made by the Bank of England (BoE) in March 2005 and by the Fed in January 2003. These reforms have been done in order to have more control over the overnight rate as well as to reduce the variability of this rate. Furthermore, when the financial crisis deepened after the collapse of Lehman Brothers in September 2008, some Central Banks have modified further the feature of their instruments in order to tackle this crisis.

Further the instruments and procedures of monetary policy, few authors argue that communication and transparency of central banks are relevant factors influencing the dynamic of very short-term rate ([13]). According to these authors the more is predictable the official rate the less it affects the dynamics of very short-term rate. In the empirical studies, most of these authors took into account the effect of the transparency measure adopted by the Fed in February 1994; which consisted to release immediately after each FOMC meeting the decisions about the official rates.

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¹ Money Market volatility might give to the market confusing messages about the stance of the monetary policy. Furthermore, very short-term volatility might be transferred up the yield curve (term structure of interest rates) and then affect the dynamic of medium and long-term rates.

well as the dynamic of other financial assets, and in turn have an impact on the real economic.

² Financial institutions use financial assets referenced to the overnight rates, such as overnight interest rate swaps (OISs) or overnight indexed futures contracts (EONIA index futures), for speculating or hedging on short-term interest rate movements.

In some situation, such as the situation marked by the Subprime crisis, these traditional instruments are not sufficient to control efficiently the overnight rate and the very short-term rates. In such situations, some Central Banks use also some unconventional measures in order to regulate the liquidity in the interbank market and then control the dynamic of the very short-term rates. Furthermore, during these situations the effects of the traditional instruments on the dynamic of the overnight rate might be different. Some authors, such as [14], [15] and [16], argue that central banks have ability to influence interest rates in situation market by liquidity risk premium, but this ability is likely low in situation market by credit risk premium. Furthermore, the first phase of the Subprime crisis (August 2007-September 2008) were mainly marked by liquidity risks whereas after the fallout of Lehman Brothers (September 2008) credit risk premium has become an important determinant of this volatility (second phase of the crisis) ([17]). In the empirical literature, there is not any article focused on the reaction of the overnight rate to its fundamental during the Subprime Crisis.

The purpose of this paper is to analyze the dynamic of overnight rates by taking into account all the major modifications in the monetary policy operating procedures in normal situation as well as during the Subprime crisis. Our aim is also to combine the different aspects analyzed in the literature, cited previously, and analyze them simultaneously in this paper. For this analyze, several countries are considered, not only the U.S.A as in most of the existing studies³; which are the U.S.A., the U.K., the euro zone.⁴ Central Banks try to keep the overnight rate very close to their policy rate and this policy rate change rarely. Owing that, we modelise the spread between these both rates (policy spread) with an asymmetric AR-EGARCH model by taking into account the main factors associated to the instruments used by the Central Bank. We also consider the impact of the modifications of these instruments' features. Further the factors related to the instruments of the Central Banks, the unconventional measures used by these Banks during the last financial crisis are also retained and analyzed in a second step with an asymmetric EGARCH model too.

This paper proceeds as follows. Section 2 describes the traditional instruments of Central Banks and their impact on the dynamic of the overnight rate. The data used for the empirical analysis are presented in section 3. Section 4 describes the asymmetric AR-EGARCH model used to evaluate the dynamic of the policy spreads. In this section, we also discuss the results obtained. Section 5 is concentrated on the reaction of the policy spreads to the instruments as well as to the unconventional measures undertook by the Central Banks during the Subprime crisis. Finally, section 6 concludes.

II) IMPACT OF THE INSTRUMENTS AND PROCEDURES USED BY CENTRAL BANKS

A. Implementation of monetary policy

Central banks try to control the overnight interest rates. Control means an attempt to minimize the variability of the overnight rate and to keep this rate around an "official rate" ([4]; [1]). For this control, central banks use a set of instruments; which are open market operations, standing facilities and minimum reserve requirement.

Official rate, Open Market operation and standing facilities

Figure 1: Behavior of the EONIA rate and the policy rates

Figure 2: Behavior of the SONIA rate and the policy rates (1)

Figure 3: Behavior of the SONIA rate and the policy rates (2)

In some countries, such as Australia, Canada, Japan and the U.S., central banks directly target the overnight rate by selecting a target level for this rate (explicit target) (group 1). Some other central banks choose a different maturity (for instance two weeks in the United Kingdom and Euro area) for its policy rate (group 2). In this case, the official rate corresponds to a repo rate. In group 1, central banks intervene in the interbank reserve market daily or more frequently in order to avoid that the overnight rate deviates from its fixed target whereas central banks of group 2 intervene less frequently (once or few times per week). Owing these facts,

³ See [9]; [26]; [6]; [18]; and [5].

⁴ Few recent studies consider the U.S.A. as well as some other countries ([3]; [29]; [24]).

⁴ Few

the speed of the convergence of the overnight rate towards the official rate is higher in countries of group 1 compared to countries of group 2 ([5]; [1]). Furthermore, the more frequently central bank intervenes the less is the variation of the interest rates' spread ([1]). Figures see figures 1-5 displaying the fluctuation of the Euro area, the UK and the US overnight rates around the official policy rates illustrate the previous arguments.

Since the control of overnight rates is not perfect, the spread between the overnight rate and the official rate, named policy spread, is often different from zero. Central banks try to minimize this spread as well as the variability of overnight rate by using standing facilities ([1]; [7]; [6]; [11]). Standing facilities comprise, in general, the marginal lending facility (overnight liquidity from central banks at a fixed rate against eligible assets) and the deposit facility (overnight liquidity deposit to central banks at a fixed rate). The rates of these facilities, unfavorable regarding the market interest rates, form the "corridor" (limit) of fluctuation of the overnight rate (see figures 1-5). A reduction in the amplitude of the corridor enables the overnight rate to be more stable and closer to the official rate ([6]).

Figure 4: Behavior of the US overnight rate and the policy rates (1)

Figure 5: Behavior of the US overnight rate and the policy rates (2)

Reserve requirements and interest rate volatility

Reserve requirements are mainly used for smoothing interest rates through two channels. First, by holding reserves, depository institutions are better buffered against unanticipated liquidity shocks. Second, the reserve requirements with an averaging provision over the maintenance period allow depository institutions to spread liquidity shocks over time and then enable to smooth overnight interest rates. However, several authors show that overnight rates display pronounced spikes in the last few days

of the 'reserve maintenance periods', when depository institutions must meet reserve requirements ([18]; [19]; [10]; [2] [3]; [5]; [8]; [7]).

The size of these spikes depends negatively on the lapse of time between the end of the 'maintenance periods' and the end of the 'computation periods'⁵ ([9]; [10]; [1]; [7]). This lapse of time depends on the type of the reserve requirement. There are three types of reserve requirement: 'lagged', 'semi-lagged' and 'contemporaneous' reserve requirement. In the 'lagged' method, depository institutions know the required amount of money at the beginning of the maintenance periods; they have then the whole maintenance period to meet their obligations.

