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Euro Area Monetary Policy in Uncharted Waters

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Euro Area Monetary Policy in Uncharted Waters[1]

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Abstract

We analyze the European Central Bank's (ECB's) response to the global financial crisis. Our 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. We also find some evidence that the ECB's non-standard measures, namely the lengthening of the maturity of monetary policy operations and the provision of funds at the fixed rate, reduced money market term spreads, facilitating the pass-through from policy to market rates. Furthermore, the results imply that the substantial increase in the ECB's balance sheet may have contributed to a reduction in government bond term spreads.

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I. INTRODUCTION

European economies are in the most severe and protracted economic and financial crisis in many decades. The crisis, which originated in the global financial sector, has spread to economic activity and resulted in significant output declines and growing unemployment. To contain the crisis, and to put the economy on a sustained recovery path, policy makers have used a combination of fiscal, financial sector, and monetary policy measures.

This paper focuses on the effectiveness of the policies undertaken by the European Central Bank (ECB) in response to the financial crisis. This topic comprises a range of policy-relevant questions. In particular, how effective have been the conventional and non-standard monetary policy measures implemented by the ECB? Have these measures helped maintain price stability and reduce tensions in the interbank market? Given the significant problems in the financial system, how effective is monetary policy in forestalling strong disinflationary pressure, particularly when policy rates are very low?

We find, first, that the functioning of the traditional transmission channels (interest rate, bank lending, broad credit, and expectations) has been impaired by the crisis. There is some evidence that policy rate transmission has weakened: the cost of credit to both businesses and households declined much less than the policy rates, as credit spreads initially increased and only recently eased somewhat. Examining the efficacy of the transmission channels in detail, we find that even during the crisis, policy rate changes have still been transmitted to market rates, but the efficiency of the transmission has been disrupted. The transmission has slowed down (the lags have become longer), and has become more noisy; the policy reaction needed to stabilize the economy has become stronger.

Our second finding is that the non-standard monetary policy measures implemented so far had some measurable effects on money market spreads and the yield curve. The non-standard measures included a major lengthening of the maturity of the ECB's refinancing operations and resulted in a sizeable increase in the ECB's balance sheet. We find some evidence that the yield curve for euro area government bonds has been somewhat lower and flatter than predicted by standard macro variables since September 2008, indicating that the policy measures may have had some beneficial effects on government bond term spreads.

The structure of the remainder of this paper is as follows. Section II discusses the evolution of the ECB's policy response since the beginning of the crisis. Section III then examines the effectiveness of the monetary transmission, focusing on the impact of the crisis. Section IV analyzes the effectiveness of the non-standard policy measures in countering deflationary risks. Section V concludes.

II. ECB'S POLICY RESPONSE TO THE CRISIS

In the beginning of the financial crisis, characterized by a sudden eruption of stress in interbank money markets in the second half of 2007, the ECB responded promptly with significant adjustments in its liquidity management operations (soon followed by other central banks). It provided liquidity in large amounts, including at term maturities, and since October 2008 eased collateral requirements to prevent them from becoming a constraint for increased funding from the ECB. On average, the overnight rate remained close to the policy rate target, but term spreads surged, reflecting sharp increases in both counterparty default risk and liquidity risk, due to severe funding pressure at longer term maturities (Čihák and Harjes, 2008).

Meanwhile, the ECB emphasized in its communications the distinction between its two core functions:[2] (i) liquidity management with the primary goal to mitigate as much as possible the risk that protracted liquidity shortages turned into bank solvency problems, and (ii) pursuit of price stability by choosing an appropriate monetary policy stance. However, the stress in money markets, characterized by sharp spikes in spreads between unsecured and secured rates for term funds, led to a significant rise in money market yields, including the one-year Euribor rate, which also affected the transmission of monetary policy in a crucial fashion. Nonetheless, the ECB insisted that its liquidity provision would not interfere with monetary policy objectives.[3]

When interbank trading came to a virtual halt in mid-September 2008, the ECB started to engage in a new mode of liquidity provision, calling it "enhanced credit support." This approach focuses primarily on banks, as they are the main source of credit in the euro area economy, and seeks to enhance the flow of credit above and beyond what could be achieved through policy interest rate reductions.

There are five main building blocks to the enhanced credit support:[4] (i) unlimited provision of liquidity through "fixed rate tenders with full allotment"; (ii) extension of the (already long) list of collateral assets, increasing in the process the share of private sector assets to 56 percent of the nominal value of securities on the list;[5] (iii) extension of the maturity of long-term refinancing operations, initially to six months, and then, in late June 2009, to twelve months, aiming to decrease uncertainty in commercial banks' liquidity planning;

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[2] See, for example, the speech by José Manuel González-Páramo on "Financial market failures and public policies: A central banker's perspective on the global financial crisis", January 2009.

[3] As argued in Berger, Harjes, and Stavrev (2008), the ECB's two pillar approach (which includes a monetary pillar which gives high prominence to monetary aggregates in determining the appropriate policy stance) may have made communication more challenging. Bulíř, Čihák, and Šmídková (2008) arrive at a similar conclusion.

[4] For a description of the ECB's enhanced credit support, see in particular the speech by Jean-Claude Trichet, President of the ECB, at the University of Munich on July 13, 2009, and "Governing Council decisions on non-standard measures," *ECB Monthly Bulletin*, June 2009, pp. 9–10.

[5] Meanwhile, the (already large) number of counterparties participating in ECB's refinancing operations increased from 1,700 before the crisis to 2,200, as refinancing through money markets became more difficult. The number of *active* counterparties before the crisis was about 450 (compared to 20 in the United States), and increased to 750 during the crisis; also, the number of counterparties that participated in the one-year longer-term refinancing operation was more than 1,100.

(iv) liquidity provision in foreign currencies, particularly the U.S. dollars, through swap lines with the Federal Reserve; and (v) outright purchases of covered bonds (for an amount of 60 billion euros), aiming to revive that market, which is important for banks' funding.

There is some indication that the ECB's measures helped to improve functioning of the money market. Liquidity premia in term euro money market spreads seem to have declined (Figure 1), primarily as a result of the ECB's proactive liquidity management. Last year's sharp rise in money market term premia reflected both increased counterparty and liquidity risks as banks were confronted with mounting losses and liquidity funding pressure, especially at term maturities. Following unlimited provision of longer-term funds at fixed-rates by the ECB, which began at the end of October 2008, term money market spreads dropped sharply and now correspond closely to measures of counterparty risk, while liquidity premia have virtually been eliminated. Spreads are still at elevated levels but are not likely to fall much further until perceptions of counterparty risk in the banking sector normalize.

Following the intensification of the financial turmoil in September 2008, the ECB effectively intermediated liquidity flows among banks in order to ease funding liquidity tensions in money markets.[6] In January 2009, to encourage the resumption of normal interbank trading activity, the ECB restored the interest rate corridor (the difference between the rates charged on lending to banks and paid on deposits) from ±50 basis points to ±100 basis points around the policy rate. (Also in January 2009, the ECB decided to tighten risk control measures for newly issued asset-backed securities and uncovered bank bonds to reduce credit risk and encourage resumption of activity in these markets.) So far during 2009, bank deposits at the ECB have declined sharply, and overnight interbank market volumes have stabilized at around 40–60 billion euros, indicating some revival of private interbank activity.

III. Has the Transmission Been Impaired?

The reduction of the policy rates has been transmitted to market rates, although the pass-through was less than full, and varied across market segments and maturities. For example, from September 2008 to February 2009, bank lending rates on new loans declined by: (i) 20–60 bps for consumer loans; (ii) 50–180 bps for house purchase loans; and, (iii) 70–250 bps for loans to non-financial corporations (Figure 2). At the same time, short-term money market rates dropped by around 300 bps, and spreads also declined but remained elevated (Figure 1).

Looking just at the interest rate changes, however, provides only a partial view of the effectiveness of the transmission mechanism. It does not address the efficacy of the interest rate channel compared to previous cycles, and, more importantly, analyzing only the transmission of policy rates to market rates is insufficient for assessing the effectiveness of

[6] The size of the ECB's balance sheet has multiplied by a factor of 1.5 between mid-2007 and early 2009. The corresponding ratios for the Bank of England's and for the U.S. Federal Reserve have been 3.0 and 2.5.

monetary policy in achieving its ultimate goal of price stability. In that regard, the effective functioning of all transmission channels, namely, the interest rate, the bank lending, and the broad credit channels, is key. Also, the ability of the central bank to maintain inflation expectations in line with the definition of price stability is crucial for the effective working of the transmission mechanism.

A comprehensive analysis is needed to determine various aspects of the effectiveness of monetary transmission. Such an analysis is of particular interest in the context of the current crisis, given the strong disinflationary pressure facing the euro area and the already low level of policy rates. A combination of several bi-variate vector autoregression (VAR) models, comprising the policy rate and a set of market interest rates, and a theory-based general equilibrium framework allows for this. The bi-variate VARs are used to assess the pass-through of policy rates to several market rates, while the theory-based model is used to examine the functioning of all channels jointly in a general equilibrium framework.

A. Transmission Channels

The functioning of each channel can be summarized as follows.[7] In the *interest rate channel*, monetary policy affects short nominal interest rates, which through expectations and sticky prices feed through to long nominal and real interest rates, and thus the user cost of capital. As a result, investment, and aggregate output adjust. In addition, interest rates influence economic activity by affecting the relative prices of present and future consumption. In the *bank lending channel*, bank credit to borrowers where asymmetric information can be especially pronounced, such as small and medium size enterprises, plays an important role. A key feature of this channel is that the central bank can affect the supply of credit provided by financial intermediaries, and thus the cost of capital to bank-dependent borrowers, not only by changing interest rates but also by changing the quantity of base money. The *broad credit channel* works through the net worth of firms. In the presence of financial frictions (imperfect information and costly enforcement of contracts), monetary policy affects not only interest rates, but also the financial position of borrowers and the relative cost of external and internal funds (external finance premium).

