

**Interest Rate Setting at the ECB Following the Financial and Sovereign Debt Crises, in
Real-Time**

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Abstract

This paper examines European Central Bank (ECB) policy decisions to adjust the repo rate. We estimate a forward-looking, ordered-logit model using real-time and expectations data. In particular, we investigate the impact of the 2007-2009 financial and sovereign debt crises on the ECB interest rate policy. We find that the repo rate is more likely to rise when real economic activity (economic sentiment) is strong, and the ECB's decision to increase the repo rate is not affected by inflation forecasts. We find the ECB responds to an increasing sovereign risk premium by lowering the repo rate. In addition, we examine whether the change in ECB Presidency from Willem Duisenberg to Jean-Claude Trichet and the recent financial crisis induced a policy shift. We do not find a regime switch from the Duisenberg presidency to Trichet presidency, but we find that the financial crisis has reduced the importance of the exchange rate, and also how strongly the ECB reacts to improvements in economic activity.

Keywords: Taylor Rule, European Monetary Policy, ECB, financial crisis, sovereign debt crisis

JEL Codes: E58, F36, F33

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1. Introduction

The purpose of this paper is to investigate the interest-rate setting process in the European Central Bank (ECB) between 1999 and 2010 and more specifically its response to the recent financial and sovereign debt crises. The magnitude of the recent crises has led the Federal Reserve and ECB to undertake unprecedented measures to mitigate the effects of the crises. For instance the ECB relaxed its collateral rules by accepting Greek government bonds despite their credit-rating downgrade. We examine if the ECB response has recently deviated from its mandate outlined in the Maastricht Treaty.

According to Article 105 (1) of the Maastricht Treaty, the primary objective for the ECB is medium-term price stability. The ECB's Governing Council defines price stability as a year-on-year increase in the Harmonized Index of Consumer Prices (HICP) for the euro area of below 2%. Given that monetary policy affects the economy with lags, to maintain price stability, ECB acts in a forward-looking manner (see ECB 2003a). Decisions are achieved by cross-checking two pillars: monetary analysis and economic analysis. Monetary analysis is based on the idea that inflation is primarily an excess money phenomenon and the analysis involves monitoring monetary conditions in the euro area. The second pillar, "economic analysis" consists of reviewing a wide range of economic and financial indicators, such as overall output, fiscal policy, wages, inflation forecasts, yield curve, exchange rate, business and consumer surveys, and asset prices. ECB policy is tailored to the changing economic landscape of the euro area and may be altered according to the shocks hitting the economy.

Policy decisions at the ECB are somewhat opaque and the minutes from the policy meetings are not publicly available. Estimating a central bank's reaction function to

macroeconomic conditions provides insight into central bank policy behavior. Numerous papers have estimated a Taylor policy rule for the ECB but most of these papers' estimations are based on limited time-series data, while longer time series allow for a more accurate estimate of the ECB's rule with greater variation in the ECB's response to economic shocks.¹

In this paper, we analyze the ECB interest rate policy and its responses to economic shocks, specifically to the recent financial crisis and the sovereign debt crisis. We develop a forward looking, ordered-logit model that we estimate with real-time data obtained from the ECB and forecast data from the European Commission and *The Economist*. In particular, we examine whether these two crises have affected the importance of several macroeconomic variables in the ECB's interest rate setting. We also check whether the switch in ECB presidents from Willem Duisenberg to Jean-Claude Trichet, and the financial crisis have induced a policy shift.

While Gerlach (2010) examines a policy shift by splitting his sample in July 2007 (when Lehman Brother's closes its subprime lender) and tests for parameter shifts, we take an additional step by not only controlling for the different episodes of the financial crisis using a variety of dummy variables, such as the run on the Northern Rock Bank, Lehman Brothers' bankruptcy, and the collapse of the Royal Bank of Scotland (RBS), but also testing the impact of the sovereign debt crisis on ECB interest rate setting using sovereign risk premia.

Our estimations indicate that the ECB focuses mostly on economic activity and not on inflation forecasts when deciding whether to change the repo rate. The repo rate is the minimum bid interest rate on short-term loans member banks can obtain from the ECB. As economic

¹ For example, Sauer and Sturm (2003), Fendel and Frenkel (2005), Gerdesmeier and Roffia (2003).

sentiment forecast increases, the repo rate is more likely to rise by a large increment. We also find that the ECB was more likely to lower the repo rate following an increase in the Greek risk premium, and when the repo rate in the previous month was already high. While the change in ECB president did not affect the policy rule, the financial crisis has decreased the importance of exchange rate fluctuations in the ECB's interest rate setting.

This paper proceeds as follows: in section 2 we provide a brief perspective of contributions to this topic in the U.S. and in Europe. In section 3 we discuss our empirical methodology and data. Our results are reported in section 4: we present our estimates using real-time inflation forecasts and economic sentiment data. Finally, the last section summarizes and concludes.

2. Previous Work

2.1 Background on Interest Rate Rules

Following Alesina and Summers' (1993) seminal study, many countries moved towards granting central bank independence from elected officials. However, central bank independence requires some degree of performance accountability and transparency. This push for monetary policy transparency created a shift in empirical research towards policy rules describing central bank behavior, such as the Taylor rule (see Taylor 1993), specifically.

$$i_t = \bar{r} + \pi_t + \gamma_\pi(\pi_t - \pi_t^*) + \gamma_y(y_t - y_t^*) \quad [1]$$

where i is the target nominal interest rate, \bar{r} is the real equilibrium interest rate at full employment, π^* is the inflation target and y^* is potential real GDP and γ_π , γ_y are positive parameters. Taylor postulated that $\bar{r} = \pi_t^* = 2$, and $\gamma_\pi = \gamma_y = 0.5$. In fact, comparisons

between the interest rate predicted by Taylor's rule mirrors the actual federal funds rate for the 1987-1992 period.

Numerous additional studies have been generated modifying Taylor's original monetary policy rule. Clarida, Gali and Gertler (1998) propose a forward-looking Taylor rule by replacing the current inflation, rate, π_t , with the expected inflation rate 12 months ahead, $E_t[\pi_{t+12}]$ (see equation 2 below). The key justifications for the forward-looking Taylor rule are the long and variable lags in the monetary policy transmission mechanism.²

$$i_t = \bar{r} + \pi_t + \gamma_\pi (E_t[\pi_{t+n}] - \pi_t^*) + \gamma_y (E_t[y_{t+n}] - y_t^*) \quad [2]$$

Orphanides (2001) notes however, that forecasts using *ex post* or revised data would not yield the same estimates associated with data available to the Federal Open Market Committee (FOMC) at the time when policy is decided. Instead, the FOMC uses Greenbook forecasts³ or real-time data⁴, to set the Federal Funds rate. Specifically, estimates derived using real-time data points to a forward-looking rule as the correct specification and not a backward looking rule.

