Does the ECB Act as a Lender of Last Resort During the Subprime Lending Crisis?: Evidence from a Regime Switching Taylor Rule Model

by

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Abstract:

We investigate whether the ECB takes the risk that vulnerable member countries such as Greece, Ireland, Italy, Portugal, and Spain could withdraw from the EMU into account when conducting its interest rate policy. By leaving the EMU, the governments of these countries could finance bank bailouts and reduce the real value of sovereign debt using national monetary policy. Using regime switching Taylor rule models, we find that since February 2007 the ECB has reduced interest rates when banking crisis risk in the countries above increases. Since June 2008 the ECB has reduced interest rates when sovereign debt crisis risk increases.

Keywords: Currency crisis; EMU; Taylor rule; ECB

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1. Introduction

The financial turmoil produced by the subprime lending crisis has been the most difficult challenge for the European Monetary Union (EMU) since its inception eleven years ago (Trichet, 2008). The subprime lending crisis, triggered by global macroeconomic imbalances and lacking policy co-ordination, insufficient banking regulation, and fast credit expansion driven by lax monetary policy, has brought many banks in the EMU to the verge of bankruptcy.[3] National bank bailout plans amounting to hundreds of billions of euros feed speculations about possible sovereign debt defaults in the most vulnerable EMU member countries – Greece, Ireland, Italy, Portugal, and Spain. The five-year yields of Greek sovereign bonds, for example, exceeded those of Germany by up to ten percent in June 2010. These financial vulnerabilities produced by the subprime lending crisis have rapidly increased the national stabilization needs in these vulnerable EMU member countries.

Being that the European Central Bank (ECB) implements a monetary policy for all members of the currency union, it cannot serve to stabilize all nations in the union at all times and consequently national monetary policy is lost as an instrument to buffer macroeconomic shocks. To buffer asymmetric macroeconomic shocks within the currency union, members of a common currency area should meet the prominent optimum currency area criteria such as price and wage flexibility, flexible labor markets, financial market integration, economic openness, high intraregional trade integration, fiscal integration and a diversified industry, political integration and similar inflation rates.[4] There is, however, substantial evidence that the EMU is far from being an optimum currency area. The pre-EMU area lacked labor market flexibility resulting in slow regional labor market adjustments (Obstfeld and Peri, 1998).

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[3] For an excellent overview of the causes and implications of the subprime lending crisis see Kouretas and Papadopoulos (2010).

[4] For excellent surveys of the optimum currency are literature, see Mongelli (2005), De Grauwe (2007), and Dellas and Tavlas (2009).

Since the introduction of the euro, the pace of labor market reforms has been slow (Hughes Hallet et al., 2008). With respect to macroeconomic convergence, Giannone et al. (2008) find that there has been little progress towards synchronization of business cycles within the euro area. Martin (2001) finds that the degree of macroeconomic convergence is small and that regional employment growth is even diverging. Busetti et al. (2007) find evidence in favor of the divergence in inflation rates. Lane (2006) shows that inflation differentials within the EMU have been much more persistent than in the United States, yielding strong intra-EMU real exchange rate movements. Dullien and Fritsche (2009) show that country-specific deviations of the unit labor costs are pronounced and hence, shocks in the EMU are expected to take a long period of time to dissipate.

As a consequence, due to these dissimilarities the subprime lending crisis has led to substantially diverging stabilization needs among EMU countries. While the benefits of the EMU, such as higher transaction costs and the absence of currency risk within the EMU, can be assumed to be relatively stable over time the costs are time-varying. Especially in the vulnerable countries (Greece, Ireland, Italy, Portugal, and Spain) the costs of EMU membership have drastically increased during the crisis since the vulnerable member countries are not able to cope with banking and sovereign debt crises at national discretion. If the central banks of the EMU member countries above were not subordinate to the ECB, they could ease their monetary policies at national discretion. In that case, they would have two options: finance bank bailouts by printing money or reduce the real value of sovereign debt by raising the inflation tax. Being members of the EMU, however, reduces the ability of these countries to cope with financial difficulties in this (inexpensive) way through monetary policy. Entering the EMU was so far considered as being irreversible. By substituting the national currency for euros at an "irrevocably fixed rate"[5], member countries loose their sovereignty over national monetary policy and had hitherto no legal means to reassert it.

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[5] Art. 123(4) Treaty Establishing the European Community (TEC).

Many authors argue, however, that sovereign states *can* choose to withdraw from the EMU (Cohen, 1993; Scott, 1998; Buiter, 1999; Eichengreen, 2007). Polling data of the Eurobarometer suggests that a withdrawal from the EMU would be democratically legitimated in several vulnerable member countries. More than 50 percent of the March 2009 polling respondents in Italy, Portugal, and Spain, for example, believed that using national monetary policy would be more effective in resolving the consequences of the subprime lending crisis than the monetary policy conducted by the ECB (Jones, 2009).[6]

The new Treaty of Lisbon includes a new provision that allows member countries to "withdraw from the Union".[7] This new provision provides for automatic withdrawal if a withdrawal agreement between the withdrawing member and the other members fails: the "Treaties shall cease to apply to the State in question" two years after the Council is notified of the state's intention to withdraw and unless that period is extended.[8] This new provision makes clear that membership in the EMU is *not irreversible* but rather an ongoing freely-made choice. Having the right to withdraw from the EMU may cause the members to re-think the pros and cons of remaining in the eurozone. Of course, the euro entails several benefits for EMU members such as low transaction costs and the absence of currency risk within the EMU (De Grauwe, 2007). The most important drawback is that EMU member countries cannot use national monetary policy in order to address national stabilization needs since the ECB implements a single monetary policy for all EMU members.