In addition to the above channels, expectations play an important role in achieving the goal of price stability. Expectations influence significantly the effectiveness of all other channels of monetary policy transmission to the extent that central bank policy is anticipated by the market and priced into the yield curve. In that regard, anchoring inflation expectations is a key feature. Several factors can enhance to role of the expectations channel. In particular, the degree of central bank credibility, predictability of central bank actions, and commitment by the central bank to vary its instrument consistently.

[7] Mishkin (1995) and Bean, Larsen, and Nikolov (2002) discuss the transmission channels in detail.

Various aspects of monetary transmission in the euro area have been analyzed in the empirical literature. Most studies have examined the effectiveness and the relative importance of transmission channels over the cycle, with some papers looking also at the asymmetric functioning of the channels during upturns and downturns. However, the effectiveness of monetary transmission during significant crisis, and in particular during the current financial crises, has been much less investigated.

In a survey of studies by the Monetary Transmission Network, Angeloni and others (2002) conclude that, while the interest rate channel is the most important for monetary policy transmission in the euro area, the other channels also play a role. The survey shows that an unexpected monetary policy tightening temporarily reduces output, with the maximum impact occurring after a year. The response of prices is much slower, with inflation barely affected in the first year and only gradually declining over the medium term. The interest rate channel, while not responsible for all of the monetary transmission, is by far the most important channel for one sixth of the euro area countries. For the rest of the member states, the interest rate effects are sizable, and in some cases interest rates are almost the sole determinant of investment fluctuations.

The interest rate channel is complemented by financial factors in several ways. In some countries, banks are an important source of business credit supply to finance investment. However, not for all countries for which loan supply matters is it important for investment, as household lending matters as well. On the characteristics that matter for the role of banks in the transmission mechanism, Angeloni and others (2002) find that bank liquidity positions seem to be important in virtually all EMU members, while bank capital and bank size seem to matter much less. In addition, the relative importance of the bank lending channel differs among euro area countries—it is significant in Germany and Italy, but there are also countries where it is insignificant.

Given the short time horizon since the beginning of the current crisis, its impact on monetary transmission in the euro area has been much less studied. IMF (2008), using a vector error correction framework comprising policy and market rates, analyzes the impact of the crisis on the interest rate transmission in the United States and the euro area. The results of the study indicate that the pass-through of policy rates onto market rates in the United States and the euro area has been disrupted, but to a different degree in the two regions and over the maturity spectrum. The disruption has been particularly evident for the long-term rates in both the United States and the euro area, while the transmission to the short rates has been less affected in the euro area.

B. Methodology

The VAR approach is used to study the first stage of the interest rate channel, namely the pass-through of policy rate changes to various market interest rates. The pass-through of policy rates to market rates is assessed by comparing the impulse responses of the models estimated over the period prior to the crisis with the impulse responses of the same models estimated including the post crisis period (through April 2009). In addition, the variation and the bias of the residuals from the VARs are used as a signal for potential malfunctioning of the pass-through since the crisis.

The theory-based framework is used to analyze in a general equilibrium setup the functioning of all channels as well as the role of expectations. The functioning and the relative importance of each channel as well as the role of expectations are assessed by looking at the impulse responses and the variance decomposition. The functioning of the transmission mechanism prior and post-crisis is evaluated by comparing the estimated coefficients over the two sub-samples as well as impulse response to standard shocks (demand, supply, and monetary policy). The theory-based framework is particularly suited for such a comparison, because the model is estimated using Bayesian techniques, which allow for a more robust estimation of the coefficients in small samples. As in the VAR approach, the residuals from the entire sample are used to gauge the degree to which the functioning of the channels was affected by the crisis.

Bi-variate VAR Regressions

The pass-through of the policy rate is estimated with bi-variate VAR regressions using monthly data as follows:

$$\begin{aligned} pr_t &= \alpha_1 + \sum_{j=1}^{3} \beta_j pr_{t-j} + \sum_{j=1}^{3} \gamma_j mr_{t-j} + \varepsilon_t \\ mr_t &= \alpha_2 + \sum_{j=1}^{3} \delta_j mr_{t-j} + \sum_{j=1}^{3} \varphi_j pr_{t-j} + \xi_t \end{aligned} \tag{1}$$

where pr_t is the ECB policy rate approximated by the overnight EONIA rate, and mr_t is one of the following market interest rates: (i) one-, three-, six-month, and one year Euribor rates; (ii) corporate bond yields of 3- to 5-year maturity rated A, AA, AAA, and BBB; (iii) new loans to non-financial corporations (up to 1 year and up to 1 million; up to 1 year and over 1 million; and over 1 year); (iv) new loans to households (housing loans 1 to 5 years and over 10 years, and other loans); (v) consumer credit (1 to 5 years and over 5 years).

The sample period is January 1999–April 2009 for interbank rates and corporate bond yields, and January 2003–April 2009 for loans to non-financial corporations and households. The lag length of the VAR models is set at 3 months, based on Akaike and Schwarz information criteria. The bi-variate VARs are estimated both in levels and first differences of the variables using ordinary least squares estimator (OLS).[8]

[8] The models with the levels of the variables are also estimated using Bayesian VAR (BVAR), following Sims and Zha (1998). The BVAR results are qualitatively similar to the OLS estimates, and available upon request.

Theory-based (General Equilibrium) Framework

For a fuller assessment of the transmission channels, a theory-based general equilibrium framework is used. In the core of the framework is a New Keynesian type model that is modified in several ways. The three main equations describe the evolution of inflation, π_t, the output gap, y_t, and the monetary policy response, captured by the policy rates, i_t (for the full model specification, see Appendix I).

Specifically, inflation is determined by:

$$\pi_t = \lambda_1 \pi 12^e_{t+12} + (1-\lambda_1)\pi 12_{t-1} + \lambda_2 (y_{t-1} + y_{t-2} + y_{t-3})/3 + \varepsilon^\pi_t \tag{2}$$

where π_t is monthly inflation (seasonally adjusted at annual rate), $\pi 12^e_{t+12}$ is expected year-on-year inflation, $\pi 12_t$ is year-on-year inflation, y_t is a measure of the output gap, and ε^π_t is a supply shock.[9] This specification implies that prices are set as a markup over marginal cost, captured by the output gap, and the degree of price flexibility and inflation inertia are captured by the weight on the expected inflation term.

Aggregate demand evolves according to:

$$y_t = \beta_1 (y_{t-1} + y_{t-2} + y_{t-3})/3 + \beta_2 y^e_{t+1} - \beta_3 (r_{t-1} - r\_eq_{t-1}) + \varepsilon^y_t \tag{3}$$

where y^e_{t+1} is the expected output gap next period, r_t is the actual short-term real interest rate, defined as the difference between the short-term nominal interest rate and expected inflation, r_eq_t is the equilibrium real interest rate, and ε^y_t is a demand shock.[10] In this aggregate demand specification, the lagged moving average output gap term reflects the degree of inertia in the economy, the forward looking output gap term captures intertemporal smoothing by economic agents, and the third term, the deviation of actual from equilibrium real interest rates, represents the interest rate channel.

[9] For the empirical analysis, which is done with monthly data, $\pi_t = 1200(p\_sa_t - p\_sa_{t-1})$, where p_sa_t is the logarithm of the seasonally adjusted harmonized index of consumer prices (HICP), and $\pi 12_t = 100(p_t - p_{t-12})$, where p_t is a logarithm of the HICP index. Economic activity is approximated by a weighted average of industrial production (30 percent share) and retail sales indexes. As initial values for the output gap y_t for the Bayesian estimation, the log-difference of the actual index from its Hodrick-Prescott filtered value is used.

[10] Given that the model is estimated with monthly data, the leads and lags in equations (2) and (3) are chosen so as to obtain dynamic responses that are in line with the dynamic response from models estimated with quarterly data and also reflect plausible lengths of price setting contracts as well as the lags with which capacity utilization affects inflation in reality.

The monetary policy reaction function is:

$$i_t = \gamma_1 i_{t-1} + (1-\gamma_1)(r\_eq_t + \pi 12^e_{t+12} + \gamma_2(\pi 12^e_{t+12} - \overline{\pi}_t) + \gamma_3 y_t) + \varepsilon^i_t \tag{4}$$

where i_t is nominal policy interest rate, $\overline{\pi}_t$ is the inflation target, and ε^i_t is a monetary policy shock. The first term in this rule captures the degree of interest rate smoothing by the central bank. The second term is the natural interest rate, and the third and fourth terms represent the usual components for a forward looking Taylor rule where the central bank reacts to the deviation of expected inflation from inflation target and the output gap.

The model is extended in several ways. First, to capture market perceptions about underlying inflation, the inflation target is allowed to be time varying as in:

$$\overline{\pi}_t = \rho \pi^{ss} + (1-\rho)\pi 12_{t-1} + \varepsilon^{\overline{\pi}}_t \tag{5}$$

where π^{ss} is the steady-state inflation, and $\varepsilon^{\overline{\pi}}_t$ is a shock to underlying inflation. Allowing for a time-varying inflation target also provides insights about central bank credibility (see for example Hördahl, Tristani, and Vestin, 2006).

Second, to test for the importance of the bank lending channel, a simple loan demand and supply block is added to the core equations (2)–(5) of the model.

In particular, loan demand is modeled as follows:

$$l_t = -\lambda_i i^l_{t-1} + \lambda_y g_{t-1} + \varepsilon^{ld}_t \tag{6}$$

where l_t is the growth of loans provided by the banking system, i^l_t is the interest rate on loans, g_t is the growth of output, and ε^{ld}_t is a loan demand shock.

Loan supply is represented by an inverse loan supply function (determining interest rates on bank loans) as follows:

$$i^l_t = \tau_1 l_{t-1} + \lambda_m \mu_{t-1} + \varepsilon^{ls}_t \tag{7}$$

where μ_t is money growth, and ε^{ls}_t is a loan supply shock. To close the loan demand and supply block, a standard money demand function is used in which money growth μ_t is determined by output growth and policy interest rates.

Finally, to capture the effect of bank lending on aggregate demand, real loan rates are added to the aggregate demand equation (3) in addition to the real short-term interest rates.[11] All of the above changes comprise a version of the model which is used to analyze the functioning of the bank-lending channel.