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Figure 6: Variation of the EONIA rate and reserve maintenance period (1)

Figure 7: Variation of the EONIA rate and reserve maintenance period (2)

In the 'semi-lagged' method, depository institutions have less time to constitute the required reserve as the maintenance periods start before the end of the computation periods. Finally, in the 'contemporaneous' method, the computation periods end just few days before the end of the maintenance periods, and then depository institutions have only few days to meet their duties. In this latter case, the pressure in the interbank market is clearly important over these few days compared to the both other cases. The variation of the overnight rates during the last days of the maintenance periods in the case of 'contemporaneous' method is much higher than in the case of the 'lagged' and 'semi-lagged' methods ([10]; [20]). A modification of the reserve system might then change the reaction of overnight rates volatility during the last days of the maintenance period ([9]; [10]; [7]). In line with the results obtained by [7], figure 8 shows that the variation of the federal funds rate during the last few days of the maintenance period is lesser in the 'lagged' configuration (after 1998) compare to the 'contemporaneous' method (before 1998).⁷

⁵ Depository institutions have to constitute required reserves over the 'maintenance period' calculated over the 'computation periods'.

⁶ In the 'lagged' method, the maintenance periods begin after the end of the computation periods. In May 1998, the Fed replaced the 'contemporaneous' method with the 'lagged' method.

According to [7], the magnitude of the overnight rates variation on the last days of the maintenance periods depends also on the frequency in which the monetary authorities intervene in the interbank market. These authors and [21] argue that this magnitude could have changed since August 1998 in U.S.A., when the Fed began to supply more liquidity during the last days of the maintenance period. Similarly to the Fed, in order to dampen the pressure on the interbank market, some central banks fixe special rates for their standing facilities. For instance, in the U.K. the standing facilities rates are in normal time 1% above (lending facility rate) and below (deposit facility rate) the Bank of England's rate (BoE), except on the final day of the maintenance period when they are 0.25% above and below this Bank's rate.

Figure 8: Variation of the US overnight rate and reserve maintenance period (1)

Figure 9: Variation of the US overnight rate and reserve maintenance period (2)

B. Behavior of overnight rate during the financial crisis of 2007-2009

The period ranging from August 2007 to September 2008 was mainly marked by liquidity risks whereas the post-Lehman Brothers collapse period (September 2008) by mainly credit risks ([1]). Central banks used any of their traditional instruments, mainly the open market operations, to tackle liquidity shocks and decrease the pressure in the markets as well as avoid market rates moving too far away from the target rate. When the crisis deepened central banks used also unconventional measures in order to tackle the liquidity risks, the creits risks as well as control the overnight rate.

First phase of the crisis: August 2007 - September 2008

The onset of the Subprime crisis on 9th August 2007 led most of financial institutions to revise up their liquidity needs as well as make them more reluctant to lend to each other, particularly at longer maturities. Owing that money markets were characterized by enormous drain of liquidity, and interbank interest rates became more volatile. Figures 7 & 9 and Table 1 illustrate these facts with the variation of the

EONIA rate and the variation of the effective federal funds rate. Furthermore, table 1 shows that the mean and the standard deviation of the policy spreads also increased. Central banks reacted immediately by providing liquidity to the markets through Fine-Tuning Operations (FTO), Main Refinancing Operations (MRO) and Long-term refinancing operations (LTRO), hence making full use of their traditional instruments. Furthermore, the Fed started to reduce strongly its target rate shortly after the beginning of the crisis in September 2007. The BoE has also decreased its policy rate, but only after December 2007, and slightly.⁸ Conversely, the European Central Bank (ECB) did not decrease its target rate till the collapse of Lehman Brothers in September 2008.

Further the traditional instruments, the Fed and the BoE created new instruments in order to provide further liquidity. In December 2007 the Fed introduced a new method for providing liquidity from twenty-eight to thirty-five days, the Term Auction facility (TAF)⁹, in order to encounter the issues posed by borrowing from the Discount window. Compared to the Discount Window, the TAF enabled to provide liquidity to a wider range of borrowers as well as with a wider range of securities as collateral, including mortgage-related instruments. Furthermore, in March 2008 the crisis forced the Fed to introduce unprecedented methods, the Primary Dealer Credit Facility (PDCF) and the Term Securities Lending Facility (TSLF)¹⁰, in order to help the broker dealers and then try to avoid the intensification of the crisis.

Similarly, the BoE was forced to act aggressively in unprecedented ways in December 2007 by offering further expanded 3 month repos, but without penalty rate and with much wider range of collateral than accepted previously. Furthermore, in April 2008 the BoE introduced the Special Liquidity Scheme (SLS) to inject liquidity and remedy the issues created by the stigma associated with borrowing from the discount window.^{11 12}

All these actions, traditional and unprecedented, reduced the pressure on the very short and short term interbank market. In the literature, most of the existing studies consider the effect of the TAF introduced by the Fed. Wu (2009), analyzing the effectiveness of the TAF, found that this measure has reduced liquidity risk premiums; however, it has been less effective in cutting counterparty risk premiums. This authors as well as Christensen et al. (2009) found that this measure lowered the level of the 3-month LIBOR-OIS spread. These actions of Central Banks enabled to put the overnight rates close to the official rate albeit more volatile (see 1, 3 and 5). According to these figures, the UK and the US overnight rates resumed to be closer to the target rates after the onset of the crisis compared to the EONIA rate. Furthermore, these figures suggest than the EONIA sound more volatile than the two other overnight rates.

Table 1: Mean and Standard deviation of the policy spreads

	EURO	United-Kingdom	United-States
pre-crisis	0,072 (0,06)	0,046 (-0,13)	0,008 (-0,06)

⁸ Between September 2007 and August 2008, the US policy rate decreased by 3.25% and the UK policy rate by only 0.75%.

⁹ In a TAF auction, the bids begin at a rate comprise between the target rate and the discount rate.

¹⁰ The PDCF enabled to provide loans to broker dealers at the discount rate and accepted a wider range of assets as collateral. Regarding the TSLF, it enabled broker dealers to borrow

Treasury securities from the Fed in exchange for various other securities for up to one month.

¹¹ Similarly to the TSLF in the US, the SLS allowed banks and building societies to swap high-quality, but temporarily illiquid, mortgage-backed and other securities for UK Treasury bills and then provide indirectly liquidity for a medium-term period, for up to 3 years.

¹² The discount window became stigmatised after August 2007 when its use was mis-interpreted as a sign of financial difficulty.

crisis: phase 1	0,008 (0,12)	0,059 (-0,10)	-0,030 (-0,17)
crisis: phase 2	-0,476 (0,25)	-0,08 (-0,21)	-0,180 (-0,26)

Value (.) represents the standard deviation.

Second phase of the crisis: after September 2008

Market activity in the unsecured market has again dried up with the reinforcement of the financial crisis following the collapse of Lehman Brothers on 16th September 2008. After this bankruptcy, market participants have stopped to trade between each other due to the credit risk at all maturity even for overnight transactions. Money market around the world froze then and unsecured interbank rates skyrocketed even overnight rate. Table 1 shows that the mean and the standard deviation of the policy spreads increased more after the collapse of Lehman Brothers (second phase). Central banks intervened urgently, decreased strongly their target rates (see figures 1, 3 and 5)¹³, and adopted unconventional measures in order to reduce the pressure in the interbank markets.

After the middle of September 2008, the previous used instruments and measures by the Fed were not sufficient to stem the crisis. Then the Fed provided massive amount of money to the markets through the Term Auction Facility (TAF). Furthermore, the Fed created in October 2008 the Commercial Paper Funding Facility (CPFF) in order to purchase three-month unsecured and asset-backed commercial paper directly from issuers, and in November 2008 the Term Asset-Backed Securities Loan Facility (TALF) in order to lend to holders of certain securities backed by recently-originated consumer and small business loans.¹⁴ All these instruments have been created in order to increase the amount of Fed credit extended to the banking system as well as to reduce the credit risks.