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[6] Jones (2009) notes that the increasing distrust towards the ECB and the euro may further complicate monetary policy in the EMU since it becomes harder for the ECB to shape economic agents' expectations.

[7] See Art. 50(1) of the Treaty of Lisbon. Art. 50(2) of the Treaty of Lisbon provides that a withdrawal agreement shall specify the member's "future relationship with the Union." This means that a country may secede from the EMU and still remain a member of the EU (Dougan, 2008).

[8] See Art. 50(3) of the Treaty of Lisbon.

As the economic centrifugal forces in the EMU are growing larger each day, it is no longer a purely hypothetical question whether a member country would consider leaving the EMU. As the crisis of the European Monetary System in 1992 illustrates, opportunistic governments may rationally decide to reassert national authority over monetary policy if the benefits of dropping out exceed the benefits of remaining in a fixed-rate regime (Obstfeld, 1994, 1996).

In order to guarantee the integrity of the EMU, the ECB will implement monetary policies that fit, in particular, the needs of the vulnerable member countries. We expect that the ECB will reduce interest rates if financial vulnerabilities in the five countries above grow. Thus, monetary easing of the ECB may partly be interpreted as a countermeasure of the ECB against the risk of a possible break-up of the EMU. We derive two vulnerability factors that may drive the incentive for governments to withdraw from the EMU. First, governments may choose to leave the EMU in order to finance bank bailouts. After reasserting sovereignty over national monetary policy, domestic banks can be bailed out by printing large amounts of the new national currency. Second, governments may withdraw from the EMU to reduce the real sovereign debt burden by seignorage. Expanding the domestic money supply enables policymakers to reduce the value of public debt in real terms by a higher inflation tax.

In order to prevent withdrawals from the EMU, we expect that the ECB reduces interest rates when banking crisis risk or sovereign default risk in the vulnerable EMU member countries increase. In order to test whether the ECB takes these vulnerability factors into account when implementing its monetary policy, we estimate a Taylor rule model where the interest rate set by the ECB is modeled as a function of financial vulnerabilities which measure the incentives to leave the EMU. We use monthly data from January 1999 to February 2010. This observation period includes a relatively tranquil period of 1999 to 2007, prior to the outbreak of the subprime crisis, as well as the crisis period of 2007 to 2010. To account for the fact that ECB's interest rate policy has responded to the financial

vulnerabilities only since the outbreak of the subprime lending crisis, we use a regime switching model to estimate the Taylor rule.

We find that since the outbreak of the subprime lending crisis the ECB has taken the risk of banking and sovereign debt crisis risk into account when setting interest rates. We find that since February 2007 and June 2008, the ECB has significantly reduced interest rates when banking crisis risk and sovereign debt crisis risk in the five vulnerable EMU member countries increase. This finding indicates that, in order to prevent withdrawals of the most vulnerable member countries from the EMU, the ECB systematically reduces the costs of bank bailout plans and sovereign debt issuance when the risk of banking or sovereign debt crisis increases. Thus, since the outbreak of the subprime lending crisis, the ECB may have become the lender of last resort for the governments of the most vulnerable EMU member countries.

The rest of the paper is organized as follows. Section 2 derives the hypotheses on the supposed incentives to withdraw from the EMU. Section 3 outlines the empirical model. Section 4 describes the data. Section 5 presents the results. Section 6 concludes.

2. Incentives to Withdraw from the EMU

Withdrawing from the EMU is a political choice that involves costs and benefits. While the costs of leaving the EMU, such as higher transaction costs, can be assumed to be relatively stable over time, the benefits are functions of the time-variant severity of the banking or sovereign debt crisis. Thus, assessing whether the ECB responds to the possibility of withdrawal from the EMU requires finding proxies for the benefits of leaving the EMU.

The following derives from the literature two hypotheses about the dependency between the risk of a currency crisis (i.e. the risk of withdrawal from the EMU) and vulnerabilities stemming from the risk of a banking crisis and the risk of a sovereign debt

crisis.[9] We expect that the incentive to withdraw from the EMU is higher, the higher the risk of a banking crisis and the higher the risk of sovereign default is. We argue that if the ECB takes these vulnerabilities into account when evaluating the risk that some countries could leave the EMU, the interest rate set by the ECB should be affected by empirical measures capturing these vulnerabilities. We expect that the ECB will reduce the interest rate if the risk of withdrawal as indicated by our empirical measures increases. In the following two sub-sections we derive the theoretical hypotheses from the literature.

2.1 Coping with Banking Crises

Several papers show that currency pegs can break down if national central banks try to avert banking crises. A banking crisis may force the central bank, acting as a lender of last resort, to bail out troubled banks by printing money which, in turn, produces inflationary pressure that can lead to a currency crisis (Diaz-Alejandro, 1985; Velasco, 1987; Calvo, 1998; Miller, 2000). Kaminsky and Reinhart (1999) present empirical evidence that currency crises often occur after the outbreak of banking crises. We argue that governments may opt to withdraw from the EMU and reassert sovereignty over national monetary policy in order to finance bank bailouts. Thus, a higher banking crisis risk may be associated with a higher risk of withdrawal from the EMU.

Hypothesis 1: If the ECB perceives the risk that vulnerable EMU member countries may leave the EMU in order to avert a domestic banking crisis, we expect that the ECB will reduce the interest rate when banking crisis risk increases.