In a second version of the model, to examine the importance of the broader credit channel, an equation that describes the corporate bond yield spread (the difference of corporate and government bond yields) is added to the loan demand and supply block. The spread term is added to the aggregate demand equation (3). As Fridman and Kuttner (1992) show, the spread between the corporate bond yield and the government bond yield captures the external finance premium, which is in general positive due to risk and liquidity premia. To close the model, the corporate bond spread, or the external finance premium is endogenized by modeling it to depend on overall economic conditions captured by the output gap and policy rate as follows:

$$sp_t = \sigma_1 i_{t-1} + \sigma_2 y_{t-1} + \varepsilon_t^{sp} \tag{8}$$

where ε_t^{sp} is a shock to corporate spread.

The above models are estimated with monthly seasonally adjusted data, using Bayesian methods over January 1995–February 2009 for the version with the bank-lending channel and January 1999–February 2009 for the version with the broader credit channel. Economic activity is approximated by a weighted average of industrial production (30 percent share) and retail sales. In addition, the following variables are used: short-term rates (approximated by the EONIA interest rate), an average of interest rates on new loans to euro area residents of 1- to 5-year maturity, AAA-, AA-, A-, BBB-rated corporate bond yields of 3- to 5-year maturity, the spread of corporate bond yield and government bond yield, HICP inflation, money supply (approximated by M3 aggregate), and bank loans to the euro area residents.

C. Results

Bi-variate VAR Regressions

The results form the VAR analysis (based on the full sample) show that policy rate changes have been transmitted to market rates, although the degree and the speed of pass-through vary (Figure 3). The impact on the 3-month Euribor rate is close to one-for-one and the speed of adjustment is fast, with the maximum impact transmitted within a month. The initial impact on corporate bond yields and new loans to non-financial corporations is similarly

[11] Instead of loan rates, quantity of loans could be used in the aggregate demand equation. These two approaches should be equivalent in principle. However, in times of severe banking sector stress, rationing of borrowers may occur, which is not fully reflected in loan interest rates. Testing whether using loans instead of loan rates in the aggregate demand equation changes the results, is left for future research.

quick, although the full adjustment is more protracted and the impact on higher-grade bond yields is smaller than on lower-grade bond yields (0.6 to 0.7 percentage point for AA- and AAA-rated bonds versus 1.2 for BBB-rated bonds). The pass-through of the policy rates on loans to households for house purchases and the speed of adjustment are somewhat lower (notice that other consumer loans adjust faster).[12]

The results also suggest that the pass-through to all market rates has slowed down during the crisis. In particular, impulse responses from the first difference bi-variate VARs imply that the time for the full adjustment of market rates has increased to over 12 months, from 3–6 months before the crisis (the results from the bi-variate VARs in levels estimated both with OLS Bayesian methods show a similar picture). The transmission to lower grade corporate bonds seems to have been particularly negatively affected, following the crisis—the initial response of the BBB-rated corporate bond yields has switched from positive before the crisis to negative thereafter (Figure 4).

In addition, the pass-through from the policy rates to market rates has become less reliable since the beginning of the financial crisis. Specifically, the variance of the residuals of the equations for the market rates has increased since the beginning of 2008 (Figure 5), in most cases significantly. This is in line with the preliminary findings in IMF (2008) that the pass-through to market rates during the crisis has become less efficient, reflecting most likely the dislocation of the markets for short-term bank financing.[13]

More importantly, as bank lending standards have tightened following the crisis, quantity effects may be at play that could further impair monetary policy effectiveness. Indeed, the role of the interest rate pass-through for monetary policy effectiveness needs to be viewed in the context of tightening lending standards. While interest rate pass-through provides an important signal for monetary policy effectiveness, in times of significant stress in credit markets quantities are also important. Indeed, the April 2009 ECB bank lending survey suggests continuing tightening of lending standards, albeit at a slower pace. In this situation, banks may have significantly reduced lending by cutting loan originations rather than raising interest rates. Also, the shift of loans from special investment vehicles back to banks' balance sheets, the so called re-intermediation, as well as continuing funding pressures for the banks may put additional pressure on banks' capital needs, thus slowing further new credit creation.

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[12] These results are consistent with the finding by IMF (2008) that the 3-month Euribor rates have more stable and reliable relation with the policy rate than other lender rates, and by Sørensen and Werner (2007) that bank rates on corporate loans appear to adjust most efficiently, followed by mortgage loan rates. Also, our findings are consistent with the conclusion by the ECB (2009) "even during the current financial crisis, the bank interest rate pass-through has worked relatively well in terms of responding to developments in the EURIBOR and longer-term market rates, although less well in terms of responding to developments in the EONIA."

[13] Altunbas, Gambacorta, and Marqués (2007) suggest that the pass-through to market rates has become less efficient already before the crisis, due to increased securitization.

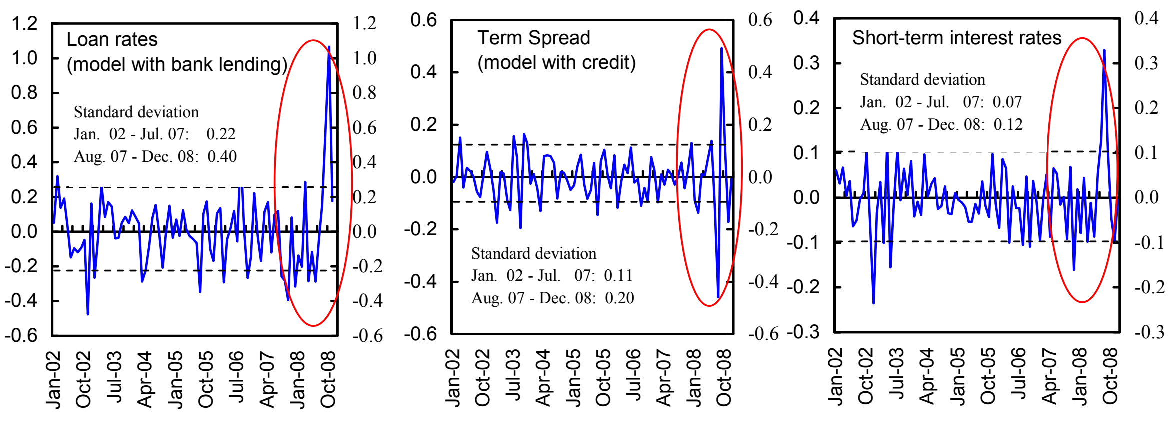
Theory-based (General Equilibrium) Framework

A comparison of impulse responses from the theory-based model estimated before and after the beginning of the crisis, indicates that after the beginning of the crisis the overall transmission has slowed (Figure 6).[14] For both supply and demand shocks, the policy reaction needed to stabilize the economy is somewhat stronger, with the time needed for the policy feedback to pass-through increasing to about 2½ years, from about 1½ year before the crisis (Figure 6, left column). Similarly, the time for a full transmission of monetary policy shocks to inflation has increased from about 2 years before the crisis to about 3 years during the crisis (Figure 6, right column). Compared with the findings from the VAR, these results suggest that not only the first stage of the transmission (i.e., the pass-through to market rates), but also the overall working of the transmission mechanism seems to have slowed down during the crisis.

At the same time, a comparison of coefficients estimated over the two samples, shows that the changes in the main structural parameters of the economy are not dramatic. The largest change took place in the coefficient capturing the reaction of policy makers to the deviation of inflation from the inflation target. This coefficient has increased from around 1.2 before the crisis to 1.4 during the crisis. The response of policy makers to fluctuations in the output gap basically remained unchanged between the two sub-samples at around 0.5.

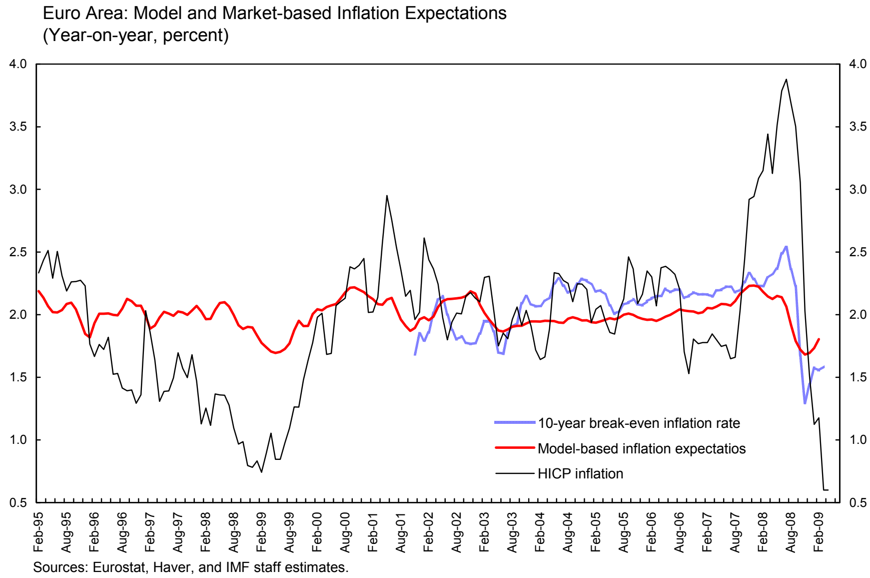
The model residuals also confirm that shocks increased since mid-2008. Indeed, the variability of the residuals from the models jumped up after mid-2008. The increased volatility of the residuals (shocks) suggests that the during the financial crisis, the transmission of monetary policy has not only become subject to longer lags (i.e., slower), it has also become less predictable (i.e. subject to more noise).

Euro Area: Residuals from the structural models
(Percentage points)



Source: IMF staff estimates.

[14] The pre-crisis sample is prior to August 2007 and the crisis sample is from September 2007 to February 2009. The choice of August 2007 as a split point of the sample is supported by Chow break-point test.