As the Fed, the BoE introduced additional measures. The BoE offered 3 month repos in greater size and a greater frequency and the eligible collateral was widened further to include securities backed by commercial mortgage assets and corporate debt. The SLS instrument was extended from 21 October to the end of January 2009. Furthermore, as the Standing facilities became stigmatized after August 2007¹⁵, these facilities have been replaced by the Operational Standing Facilities in October 2008 in order to absorb essentially technical frictions in the overnight money markets. The maturity of these new facilities remained overnight and the rate at +/-25 basis points relative to the target rate. In October 2008 the BoE introduced also the Discount Window Facility (DWF) in order to enable banks and building societies to borrow gilts against a wide range of collateral for 30 days, at fees depending on the type of collateral and the size of drawing. Due to the ongoing stresses in financial markets, the BoE proposed also the DWF with a term of 364 days.

Regarding the ECB, this Bank did not create a new measure, but transformed strongly its traditional instruments after the collapse of Lehman Brothers. Indeed, in October 2008 this Bank replaced the minimum bid rate with the fixed rate tenders with full allotment.¹⁶ This measure became effective in October 2008 for the MROs, the LTROs and the US dollar operations. Furthermore, this Bank has enlarged the list of collateral eligible for the open market operations and increased the number and frequency of refinancing operations. In order to reduce the volatility of the EONIA rate as well as to avoid that the MRO rate lose signaling power, as overnight rates declined after the collapse of Lehman Brothers, in October 2008 the ECB narrowed the amplitude of the corridor formed by the rates of the standing facilities to 100 basis points. This measure increased the attractiveness of the deposit facility for excess reserves. All these measures enabled to resolve the liquidity problem, but the credit risks did not reduce.

As the Fed's target rate was decreased to 0-0.25% at the end of 2008, this Bank could not decrease it further in order to stipulate the economy. Owing that, in March 2009 the Fed proposed the Quantitative Easing (QE) method to inject money into the economy by creating new money and then using it to purchase assets (government bonds and mortgage-related securities) in order to lower borrowing costs and thereby stimulate the economy. In the same line, in March 2009, the BoE announced the Asset Purchase Facility (APF) in order to purchase assets financed by issuing central bank reserves. Regarding the ECB, until May 2009, this Bank addressed the crisis within its existing framework and was not forced to create new tools. However, in June 2009 this Bank started to use the QE method by buying covered bonds from financial institutions. Furthermore, the ECB proposed in June the first one-year long-term refinancing operations (LTRO) at a rate equal to the MRO rate (=1%).

Through all these measures the Fed and the BoE managed to control a bit the overnight rate close to their target rate (see figures 3 and 5). Conversely, the ECB did not manage to approach the EONIA rate towards its policy rate (see figure 1). This behavior of the EONIA rate is due to the credit risks and the increased attractiveness of the deposit facility, which encouraged financial institutions to put their excess reserve to the ECB at a bit lower rate than to trade each others. The trading volume in EONIA declined then and the EONIA rate went far away from the target rate towards the deposit facility rate. As the market started to recover at the end of 2008, the ECB decided to enlarge the amplitude of the corridor in December 2008 in order to resume the activity in the overnight market. However, this enlargement has not got the expected results. Indeed, according to the figure 1 the overnight rate stayed still far away from the target rate and close to the deposit facility rate in 2009.

¹³ The Fed decreased its target rate after September 2008 by 175 points basis between October and December 2008. This rate decreased to 0-0.25% at the end of 2008. As for the BoE, it strongly decreased its policy rate between October 2008 and March 2009 from 5% to 0.5%. From the beginning of the crisis till the collapse of Lehman Brothers the ECB did not decrease its target rate, but between October 2008 and May 2009, the ECB's target rate was lowered by a cumulative 3.25% and reached 1%.

¹⁴ The Emergency Economic Stabilization Act (EESA), signed in October 2008, gave the Fed increased power over short-term interest rates by allowing it to pay interest on reserves and to create the CPFF as well as the TALF.

¹⁵ Standing Lending Facility became stigmatized after August 2007 when its use was misinterpreted as a sign of financial difficulty.

¹⁶ Under the minimum bid rate system the liquidity was limited. So, in order to get liquidity from the ECB financial institutions tended to over-bid and then widen strongly the spread between the marginal rate and the minimum rate.

III) DATA DESCRIPTION

In this article, we analyze the dynamics of three daily overnight interest rates; the effective federal funds rate, the European Overnight Index Average rate (EONIA), and the Sterling Overnight Index Average rate (SONIA). The EONIA is a volume weighted average rate of all overnight unsecured lending transactions initiated within the euro area by a particular panel of banks. Similarly, the Sonia is the weighted average rate of all unsecured Sterling overnight cash transaction brokered in London between midnight and 4.15 pm. The federal funds rate ranges from January 1st 1990 to December 31th 2009. Regarding the EONIA rate, it ranges from January 1st 1999 to December 31th, 2009. As for the Sonia rate, it covers the period from January 1st to December 31th 2009.

For each country, we also use the target rate of the monetary policy. These rates correspond to the federal funds rate target in the USA, the two-week repo rate in the UK and in the Euro area. The target rate change rarely. Furthermore, central banks try to keep the overnight rate close to their target rate. Owing these fact, in this article we analyze the dynamic of the spread between the overnight rate and the target rate (policy spread) as several authors, such as [5], [8], [1], [22] and [16].

Table 2:
Descriptive Statistics

	EURO	UK	US
Dickey-Fuller			
With intercept and trend	-15,75*	-48,78*	-46,49*
With intercept	-14,11*	-46,73*	-45,13*
Without intercept	-14,11*	-45,12*	-45,06*
Phillips-Perron			
with intercept	-14,11*	-46,73*	-45,13*
Ljung-Box			
1	13,46*	39,22*	0,41*
5	32,64*	214,20*	55,84*
10	51,17*	275,98*	263,84*
Sign and size bias effects			
Size effect	0,01* (0,00)	0,19* (0,00)	-0,01 (0,23)
Negative shocks	-0,13* (0,00)	-0,47* (0,00)	-0,41* (0,00)
Positive shocks	0,06* (0,00)	0,32* (0,00)	0,10* (0,00)

Values (.) correspond to the p-value.

* and ** indicate that the corresponding coefficient is statistically significant at the 5% and 10 %, respectively.

The three policy spreads retained in this analysis are stationary. Indeed, the results of the standard DF (1976) test and the Phillips-Perron (1988) test, enables to reject the hypothesis of unit root for any of the policy spread (Table 2). Furthermore, according to the results of Ljung-Box statistics (see Table 2), the null hypothesis of homoskedasticity is rejected at the 5% level for all spreads. Thus, the conditional

volatility of all policy spread are time series dependent. These policy spreads are also conditionally heteroscedastic. Finally, table 2 suggests that the results of the test for sign and size bias, proposed by Engle and Ng (1993), show that there is substantial evidence of asymmetric effects. The reaction of the conditional volatility of these policy spreads to the shocks depends on the sign and the size of those shocks.