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[9] In accordance with second-generation models of currency crises, we define the withdrawal from a fixed exchange rate regime (such as the EMU) as the outbreak of a currency crisis (Obstfeld, 1994, 1996).

2.2 Coping with Sovereign Debt Crises

Governments of highly indebted countries may withdraw from the EMU in order to avert the outbreak of a sovereign debt crisis. After reasserting sovereignty over national monetary policy, the government can reduce the real sovereign debt burden by increasing the inflation tax. Several empirical studies confirm that currency and debt crises often occur together (Reinhart, 2002; Dreher et al., 2006; Herz and Tong, 2008). To capture the dependency of both types of crisis, many theoretical approaches apply a second-generation currency crisis framework, which assumes rational expectations and allows for self-fulfilling crises (Bauer et al., 2003; Benigno and Missale, 2004). These models assume that the government minimizes a loss function, which weights the losses associated with a currency and/or debt crisis. The government can choose between devaluing the currency and/or defaulting on the sovereign debt. As a general result, these papers find that the outbreak of a twin sovereign debt and currency crisis is more probable if the government is highly indebted. As both types of crises are interrelated, we expect that a higher sovereign default risk increases the risk of withdrawals from the EMU as perceived by the ECB and thus leads to lower interest rates.

Hypothesis 2: If the ECB perceives the risk that vulnerable EMU member countries may leave the EMU in order to avert a sovereign debt crisis, we expect that the ECB will reduce the interest rate when sovereign debt crisis risk increases.

3. Empirical Model

To test our hypothesis that the ECB takes the risk of withdrawals from the EMU into account when setting interest rates we apply a simple Taylor rule model as outlined in Eq. (1):[10]

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[10] For similar versions of a basic Taylor rule model see, for example, Gerlach and Schnabel (2000) or Adolfson (2007).

$$i_t = \alpha + \delta \tilde{i}_{t-1} + \beta \pi_t + \gamma Gap_t + \chi i_t^{\text{int}} + \theta Z_t + \upsilon_t. \tag{1}$$

Eq. (1) assumes that the nominal interest rate set by the ECB in period t, i_t, is determined by inflation, π_t, the output gap, Gap_t, an aggregate international interest rate measure, i_t^{int}, a smoothing term, $\delta \tilde{i}_{t-1}$, and some additional exogenous variables, Z_t. The aggregate international interest rate measure, i_t^{int},[11] controls for the ECB's reaction to international interest rate trends in order to reduce exchange rate volatility.[12] The smoothing term, $\delta \tilde{i}_{t-1}$, accounts for the fact that central banks prefer interest rate smoothing in order to avoid extreme shocks to the economy (Clarida et al., 1998).

To test whether the ECB's interest rate decisions are affected by the risk of withdrawals from the EMU, we specify the Taylor rule equation as outlined in Eq. (2):

$$i_t = \alpha + \delta \tilde{i}_{t-1} + \beta \pi_t + \gamma Gap_t + \chi i_t^{\text{int}} + \theta_1 VUL_t^{Bank} + \theta_2 VUL_t^{Sov} + \upsilon_t, \tag{2}$$

where the interest rate set by the ECB is influenced by two vulnerability variables: banking crisis risk, VUL_t^{Bank} and sovereign default risk, VUL_t^{Sov}, in the five vulnerable EMU member countries. Higher banking crisis risk or sovereign default risk increases the incentive for the vulnerable member countries to withdraw from the EMU. If the ECB wants to preserve the

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[11] The international interest rate is calculated using a weighted average of the policy interest rates of the G7 countries excluding the EMU countries. As a weighting scheme we use annual GDP weights.

[12] Giannellis and Papadopoulos (forthcoming) find that interest rate shocks drive exchange rate volatility of the potential EMU candidate countries Poland and Hungary and of France, Italy, and Spain during the pre-EMU period. In order to reduce exchange rate volatility, the ECB may therefore be tempted to align its interest rate with the interest rates of other major economies.

integrity of the EMU, we would expect the ECB to reduce interest rates when the risk of withdrawals increases, i.e. we expect negative values for the corresponding coefficients θ_1 and θ_2. To estimate our model we use a regime switching approach, the reason for which is explained in the following. Our observation period includes the relatively tranquil pre-crisis period of 1999 to 2007 as well as the crisis period of 2007 to 2010. We expect that prior to the outbreak of the subprime crisis the risk of withdrawals from the EMU was rather low, for the reason that financial vulnerabilities were too small to justify reasserting sovereignty over national monetary policy. Since the outbreak of the subprime crisis in 2007 the ECB may have perceived a realistic risk that vulnerable countries may withdraw from the EMU in order to cope with banking and sovereign debt crises. Thus, we expect that the ECB has responded to the financial vulnerabilities only since the outbreak of the subprime crisis which has increased the need for the ECB to align its monetary policies with the needs of the vulnerable countries in order to prevent withdrawals from the EMU.

In order to detect if and when the ECB began to align its monetary policy with the stabilization needs of vulnerable EMU countries, we apply a regime switching approach building upon the work of Quandt (1960), Andrews (1993), Andrews and Ploberger (1994), and Hansen (1997) to estimate the Taylor rule model and identify regime switches. Due to the sequence of events in the current crisis we allow for individual break points for each vulnerability variable, i.e. the regime switches concerning the ECB's reaction to the risk of a banking or a sovereign debt crisis might have occurred at different points in time. We would expect that the ECB has taken banking crisis risk into account much earlier than the risk of a sovereign debt crisis since the banking crisis already broke out in 2007, while a considerable sovereign default risk in the five considered countries was not perceived until 2008.