In addition to modifications of the Taylor rule, the estimated coefficients' reliability has been called into question. Central banks typically adjust interest rates in smaller increments than implied by the rule, resulting in serial correlation.⁵ For example, the U.S. Federal Reserve changes the Federal Funds Rate in increments of 25 or 50 basis points rather than a full 100 basis point change.⁶ The debate in the literature is whether the statistical significance of a lagged

² For a survey of the literature see the *Journal of Economic Perspectives* symposium: *Journal of Economic Perspectives* 9 (Fall 1995).

³ The Greenbook is produced before each meeting of the Federal Open Market Committee. Given assumptions on monetary policy, the Board of Governors prepares projections on future economic activity.

⁴ Real-time data reflects, at each date (say May 2002), exactly what the macroeconomic data looked like at that date, May 2002.

⁵ This is perhaps due to minimized excessive volatility in short term rates to encourage capital market stability and to raise central bank credibility.

⁶ During 2001, the Federal Reserve lowered the Federal Funds Rate eleven times from 6.5% to 1.75%.

dependent variable in the policy rule is due to "interest rate smoothing " or due to the central bank's response to serially correlated exogenous shocks (Rudebusch 2002). According to Rudebusch (2002), if the central bank is responding to serially correlated shocks, the interest rate rule suffers from omitted variable bias and is therefore misspecified.

2.2 *Monetary Policy Rules and Central Bank Behavior in Europe*

Monetary policy rules have also been estimated for European central banks. Clarida, Gali, Gertler (1998) find evidence that the US, Japan and Germany used forward-looking rules and employ an implicit form of inflation targeting. In contrast, the central banks of the UK, France and Italy were heavily influenced by Bundesbank policy, even prior to joining the ERM. Effectively, the UK, France and Italy set their short-term rate as a weighted average of domestic economic conditions and the German rate. Here, the German rate can be thought of as the benchmark (default-free) rate for European countries.

Many papers have developed a forward-looking policy rule for the ECB itself (Faust, Rogers and Wright (2001), Sauer and Sturm (2003), Fendel and Frenkel (2005), Gorter, Jacobs, and Haan (2008) among others)⁷ and all have found that the nominal interest rate rises by more than the increase in the inflation rate (an inflation stabilizing policy), and that the output gap is a significant factor in setting the short-term rate. Given that the ECB pays attention to M3, Fendel and Frenkel (2005) also include excess money growth, measured as deviations in the growth of M3 from its reference level of 4.5%, and find that all the explanatory variables become

⁷ Fendel and Frenkel (2005) estimate a forward-looking policy rule for the ECB using monthly data from 1999 to 2004. They use the European Overnight Index Average Rate (EONIA rate) as the ECB's policy instrument. The average is calculated from banks participating in the euro-zone market (these maybe EU banks or non-EU banks). Like the U.S. Federal Funds rate, this interest rate is serves as a benchmark for other interest rates. Sauer and Sturm (2003) also use the EONIA and Gorter *et al.* (2008) use the 3 month EUROBOR.

insignificant.⁸ Carstensen (2006) also finds that monetary growth measures are not important for interest rate setting. He estimates an ordered probit model to test a backward looking rule for the main refinancing operations (MRO) rate since changes occur in increments of 25 basis points. He chooses a backward-looking rule to maximize the number of observations. Gerdesmeier and Roffia (2003) use "euro-area" data from January 1985 to February 2002 and include other variables in the standard Taylor rule such as the euro-effective exchange rate, inflation forecasts, world commodity prices, the federal funds rate, stock prices (DJ Euro Stoxx 50), and the money growth gap in M3. Since the ECB was not operational until 1999, they compile a fictitious euro area 3-month interest rate using 1999 GDP weights at PPP exchange rates.⁹ They find that the deviation of M3 growth from its 4.5% reference value is a statistically significant predictor of the short-term policy rate.

Following Orphanides (2001), studies have estimated the ECB's reaction function using European real-time data (Gerdesmeier and Roffia 2003, 2004, Sauer and Strum 2003, and Gorter *et al.* 2008). Consistent with Orphanides (2001) they find that estimates derived from *ex post* data provide unrealistic or biased estimates of actual historical policy. Consequently, Gerlach (2007, 2010) and Gorter *et al.* (2008) use expectations data for inflation and output growth. Gerlach (2007) estimates an ordered probit model using expectations data. Unlike previous studies, Gerlach uses the target repo rate as his policy instrument, expected inflation forecasts¹⁰ and economic sentiment indicator (ESI) as the measure for real economic activity because notes that the ECB Monthly Bulletins never mention an output gap but rather business and consumer

⁸ Possibly due to multicollinearity.

⁹ For example, for the HICP, they calculate a weighted average of national CPI's using consumption expenditure weights.

¹⁰ The target repo rate is the minimum bid rate. Since the repo rate is adjusted in increments of 25 basis points an ordered probit or logit model is warranted.

confidence. He also includes a three-month, moving average of M3 growth since the Monthly Bulletins often publically discuss monetary developments and the change in the nominal effective exchange rate. Gerlach finds that higher economic sentiment is associated with an increase in the repo rate while expected headline inflation has no explanatory power. He suggests that the inflationary developments are often demand driven and are therefore captured by increasing economic activity. Further, the Governing Council does react to M3 growth and the nominal exchange rate. Gerlach (2010) estimates an ordered logit model and splits his sample in July 2007 to examine the shift in ECB policy during the financial crisis. He finds that the ECB employed steep cuts in the repo rate and this is mostly due to a decline in economic activity and a shift in the ECB's reaction function.

3. Data and Empirical Methodology

3.1 Empirical Methodology

We follow Gerlach (2010) by adopting a forward-looking ordered-logit model to examine the ECB's interest-rate setting decisions. Our interest rate is the main refinancing operations rate (MRO rate or repo rate). Since the focus of the paper is the analysis of the ECB decision-making process, the repo rate, which is set at the ECB Governing Council, is more appropriate than the EONIA rate. It is important to remember that the actual repo rate might differ from the ECB's target repo rate because the ECB sets its interest rate in increments of 25 basis points (figure 1).

Figure 1 here

Besides controlling for economic activity and inflation developments, the baseline, ordered-logit model is augmented with an interest-rate smoothing term (see Castelnuovo 2005)

and other economic variables which might affect the interest setting policy of the central bank.¹¹

We also check whether the ECB's decision to change the repo rate might be affected by previous changes in the repo rate.

$$i_t^* - i_t = \beta_0 i_{t-1} + \beta_1 \Delta i_t + \gamma_\pi \pi_t + \gamma_y y_t + \gamma_x x_t + \varepsilon_t \quad [3]$$