IV) EMPIRICAL ANALYSIS OF THE POLICY SPREAD OVER 'NORMAL' PERIOD

A) Model

Very short-term rates are characterized by the 'mean reverting' and the heteroscedasticity. Authors, analyzing the dynamics of overnight rates, formalize the 'mean reversion' as the adjustment of this rate towards the official policy rate ([5], [8], [1]; [23]; [21]). Regarding the heteroscedasticity, authors studying the impact of monetary policy instruments and procedures on the dynamics of overnight rates use mainly EGARCH model ([2] [3]; [1]; [6]; [11]; [7]). Furthermore, the results obtained in the previous section show that the reaction of the conditional volatility of the policy spreads to the shocks depends on the sign and the size of those shocks. We modelise the dynamics of the policy spreads with an asymmetric AR-EGARCH model. According to section 2, the main fundamentals of the policy spreads dynamics correspond to the open market operations rate, factor related to the standing facilities, and the last days of the maintenance periods. Furthermore, a modification of the features of these instruments might have an impact on the dynamics of the policy spreads ([9]; [10]; [11]; [12]; [7]). We then take into account the impact of the main modifications of monetary policy instruments and procedures; display in table A1 (appendix). The asymmetric AR-EGARCH model with exogenous structural breaks can be written as follow:

$$r_t - r_t^* = a + b[r_{t-1} - r_{t-1}^*] + c\Delta r_{t-1}^* + ModifM + \varepsilon_t, \quad (1)$$

$$\log(h_t) = w + \alpha \frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} + \beta \log(h_{t-1}) + \varphi \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \sum_0^I \lambda_i M_i + \delta D_i^* + ModifV, \quad (2)$$

Where,

$$ModifM = \sum_{q1=1}^{Q1} b_{q1} [r_{t-1} - r_{t-1}^*] D_{q1}^{r*} + \sum_{q2=1}^{Q2} a_{q2} r^* D_{q2}^{r*},$$

$$ModifV = \sum_{q3=1}^{Q3} w_{q3} D_{q3}^{SF} + \sum_{k1=1}^{K1} \sum_{i=0}^I \lambda_{i,k1} D_{k1}^{RR} M_i + \sum_{k2=1}^{K2} w_{k2} D_{k2}^{RR}.$$

The term $b[r_{t-1} - r_{t-1}^*]$ formalizes the 'mean reversion' of the overnight rate (r_t) towards the official rate (r_t^*) with the speed $b^*=(1-b)$. This speed of adjustment can change with the modifications of the open market operations' features ([4]; [1]). Changes are accounted by the term $\sum_{q1=1}^{Q1} b_{q1} [r_{t-1} - r_{t-1}^*] D_{q1}^{r*}$, where $Q1$ corresponds to the number of modifications and dummy variable D_{q1}^{r*} is equal

to 1 after the $q1^\circ$ modification. Any modifications of the open market operations' features could affect the impact the dynamic of the policy spreads. This possible impact is

accounted by $\sum_{q2=1}^{Q2} a_{q2} \Delta r^* D_t^{r*}$, with dummy variable D_t^{r*}

equal to 1 after the modifications $q2$.

A modification of the standing facilities' features (SF) might impact the variability of interest rates spreads ([11]). The effect of this impact is accounted by the parameter w_{q3} , with $q3$ representing the $q3^\circ$ modification. Dummy variable D_{q3}^{SF} is equal to 1 after the $q3^\circ$ modifications.

The term $\sum_0^I \lambda_i M_i$ represents the impact of the last days of

the maintenance period. Dummy variable M_i , with $i=0, \dots, I$, is equal to 1 i days before the settlement days and 0 otherwise. Referring to the results obtained by [2] [3] and [7], only the last four days has been retained; $I=3$. The parameter λ_i measures the effect of the dummy variable M_i related to the day i . The value of these parameters can change with the modifications related to the reserve system ([9]; [10]; [7]).

These changes are formalized by $\sum_{k1=1}^{K1} \sum_{i=0}^I \lambda_{i,k1} D_{k1}^{RR} M_i$, with

dummy variables D_{k1}^{RR} equal to 1 after the $k1^\circ$ modification ($k1=1, \dots, K1$ and $K1$ corresponds to the number of modifications). Furthermore, a modification of the reserve ratio, like in the USA in April 1992 when the Fed lowered the reserve ratio on transaction deposit, could affect the volatility of the policy spread. The impact of such modifications is

accounted by the term $\sum_{k2=1}^{K2} w_{k2} D_{k2}^{RR}$, with dummy variables

D_{k2}^{RR} equal to 1 after the $k2^\circ$ modification ($k2=1, \dots, K2$ and $K2$ corresponds to the number of modifications).

B) Empirical results

We first evaluated the reaction of the policy spreads to the Central banks' instruments over 'normal' period. We implemented this analysis on the period prior to the Subprime crisis. The periods retained stop on June 30th 2006 for the three policy spreads.¹⁷ The results of this analysis are presented and discussed in what follow.

General results

As expected¹⁸, our results reveal that the conditional volatility of the policy spread is higher on the last days of the maintenance period (Table 4). This reaction is more important in the Euro zone than in the U.S.A on the two last days (λ_0 and λ_1). These results concern the behavior of the US policy spread before May 1998 ('contemporaneous' method) and the behavior of the Euro area policy spread after 1999 ('lagged' method). Owing that, our finding is surprising. Indeed, the variation of interest rate should be more pronounced with the 'contemporaneous' method than with the 'lagged' method (see section 2). The frequency of the central

banks' intervention in the interbank market can explain our results ([7]; [21]). The Fed intervenes in a daily frequency to provide liquidity in this market whereas the ECB intervenes less frequently (once a week) and very occasionally this Bank resorts to fine turning operations (FTO) with a maturity of one day on the last day of a maintenance period. Another explanation is based on the period related to these results. Indeed, the US results concern the period ranging from January 1990 to May 1998 whereas the Euro zone results concern the period after January 1999.

As we detailed in section II, the speed of the adjustment of the overnight rate towards the target rate is higher in countries, such as the U.S.A., where monetary authorities intervene daily in the interbank market and have an implicit target rate than in countries, such the Euro zone, where the authorities opted for a repo rate as a target rate and intervene less frequently ([4]; [3]). In line with this view, our results show that the adjustment of the effective federal funds rate towards the Fed's target rate is higher than the adjustment of the SONIA rate towards the target rate (see table 3). This later adjustment is higher than the adjustment speed of the EONIA rate towards the ECB's target rate (b). The policy rate in the UK is a repo rate as in the Euro-area, but the BoE intervenes daily in the interbank market.

Impact of the modifications

The Euro-area

Since the onset of the single currency, the ECB made a major reform in March 2004 in order to reduce the volatility of the very short-term interest rates in normal time and at the end of the maintenance period (ECB, 2006). The reduction of this volatility could diminish the volatility of medium and long-term rates and then enables a better implementation of the monetary policy. This reform consisted to shorten the maturity of the main refinancing operations to one week as well as changing the timing of the reserve maintenance period (see Table A1 appendix).¹⁹ According to our results (Table 4), since March 2004 the volatility of the policy spread has decreased; the estimated coefficient w_{04} is significant and negative. Similar results are found by the [24] [25]. However, the effect of this reform on the behavior of the policy spread on the last days of the maintenance period is not clear. Indeed,

this spread reacts more strongly on the last day (λ_0) and two days (λ_2) before the end of the maintenance period and reacts less one day (λ_1) and three day (λ_3) before the reserve settlement day.