The algorithm to simultaneously determine the individual break points in the coefficients of the vulnerability measures is explained in the following. In the first step, we estimate the following regime switching equation Eq. (3):

$$i_t = \alpha + \delta i_{t-1} + \beta \pi_t + \gamma Gap_t + \chi i_t^{\text{int}} + \theta_1 VUL_t^{Bank} + \theta_2 VUL_t^{Sov}$$
$$+ \Delta \theta_1 D_{1,t}(k_1) VUL_t^{Bank} + \upsilon_t,$$

(3)

where we allow for a regime break in the coefficient of the banking crisis variable in the period k_1, where $D_{1,t}$ is a dummy which has the value 0 before and 1 beyond the break point. That is, we test the null hypothesis of no change in the reaction parameter of the banking crisis variable, i.e. $\Delta \theta_1 = 0$. This simple Chow-test is performed for each possible break point k_1.

In order to detect the most significant break point, we perform the Quandt-Likelihood-Ratio test (QLR), whose F-statistic is given by

$$F_N\left(\frac{k_1}{N}\right) = \frac{(SSR_{1,N} - (SSR_{1,k_1} + SSR_{k_1+1,N}))}{(SSR_{1,k_1} + SSR_{k_1+1,N})} \cdot \frac{(N-2K)}{K},$$

(4)

where $SSR_{i,j}$ is the sum of squared residuals in the (sub)sample [i,j], N is the total number of observations, and K is the number of parameters. The most likely break point k_1 is characterized by the maximum F-statistic for all 104 potential break points in the period May 2000 to December 2008:[13]

$$QLR = \max_{k_1} F_N\left(\frac{k_1}{N}\right).$$

(5)

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[13] Due to multicollinearity, we trimmed 10% of the observations.

In order to test for the significance of the regime switch, we use the distribution of the F-statistic derived by Andrews (1993) and the corresponding asymptotic p-values derived by Hansen (1997). The month, k_1, with the largest F-statistic is determined as the most likely regime break in the determination of the ECB's interest rate policy with respect to banking crisis risk.

Andrews and Ploberger (1994) develop two additional tests for single structural change with optimal power, the Exponential F-statistic (*EXP*) and the Average F-statistic (*AVE*). Both tests examine whether there is a significant shift in selected regression parameters in the sample period. The test statistics are given by

$$EXP = \ln\left(\frac{1}{M}\sum_{k_1=1}^{M}\exp\left(\frac{1}{2}F_N\left(\frac{k_1}{N}\right)\right)\right), \tag{6}$$

$$AVE = \frac{1}{M}\sum_{k_1=1}^{M}F_N\left(\frac{k_1}{N}\right). \tag{7}$$

Given the regime break with respect to banking crisis risk, k_1, we determine the regime break with respect to sovereign debt crisis risk using Eq. (8):

$$
\begin{aligned}
i_t = {} & \alpha + \delta \tilde{i}_{t-1} + \beta\pi_t + \gamma Gap_t + \chi i_t^{\text{int}} + \theta_1 VUL_t^{Bank} + \theta_2 VUL_t^{Sov} \\
& + \Delta\theta_1 D_{1,t}(k_1)VUL_t^{Bank} + D_{t,1}(k_1) + \Delta\theta_2 D_{2,t}(k_2)VUL_t^{Sov} + \upsilon_t,
\end{aligned}
\tag{8}
$$

where we take the break in the banking crisis coefficient as given and test for a regime break in the coefficient of the sovereign debt crisis risk variable in k_2, where $D_{2,t}$ is a dummy

which has the value 0 before and 1 beyond the break point.[14] Under the null of this Chow breakpoint test, the coefficient of the sovereign debt crisis risk variable does not change, i.e. $\Delta\theta_2 = 0$. This Chow-test is performed for each possible break point k_2. In order to detect the most significant break point, k_2, we perform the Quandt-Likelihood-Ratio test (QLR) and choose the maximum F-statistic as outlined in Eq. (5). The month, k_2, with the largest and significant F-statistic is determined as the most significant regime break in the determination of the ECB's interest rate policy with respect to sovereign debt crisis risk.[15]

The regime switching approach described above allows us to determine the most likely date of the regime change for each vulnerability variable. The potential break points are then used to estimate the final Taylor rule:

$$i_t = \alpha + \delta i_{t-1} + \beta\pi_t + \gamma Gap_t + \chi i_t^{\text{int}} + \theta_1 VUL_t^{Bank} + \theta_2 VUL_t^{Sov} + \Delta\theta_1 D_{1,t}(k_1)VUL_t^{Bank}$$
$$+ \Delta\theta_2 D_{2,t}(k_2)VUL_t^{Sov} + D_{t,1}(k_1) + D_{t,2}(k_2) + \upsilon_t. \tag{9}$$

Based on Eq. (9) the pre-crisis marginal effects (ME_{pre}) and the post-crisis marginal effects (ME_{post}) of the vulnerability variables on the interest rate decisions and the respective variances can be calculated by

$$ME_{Bank}^{pre} = \hat{\theta}_1, \qquad \text{Var}[ME_{Ban}^{pre}] = \text{VAR}[\hat{\theta}_1], \tag{10}$$

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[14] The time dummy for banking crisis risk, $D_{t,1}(k_1)$, has to be incorporated in the estimation equation in order to be able to interpret the marginal effects in models with interaction terms (Brambor et al., 2005).