Where π_t, y_t, x_t denote respectively various measures of the inflation rate, real economic activity, and other economic variables used to assess current economic and financial developments. i_t^* is the repo interest rate, it is a latent variable since we only observe the target interest rate and the change in the interest rate, which depends on the value of the latent variable relative to a set of cut points (α_i). To measure the change in the repo rate, we construct a discrete variable, z , to capture the six policy responses we observe between January 1999 and May 2010 (Table 1):

$$\begin{aligned} z = 1 & \text{ when } \Delta i_t = -0.75\% \quad \text{if } i_t^* - i_t < \alpha_1 \\ z = 2 & \text{ when } \Delta i_t = -0.50\% \quad \text{if } \alpha_1 < i_t^* - i_t < \alpha_2 \\ z = 3 & \text{ when } \Delta i_t = -0.25\% \quad \text{if } \alpha_2 < i_t^* - i_t < \alpha_3 \\ z = 4 & \text{ when } \Delta i_t = 0 \quad \text{if } \alpha_3 < i_t^* - i_t < \alpha_4 \\ z = 5 & \text{ when } \Delta i_t = +0.25\% \quad \text{if } \alpha_4 < i_t^* - i_t < \alpha_5 \\ z = 6 & \text{ when } \Delta i_t = +0.50\% \quad \text{if } \alpha_5 < i_t^* - i_t < \alpha_6 \end{aligned} \quad [4]$$

Since our dependent variable has more than two categories and the values of these categories have a meaningful sequential order, the ordered-logit model is more appropriate than the ordinary least squares (OLS) model. When the dependent variable is categorical, OLS method can no longer produce the best linear unbiased estimator (BLUE) and the homogeneity

¹¹ Castelnuovo (2005) shows that the lagged interest rate in the euro area is due to interest rate smoothing rather than omitted economic shocks.

of variance is violated. Moreover, as shown in figure 2, linear regression like OLS will generate predicted values outside the limited number of values the dependent variable actually take (in our case 1 to 6).

Figure 2 here

3.2 *Data*

We use monthly data spanning from January 1999 to May 2010. Whenever possible we use real-time data obtained from the ECB website. This is an experimental dataset constructed to provide historical vintages of data published in the Monthly Bulletin (see Giannone et al, 2010). The dataset includes monthly data that were available to the ECB on the working day preceding each first monthly Governing Council's meeting.¹²

Most of the empirical literature on monetary-policy reaction functions measures economic activity using the output gap. However, using the output gap is problematic for several reasons. First, national account data are released with a considerable lag, and are subject to numerous revisions. One solution is to use real-time data on GDP to construct the output gap. However, as shown by Orphanides and van Norden (2002, 2005) output-gap estimates in real-time do not yield more reliable estimates of the central banks' reaction function. Further, since GDP data are not available on a monthly frequency, papers using monthly data proxy GDP with industrial production¹³, even though, industrial production tends to be very volatile and accounts for a fraction of economic activity in Europe.

¹² The Governing Council meets twice a month, but monetary policy decisions occur mostly during the first of the bi-monthly meeting of the Council as it assesses the economic and monetary development in the euro-zone.

¹³ Fourçans and Vranceanu, 2004; Gerdesmeier and Roffia, 2004; Heinemann and Huefner, 2004

An alternative measure of economic activity often referred to in the ECB Monthly Bulletins (Gerlach, 2007) is survey data. The econometric analysis presented and discussed below, uses two different forecasts of economic activity in the eurozone¹⁴. The first series is the Economic Sentiment Indicator (ESI) developed by the European Commission (available on the ECB website). It is a composite indicator calculated as a weighted average of indicators for the industry, service sector, consumers, construction sector, and retail trade. The ESI reflects firms and households' opinions about the economy over the next 12 months. A reading of the ESI above 100 indicates above average economic sentiment. Our second measure of economic activity is constructed from expected real GDP growth forecasts published in *The Economist* monthly poll of forecasters. As shown in figure 3, these two forecast measures of economic activity are strongly correlated with the current output gap, but not with the output gap at $t+12$.¹⁵ The correlation coefficient is 0.67 for the real GDP growth rate forecast and 0.69 for the ESI. The strongest correlation between these two economic forecast measures and a measure of the output gap is obtained between these forecasts at time t and the output gap at $t+3$ ($\rho=0.70$ for the real GDP growth forecast data from *The Economist*, and $\rho = 0.80$ for the ESI). These strong correlations indicate that these two subjective measures of economic activity forecasts are good proxies for economic activity.

Figure 3 here

Inflation is measured as the annual rate of change in the Harmonized Index of Consumer Prices (headline HICP). To capture the forward-looking nature of monetary policy, we measure future inflation by constructing a measure of expected inflation based on *The Economist's* polls

¹⁴ Gerlach (2007) uses the same two forecast variables.

¹⁵ This seasonally-adjusted, real-time series of industrial production excludes the construction sector because the latter is too seasonal.

of forecasters. We did check the robustness of our results using real-time headline inflation at $t+12$, and the results are the same.¹⁶ Interestingly, *The Economists'* inflation forecast is strongly correlated with the *current* headline inflation ($\rho=0.835$) and not with $t+12$ headline inflation ($\rho = -0.269$) (see figure 4).

Figure 4 here

We control for the relevance of the monetary pillar by first adding a money growth gap variable which is calculated as the difference between the annualized growth rate of real-time M3 and the reference value of 4.5%. Prior to May 2008, the annual growth rate of the broad monetary aggregate, M3 was annually maintained at a medium-term reference rate of 4.5%. However after 2008, once inflationary expectations were anchored, the annual review of M3 deviations from the reference rate of 4.5% were "de-emphasized" and now the ECB uses a money-demand and money-supply indicator models to assess excess money conditions¹⁷. The money growth gap is constructed using a three-month moving average of M3 growth rate (Gerlach, 2007). As shown in figure 5, the M3 annual growth rate was larger than 4.5% between 1999 and early 2009. The spike in early 2001 can be explained by the increased preference for liquidity induced by a prolonged period of asset price volatility and drop in equity prices (ECB 2003a, 2004).

Figure 5 here

We also estimate whether monetary growth considerations had a larger influence on ECB policy before May 2003 (following the de-emphasis in the reference rate) by interacting the

¹⁶ The results using $t+12$ inflation are available upon request.

¹⁷ For example, euro area inflation can be modeled with a Phillips Curve relationship and M3 growth patterns in 2 year plus horizon can predict medium term inflation (ECB 2003a).

money growth gap variable with a time dummy equal to one before May 2003 and zero afterwards. We would expect the coefficients on the money growth gap and the monetary pillar dummy to be positive, since an increase in money growth above the reference rate signals a possible rise in inflation and could trigger an increase in the repo rate.

As indicated in ECB (2003a), the economic pillar of the ECB monetary policy is not only based on the development in overall output, but also on other economic and financial considerations, such as developments in the exchange rate, the balance of payments of the euro area, and a broad range of price and cost indicators. We use two measures of the exchange rate: the euro-dollar exchange rate, as well as the nominal effective exchange rate. The nominal effective exchange rate is based on weighted averages of bilateral, euro exchange rates against 21 major trading partners of the euro area. If this index rises, the euro appreciates making the ECB more likely to lower the repo rate. Since price stability is the primary objective of the ECB's monetary policy, we would expect the repo rate to be positively related to commodity and stock prices. Developments in the balance of payments are captured by a monthly forecast of the eurozone current account obtained from *the Economist's* monthly polls of forecasters. We use the price of a barrel of crude oil, and more specifically the brent crude -1 month forward price to control for the impact of world commodity prices on ECB interest rate decisions. This series is obtained from the ECB real-time database.