This reform has been made also in order to enhance the controllability of the EONIA rate, and then keep this rate more closely to the target rate. However, our result, display in table 3, reveal that since March 2004 the adjustment speed of the EONIA rate towards the key rate has reduced (b_{04}) by 0.1132 to 0.103 ($=1-b-b_{04}=1-0.7838-0.1132$). This finding, which is unintended by the ECB, is also obtained by few authors, such as [26], [13], [25]. After noticing this unintended result, the ECB injected more liquidity to the interbank market (ECB, 2006) [25]. However, these injections did not influence the adjustment speed of the

¹⁷ For the Euro area, we then retained the period ranging from the 1st January 1999 to June 30th 2006. Regarding the UK, the period ranges from 1st January 1994 to June 30th 2006. Finally, for the USA, this period ranges from 1st January 1990 to June 30th 2006 for the USA.

¹⁸ See section 2.

¹⁹ Since March 2004, the maintenance period begins on the settlement day of the first MRO following the Governing Council meeting and ends on the day preceding the corresponding settlement day in the following month. Prior to March 2004, the maintenance period begins on the 24th calendar day of each month and ends on the 23th calendar day of the following month.

EONIA rate towards the policy rate. This worseness of this adjustment speed is not clear why it happened. The sole explanation provided is from [26], who show that the policy spread is not integrated in the same order before and after March 2004.

The United-States

Over the period ranging from January 1990 to December 2005, the Fed has modified several times the characteristics of its instruments and undertook transparency measures (see Table A1, Appendix). Most of these modifications concerned the reserve requirement system. In April 1992, this bank lowered the reserve ratio on transaction deposits from 12% to 10%. According to our results, this reduction did not influence significantly the volatility of the policy spread (w_{92} ; Table 4). However, the substitution of the 'contemporaneous' method by the 'lagged' method in May 1998 has been perceived as a mean of lower variation of the overnight rate and then of the policy spread on the last days of the maintenance period. In accordance with the finding of [7], our results reveal a lower volatility of the policy spread during the last days of the maintenance period. For instance, on the period prior to May 1998, the conditional volatility of the policy spread amplified by 1,2068 ($=\lambda_0$) on the last day whereas after 1998 this reaction is strongly reduced to 0,2506 ($=1,2068-0,9562=\lambda_0+\lambda_{0,1}$). This finding can be explained by the longer time that banks have had to meet their duty ([7]), but also by the fact that the Fed had provided more liquidity on the interbank market during the last days of the maintenance period since August 1998 ([21]).

Table 3: Empirical Results (mean)

	EURO area	UK	US
A	0,0086* (23,02)	0,0008 (0,20)	0,0045* (7,02)
B	0,7838* (49,06)	0,3391* (6,66)	0,3611* (40,91)
C	0,0014 (0,08)	-2,1030* (-2,22)	-0,004* (-2,96)
b₉₄ (US) ; b₉₇ (UK)		0,0759 (1,40)	-0,074* (-8,34)
b₀₄ (EURO) ; b₀₅ (UK)	0,1132* (14,89)	0,1433* (3,14)	
c₉₄ (US) ; c₉₇ (UK)		2,4195* (2,42)	0,0465 (0,27)
c₀₀ (US)			0,0111 (0,06)
c₀₃ (US)			-0,0402 (-0,89)

* and ** indicate that the corresponding coefficient is statistically significant at the 5% and 10 %, respectively.

Further these modifications, the Fed replaced the discount window by a new borrowing facility in January 2003. The discount window rate was very attractive for banks as it was below the federal funds rate. However, using this instrument meant to be subject to considerable administration by the Fed

and be perceived by the market as financially weak. Owing that, depository institutions were not encouraged to use it. The Fed replaced it then by the new borrowing facility, which rate is 100 point basis above the official target rate and using this instrument does not imply any administrative review by this Bank. Table 3 shows that this substitution did not have any impact on the level of the policy spread (a_{03}). However, after January 2003 the volatility of the policy spread decreased significantly on the release day of the monetary policy decisions (w_{03}) (Table 4).

- Table 4: Empirical Results (volatility)

	EURO	UK	US
λ_0	1,7291* (9,76)		1,2068* (13,25)
λ_1	1,7837* (10,92)		0,3042* (3,23)
λ_2	0,2411 (1,16)		1,3898* (12,95)
λ_3	1,7141* (9,58)		0,4018* (4,35)
$\lambda_{0,04}(\text{EURO}) \lambda_{0,98}(\text{US})$	0,6833* (2,07)		-0,9562* (-7,18)
$\lambda_{1,04}(\text{EURO}) \lambda_{1,98}(\text{US})$	-0,5150* (-2,06)		0,1872 (1,24)
$\lambda_{2,04}(\text{EURO}) \lambda_{2,98}(\text{US})$	1,8393* (6,26)		-1,1983* (-7,35)
$\lambda_{3,04}(\text{EURO}) \lambda_{3,98}(\text{US})$	-0,5179* (-1,96)		-0,3597* (-2,43)
$w_{04}(\text{EURO}), w_{97}(\text{UK}), w_{92}(\text{US})$	-0,9317* (-14,24)	-0,0149 (-1,08)	0,0047 (0,21)
$w_{98}(\text{UK}), w_{94}(\text{US})$		-0,0768* (-4,72)	0,0219 (1,07)
$w_{01}(\text{UK}), w_{98}(\text{US})$		-0,0395* (-2,93)	-0,0272 (-0,73)
$w_{05}(\text{UK}), w_{03}(\text{US})$		-0,1228* (-4,11)	-1,2480* (-4,62)
δ	-4,9957* (-4,04)	-0,7393** (-1,80)	0,2125 (1,27)
δ_{94}			0,8264* (3,93)
δ_{00}			-0,578** (-1,84)

* and ** indicate that the corresponding coefficient is statistically significant at the 5% and 10 %, respectively.

Finally, the last type of modification that the Fed undertook regards its transparency and credibility. Like most central banks of industrialized countries the Fed took new measures in order to improve its transparency and then its credibility.

The main measures were the immediate disclosure of the FOMC decisions about the target rate since February 1994²⁰ and in 2000 balance of risk statement was introduced. By improving the predictability of the Fed's decisions²¹, these both measures can be benefit for the dynamic of the very short-term rate. [21] show that the transparency measure adopted in February 1994 has significantly increased this bank's influence on the federal funds rate. In line with these authors' finding, our results display in table 3 suggest that after February 1994 the adjustment of the effective federal funds rate towards the target rate is more pronounced. Indeed, on the period prior to 1994 the adjustment speed is equal to 0.639 (=1-b=1-0.3611) and to 0.714 [=1-0.361+0.075=1-b₉₄] after the immediate announcement of the Fed's decisions. Conversely, this transparency measure did not affect significantly the conditional volatility of the policy spread (Table 4). Regarding the transparency measure adopted in January 2000, it has reduced significantly the reaction of the policy spread's volatility on the release day of the target rate's decisions (c₀₃) as found by [21]. This reaction is equal to 0.826 on the period before January 2000 and to 0.248 (=0.826+(-0.578)) after this date.

The United-Kingdom

In May 1997, the Bank of England replaced its target rate, the so-called minimum Band 1 dealing rate²², by the two-week repo rate as a target rate. Furthermore, this Bank widened the range of counterparties that are able to participate in the Bank's auctions as well as extended the pool of securities eligible for use in the Bank's open market operations. Table 3 suggests that this reform affects mainly the reaction of the policy spread to the variation of the target rate. Conversely, this reform did not influence significantly the conditional volatility of the policy spread. Similar results are found by [11].