[15] We also tested whether the optimum regime break in the banking crisis risk variable detected using Eq. (3) also holds true when including the break in the sovereign debt crisis risk variable in the regime switching equation (Eq. (3)). For all regime switching models tested, the results for the regime switches remain robust when controlling for regime switches in the other crisis variable.

$$ME_{Sov}^{pre} = \hat{\theta}_2, \qquad Var[\ ME_{Sov}^{pre}\ ] = VAR[\ \hat{\theta}_2\ ]), \tag{11}$$

$$ME_{Bank}^{post} = \hat{\theta}_1 + \Delta\hat{\theta}_1, \quad Var[\ ME_{Bank}^{post}\ ] = Var[\ \hat{\theta}_1\ ] + Var[\ \Delta\hat{\theta}_1\ ] + 2Cov[\ \hat{\theta}_1\Delta\hat{\theta}_1\ ], \tag{12}$$

$$ME_{Sov}^{post} = \hat{\theta}_2 + \Delta\hat{\theta}_2, \quad Var[\ ME_{Sov}^{post}\ ] = Var[\ \hat{\theta}_2\ ] + Var[\ \Delta\hat{\theta}_2\ ] + 2Cov[\ \hat{\theta}_2\Delta\hat{\theta}_2\ ]. \tag{13}$$

4. Data

We use monthly data from the period January 1999 to February 2010. We measure the risk of a banking crisis by computing probabilities of default of individual banks from the five vulnerable EMU member countries. According to the structural credit risk model of Merton (1974), the equity of a firm can be interpreted as a call option that enables the shareholders to buy the firm (the underlying asset) by repaying the firm's debt (the strike price). In the Merton model the firm defaults at the payment date only if the stochastic value of the firm's assets is lower than the debt service payment. Since equity is only valuable if the firm value exceeds the value of debt at maturity, the today's market value of equity can be used to infer the probability that banks default on their debt in the future. A sketch of the Merton (1974) structural credit risk model is explained in Appendix A1. Applying the pricing formulas of the Merton (1974) model we compute a monthly probability of default for each bank included in the sample.[16] In order to obtain an aggregate measure of bank default risk for each country we aggregate the probabilities of default of individual banks in each country using the value of total assets as a weighting scheme. Our banking crisis risk measure for the five vulnerable EMU member countries is calculated as a weighted average of the country-specific probabilities of bank default indices using real GDP weights as the weighting scheme.

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[16] The banks included in the sample for each country are listed in Table A1 in the Appendix.

To quantify the risk of a sovereign debt crisis risk we use sovereign yield spreads. Sovereign yield spreads are calculated as the difference between the redemption yield on domestic sovereign bonds and the redemption yield on German sovereign bonds. We use data on sovereign bonds with a maturity of six years provided by DATASTREAM.[17] To obtain aggregate measures of sovereign default risk we aggregate the country-specific sovereign yield spreads using real GDP weights.

The dependent variable in our regression is the *Euro OverNight Index Average* (Eonia). To estimate the output gap we apply the Hodrick and Prescott (1997) filter to monthly data of the (seasonally adjusted) index of the industrial production of the EMU taken from the OECD database.[18] Due to delayed publication of data we assume the ECB to consider lagged values of the output gap in the reaction function. Allowing lags up to three months, we select the appropriate lag length based on the *Akaike* and *Bayesian* information criteria. Inflation is measured using year-on-year inflation rates based on consumer prices from the OECD. Data on policy interest rates of non-EMU G7 countries used to calculate the international interest rate are taken from national central banks. Data on GDP used as a weighting scheme for the calculation of the international interest rate is taken from the OECD database.

5. Results

Before estimating our models, we check for unit roots in the variables using the Augmented-Dickey-Fuller test and the Phillips-Perron test. The results of the unit root tests (reported in

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[17] We use sovereign bonds with a maturity of six years, since they have higher explanatory power in our estimations than sovereign bonds of different maturities. However, we estimated our models using different maturities, the results of which are similar to the results reported in Table 1.

[18] In our estimations, we use a smoothing parameter of 100,000. We check for robustness using a smoothing parameter of 14,400 as proposed by Hodrick and Prescott (1997).

Table A2 in the Appendix) indicate that the *EONIA*, the inflation rates, the international interest rate, and the vulnerability variables are not stationary in levels and are consequently used in first differences. The estimation equation is given by

$$
\begin{aligned}
\Delta i_t = {} & \alpha + \delta \Delta i_{t-1} + \beta \Delta \pi_t + \gamma Gap_t + \chi \Delta i_t^{\text{int}} + \theta_1 \Delta VUL_t^{Bank} + \theta_2 \Delta VUL_t^{Sov} \\
& + \Delta \theta_1 D_{1,t}(k_1) \Delta VUL_t^{Bank} + \Delta \theta_2 D_{2,t}(k_2) \Delta VUL_t^{Sov} + D_{t,1}(k_1) + D_{t,2}(k_2) + \upsilon_t \,.
\end{aligned}
\tag{14}
$$

Table 1 reports the estimation results for the Taylor rule model (Eq. (14)). The upper panel of Table 2 reports the break point dates for the banking and sovereign debt crisis variables (based on the regime switching equations (3) and (8)) and the associated Maximum, Exponential, and Average F-statistics calculated using Eqs. (5) to (7). The lower panel of Table 2 reports the marginal effects of the banking and sovereign debt crisis variables on the interest rate together with the significance levels determined applying Eqs. (10) to (13).