Most of the aforementioned economic variables included in the specification are standard in the literature. However, our primary focus is to examine the ECB's decision-making following the recent 2007-2009 financial crisis and the 2009-2010 sovereign debt crisis. First we control for the effects of the financial crisis using 3 dummy variables to capture 3 key episodes: the run on the Northern Rock Bank in the UK in September 2007 (when this bank asked the

Bank of England for a liquidity support facility), Lehman Brothers' filing for bankruptcy in September 2008, and the nationalization of the Royal Bank of Scotland (RBS) in October 2008. Then, we test whether the financial crisis induced a shift in the ECB's reaction function by splitting the sample at a key episode of the crisis (the bank run on Northern Rock). To examine the recent 2009-2010 sovereign debt crisis we include a risk premium measure for Greece, Ireland, Portugal, and Spain. Our risk premium variable is constructed as a bond spread calculated as the difference in yields between the 10 year government bond in these four countries and Germany's (default free) 10 year government bond.¹⁸ A rise in the risk premium on sovereign bonds is often associated with rising fiscal imbalances and may indicate an increase in perceived default risk. A rising sovereign bond yield can also occur if there is a decline in economic activity which causes a deterioration in the government's fiscal situation, or if there is a global financial crisis resulting in uncertainty, causing investors to seek safer, higher quality bonds (such as German or U.S. bonds). As shown in figure 6, Greece's risk premium declined significantly following the introduction of the euro in 1999 and its adoption of the euro 2 years later. After remaining quite low throughout the 2000's, these four countries' risk premia surged again in 2008 (especially for Greece and Ireland) and 2009-2010, as the global crisis and recession worsened their debt situation. Because an increase in a country's risk premium is associated with a general deterioration of this country's economy, we would expect the risk premium and the repo rate to be negatively related, as the ECB is likely lower the repo rate to stimulate the European economy.

Figure 6 here

¹⁸ Gorter *et al.* (2008) also include a risk premium to capture systemic risk in the euro area. Their risk is measured by Long term Corporate BBB Bonds minus the 10 year eurozone government bond.

An alternative measure to proxy the sovereign debt crisis is to include a dummy for the announcement of the EU bailout or to use credit ratings for country risk (such as Standard and Poor's or Moody's), however, we believe that the government debt risk premium is a superior proxy for the crisis as it is clear that Greece and Ireland, for instance, were experiencing difficulties long before the bailouts and the risk premium will capture market expectations. Moreover, Ireland only received a bailout package from the EU in November 2010. Additionally, there have been episodes when credit rating agencies failed to down-grade sovereign bonds even though default risk or country specific risk was rising.¹⁹ We also consider a possible "regime" change within the ECB following the change in ECB presidents, by adding a time dummy for Mr. Trichet's presidency, which started in November 2003. Summary statistics for these variables are provided in table 2.

4. Results

4.1 Baseline model

In this section we present the results of the estimations of the ECB policy rule described in section 3. Table 3 reports the results using the entire sample period from January 1999 to May 2010 and table 4 presents the data for the pre-crisis period January 1999 to August 2007 which coincides with the bank run on Northern Rock Bank.²⁰ The regression results for the baseline model are reported in column 1 of tables 3 and 4. In the other columns of the tables, the baseline model is augmented with the Trichet dummy variable (column 2) and then with other variables capturing the monetary and economic pillars. We also report some robustness checks when we

¹⁹ An example is the Asian financial crisis.

²⁰ We could not examine the policy decision after the crisis of August 2008 to May 2010 due to the lack of time-series observations.

use the nominal effective exchange rate instead of the US dollar/euro exchange rate (column 4) and real GDP growth forecast instead of ESI (column 5).

As indicated earlier, the Governing Council generally discusses monetary policy at its first monthly meeting, and thus does not have access to most of the data described in the previous section (with the exception of the data obtained from the ECB real-time data set). To reflect this data constraint, we use the one-month lag of the forecast series for economic activity, inflation, the current account, as well as the exchange rate and crude oil price (Gerlach, 2007). We use the risk-premium data contemporaneously in our model since risk premia reflect anticipated and unanticipated debt market developments in an efficient market. The rise in a risk premium captures the expectations of investors to perceived risk. We can assume that market participants are able to anticipate the uncertainty in Europe arising from the Northern Rock collapse and the current debt crisis since typically there are warning signs of government debt problems (large budget deficits) long before the government announces a default or even possible contagion. Often, the inclusion of a risk premium in a policy rule can raise concern of endogeneity. We do not believe we have an endogeneity problem in this case as a change in the repo rate would affect both the German and Greek yields simultaneously and its effect on the difference between the yields will be minimal.

Starting with the baseline model in column 1 of table 3, the higher the repo rate is in the previous month, the less likely the ECB is to raise the current repo rate. If we focus on the marginal effect of a change in the lagged repo rate on the probabilities of a change in the current repo rate²¹, we find that a 100-basis points increase in the lagged repo rate decreases the

²¹ This can be obtained with the `prchange` command in STATA.

probability of a 25-basis points increase in the current rate by 6%, but increases the probability of a 50 points and 25 points- decrease by 2.7% and 1.4% respectively. Unlike Gerlach (2007), we do not find robust evidence that a previous change in the repo rate affects the probability of a change this month (the coefficient is negative and statistically significant in only 3 of the 6 specifications). However, consistent with Gerlach (2007, 2010), the ECB is more likely to raise its repo rate when economic activity (ESI) is strong. A 100 basis points increase in the ESI is associated with a large change in the probability of a 25-points increase in the repo rate (+1.1%). The ECB's decision however is not affected by the expected inflation rate (inflation forecast). As pointed out Gerlach (2010), this lack of statistical significance might stem from collinearity between economic activity and inflationary developments (0.398 for our sample) as the latter are often demand driven and are therefore captured by increasing economic activity.

We also test whether a change in the ECB presidency is associated with a change in policy-making, a regime change. We do not find strong evidence that the ECB is more likely to raise the repo rate under Mr. Trichet, as the statistical significance of that coefficient found in column 2 disappears once we control for other macroeconomic variables. When we augment the specification with additional macroeconomic variables (column 3), we find that the ECB is more likely to raise its interest rate when the money growth gap is high. The positive coefficient on the monetary pillar dummy (even when combined with the negative coefficient on the interaction term with the money growth gap) indicates that the ECB placed more weight on the monetary growth gap in its decision-making before May 2003. This confirms the reduced emphasis on the monetary pillar after May 2003. We find no evidence that the forecasted, current account balance, or the exchange rate (against the US dollar or a basket of currencies) affects ECB's decision making. However, the ECB does respond to change in crude oil prices. A 1% increase

in the price of crude oil has the largest marginal effect on the probability of a 25-points increase in the repo rate (probability increases by almost 8%) and on the probability of a 25-points decrease in the repo rate (probability decreases by 3%). While the ESI variable might capture the demand-driven inflationary pressures, our crude oil price variable might capture those caused by supply shocks.