As expected, the overnight lending facility, introduced in June 1998, and the overnight deposit facility, introduced in June 2001, have enabled to reduce the volatility of the policy spread (w₉₈ and w₀₁; table 4). The significant effect of the lending facility is also shown by [11].

In order to reduce the volatility of the SONIA rate, have a less complex system²³, and improve the expectations of market participants²⁴ ([27]), some modifications of the BoE's traditional instruments have been done in March 2005. This reform consisted to narrow the amplitude of the corridor formed by the existing overnight lending and deposit facilities, and indexing the rate charged on the two-week reverse repos undertaken by the Bank in its daily open market operations to the MPC repo rate. As expected this reform has enabled to reduce the volatility of the policy spread (w₀₅; Table 4). Conversely, surprisingly the adjustment speed of the SONIA rate towards the policy rate decreased after March 2005 (b₀₅).

V) ANALYZE OF THE IMPACT OF THE SUBPRIME CRISIS

In order to alleviate the pressure on the money markets as well as to resume the activity of these markets during the last

financial crisis, Central Banks have used their traditional instruments as well as some unconventional measures. We analyze in this part the effects of these tolls on the dynamics of the policy spreads.

A) Model

For this analysis, we retain the model described by the equations 1 and 2, but we formalize *ModifM* and *ModifV* differently. These both components comprise the modifications related to the traditional instruments used by the Central Banks as well as the unprecedented measures undertaken by these Banks during the period retained in this part; which ranges from July 1st 2005 to December 31th 2009. These modifications and unconventional measures, presented in section 2.2, have been done in order to provide liquidity and then alleviate the pressure in the money market as well as control the overnight rate as well as encourage depository institutions to trade each others. Specially, these modifications and measures should have enhanced the control of the Central Banks on the very short-term rates as well as reduce the volatility of those rates. We formalize the effect of these modifications and the unprecedented measures on the volatility of the policy spreads by modeling *ModifM* and *ModifV* as follow:

$$\begin{aligned} \text{ModifM}^{EURO} &= b_{08/07}[r_{t-1} - r_{t-1}^*]D^{08/07} \\ &+ b_{10/08}[r_{t-1} - r_{t-1}^*]D^{10/08} + a_{06/09} \\ \text{ModifM}^{UK} &= b_{08/07}[r_{t-1} - r_{t-1}^*]D^{08/07} \\ &+ b_{10/08}[r_{t-1} - r_{t-1}^*]D^{10/08} + a_{04/08} + a_{03/09} \\ \text{ModifM}^{US} &= b_{08/07}[r_{t-1} - r_{t-1}^*]D^{08/07} \\ &+ b_{10/08}[r_{t-1} - r_{t-1}^*]D^{10/08} + a_{12/07} + a_{03/09} \\ \text{ModifV}^{EU} &= w_{08/07}D^{08/07} + w_{10/08}D^{10/08} + w_{06/09}D^{06/09} \\ &+ \lambda_0 M_0 + \lambda_{0,08/07}M_0D^{08/07} + \lambda_{0,10/08}M_0D^{10/08} \\ \text{ModifV}^{UK} &= w_{08/07}D^{08/07} + w_{04/08}D^{04/08} \\ &+ w_{10/08}D^{10/08} + w_{03/09}D^{06/09} + \lambda_0 M_0 \\ \text{ModifV}^{US} &= w_{08/07}D^{08/07} + w_{12/07}D^{12/07} \\ &+ w_{03/08}D^{03/08} + w_{10/08}D^{10/08} + w_{03/09}D^{06/09} \\ &\lambda_0 M_0 + \lambda_{0,08/07}M_0D^{08/07} + \lambda_{0,10/08}M_0D^{10/08} \end{aligned}$$

The term $w_{10/08}D^{10/08}$ formalizes the effects on the volatility of the modifications of the instruments' features realized in October 2008, the introduction in October 2008 of unprecedented measures (and in November 2008 in the case of the USA) as well as the intensification of the pressure on the money markets after the collapse of Lehman Brothers. We modelise all these effects with only one variable in order to avoid collinearity problem. We also take into account the possible change of the behavior of the policy spread during the last days of the maintenance periods. As our model comprise a large number of variables for the period retained, we then consider only the last day of the maintenance period

²⁰ Before February 1994, the decisions about the official rate had to be inferred by the public from this bank's open market operations.

²¹ See [16], [17] and [28].

²² The minimum rate at which the Bank was willing to discount bills with up to 14 days maturity.

²³ Before March 2005, there were four rounds of refinancing operations each day and on most

days there are at least two.

²⁴ Before March 2005, it was harder to decipher expectations from ultra short-term money market rates. Because the daily 2-week repos span the MPC meeting but were conducted existing rate.

(λ_0 , $\lambda_{0,08/07}$ and $\lambda_{0,10/08}$) instead of few days.

Furthermore, we do account only the effect of the measures introduced in December 2007 and in March 2009 by the Fed on the level of the US policy spread in order to avoid any collinearity problem. In the case of the UK, as the reserve requirement system has been introduced only in June 2006, we do not retain the possible change of the UK policy spread on the last day after the onset of the crisis and after the collapse of Lehman Brothers.²⁵

B) Empirical results

Table 5 reveals that the adjustment speed of the overnight rate towards the policy rate increased in the Euro area and the UK during the first phase of the financial crisis (between August 2007 and September 2008) whereas it decreased slightly in the USA. The massive injection of liquidity into the interbank markets through the traditional instruments and through the unprecedented measures enabled to control the overnight rate. This finding is in line with the argument postulated by [14], [15] and [16]. These authors argue that central banks have ability to influence interest rates in situation marked by liquidity risk premium.

Conversely, in situation marked by credit risks it is much harder for central banks to control the overnight rates as it is suggested by our results. After the collapse of Lehman Brothers in September 2008, the adjustment speed of the overnight rate towards the policy rate decreased in the three cases ($b_{10/08}$; Table 5). The speed was nil in the Euro area whereas this speed was equal to 0.34 and 0.15 in the UK and the USA, respectively. These speeds were equal to 0.39, 0.42 and 0.57 in the case of the Euro area, the UK and the USA, respectively, on the period ranging from August 2007 to September 2008. These findings are also illustrated in the figures 1, 3 and 5. Figure 1 shows clearly that the EONIA rate has tended towards the deposit facility rate and then has gone far from the target rate after the collapse of Lehman Brothers. This collapse is not the direct cause of this latter fact, but this fact can be explained mainly by the measures undertaken by the ECB after this collapse in order to provide liquidity into a frozen market. The ECB provided unlimited liquidity to the markets and took the role of intermediary on the interbank. Furthermore, this Bank narrowed the amplitude of the corridor formed by the standing facilities' rates. These both measures and the existing credit risks can explain our finding about the adjustment speed of the EONIA rate towards the policy rate.