We estimate four Taylor rule specifications using different variables measuring the output gap and sovereign default risk. Specifications (I) to (III) use a HP-filtered output gap on the basis of a smoothing parameter of 100,000 while Specification (IV) uses a smoothing parameter of 14,400 In Specifications (I) and (IV) we measure sovereign default risk using sovereign bonds with a maturity of six years while we use maturities of four and eight years in Specifications (II) and (III).

Generally, the results are quite robust across different specifications. In all specifications the coefficient for the lagged change in the interest rate is insignificant indicating that the ECB does not focus on interest rate smoothing. The standard Taylor rule coefficients for (the change in) inflation and the output gap are positive and significant at least at the 5%-level, which suggests that – in accordance with the Taylor rule – the ECB tightens (eases) monetary policy when inflation and the output gap increase (decrease). The coefficient of the international interest rate is positive and significant, which indicates that the ECB tends

to coordinate its interest rate policies with the central banks of the non-EMU G7 countries in order to reduce exchange rate volatility.

According to our hypotheses, the coefficients for the breaks in the coefficients of the banking crisis and the sovereign debt crisis variables are negative and significant. This result suggests that since the regime changes (discussed below) the ECB has significantly responded to changes in banking and sovereign debt crisis risk in the five considered vulnerable EMU member countries when conducting its interest rate policy.

The results for the break point analysis in Table 2 indicate a regime break for the banking crisis variable (k_1) in February 2007. The results for the marginal effects suggest that there is no significant impact of banking crisis risk on the ECB's interest rate decisions prior to February 2007, while beyond that date the marginal effect is negative and significant at the 1%-level in all specifications. According to Specification (I) a one percentage point increase in banking crisis risk in the considered five vulnerable EMU member countries yields a 0.09 percentage point decrease in the interest rate set by the ECB. That is, the ECB's interest rate policy is more expansive when the risk of a banking crisis in the five vulnerable countries increases. Thus, we find evidence in favour of *Hypothesis 1*. Since the outbreak of the banking crisis, the ECB has reduced the interest rate when banking crisis risk increases in order to reduce the costs for national bank bailouts. The ECB thereby deteriorates the incentives of vulnerable member countries to leave the EMU in order to finance bank bailout by printing national money.

For the sovereign debt crisis risk variable, the results for the break point analysis in Table 2 indicate a regime break in June 2008 (k_2). The marginal impact of the sovereign debt crisis risk variable on the interest rate is negative and significant since June 2008.[19] According

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[19] Before the regime switch in June 2008, the sovereign default risk variable has a positive and significant impact on the interest rate. This relatively tranquil period was characterized by very low sovereign default risk and thus withdrawing from the EMU was not a desirable option for member countries. Possibly, in times when there is

to specification (I) a one percentage point increase in the sovereign default risk yields a 1.2 percentage point decrease in the interest rate set by the ECB. This result is supportive for *Hypothesis 2*. Since the outbreak of the sovereign debt crisis, the ECB has reduced the interest rate in response to an increase in sovereign default risk in the five considered economies in order to reduce the costs of issuing new sovereign debt. The fact that the regime break with respect to sovereign default risk occurs much later than the regime break with respect to banking crisis risk comes as no surprise because the doubts that vulnerable EMU member countries may default on their debt only emerged when billion euro bank bailout packages had to be financed, following the outbreak of the banking crisis in 2007. The regime break in June 2008 is dated just after JP Morgan took over Bear Sterns on May 30, 2008 to prevent a collapse of the bank. After the takeover of Bear Sterns and the bankruptcy of Lehman Brothers in September 2008 it became imminent that the subprime lending crisis would spread over to Europe. Since then, EMU-based banks are suffering under considerable asset write-offs and the national bank bailout packages may overtax the fiscal capacities of these vulnerable countries.[20] Thus, the ECB may have become the lender of last resort for the EMU governments's sovereign debt.

6. Conclusion

We have shown that since the outbreak of the subprime lending crisis the ECB has taken the risk of banking and sovereign debt crisis risk into account when conducting its interest rate policy. Using a regime switching model we have found that since February 2007 and June

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hardly any risk of withdrawal higher yield spreads might induce tighter interest rate policy of the ECB because the ECB tries to prevent further sovereign borrowing in order to reduce inflationary pressure.

[20] The deposit guarantee of the Irish government for Irish banks, for example, amounted to around 300 billion euros which was around twice the Irish GDP.

2008, the ECB has significantly reduced interest rates when banking crisis risk and sovereign debt crisis risk increased in the five vulnerable EMU member countries – Greece, Ireland, Italy, Portugal, and Spain. In order to prevent withdrawals of the most vulnerable member countries from the EMU, the ECB systematically reduces the interest rates in order to reduce the costs of bank bailout plans and sovereign debt issuance when the risk of banking or sovereign debt crisis increases. In that sense, the ECB may have become the lender of last resort for the governments of these vulnerable EMU members.

Table 1: Results of the Taylor rule model.