4.2 Responses to the Financial Crisis and Sovereign Debt Crisis

Table 3, column 6 presents our analysis of the ECB's response to several episodes of the financial crisis and the European sovereign debt crisis using data for the entire sample. The lower AIC value of this specification indicates the relevance of these additional variables for the analysis of the ECB interest rate policy. Of the three dummy variables representing the banking collapse, only the coefficient on Northern Rock dummy is negative and statistically significant. This indicates that the ECB is less likely to increase the repo rate in response to a potential banking crisis. This shock affected mostly the probability of a 50-points decrease in the repo rate (+11%) and the probability of no change (-18.3%). Surprisingly, the coefficient on the Lehman Brothers' dummy is positive and statistically significant. We believe that this unexpected sign is due to the concomitance between this bank's filing for bankruptcy and rising inflation concerns (as explained in the editorial of the July 2008 ECB Monthly Bulletin, the inflation in May 2008 was 3.7% and was expected to reach 4% in June) which are not captured by the inflation forecast variable and pushed the ECB to raise its repo rate to 4.25%. Of the four-country risk premia included in the regression, only the Greek risk premium affects ECB policy. Specifically, the

ECB is less likely to increase the interest rate when the Greek risk premium rises.²² A change in the Greek risk premium decreased the probability of a 25-points increase in the repo rate (probability of this change drops by 4.4%). The lack of significance of the other three countries (especially Ireland) risk premia might be due to our sample period which ends in May 2010, before Ireland received a rescue package from the EU in November 2010. The lack of significance may also be due to the multicollinearity of the risk-premium variables, which would also reduce the economic and statistical significance of the Greek risk premium variable.

To check whether the 2007-2009 financial crisis has induced a shift in the policy reaction, we run the same analysis as the one presented in table 3 but on the time period preceding the financial crisis (from January 1999 to August 2007 when the Northern Rock Bank faced problems raising funds on the money market).²³ The results are presented in table 4. To assess whether the financial crisis induced a policy shift in the ECB interest rate setting, we jointly test whether the coefficients obtained with the pre-crisis sample period are statistically similar to those obtained with the entire sample period (presented in table 3). The low p-values reported for the Wald tests indicate that the coefficients for the pre-crisis period are statistically different, thus providing some evidence that the recent financial crisis induced a policy shift.

One key difference in our results is that, in the pre-crisis period, the ECB was also less likely to raise its interest rate if the repo rate had already been increased in the previous month. The rapid drop in the repo rate observed between October 2008 and April 2009 explains why this finding is more robust in the pre-crisis period. The ECB's interest rate policy is still heavily

²² In the pre-crisis period (before September 2007), the Greek risk premium is insignificant while the Irish risk premium is positive and significant. Increasing Irish economic growth is associated with a lower likelihood of government debt default and higher inflationary expectations in Ireland, and therefore the ECB is more likely to increase the repo.

²³ When we use Lehman Brother's as the cut-off point, the results are the same.

influenced by the expected economic activity, which had a slightly stronger impact on interest rate setting before the crisis. When we consider the pre-crisis period, higher inflation forecasts still do not affect the odds of a change in the repo rate. As for money growth gap, the coefficients on this variable remains positive as expected, but the coefficient on the monetary pillar dummy variable and the interact term are not statistically insignificant. This result implies that the de-emphasizing of M3 growth gap was mostly triggered by the 2007-2009 economic crisis rather than by the announcement made in May 2003.

Among the other economic considerations (current account balance, exchange rate, and crude oil price) that would warrant ECB attention, higher crude oil prices still increase the odds of an increase in the repo rate, while an appreciation of the euro relative to the US dollar or a basket of currencies (increase in these two exchange rates) is now associated with decrease in the odds of an increase in the repo rate.

5. Policy Implications and Concluding Remarks

This paper examines the ECB's response to a variety of economic events using real-time and forecast data. As our baseline, we estimate a forward-looking logit model similar to Gerlach (2007, 2010). We then augment the model with variables that capture the financial and sovereign debt crises that may warrant an ECB response. One clear result is that the ECB heavily weights economic sentiment in its policy decisions over inflation concerns. Our paper also shows that output deviations are not the only factors influencing policy. We also find that its policy decisions were affected by the run on the Northern Rock Bank and by the worsening of the Greek debt crisis. In particular, the ECB was more likely to lower the repo rate in response

to these crises, everything else held constant. Not only has the financial crisis led to a drop in the repo rate by worsening the economic environment of the eurozone, it has also induced a shift in the ECB reaction function, lowering notably the central bank's responsiveness to a change in the exchange rate between the euro and the US dollar. Our results show that, while the change in ECB president did not affect the policy rule, the financial crisis did decrease the importance of exchange rate fluctuations in ECB's interest rate setting.

The ECB is often criticized for being unclear on policy changes. Since the ECB does not publicly release minutes to policy meetings, markets are often left wondering the direction of future policy and how the ECB arrives at its decisions. Our paper provides some insight into ECB behavior following the recent financial and sovereign debt crises. Assuming that the policy shift induced by the financial crisis is temporary, our pre-crisis model could be used to forecast the probabilities of a change in the repo rate. To further clarify how the ECB arrives at its policy decisions, we plan to investigate how national economic considerations affect ECB policy, and whether the recent financial and sovereign debt crises have affected the weights put on different countries' economic outcomes.

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Figures and Tables

Figure 1: Repo Rate in the Euro Area (changing composition), Jan.1999-May 2010.

Source: elaboration on data from ECB website.

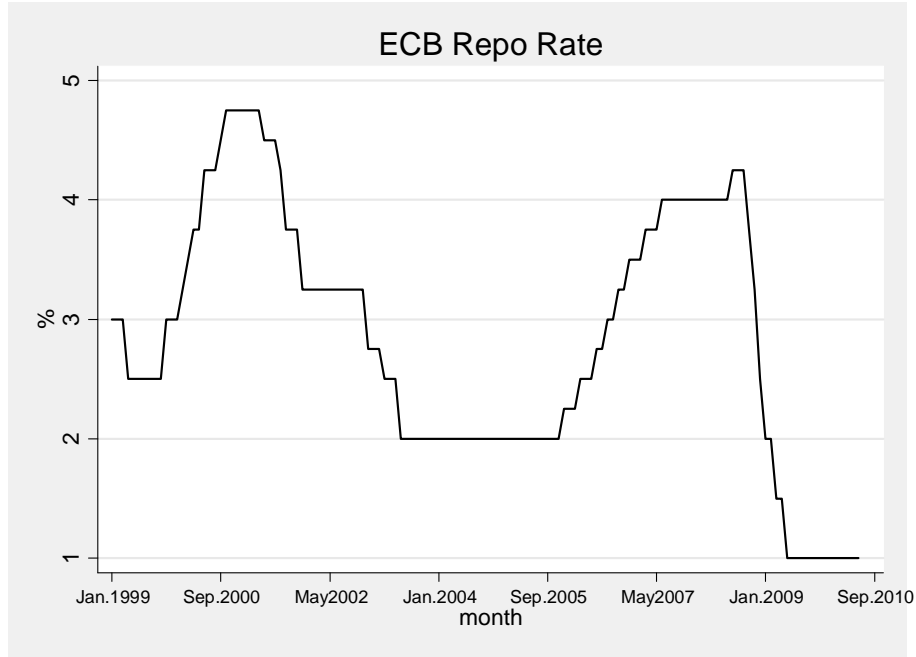


Figure 2: Graphical Representation of a Simple Linear Normal Regression.