Another sign of the decreased efficiency of transmission is that inflation expectations, while remaining broadly stable over the estimation period, declined significantly in the last quarter of 2008, reflecting the significant deterioration in economic activity. As shown in the text chart, inflation expectations derived from the model declined significantly in the fourth quarter of 2008, but as policies eased significantly to counter the strong disinflationary pressures, inflation expectations recovered since the beginning of 2009. This development of the model-derived inflation expectations agrees with market-based measures of inflation expectations.[15]

Going beyond the impact of the crisis on the transmission, the model results suggest that the interest rate channel is the dominant transmission channel. In particular, it accounts for over 30 percent of inflation variation and close to 50 percent of output variation. Importantly, the results imply a major role of expectations, which account for around 40 percent of inflation variation and about 30 percent of output variation. The results also suggest some role for the bank-lending and credit channels, which explain about 15 percent and 10 percent of output variation, correspondingly. These findings are broadly in line with previous literature. For example, Angeloni and others (2002) conclude that the interest rate channel is the most important for monetary policy transmission in the euro area and that the bank lending channel also plays a role, with different relative importance in different euro area countries.

IV. Monetary Policy and The Return of The Liquidity Trap

The recent non-standard ECB measures have been primarily implemented to ease systemic liquidity risk in the banking sector and support the transmission of lower policy rates to money market rates, but they may have also helped in countering deflationary risks. To study this impact, we use a macro-financial model developed by Bernanke, Reinhart, and Sack

[15] The market-based measures of inflation expectations need to be interpreted with caution, given the problems in the markets during the crisis. Nonetheless, the measures still contained useful information, as illustrated by their high correlation (a correlation coefficient of 75 percent) with the model-derived inflation expectations.

(2004) to analyze the effect of the non-standard measures on the term spreads of euro area government benchmark bonds.

A. Overview

Overnight interest rates have come to record lows in many advanced economies, including in the euro area. Such situations in which conventional monetary policies become constrained or ineffective, despite the need for further monetary easing, were described as liquidity traps by Keynes (1936). The experience of Japan in the 1990s and 2000s and the possibility of deflation in the United States in the mid–2000s reignited interest in this topic. The current economic and financial crisis and the emergence of significant deflationary risks in many economies across the globe has again brought this issue to the fore of many debates.

Krugman (1998), analyzing the Japanese experience, emphasized the importance of inflation expectations in a liquidity trap where nominal interest rates cannot be lowered any further and additional injections of base money may have no effect if the private sector views base money and short-term (government) bonds as perfect substitutes. If the private sector expects deflation, a central bank could lower real interest rates by convincing markets that it would generate future inflation. However, Krugman's analysis is based on a two-period model. In a multi-period model, a central bank would face some difficulties to re-anchor inflation expectations after having successfully promised to be temporarily "irresponsible".

Eggertsson and Woodford (2003) present a dynamic analysis of monetary policy in a liquidity trap, emphasizing the role of expectations regarding future policy in determining the severity of the distortions that result from hitting the lower bound. They show that the creation of inflation expectations can be reconciled with maintaining the credibility of the central bank's commitment to long-run price stability through a history-dependent policy, such as price level targeting. However, price level targeting faces other challenges and such a regime change would likely require some time to implement.

There is a number of practical measures with which central banks may be able to further ease the monetary policy stance once policy rates have reached levels closer to zero : (i) shaping the expectations of the public about future settings of the policy rate; (ii) increasing the money supply beyond the level needed to set the policy rate at zero; and (iii) providing liquidity to specific credit markets that are considered dysfunctional (Bernanke, Reinhart, and Sack, 2004).

Shaping the Public's Expectations About Future Policy Rate Settings

If a central bank can convince the markets that its policy rate will remain low for longer than markets previously expected, it may add further stimulus to the economy. Usually, central banks do not provide unconditional commitments for their policy rates, especially over the medium term.[16] In normal times, it is most common for inflation targeting central banks to conditionally commit that the central bank will set the policy rate to levels such as to maintain expected inflation close to its target. Some central banks, including the U.S. Federal Reserve and the Bank of Canada, have recently emphasized that they expect to keep rates low as long as deflationary risks persist, or inflation remains significantly below the target.[17] A much stronger signal to keep rates low as long as needed is the provision of term funds at the policy rate. The ECB's policy in this regard has initially been targeted at reducing liquidity premia in term money markets. Nonetheless, the extension of maturity and the explicit commitment to continue the refinancing operations for a clearly defined period had also a powerful impact on policy rate expectations.

Quantitative Easing

An increase in the money supply could also have a stimulating effect on the economy and raise inflation expectations. An increase in the monetary base can be brought about by open market operations, such as central bank purchases of assets, or by other (more "passive") measures, such as easing the collateral requirements for central bank lending. Additional money supply may directly lower nominal bond yields by raising demand for bonds and triggering a portfolio rebalancing. While the transmission to higher inflation expectations through the portfolio-rebalancing channel would also seem to require a subsequent increase in other broader monetary aggregates, markets may also interpret such operations as a signal that policy rates may remain low longer than anticipated and that at least some of the increase in money supply is going to be permanent. Such operations, if effective, should flatten the yield curve over the near- to medium-term.

Credit Easing

A key characteristic of the current financial crisis has been the breakdown of several specific credit markets, such as markets for asset-backed commercial paper, including for residential, commercial mortgage and credit card debt backed securities, that had increasingly become an important funding/credit source, especially in the United States but also in the euro area. Transaction costs, incomplete or asymmetric information and other financial market frictions could drive a wedge between their prices and other financial assets. A sharp increase in credit risk for these securities, but also severe risk aversion together with a lack of transparency for these products and their pricing, virtually stopped secondary market activity. Given the importance of these markets in the United States, the Fed decided to intervene directly in these markets to restart private activity and bring down any possible liquidity premia. The

[16] In the years before the crisis, the ECB developed a system of code words that effectively pre-announced the next adjustments in policy rates. However, these pre-announcements have occurred only several weeks before the policy decisions, and were arguably only a weak form of commitment (e.g., Heineman and Ullrich, 2005).

[17] On April 30, 2009, the Fed's Federal Open Market Committee stated that "The Committee will maintain the target range for the federal funds rate at 0 to ¼ percent and anticipates that economic conditions are likely to warrant exceptionally low levels of the federal funds rate for an extended period."

ECB initially supported these markets indirectly by broadening its collateral requirements, and more recently through direct interventions in the covered bond market (as part of the "enhanced credit support"). Such measures are targeted directly at restoring the transmission of low policy rates, as pointed out above. Moreover, if successful, they should stimulate activity and lower the risk of deflation. However, they also shift credit risk to the central bank and may prove more difficult to reverse than other measures once market conditions normalize.

B. Empirical Assessment

This section studies the effects of the recent non-standard ECB measures as a means of countering deflationary risks. Although these "enhanced credit support" measures have been primarily implemented to support the flow of credit in the economy, they may have also affected term spreads and the yield curve of euro area government benchmark bonds through the channels discussed above. To investigate if such effects occurred, we use a macro-financial model as applied by Bernanke, Reinhart, and Sack (2004) to study these effects.

The Model

Most term structure studies have used latent factor models to explain movements in the term structure, and usually these factors are not given any macroeconomic interpretation. Instead, many standard finance models (such as Dai and Singleton, 2000) relate the yield curve only to current and past interest rates. Following Ang and Piazzesi (2003), the Bernanke, Reinhart, and Sack (2004) model incorporates macro variables as factors which determine the pricing kernel that prices all bonds in the economy. This approach recognizes that interest rates and other macroeconomic variables evolve jointly over time and affect each other. Contrary to the Ang and Piazzesi (2003) approach, all shocks affecting the pricing kernel are driven by observable macro factors in the Bernanke, Reinhart, and Sack (2004) model. This model is therefore best described as a vector autoregression (VAR)-based model that additionally imposes a no-arbitrage condition which is commonly applied in affine term structure finance models. Alternatively, other studies use small-scale rational expectations models usually based on a New Keynesian Phillips curve to describe the economy, instead of a VAR (Rudebusch and Wu, 2003; Hördahl, Tristani, and Vestin, 2006).

The model used here follows closely Rudebusch, Swanson, and Wu (2006). It comprises four macroeconomic variables as state variables, which are the factors for pricing bonds: (i) a measure of output gap obtained by detrending with a Hodrick-Prescott filter an index of economic activity that is the weighted average of seasonally adjusted industrial production (30 percent weight) and retail sales (70 percent weight); (ii) year-on-year HICP inflation; (iii) the monthly average of overnight interest rate (EONIA); and (iv) the one-year Euribor interest rate as a proxy for market expectations of short-term rates and inflation that may not be fully captured by the other variables, given that separate data for interest rate futures and inflation expectations in the euro area are only available very recently. Data are monthly observations from January 1999 to January 2009.

The state variables (monthly data) follow a VAR model with three lags, which can be stacked into a 12-element vector X_t and described by a VAR(1) model:

$$X_t = \mu + AX_{t-1} + \Sigma\varepsilon_t \tag{9}$$

where X_t is a vector of state variables, Σ is a matrix of Choleski decomposition of the VAR innovations.

The pricing kernel, or stochastic discount factor, with which bonds are priced in the model is conditionally log-normal distributed with functional form:

$$m_{t+1} = \exp(-i_t - \frac{1}{2}\lambda_t^{'}\lambda_t - \lambda_t^{'}\varepsilon_{t+1}) \tag{10}$$

where i_t is the one-period nominal interest rate and λ_t is a vector of market prices of risk associated with the innovations ε_{t+1} from the VAR.

The prices of market risk are assumed to be linear in the state variables:

$$\lambda_t = \lambda_0 + \lambda_1 X_t \tag{11}$$

The prices of risk are assumed to depend only on the contemporaneous state of the economy, which given the specification of the state vector X_t means that only the first four elements in the twelve-by-one vector λ_0 and the upper-left four-by-four part of the twelve-by-twelve matrix λ_t are non zero.