Dependent variable: Δi		(I)	(II)	(III)	(IV)
Δi (lagged)		0.061	0.108	0.052	0.120
		(0.651)	(0.965)	(0.553)	(0.982)
$\Delta \pi$		0.092 *	0.091 *	0.092 *	0.079
		(1.668)	(1.715)	(1.700)	(1.459)
GAP	1	0.023 ***	0.023 ***	0.022 ***	
		(4.558)	(4.585)	(4.520)	
	2				0.024 ***
					(3.602)
ΔVUL^{Bank}		0.017	0.017	0.014	0.013
		(0.916)	(0.917)	(0.745)	(0.715)
ΔVUL^{Sov}	1	1.176 ***			1.180 ***
		(3.266)			(3.034)
	2		1.227 **		
			(2.292)		
	3			0.892 ***	
				(2.766)	
$D_1(k_1)$		-0.001 ***	-0.001 ***	-0.001 **	-0.000
		(-2.620)	(-2.654)	(-2.316)	(-1.359)
$D_2(k_2)$		0.001 ***	0.001 ***	0.001 **	0.000
		(2.673)	(3.027)	(2.328)	(0.512)
$\Delta \theta_1 D_1(k_1)\Delta VUL^{Bank}$		-0.132 ***	-0.127 ***	-0.131 ***	-0.099 ***
		(-4.028)	(-3.671)	(-4.051)	(-3.189)
$\Delta \theta_2 D_2(k_2)\Delta VUL^{Sov}$		-2.558 ***	-2.552 ***	-2.341 ***	-2.388 ***
		(-5.759)	(-4.146)	(-5.574)	(-5.299)
Δi^{int}		0.475 ***	0.440 ***	0.499 ***	0.445 ***
		(4.125)	(3.690)	(4.22)	(3.706)
α		0.0001	0.0001	0.0001	0.0001
		(1.006)	(0.965)	(0.825)	(0.982)
k_2		June. 2008	June. 2008	June. 2008	June. 2008
k_1		Feb. 2007	Feb. 2007	Feb. 2007	Feb. 2007
F-statistic		17.43 ***	16.05 ***	17.28 ***	15.56 ***
Adj. R-squared		0.556	0.535	0.554	0.526
No. of obs		132	132	132	132

Note: The t-statistics (in parentheses) are calculated using White-heteroskedasticity-consistent standard errors (White, 1980). *, **, and *** indicates significance on the 10%, 5%, and 1% levels. Specifications (I) to (III) use a HP-filtered output gap with a smoothing parameter of 100,000. In Specification (IV), the output gap is calculated with a smoothing parameter of 14,400. In Specifications (I) and (IV) sovereign default risk is measured by sovereign bonds with a maturity of 6 years while maturities of 4 and 8 years are used in Specifications (II) and (III).

Table 2: Analysis of the break points and marginal effects.

	(I)	(II)	(III)	(IV)
Break point tests				
ΔVUL^{Bank}	Feb. 2007	Feb. 2007	Feb. 2007	Feb. 2007
Maximum LR F-statistic	12.61 ***	10.64 **	12.86 ***	8.36 *
Exponent. LR F-statistic	4.89 ***	4.03 ***	5.00 ***	3.13 **
Average LR F-statistic	8.84 ***	7.34 ***	5.91 ***	5.76 ***
ΔVUL^{Sov}	June. 2008	June. 2008	June. 2008	June. 2008
Maximum LR F-statistic	20.39 ***	11.02 **	20.62 ***	20.23 ***
Exponent. LR F-statistic	6.78 ***	2.33 **	7.22 ***	6.64 ***
Average. LR F-statistic	5.98 ***	1.88	4.87 ***	5.05 ***
Marginal effects				
ΔVUL^{Bank}				
before break	0.017	0.017	0.014	0.013
after break	-0.115 ***	-0.110 ***	-0.116 ***	-0.086 ***
ΔVUL^{Sov}				
before break	1.176 ***	1.227 **	0.892 ***	1.180 ***
after break	-1.383 ***	-1.326 ***	-1.448 ***	-1.209 ***

Note: *, **, and *** indicates significance on the 10%, 5%, and 1% levels. Columns (I) to (IV) represent the specifications as explained in Table 1. Break dates and the LR F-statistics are determined using the QLR procedure explained in Section 4. The three break point statistics are generated using the regime switching equations (3) and (8). The asymptotic p-values for the F-statistic are taken from Hansen (1997).

Appendix A1: Calculation of the Probabilities of Bank Default

Merton (1974) assumes that the total value of the firm is a stochastic variable and follows a geometric Brownian motion as outlined in Eq. (A1):

$$dV = \mu_V V dt + \sigma_V V dW ,$$ (A1)

where V is the total value of the firm, μ_V is the expected rate of return on the firm value, σ_V is the volatility of the firm value, and dW is a standard Wiener process. [21]

It follows from Eq. (A1) that the log returns to the firm value, w, for equidistant intervals $T - t$ are independently identically normally distributed:

$$w_{t,T} \sim i.i.d.[(\mu_V - \frac{\sigma_V^2}{2})(T - t); \sigma_V \sqrt{T - t}] .$$ (A2)

Using these assumptions on the firm value and assuming that the total debt, F_T, is due at a single date of maturity, T, Merton shows that the market value of a firm's equity, E_t, is calculated according to Eq. (A3):

$$E_t = V_t \cdot N(d + \sigma_V \sqrt{T - t},) - F_T \cdot e^{-r(T - t)} \cdot N(d) ,$$ (A3)

$$d = \frac{ln(V_t / F_T) + (r - \sigma_V^2 / 2)(T - t)}{\sigma_V \sqrt{T - t}} ,$$

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[21] In addition Merton (1974) makes the typical assumptions of neoclassical finance theory. He assumes, for example, perfect capital markets where borrowing and lending at an identical risk-less and constant interest rate is possible.

where r is the risk-less interest rate, N(…) describes the value of the cumulative standard normal distribution for the argument in parentheses.

The pricing equation of equity (Eq. (A3)) can be used to back out the unobservable value of the firm and its volatility by using observable data on the value of equity, E_t, the time to maturity, $T - t$, the debt servicing payment at maturity, F_T, and the risk-less interest rate.