Source: elaboration on data from ECB website and The Economist

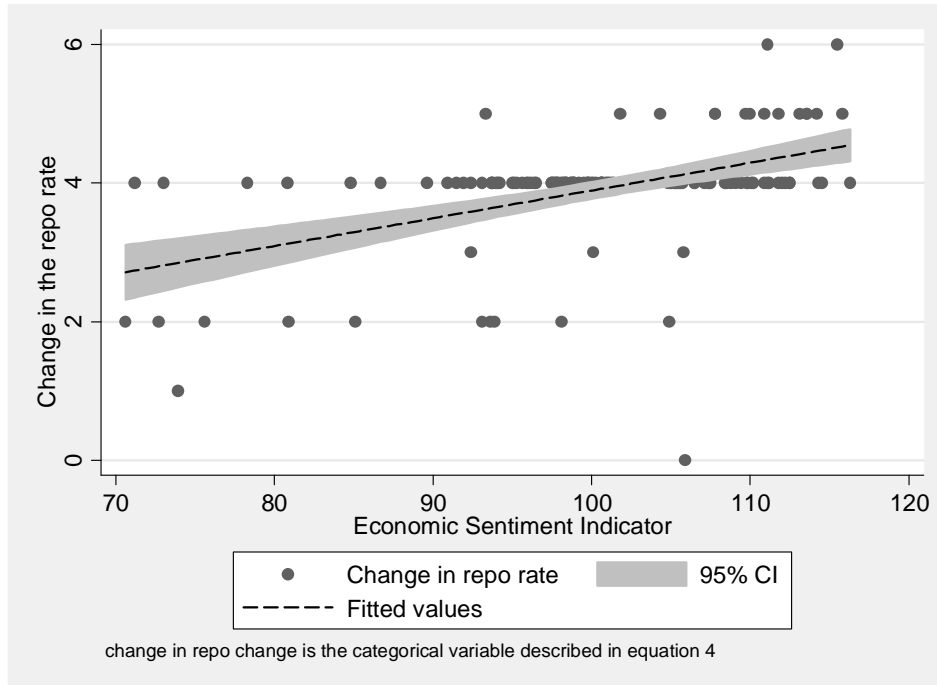


Figure 3: The Economic Sentiment Indicator and *The Economist* Poll of Forecasters, Jan.1999-May2010.

Source: elaboration on data from ECB website and The Economist

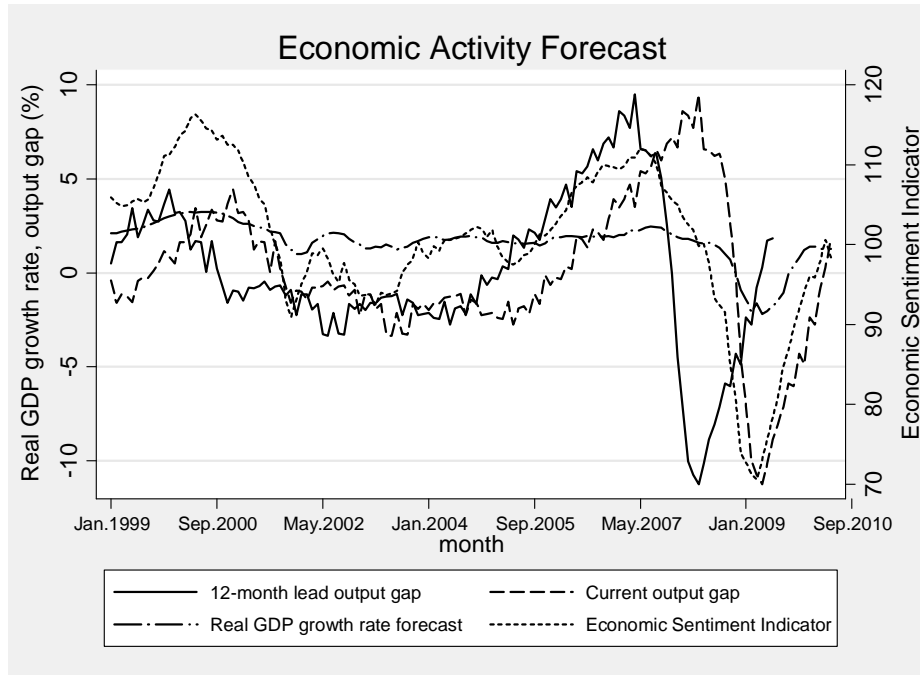


Figure4: Annual inflation rate in the Euro Area (changing composition), Jan.1999-May 2010.

Source: elaboration on data from ECB website.

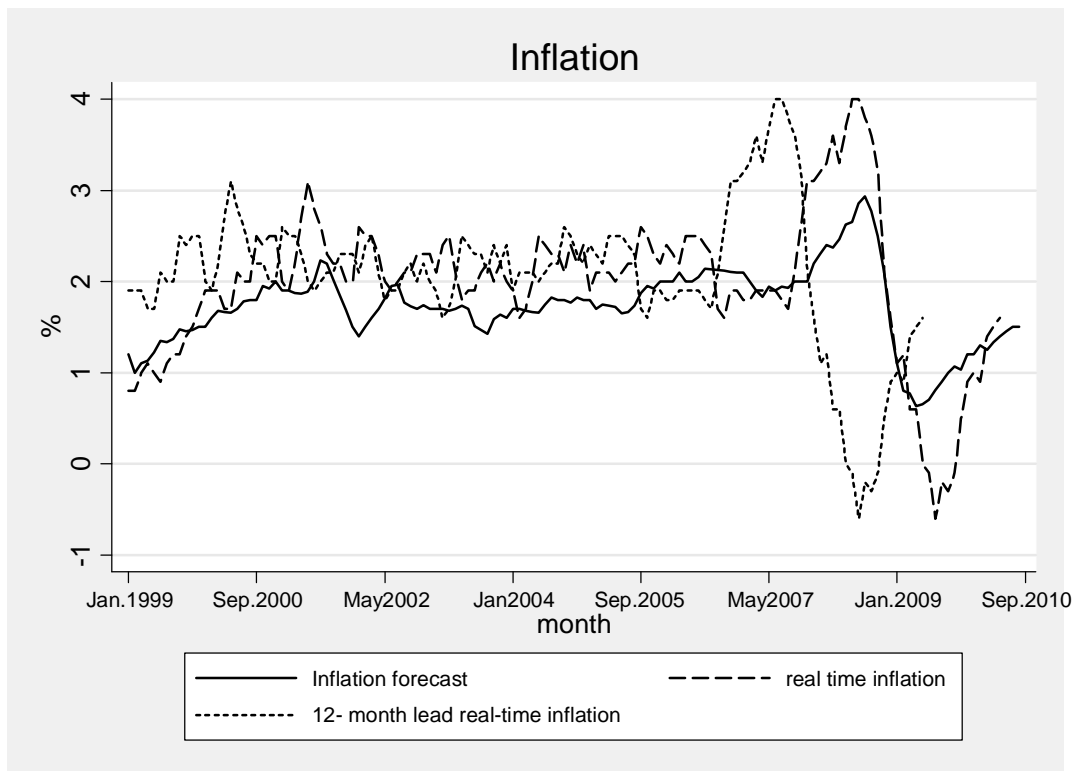


Figure5: Real-time and Revised Growth Rates of M3 in the Euro Area (changing composition), Jan.1999-May 2010.