Bonds in the model are priced according to the standard relationship with the stochastic pricing kernel:

$$P_t^n = E_t m_{t+1} P_{t+1}^{n-1} \tag{12}$$

where P_t^n denotes the price of an n-period zero-coupon bond at time *t*. The existence of a strictly positive discount factor m_t implies that there are no arbitrage opportunities in bond markets (see, Cochrane 2001). Let y_t^n denote the corresponding continuously compounded yield on the same zero-coupon bond. We use annualized monthly average yields for synthetic euro area government bonds with 2, 3, 5, 7, 10, 15, 20, and 30 year maturities bond yields. As shown in Ang and Piazzesi (2003), using the above macro-finance model, the yield of a zero-coupon bond at maturity *1* to *n* can be expressed as a linear function of the state variables:

$$y_t^n = \frac{1}{n}(a_n + b_n^{'} X_t), \tag{13}$$

where $a_0 = 0$, $b_0^{'} = 0$ and the scalar a_n and the four-by-one vector $b_n^{'}$ are computed recursively as follows:

$$\begin{aligned} a_{n+1} &= \delta_0 + a_n + b_n^{'}(\mu - \Sigma\lambda_0) - b_n^{'}\Sigma\Sigma^{'}b_n, \\ b_{n+1} &= \delta_1 + (A - \Sigma\lambda_1)^{'} b_n, \end{aligned} \tag{14}$$

where the scalar δ_0 (a scalar) and δ_1 (a four-by-one vector) describe the one-period interest rate as a function of the state of the economy

$$y_t^1 = i_t = \delta_0 + \delta_1^{'} X_t. \tag{15}$$

Since the one-period interest rate is included in the state vector, δ_0=0 and all elements of $\delta_1^{'}$ are zero, except for that element that picks out the current value of the one-period interest rates in the state vector, approximated by the monthly average of the EONIA. The element corresponding to the policy rate (approximated by EONIA) is equal to one while the rest are zeros.

Results

The model is estimated in two stages (Rudebusch, Swanson, and Wu, 2006). First, the VAR model is estimated. Second, the coefficients from the VAR model are taken as given, and the stochastic pricing kernel factor loadings are estimated using nonlinear least squares to fit the bond yield data over the period 1999M1–2009M1.

The main estimation results are presented in Tables 1 and 2 and in Figure 7. The VAR coefficient estimates for the euro area have features similar to those reported by Rudebusch, Swanson, and Wu (2006) for the United States. The sum of each variables' own lags is near unity, as is the coefficient of each variable's first lag.

Table 1. VAR Parameter Estimates

Coefficient estimates	y_t	π_t	rs_t	rl_t
y_{t-1}	0.617	0.087	0.040	0.089
π_{t-1}	0.125	1.144	0.073	0.056
rs_{t-1}	0.247	0.086	1.141	0.230
rl_{t-1}	0.269	-0.081	0.085	0.427
y_{t-2}	0.102	-0.013	-0.011	0.032
π_{t-2}	0.232	-0.371	0.005	-0.036
rs_{t-2}	0.100	-0.111	-0.199	-0.003
rl_{t-2}	-0.048	0.244	-0.016	0.253
y_{t-3}	0.276	0.001	0.006	-0.041
π_{t-3}	-0.679	0.125	-0.131	-0.016
rl_{t-3}	-0.317	-0.078	-0.004	0.014
rl_{t-3}	-0.305	-0.090	-0.070	0.026
constant	0.802	0.339	0.326	0.086
Cholesky-factored residual variance				
	0.477	0.000	0.000	0.000
	-0.006	0.202	0.000	0.000
	0.020	0.048	0.208	0.000
	0.007	0.043	0.024	0.166

Source: IMF staff estimates.

The estimated risk factor loadings are similar in size. Bernanke, Reinhart, and Sack (2004) found inflation expectations one-year ahead of particular importance. Given that such time series data (as well as data for interest rate futures for the euro area) have become available only very recently, one-year Euribor rates are used instead. Risk factor loadings and variance of this variable are comparable to those for other variables (Table 1).

Table 2. Risk Factor Loadings

λ_0	$\lambda 1$			
5.8064	0.10665	0.18516	-0.75491	-0.17347
-3.4934	-0.05948	-0.11369	0.41976	0.14019
1.0628	0.019663	0.030768	-0.1237	-0.04697
-0.88776	-0.01009	-0.01366	0.070758	0.066151

The predicted yields from the model track actual bond yields very closely (Figure 7, first panel). The estimates of the long-run “risk-free” yields during 1999M1–2009M1 are slightly above 3 percent for long-term yields. Short-term (two-year) model residuals (Figure 7, second panel) do not have an obvious trend, but model residuals for long-term government bonds have been more or less consistently negative since 2004–05. This reflects the fact that, as in the United States (where former Federal Reserve chairman Greenspan famously called it a "conundrum"), long-term rates did not rise much when the ECB raised its policy rates. The residuals have fluctuated since the onset of the crisis, but sharply turned negative in October 2008, when the ECB introduced a host of new non-standard measures. In the subsequent period, the actual yield curve has become lower and flatter than the predicted yield curve, as illustrated by the latest observation in Figure 7, bottom panel.

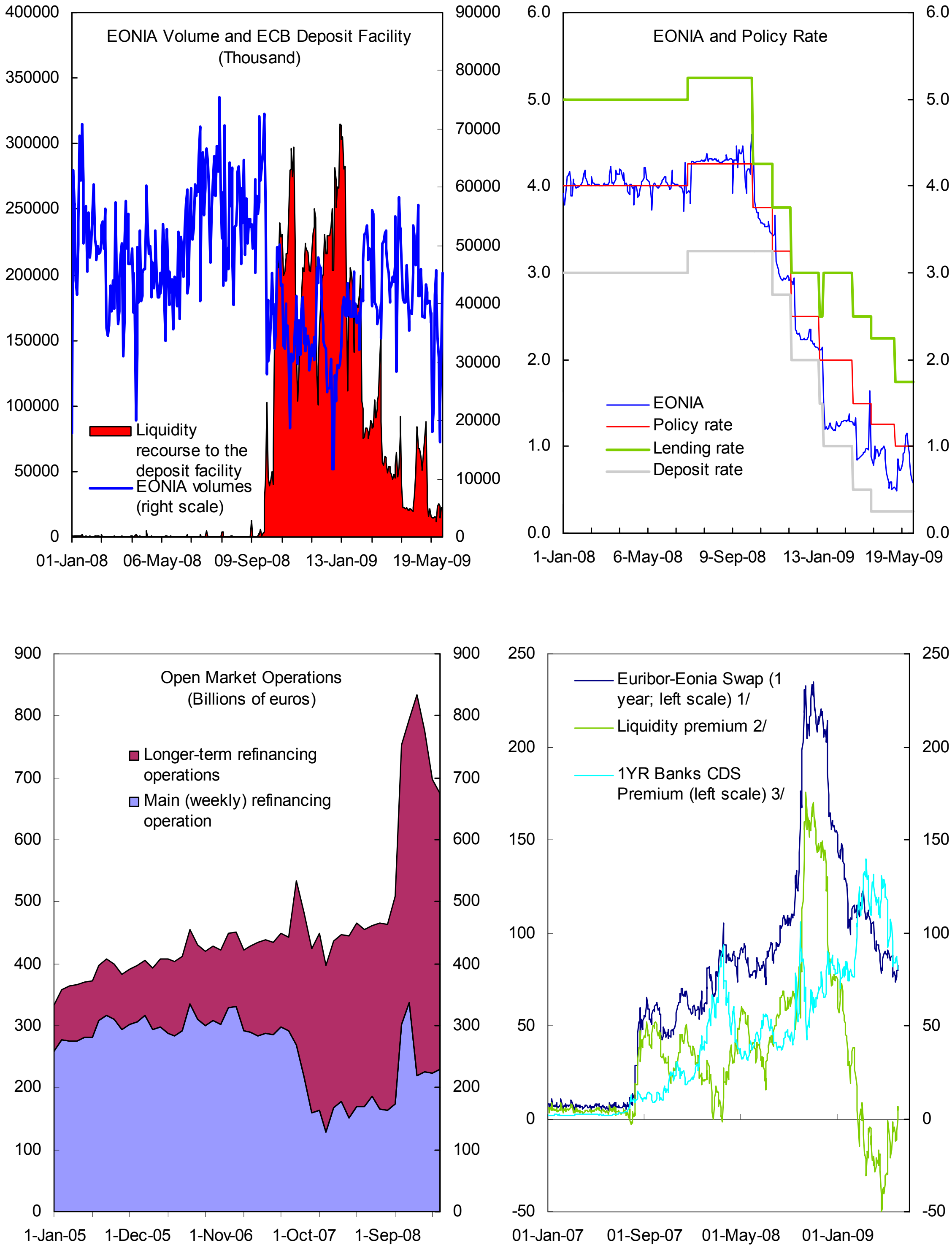
These results provide some indication that the ECB's policy actions during the crisis had some effect on yields, although the results should be treated only as preliminary and illustrative. The lower level of the yield curve is likely to reflect the increase in the monetary base and the relative supply of money relative to bonds, as suggested by the portfolio rebalancing channel. Moreover, the flattening of the yield curve could imply that markets interpreted the ECB's policy actions as implicit commitments to keep policy rates low longer than anticipated and the current state of the economy (as captured by the simple VAR) would suggest. This finding should be interpreted cautiously, given that the time period under investigation is short, and given that we analyze the impact of the ECB's measures only indirectly (also, the flattening has been most pronounced at the long end, while market expectations of an increase period of low policy rates should have a greater effect at the short end of the yield curve; and there are other possible explanations for the observed behavior in the model's residuals, including capital flows associated with "flight to safety"). Despite these caveats, the fact that the level of the yield curve has been lower and the slope flatter over the past months than predicted by the macroeconomic variables can give some comfort to those concerned about deflation.

V. Conclusions

The analysis of the effectiveness of monetary policy in the context of the financial crisis suggests that the traditional transmission channels (interest rate, bank lending, and broad credit) have continued to operate, but at a lower efficiency. During the crisis, the transmission has slowed down (the lags have become longer), the policy reaction needed to stabilize the economy has become stronger, and the transmission has become subject to more noise (illustrated by the increased residuals in the estimates during the crisis). Also, inflation expectations, while remaining broadly stable, declined significantly in the last quarter of 2008, reflecting the major deterioration in economic activity.