A practical problem to solve the system is, however, that only one pricing equation (Eq. (A3)) is used to calculate two unknown parameters – the value of the firm, V_t, and its volatility, σ_V. A common approach to solve that problem is to make use of the dependency of the equity volatility, σ_E, and the volatility of the firm value, σ_V, as outlined in Eq. (A4) (see Gropp et al., 2006):

$$\sigma_E = \frac{\partial E}{\partial V} \frac{V}{E} \sigma_V = \frac{V}{E} N(d + \sigma_V \sqrt{T - t})\sigma_V. \tag{A4}$$

Using Eqs. (A3) and (A4) the value of the firm, V_t, and its volatility, σ_V, can be calculated simultaneously. Having calculated V_t and σ_V we can calculate the probability of default in the present date t for a future date of maturity T by using the standard normal distribution according to Eq. (A5):

$$PoD_{t,T} = N\left(\frac{\ln(F_T / V_t) - (\mu_V - \sigma_V^2 / 2)(T - t)}{\sigma_V \sqrt{T - t}} \right). \tag{A5}$$

We calculate the probability of default for a number of individual banks in the five vulnerable EMU member countries. We use the standard assumptions on the payment framework as follows. Debt at maturity is calculated as short term debt plus ½ long term debt. The time to maturity is assumed to be one year. To measure the risk-less interest rate we use the one-year-EURIBOR. To measure the value of a bank's equity we use the weekly stock price times the number of outstanding shares. All data is taken from DATASTREAM.

Table A1: Domestic Banks Included in the National Banking Crisis Risk Indices.

Country	Included domestic banks
Greece[a]	Alpha Bank, Attica Bank, Bank of Greece, Piraeus Bank, Marfin Egnatia, EFG Eurobank Ergasia, Emporiki Bank of Greece, General Hellenic Bank, National Bank of Greece
Ireland	Allied Irish Banks, Bank of Ireland
Italy	Banca Carige, Intesa Sanpaolo, Banco Populare Etruria, Banco Populare di Milano, Banco Populare Sondrio, Banco Populare di Spoleto, Banco Populare d'Emilia Romagna, Banca Desio Brianza, Banco di Sardegna, Banco Populare, Credito Bergamasco, Credito Emiliano, Credito Valtellinese, Mediobanca, Unicredit
Portugal	Banco BPI, Banco Espirito Santo, Banif SGPS, Banco Commercial Port, Finibanco
Spain	Banco de Valencia, Banco Espanol de Credito, Banco Guipuzcoano, Banco Pastor, Banco Popular Espanol, Bankinter, Banco Santander, Banco Bilbao Vizcaya Argentaria

[a] Greek banks are included thru January 2001, when Greece joined the eurozone.

Appendix A2: Unit-root tests

Table A2: Results of the unit-root tests.

Variable	Augmented-Dickey-Fuller test						Phillips-Perron test					
	(I)		(II)		(III)		(I)		(II)		(III)	
i	-1.04		-1.33		-1.69		-1.04		-1.12		-1.54	
i^{int}	-1.29		-1.95		-2.45		-1.33		-1.07		-1.42	
π	-0.87		-2.49		-2.55		0.91		-2.46		-2.41	
$GAP\,1$	-4.34	***	-4.34	***	-4.31	***	-2.89	***	-2.87	*	-2.87	
$GAP\,2$	-3.57	***	-3.57	***	-3.56	**	-2.22	**	-2.22		-2.22	
$VUL^{Sov}\,1$	-0.51		-1.30		-1.82		-0.87		-1.51		-2.10	
$VUL^{Sov}\,2$	0.01		-0.61		-1.24		-0.64		-1.24		-1.78	
$VUL^{Sov}\,3$	-0.48		-1.23		-1.95		0.02		-0.71		-0.95	
VUL^{Bank}	-2.23	**	-2.58	*	-2.87		-2.02	**	-2.36		-2.57	
Δi	-3.83	***	-3.84	***	-3.94	**	-6.82	***	-6.87	***	-6.93	***
Δi^{int}	-4.25	***	-4.30	***	-4.30	***	-9.90	***	-9.88	***	-10.03	***
$\Delta \pi$	-9.06	***	-9.03	***	-9.12	***	-9.19	***	-9.16	***	-9.23	***
$\Delta VUL^{Sov}\,1$	-7.06	***	-7.06	***	-7.17	***	-7.21	***	-7.21	***	-7.28	***
$\Delta VUL^{Sov}\,2$	-5.78	***	-5.79	***	-6.03	***	-5.98	***	-6.00	***	-6.27	***
$\Delta VUL^{Sov}\,3$	-7.16	***	-7.17	***	-7.29	***	-7.09	***	-7.09	***	-7.10	***
ΔVUL^{Bank}	-7.82	***	-7.79	***	-7.82	***	-7.82	***	-7.79	***	-7.84	***

Note: The table reports the test statistics of the unit-root tests under the null hypothesis of a unit-root in the time-series. *, **, and *** indicates a rejection of the null on the 10%, 5%, and 1% levels. The tests incorporate (I) no exogenous regressors, (II) an exogenous intercept or (III) an intercept and a trend in the test equations. *Gap*1 and 2 are constructed with a HP-smoothing parameter of 14,400 and 100,000. Vul^{Sov} 1, Vul^{Sov} 2 and Vul^{Sov} 3 represent the sovereign yield spreads with a maturity of 6, 4 and 8 years.

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