Source: elaboration on data from ECB website.

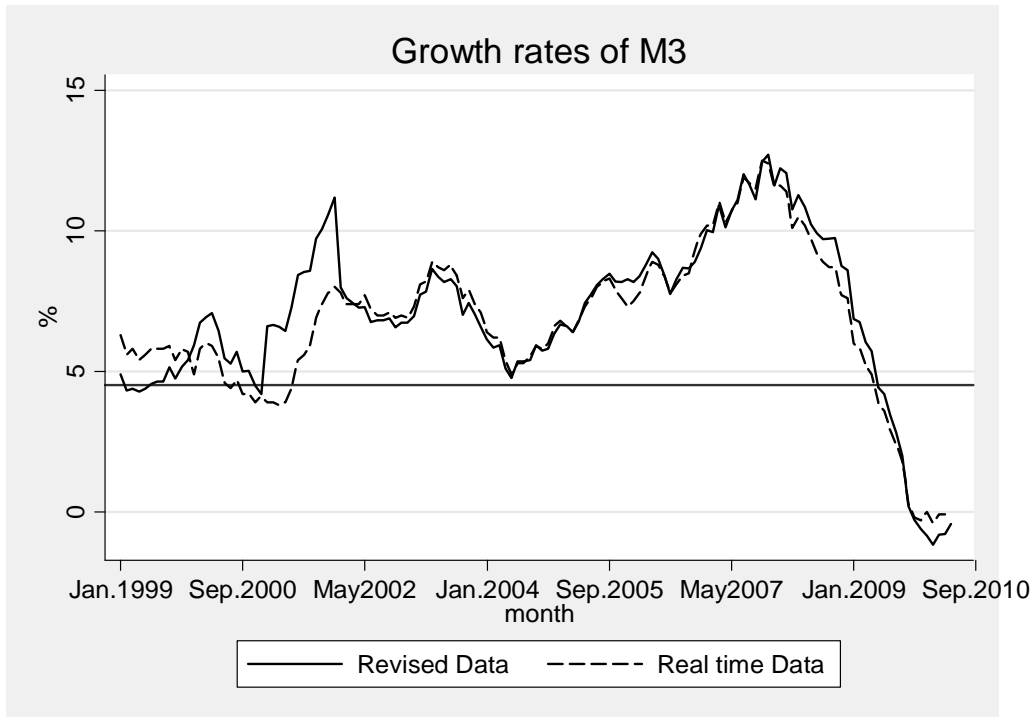


Figure 6: Countries' Risk Premia

Source: elaboration on data from ECB website and IFS.

N.B. Interest Rate Spread between Countries and German 10 yr Bonds

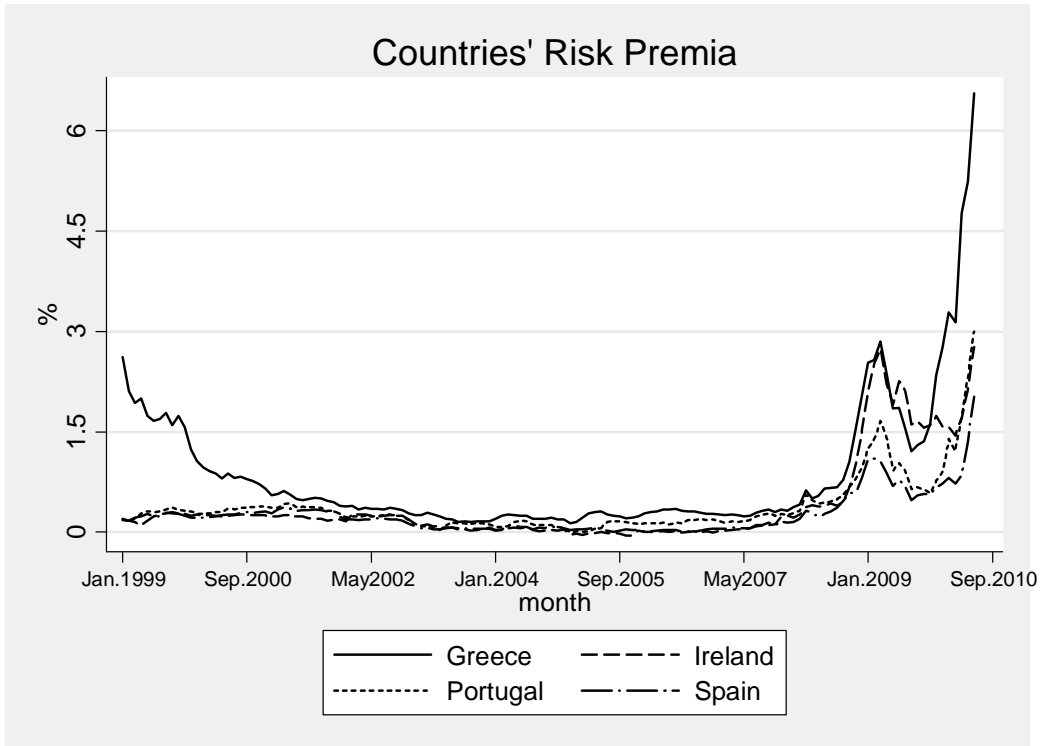


Table 1: Changes in ECB repo rate, January 1999 to June 2010*Source: elaboration on data from ECB website.*

Change in repo rate	Frequency	Percent
-0.75%	1	0.73%
-0.50%	10	7.30%
-0.25%	3	2.19%
0 (no change)	107	78.1%
+0.25%	14	10.22%
+0.5%	2	1.46%
Total	137	100%

Table 2: Summary statistics*Source: elaboration on data from ECB website, the Economist, and IFS.*