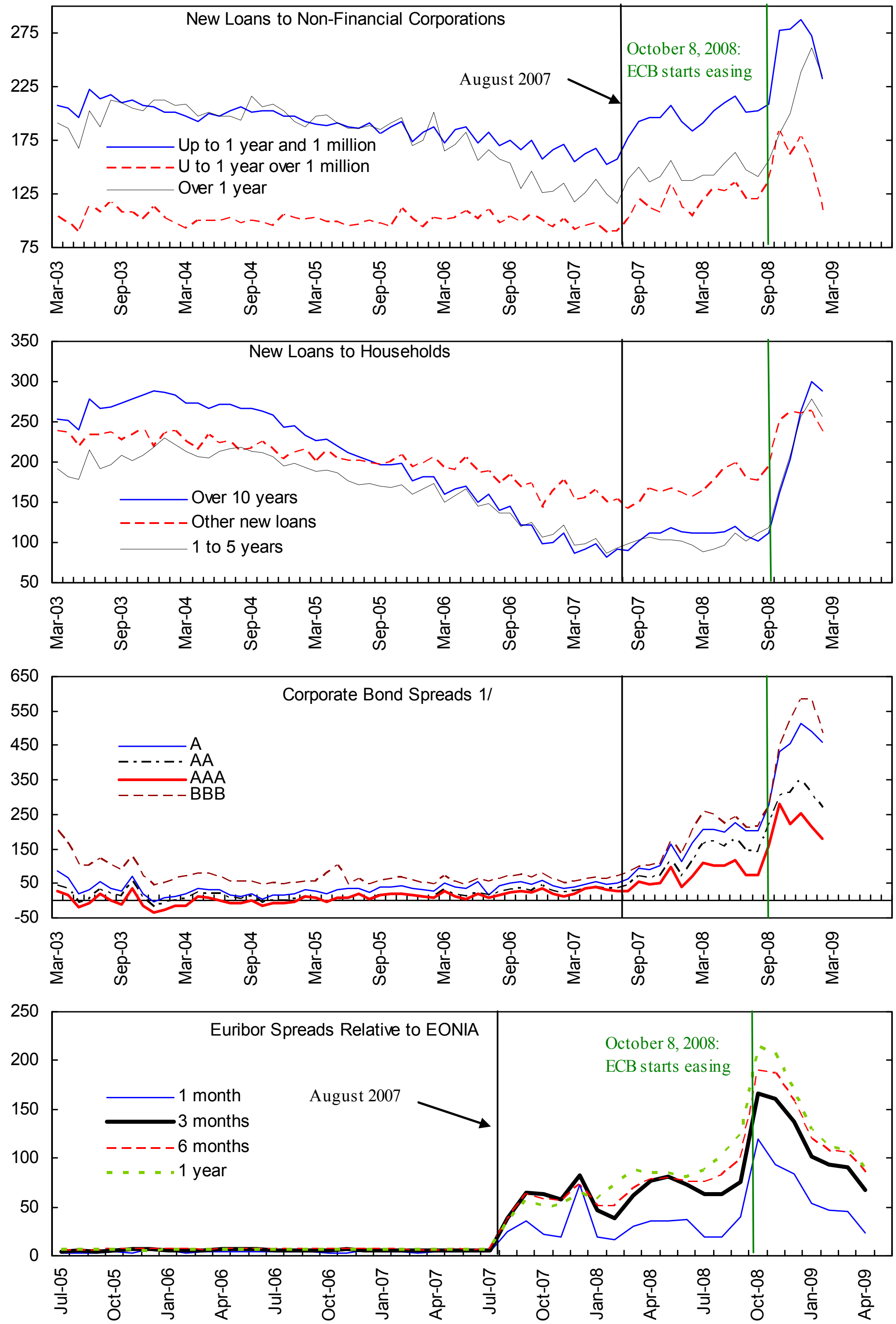
The ECB's non-standard measures, such as a major lengthening of the maturity of monetary operations and a significant increase of its balance sheet, likely have contributed to reducing term spreads in money markets, although the evidence for this is only preliminary and indirect at this point. They may also have had some beneficial effects on government bond term spreads and the level of the yield curve.

Figure 1. Euro Area: Recent Developments of the ECB's Liquidity Operations
(Percent, or in units as indicated)



Sources: DataStream; and Bloomberg.
1/ Euribor refers to "the best price between the best banks" provided by Euribor panel members.
2/ The liquidity premium is the difference between the Euribor - Eonia Swap spread and the CDS premium.
3/ The one-year banks CDS premium is the average of premia for the "best" five Euribor panel banks out of 24 with the lowest premium.

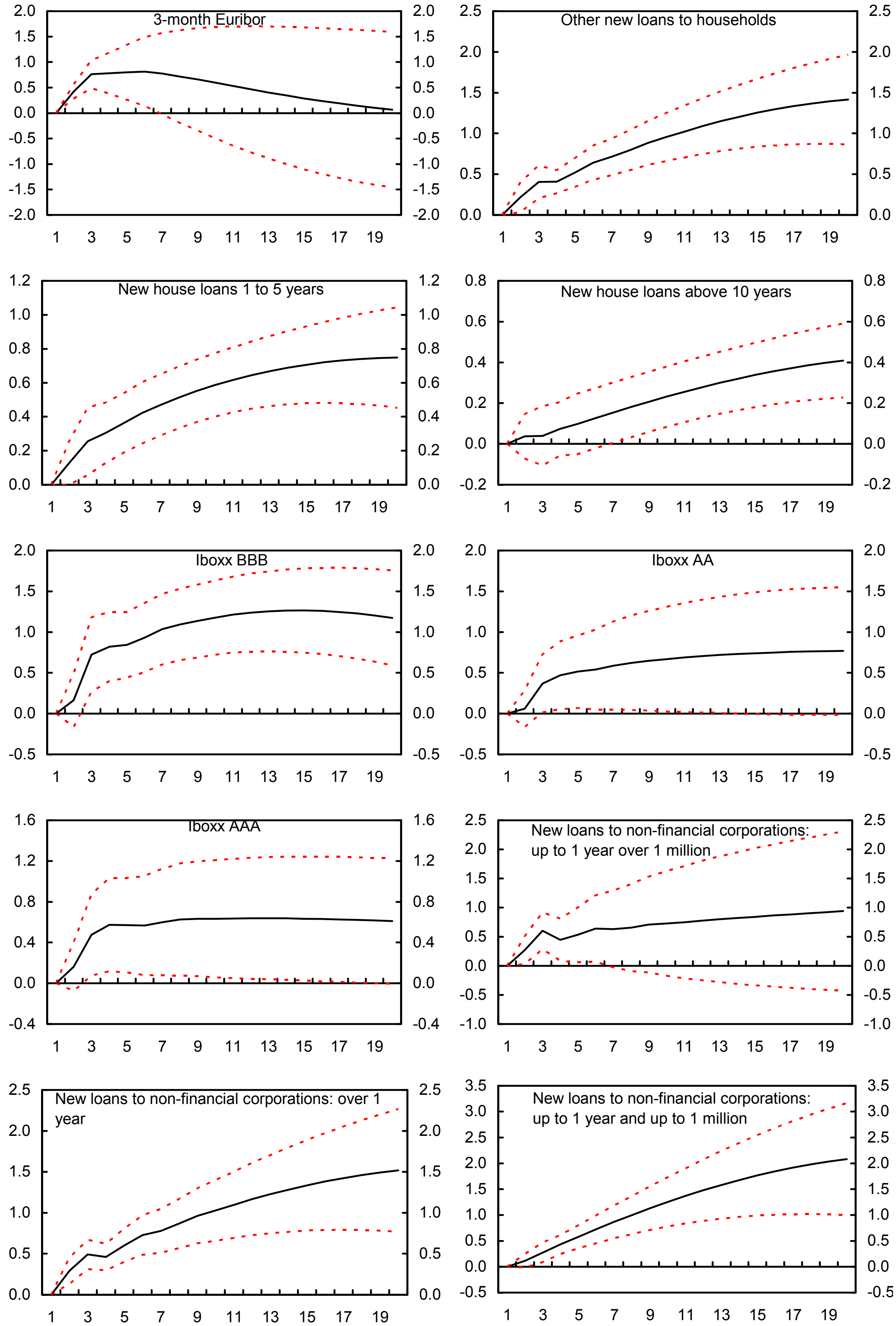
Figure 2. Euro Area: Cost of Borrowing by Businesses and Households
(Spreads relative to the ECB policy rate, basis points)



Sources: Haver and IMF staff calculations.
1/ Corporate bonds 3-5 year maturity relative to 5-year benchmark government bond index.