As expected, the onset of this crisis in August 2007 has increased the volatility of very short-term rate and then the volatility of the policy spreads (see Table 5). Indeed, all the estimated coefficients ($w_{08/07}$) are significant and positive. The Fed and the BoE used their traditional instruments as well as took unprecedented measures in order to tackle the liquidity risks and then dampen the pressure on the markets (see section 2.3). According to the table 5, the introduction of the TAF in December 2007 by the Fed reduced significantly the level of the policy spread ($a_{12/07}$), but did not have the expected effect on the volatility of this spread ($w_{12/07}$). Indeed, our results suggest that after December 2007 the volatility of

the US policy spread increased more. The effect on the level of this policy spread is in line with the results found by Wu (2009) and Christensen (2009). These authors showed that this measure enabled to lower the level of the 3-month LIBOR-OIS spread. As for the measures introduced in March 2008 in order to provide liquidity directly through the PDCF or indirectly through the TSLF, they did not sound alleviate significantly the situation in the US money market. Regarding the UK, after the introduction of the SLS in April 2008 the level of the UK policy spread decreased ($a_{04/08}$), but the volatility of this spread increased ($w_{04/08}$).

Table 5: Empirical results: Impact of the crisis

	EURO	UK	US
B	0,910* (49,51)	0,635* (374,86)	0,331* (86,17)
$b_{08/07}$	-	-	-
	0,305* (-7,90)	0,061* (-2,13)	0,095* (24,49)
$b_{10/08}$	0,409* (12,56)	0,087* (14,39)	0,424* (55,27)
$a_{04/08}$ (UK), $a_{12/07}$ (US)	-	0,004* (-16,67)	-
	-	-	-
$a_{06/09}$ (Euro), $a_{03/09}$ (UK,US)	0,061* (10,44)	0,028* (-132,47)	0,006* (-4,82)
λ_0	3,711* (17,60)	1,623* (5,65)	1,378* (8,12)
$\lambda_{0,08/07}$	-	-	-
	1,397* (-3,35)		1,644* (-6,70)
$\lambda_{0,10/08}$	-	-	-
	0,298 (0,64)	4,904* (-15,28)	0,691* (-2,16)
$w_{08/07}$	1,090* (11,40)	0,916* (5,39)	0,602* (4,62)
$w_{12/07}$			0,261* (2,43)
$w_{04/08}$ (UK), $w_{03/08}$ (US)		0,093* (2,28)	-0,106 (-1,06)
			-
$w_{10/08}$	0,503* (5,43)	0,226* (4,04)	0,313* (-3,00)
	-	-	-
$w_{06/09}$ (Euro), $w_{03/09}$ (UK,US)	0,514* (-4,91)	0,676* (-12,86)	0,646* (-3,85)

* and ** indicate that the corresponding coefficient is statistically significant at the 5% and 10 %, respectively.

Conversely to the unprecedented measures adopted during the first phase of the crisis, the QE method used in 2009 sound alleviate significantly the money markets situation. Indeed, our results show that the level as well as the volatility of the

²⁵ In this part of the analysis, we do not take into account, in equation 2 describing the conditional volatility of the policy spread, the term $\sum_{i=0}^T \lambda_i M_i$. We replace it by $\lambda_0 M_0$ representing the effect of the last day of the maintenance period.

US and the UK policy spreads decreased significantly after March 2009 (a03/09 and w03/09). This decreased happened in June 2009 in the Euro area as the ECB introduced this measure further in June 2009 (w06/09).

The collapse of Lehman Brothers intensified the crisis and then increased more the volatility of interest rates. According to our results the unconventional measures undertaken and the modifications done by the Central Banks did not enable to reduce this volatility to the level prevail over the first phase of the crisis, except in the case of the USA. Indeed, table 5 reveals that the conditional volatility of the Euro area and the UK policy spreads increased further after the collapse of Lehman Brothers as the crisis intensified (w10/08) whereas the volatility of the US policy spread decreased significantly after October 2008. This finding suggests that the measures undertaken by the Fed have been more efficient than the measures adopted by the ECB and the BoE.

Our last finding concerns the reaction of the volatility during the last day of the maintenance period. Results in table 5 suggest that the volatility of the Euro area and the US policy spreads decreased significantly after August 2007 ($\lambda_{08/07}$).

In line with [16], we can explain this finding by the fact that after the onset of this crisis, financial institutions increased demand for central bank liquidity and preferred to hold more deposits with central bank than necessary at the beginning of the maintenance period as a precautionary measure. These authors plot the behavior of the Euro area policy spread over the maintenance period. According to their figure, on the period prior to the crisis this spread increased during the last days of the maintenance periods whereas after August 2007 this spread decreased slightly.

IV) CONCLUSION

In this article we analyzed the reaction of the dynamic of the spread between the overnight rate and the target rate (policy spread) to its fundamentals; which are associated to the traditional instruments used by Central Bank in order to implement its monetary policy. These instruments are the open market operations, the standing facilities and the reserve requirements. We implemented this analysis during normal time and during the Subprime crisis. Indeed, during this crisis using the traditional instruments were not all the time sufficient enough in order to control overnight rates. Then, the ECB, the BoE and the Fed have also used some unconventional measures in order to resume the normal functioning of the frozen interbank markets.

Our results suggest that most of the modifications of the traditional instruments' features adopted by the three Central Banks do not influence significantly the adjustment speed of the overnight rates towards the target rate. However, these modifications have affected mainly the volatility of the policy spreads. As expected, the variability of the US policy spread on the last days of the maintenance periods is lesser after May 1998 when the Fed substituted the 'contemporaneous' method by the 'lagged' method. The substitution of the Discount Window by the New Borrowing Facility in January 2003 has also reduced the volatility of the US policy spread. Similar results are also obtained with the transparency measure adopted by the Fed in 2000 when this Bank introduced the balance of risk statements. Regarding the UK, the introduction of the lending facility in June 1998 and further the deposit facility in June 2001 have also enabled to reduce the volatility of the UK policy spread. Similar positive impact

on the volatility of the UK policy spread has been also obtained with the reform undertaken by the BoE in March 2005. Finally, in the Euro area, the reform undertaken by the ECB in March 2004 has reduced the volatility of the policy spread.

The effects of the instruments used by Central Banks on the dynamic of the policy spreads depend on the feature of those instruments but also on the financial situation. Indeed, these effects have changed since the onset of the Subprime crisis marked at the beginning with mainly liquidity risks and further with mainly credit risks. In line with the arguments of [14], [15] and [16], our results suggest that the three Central Banks managed to keep the overnight rate close to their target rate after the great disturbance caused by the onset of this crisis over the first phase of the crisis marked mainly by liquidity risks. However, the control of the overnight rates by these Banks weakened strongly after the collapse of Lehman Brothers when the credit risks were important. The situation was the worse in the Euro area, where the EONIA rate went far away from the target rate and approached the deposit facility rate. This result is explained by the actions of the ECB after September 2008.

The unconventional measures introduced by the BoE and the Fed over the first phase of the crisis enabled to reduce the level of the policy spreads. Whereas, the unprecedented measures undertaken after September 2008, especially the Quantitative Easing method, reduced significantly the level as well as the volatility of the three policy spreads.

Finally, according to our results the measures adopted by the Fed just after the collapse of Lehman Brothers, in October-November 2008, sound more efficient than the measures introduced by the BoE and the ECB. Indeed, the conditional volatility of the US policy spread decreased after October 2008 whereas it increased in the Euro area and the UK.