Variable	Obs	Mean	Std. Dev.	Min	Max	Missing data
Repo rate	137	2.86	1.06	1.00	4.75	
Change in repo rate	136	-0.01	0.18	-0.75	0.50	Jan-99
Inflation rate	137	1.99	0.81	-0.60	4.00	
Economic Sentiment Index	137	100.46	9.63	70.60	116.30	
Real GDP growth forecast	137	1.69	1.08	-2.20	3.25	
Inflation rate forecast	137	1.73	0.42	0.63	2.93	
Money growth gap Current Account forecast	136	2.29	2.69	-4.90	8.00	May-10
\$/euro exchange rate	137	1.18	0.20	0.85	1.58	
Nom. Effective exch. Rate	137	105.53	10.88	83.94	122.99	
Crude oil price	137	38.81	15.97	9.41	85.93	
Greece risk premium	137	0.80	0.89	0.13	5.24	
Ireland Risk Premium	137	0.38	0.62	-0.05	2.74	
Portugal Risk Premium	137	0.35	0.37	0.00	2.29	
Spain Risk Premium	137	0.24	0.26	0.00	1.35	

Table 3: Whole Sample Period

sample period	Jan1999-May2010					
	1	2	3	4	5	6
Lagged repo rate	-1.267*** [0.349]	-0.956** [0.385]	-4.212*** [0.937]	-4.090*** [0.930]	-4.457*** [0.936]	-6.514*** [1.896]
Lagged change in repo rate	-0.214 [0.229]	-0.286 [0.235]	-0.718** [0.340]	-0.724** [0.337]	-0.303 [0.302]	-0.761** [0.326]
Measure of Economic Activity						
Econ. Sentiment Index	0.234*** [0.047]	0.271*** [0.062]	0.314*** [0.074]	0.306*** [0.072]		0.525*** [0.125]
Real GDP growth forecast					3.001*** [0.739]	
Inflation forecast	0.248 [0.730]	-0.685 [0.982]	-1.114 [1.234]	-1.289 [1.252]	-2.717* [1.416]	1.009 [1.841]
Trichet Presidency		1.246* [0.652]	-0.723 [1.450]	-0.354 [1.446]	0.022 [1.511]	-1.023 [2.069]
Money growth gap			1.035*** [0.272]	1.022*** [0.278]	1.334*** [0.295]	1.347** [0.526]
Money Pillar*Money growth gap			-2.660*** [0.942]	-2.575*** [0.954]	-3.240*** [0.882]	-3.033** [1.371]
Money Pillar Dummy			11.367*** [3.585]	10.761*** [3.782]	13.216*** [3.550]	15.383*** [5.649]
Current Account Forecast			-1.443 [1.151]	-1.187 [1.115]	-3.074** [1.370]	-1.907 [1.517]
Exchange rate						
US dollar/Euro exchange rate			1.301 [4.155]		2.113 [3.850]	8.955 [7.041]
Nom. Effective Exch. Rate				-1.482 [8.365]		
Crude oil price			6.395*** [1.785]	6.569*** [1.698]	6.066*** [1.693]	3.318 [2.154]
RBS						-0.891 [1.614]
Lehman Brothers						5.401** [2.409]
Northern Rock						-3.798*** [1.345]
Greece Risk Premium						-4.552*** [1.619]
Ireland Risk Premium						2.288 [2.828]
Portugal Risk Premium						6.609 [4.443]
Spain Risk Premium						3.843 [6.765]
Observations	136	136	136	136	135	136
Pseudo Rsquare	0.2413	0.2568	0.3959	0.3955	0.3662	0.4622
AIC	183.615	182.238	163.872			163.395

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4: Pre-Crisis Sample Period

sample period	Jan 1999- August 2007				
	1	2	3	4	5
Lagged repo rate	-2.203*** [0.691]	-2.486*** [0.731]	-6.258*** [2.133]	-5.456*** [1.878]	-4.730*** [1.068]
Lagged change in repo rate	-0.640** [0.322]	-0.670** [0.342]	-1.134** [0.569]	-1.135* [0.589]	-0.691 [0.473]
Measure of Economic Activity					
Econ. Sentiment Index	0.466*** [0.117]	0.467*** [0.100]	0.748*** [0.180]	0.633*** [0.151]	
Real GDP growth forecast					6.137*** [1.450]
Inflation forecast	1.894 [1.323]	3.032 [2.679]	-0.856 [3.503]	-0.84 [3.321]	-4.566 [3.130]
Trichet Presidency		-0.858 [1.337]	2.615 [2.636]	0.612 [2.346]	1.855 [2.345]
Money growth gap			1.978** [0.976]	1.418* [0.845]	1.623*** [0.530]
Money Pillar*Money growth gap			-1.557 [1.793]	-0.832 [1.751]	-1.809 [1.162]
Money Pillar Dummy			6.194 [7.051]	3.244 [7.005]	6.957 [4.636]
Current Account Forecast			0.108 [1.973]	-0.4 [1.714]	-3.179* [1.666]
Exchange rate					
US dollar/Euro exchange rate			-30.088*** [9.149]		-12.735* [7.376]
Nom. Effective Exch. Rate				-37.972*** [13.127]	
Crude oil price			4.595* [2.678]	5.205** [2.648]	4.566* [2.423]
Observations	103	103	103	103	102
Pseudo Rsquare	0.2984	0.3021	0.4549	0.4452	0.3664
Wald Test that pre-crisis coefficients = whole period coefficients	9.25	9.73	21.98	19.56	21.68
[p-value]	[0.0553]	[0.0833]	[0.0245]	[0.0518]	[0.0270]

Robust standard errors in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

Data Appendix

Variable definitions:

- Repo rate: target interest rate on the main refinancing operations Inflation rate: computed as annualized percentage change in the Harmonized Index of Consumer Prices in percentage points.
- Headline inflation forecast: forecast of annual growth rate in consumer prices from the Economist poll of forecasters
- Economic Activity forecast: economic sentiment indicator (European Commission) and the real GDP growth rate forecast from the Economist poll of forecasters
- Current Account forecast: Current Account (as a % of GDP) forecast from the Economist poll of forecasters
- Money growth gap: difference between the annualized growth rate of M3 and a reference value of 4.5%
- Trichet dummy variable = 1 after Jean-Claude Trichet became President of the European Central Bank in November 2003.
- Nominal Effective Exchange rate: based on weighted averages of bilateral euro exchange rates against 21 major trading partners of the euro area. If this index rate goes up, more foreign currency can be obtained, on average, for €1. It therefore becomes more expensive, on average, for those who want to exchange foreign currency for euro. Likewise, if this index rate goes down, less foreign currency can be obtained, on average, for €1 and, in turn, it becomes less expensive to exchange foreign currency into euro.
- Crude Oil Price: Brent crude -1 month forward price of a barrel of oil
- country risk premium: difference between the long-term government bond yields of Greece and Germany

Sample:

- January 1999 to May 2010 data for the euro Area. The composition of the euro area changes with the actual number of member countries:
- Euro area changing composition:

Adoption in

- January 1999: Euro11 (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain)
- January 2001: Euro12 (Greece)
- January 2007: Euro 13 (Slovenia)
- January 2008 Euro 15 (Cyprus and Malta)
- January 2009: Euro 16 (Slovakia)
- January 2011: Euro 17 (Estonia) not relevant for our paper

Sources:

Data are obtained from the ECB website, IFS and Eurostat