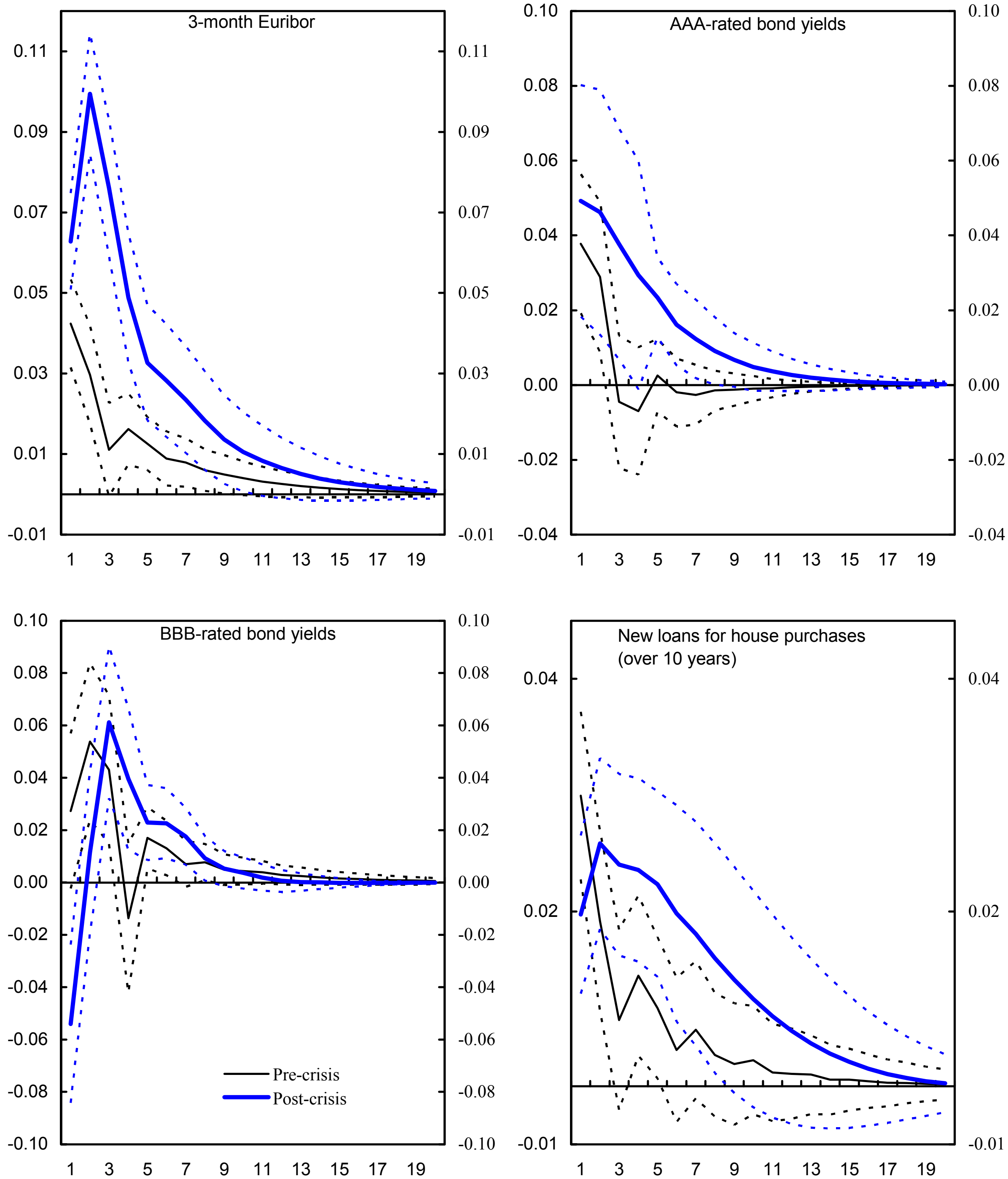
Figure 3. Euro Area: Pass-through of The ECB Policy Rate Changes to Market Rates

(Response to non-factorized one unit innovations, 85 percent confidence interval)



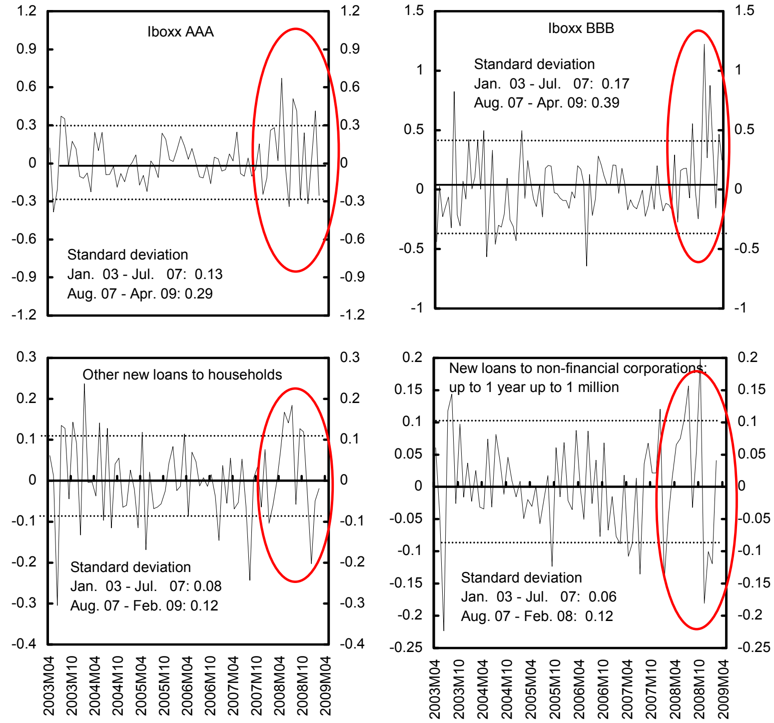
Sources: ECB and IMF staff estimates.

Figure 4. Euro Area: The Impact of Crisis on Policy Rate Pass-through
(VARs in first Difference, Response to Cholesky One S.D. Innovations, 85 percent confidence interval)



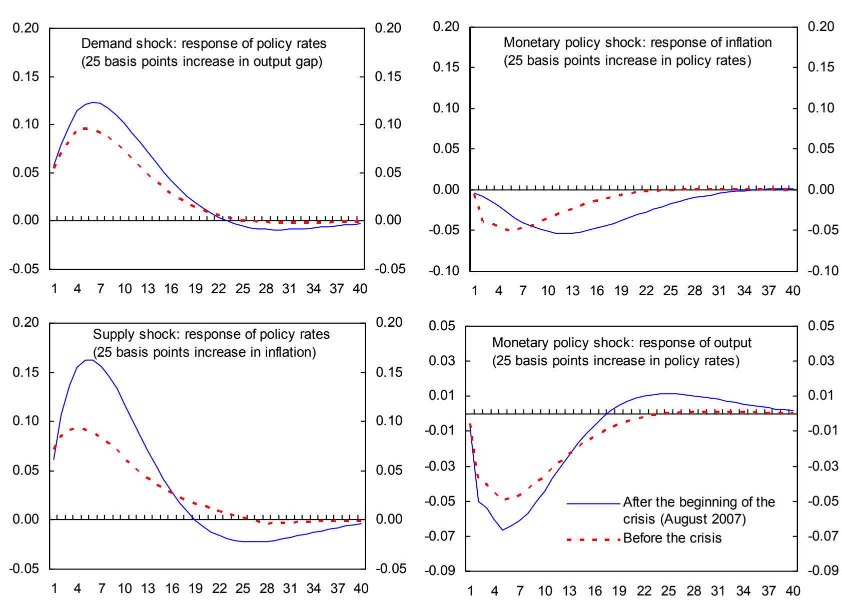
Source: IMF staff estimates.

Figure 5. Euro Area: VAR Residuals of Market Rates
(Percentage points)



Sources: ECB; and IMF staff estimates.

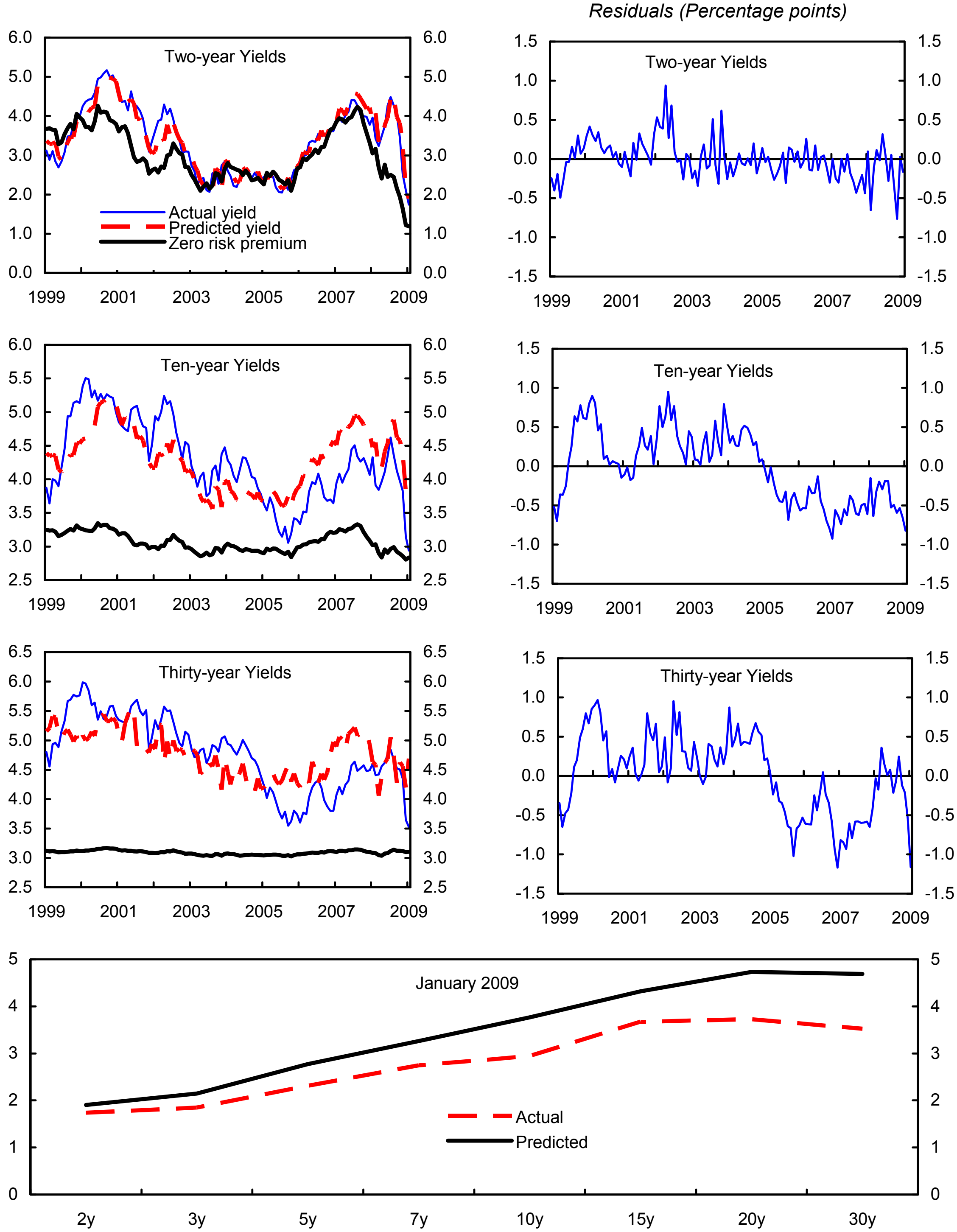
Figure 6. Euro Area: Effectiveness of Monetary Policy
(Pre- and Post- Crisis in basis points)



Source: IMF staff estimates.