BIBLIOGRAPHY

- [1] J. Beirne, G. M. Caporale and N. Spagnolo, "Liquidity risk, credit risk and the overnight interest rate spread: A stochastic volatility modeling approach," *CESifo Working Paper*, vol. 3115, 2010.
- [2] C. Borio, "Monetary policy operating procedures in industrial countries," *BIS Working Paper*, vol. 40, 1997.
- [3] Cohen, "Monetary policy procedures and volatility transmission along the yield curve," *Bank for International Settlement*, 1999.
- [4] P. Balduzzi, G. Bertola and S. Foresi, "A model of target changes and the term structure of interest rates," *Journal of Monetary Economics*, vol. 39, p. 223–249, 1997.
- [5] P. Balduzzi, G. Bertola, S. Foresi and L. Klapper, "Interest rate targeting and the dynamics of short-term rates," *Journal of Money, Credit and Banking*, vol. 30(1), p. 26–49, 1998.
- [6] W. Barrett, M. Slovin and M. Sushka, "Reserve regulation and recourse as a source of risk premia in the fed funds market," *Journal of Banking and Finance*, vol. 12, p. 575–584, 1988.
- [7] L. Bartolini, G. Bertola and A. Prati, "Day-to-day monetary policy and the volatility of the federal funds interest rate," *Journal of Money, Credit and Banking*, vol. 34(1), 2002.
- [8] F. Benito, A. Leon and J. Nave, "Modeling the euro overnight rate," *Journal of Empirical Finance*, vol. 14, p. 756–782, 2007.
- [9] J. Y. Campbell, "Money announcement, the demand for bank reserves, and the behavior of the federal funds rate within the statement week," *Journal of Money, Credit and Banking*, vol. 19, p. 56–67, 1987.

- [10] E. C. Bank, "The transmission of overnight interest rate volatility to longer-term interest rates in the euro area money market," *Monthly Bulletin* August, p. 24–26, 2005.
- [11] E. C. Bank, "The Eurosystem's operational framework and the volatility of the overnight interest rate," *Monthly Bulletin* July, p. 24–29, 2006.
- [12] J. D. Hamilton, "The daily market for fed funds," *Journal of Political Economy*, p. 26–56, 1996.
- [13] J. D. Hamilton, "The daily market for federal funds," *Journal of Political Economy*, vol. 104(1), p. 26–56, 1996.
- [14] U. Hassler and D. Nautz, "On the persistence of the EONIA Spread," *Economics Letters*, vol. 101, pp. 184–187, 2008.
- [15] H. Hesse and N. Franck, "The effectiveness of central bank interventions during the first phase of the subprime crisis," *IMF Working Paper*, vol. WP/09/206, 2009.
- [16] K. Kuttner, "Monetary policy surprises and interest rates: Evidence from the Fed funds futures market," *Journal of Monetary Economics*, vol. 47, p. 523–544, 2001.
- [17] J. Lange, B. Sack and W. Whitesell, "Anticipations of monetary policy in financial markets," *Journal of Money, Credit and Banking*, vol. 35, p. 889–908, 2003.
- [18] Lasser, "The effect of contemporaneous reserve accounting on the market for the federal funds," *Journal of Banking and Finance*, p. 1047–1056, 1992.
- [19] J. Lee, "Federal funds target changes and interest rate volatility," *Journal of Economics and Business*, vol. 54, p. 159–191, 2002.
- [20] D. Nautz and C. Offermanns, "The Dynamic Relationship between the Euro Overnight Rate, the ECB's Policy Rate and the Term Spread," *International Journal of Finance and Economics*, pp. 287–300, 2007.
- [21] D. Nautz and S. Schmidt, "Monetary policy implementation and the federal funds rate," *Journal of Banking and Finance*, p. 1274–1284, 2009.
- [22] S. Nobili, "Liquidity risk in money market spreads," In *ECB Workshop on Challenges to Monetary Policy Implementation beyond the Financial Market Turbulence*, 2009.
- [23] G. Perez-Quiros and H. R. Mendizabal, "The daily market for funds in Europe: Has something changed with the EMU?," *European Central Bank Working Paper*, 2001.
- [24] A. Prati and L. Bartolini and G. Bertola, "The overnight interbank market: evidence from the G7 and the euro," *Journal of Banking and Finance*, p. 2045–2083, 2003.
- [25] C. Soares and P. M. M. Rodrigues, "Determinants of the Eonia spread and the financial turmoil of 2007–2009," *Economic Bulletin Banco de Portugal*, p. 109–129, 2010.
- [26] A.P. Spindt and R.J. Hoffmeister, "The micromechanics of the federal funds market: Implications for day-of-the-week effects in funds rate variability," *Journal of Financial and Quantitative Analysis*, vol. 23(4), p. 401–416, 1988.
- [27] P. M. W. Tucker, "Managing the central bank's balance sheet: Where monetary policy meets financial stability," *Lecture by Tucker to mark the fifteenth anniversary of Lombard street research*, 2004.
- [28] S. Tuysuz, "Does the Fed's transparency is the main factor influencing the response of U.S. interest rates to macroeconomic and monetary news?," *Middle Eastern Finance and Economics*, 2011.
- [29] A. V. Wetherilt, "Money market operations and volatility of UK money market rates," *Bank of England Working Paper*, vol. 174, p. 420–429, 2002.
- [30] F. Würtz, "A comprehensive Model on the Euro Overnight Rate," *ECB Working Paper*, 2003.

	EURO	United-States	United-Kingdom
Reserve regime	Lagged	contemporaneous regime until 06/08	
Maintenance period	Until 03/04, from the 24th of each month to the 24th of the following month Since 03/04, the maintenance period begins on the settlement day of the first MRO following the Governing Council meeting and ends on the day preceding the corresponding settlement day in the following month.	Lagged regime since 05/08 Since 08/08, two weeks from the 3rd Thursday after the beginning of the computation period	Until 05/07 MRO, Board 1. Leading Rate and two-week repo rate since then up to 13 / 14 repo 14/7 At least twice daily until 06/08 and twice daily since then From 06/08 to 10/08, lending facility rate= official repo rate + 1% After 10/08: Operational lending facility rate= official repo rate + 0.25% From 06/01 to 10/08, standing deposit rate = official repo rate + 1% After 10/08: Operational deposit facility rate=official repo rate +0.25%
Operating target	O/N rate	O/N rate	
Official policy rate	Repo rate: fixed repo rate until 06/09; then variable repo rate auctions until 10/08 and fixed repo rate from then Until 03/04, two weeks and one week since then repo 14 until 06/09 and 7 since then weekly	federal funds rate target (O/N target rate) 1 repo 14 Daily Since 01/03, borrowing facility rate = O/N target + 1% Until 01/03 Discount window rate < official rate	
Maturity (days)			
Main operation			
Maturity (days)			
Frequency of intervention			
Interest rate ceiling	Marginal lending facility rate = repo rate + 1% until 10/08 and + 0.5% between 10/08 and 01/09 From 01/09 to 04/09 = repo rate + 1% and then + 0.75% Marginal deposit facility rate = repo rate + 1% until 10/08 and + 0.5% between 10/08 and 01/09		
Interest rate floor			

O/N: overnight

UK: Prior to 06/08, only limited number of participants had access to a late funding facility and their borrowing capacity was limited by quotas. Hence, the late funding rate did not effectively cap the overnight rate.
UK: The facilities are currently priced at +/- 1% above and below the Bank Rate, except on the final day of the monthly maintenance period when they are priced at +/-0.25%.
In March 2003, the Fed reduced the Discount window operation with the borrowing facility operation.