Figure 7. Euro Area Macro-Financial Model: Government Bond Yields and Model Estimates 1/

(Percent)



Sources: DataStream; and IMF staff calculations.

1/ Euro area synthetic government bond yields.

Appendix I. Small Theory-Based Model for the Euro Area

This appendix describes the equations of the theory-based model, discusses the data that are used for its estimation, and provides the estimates of the coefficients.

The three main equations describe the evolution of inflation, π_t, the output gap, y_t, and the monetary policy response, captured by the policy rates, r_t.

Inflation Equation (Phillips Curve)

$$\pi_t = \lambda_1 \pi 12^e_{t+12} + (1-\lambda_1)\pi 12_{t-1} + \lambda_2 (y_{t-1} + y_{t-2} + y_{t-3})/3 + \varepsilon^{\pi}_t \tag{A1}$$

where π_t is monthly inflation (seasonally adjusted at annual rate), $\pi 12^e_{t+12}$ is expected year-on-year inflation, $\pi 12_t$ is year-on-year inflation, y_t is a measure of the output gap, and ε^{π}_t is a supply shock. This specification implies that prices are set as a markup over marginal cost, captured by the output gap; and the degree of price flexibility and inflation inertia are captured by the weight on the expected inflation term.

For the empirical analysis, which is done with monthly data, $\pi_t = 1200(p\_sa_t - p\_sa_{t-1})$, where p_sa_t is the logarithm of the seasonally adjusted harmonized index of consumer prices (HICP), and $\pi 12_t = 100(p_t - p_{t-12})$, where p_t is the logarithm of the HICP index. Economic activity is approximated by a weighted average of industrial production (30 percent share) and retail sales indexes. As initial values for the output gap y_t for the Bayesian estimation, the log-difference of the actual index from its Hodrick-Prescott filtered value is used.

Aggregate Demand

$$y_t = \beta_1 (y_{t-1} + y_{t-2} + y_{t-3})/3 + \beta_2 y^e_{t+1} - \beta_3 (r_{t-1} - r\_eq_{t-1}) - \theta_l \hat{r}^l_{t-1} - \theta_{sp} sp_{t-1} + \varepsilon^y_t \tag{A2}$$

where y^e_{t+1} is the expected output gap next period, r_t is the actual short-term real interest rate, defined as the difference between the short-term nominal interest rate and expected inflation, r_eq_t is the equilibrium real interest rate, $\hat{r}^l_t$ is the deviation of the real rate of loans from equilibrium, sp_t is the spread between corporate bonds and government bonds, and ε^y_t is a demand shock.

In this aggregate demand specification, the lagged moving average output gap term reflects the degree of inertia in the economy and the forward looking output gap term captures intertemporal smoothing by economic agents. The third term, the deviation of actual from equilibrium real interest rates, represents the interest rate channel, while the fourth and fifth terms capture the effects of the bank lending and the broader credit channels, respectively.[18]

Given that the model is estimated with monthly data, the leads and lags in equations (A1) and (A2) are chosen so as to obtain dynamic responses that are in line with the dynamic response from models estimated with quarterly data and reproduce plausible lengths of price setting contracts and the lags with which capacity utilization affects inflation in reality.

Monetary Policy Reaction Function

$$i_t = \gamma_1 i_{t-1} + (1-\gamma_1)(r\_eq_t + \pi 12^e_{t+12} + \gamma_2(\pi 12^e_{t+12} - \overline{\pi}_t) + \gamma_3 y_t) + \varepsilon^i_t \qquad \text{(A3)}$$

where i_t is the nominal policy interest rate, $\overline{\pi}_t$ is the inflation target, and ε^i_t is a monetary policy shock. The first term in this rule captures the degree of interest rate smoothing by the central bank. The second term is the natural interest rate, and the third and fourth terms represent the usual components for a forward looking Taylor rule where the central bank reacts to the deviation of expected inflation from inflation target and the output gap.

The model is extended in several ways. First, to capture market perceptions about underlying inflation, inflation target is modeled as time varying.

Inflation Target

$$\overline{\pi}_t = \rho \pi^{ss} + (1-\rho)\pi 12_{t-1} + \varepsilon^{\overline{\pi}}_t \qquad \text{(A4)}$$

where π^{ss} is the steady-state inflation, and $\varepsilon^{\overline{\pi}}_t$ is a shock to underlying inflation. Allowing for a time-varying inflation target also provides insights about central bank credibility (see for example Hördahl, Tristani, and Vestin, 2006).

Second, to test for the importance of bank lending channel, a simple loan demand and supply block is added to the core equations (A1)–(A4) of the model.

[18] Instead of loan rates, the quantity of loans could be used in the aggregate demand equation (A2). In principle, having loan rates or the quantity of loans in the aggregate demand equation should be equivalent. However, in times of severe stress in the banking system rationing of borrowers may occur, which is not fully reflected in loan interest rates. Testing whether using loans instead of loan rates in the aggregate demand equation changes the results, is left for future research.

Loan Demand

$$l_t = -\lambda_i i^l_{t-1} + \lambda_y g_{t-1} + \varepsilon^{ld}_t \tag{A5}$$

where l_t is growth of loans provided by the banking system, i^l_t is the interest rate on loans, g_t is growth of output, and ε^{ld}_t is a loan demand shock.

Loan Supply

Loan supply is represented by an inverse loan supply function (determining interest rates on bank loans) as follows:

$$i^l_t = \tau_1 l_{t-1} + \lambda_m \mu_{t-1} + \varepsilon^{ls}_t \tag{A6}$$

where μ_t is money growth, and ε^{ls}_t is a loan supply shock. To close the loan demand and supply block, a standard money demand function is used in which money growth μ_t is determined by output growth and policy interest rates.

Credit Spread

To examine the importance of the broader credit channel, an equation that describes the corporate bond yield spread (the difference of corporate and government bond yields) is added to the model. As Fridman and Kuttner (1992) show, the spread between the corporate bond yield and government bond yield captures the external finance premium, which is in general positive due to risk and liquidity premia. The corporate bond spread is modeled to depend on overall economic conditions captured by the output and policy rate as follows:

$$sp_t = \sigma_1 i_{t-1} + \sigma_2 y_{t-1} + \varepsilon^{sp}_t \tag{A7}$$

where ε^{sp}_t is a shock to the corporate spread.

Equilibrium Growth

$$g_t = \tau g^* + (1-\tau) g_{t-1} + \varepsilon_{g,t} \tag{A8}$$

where g_t is the quarterly real GDP growth at annual rate, g^* is steady state real GDP growth and ε_g is a shock to steady state growth.

Equilibrium Output

$$\bar{y}_t = \bar{y}_{t-1} + \frac{g_t}{4} + \varepsilon_{\bar{y},t} \tag{A9}$$

where, $\bar{y}_t$ is the log of the level of equilibrium real GDP, g_t is the quarterly real GDP growth at annual rate, and $\varepsilon_{\bar{y},t}$ is a shock to equilibrium output.

Equilibrium Real Interest Rate

$$r_t^n = \rho r^* + (1-\rho) r_{t-1}^n + \varepsilon_{r_t^n,t} \tag{A10}$$

where, r^* is steady state real interest rate and $\varepsilon_{r_t^n,t}$ is a shock to equilibrium real interest rates.

Real Interest Rate

$$r_t = i_t - \pi 12_{t+12}^e \tag{A11}$$

The model is estimated with monthly seasonally adjusted data, using Bayesian methods over the period January 1995 to February 2009 for the version with the bank-lending channel and from January 1999 to February 2009 for the version with the broader credit channel. Economic activity is approximated by a weighted average of industrial production (30 percent share) and retail sales. In addition, the following variables are used: short-rates approximated by EONIA interest rate, an average of interest rates on new loans to euro area residents of 1- to 5-year maturity, AAA-, AA-, A-, BBB-rated corporate bond yields of 3- to 5-year maturity, the spread of corporate bond yield and government bond yield, HICP inflation, money supply (approximated by M3 aggregate), and bank loans to the euro area residents.

Euro Area: Estimates of Model Parameters

Parameter	Estimate	St. dev.	t-stat	Prior distrib.	Prior st. dev.
λ_1	0.77	0.05	16.65	beta	0.05
λ_2	0.12	0.06	1.92	gamm	0.10
β_1	0.74	0.10	7.57	gamm	0.10
β_2	0.14	0.05	2.73	beta	0.05
β_3	0.20	0.05	4.22	gamm	0.05
θ_l	0.08	0.04	1.76	gamm	0.05
θ_{sp} 1/	0.05	0.02	2.08	gamm	0.05
γ_1	0.83	0.15	5.40	beta	0.15
γ_2	1.38	0.27	5.14	gamm	0.35
γ_3	0.47	0.15	3.20	gamm	0.15
τ	0.04	0.02	2.10	beta	0.05
π^{ss}	1.98	0.16	11.99	norm	0.50
g^*	1.80	0.50	3.64	norm	0.50
ρ	0.05	0.02	2.95	beta	0.07
r^*	1.49	0.21	7.23	norm	0.50
λ_i	0.34	0.12	2.91	gamm	0.10
λ_y	0.73	0.30	2.45	gamm	0.10
τ_i	0.15	0.04	3.89	gamm	0.10
λ_m	0.33	0.19	1.69	gamm	0.10
σ_1	0.48	0.07	6.45	gamm	0.10
σ_2	1.12	0.12	9.68	gamm	0.10

Source: IMF staff estimates.
1/ The sample starts in January 1999.

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