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The interest rate pass-through in the euro area during the sovereign debt crisis

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We investigate the pass-through of monetary policy to bank lending rates in the euro area during the sovereign debt crisis, in comparison to the pre-crisis period. We make the following contributions. First, we use a factor-augmented vector autoregression, which allows us to assess the responses of a large number of country-specific interest rates and spreads. Second, we analyze the effects of monetary policy on the components of the interest rate pass-through, which reflect banks' funding risk (including sovereign risk) and markups charged by banks over funding costs. Third, we not only consider conventional but also unconventional monetary policy. We find that while the transmission of conventional monetary policy to bank lending rates has not changed with the crisis, the composition of the IP has changed. Specifically, expansionary conventional monetary policy lowered sovereign risk in peripheral countries and longer-term bank funding risk in peripheral and core countries during the crisis, but has been unable to lower banks' markups. This was not, or not as much, the case prior to the crisis. Unconventional monetary policy helped decreasing lending rates, mainly due to large shocks rather than a strong propagation.

Keywords

Interest rate pass-through, factor model, sovereign debt crisis, unconventional monetary policy

JEL Classification

E5, E43, E44, C3

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1 Introduction

In the euro area, banks play a crucial role in the transmission of monetary policy, currently accounting for roughly 50 percent of firm loans and 90 percent of loans to private households. Angeloni, Kashyap and Mojon (2003), summarizing the results of the Eurosystem Monetary Transmission Network, conclude that the interest rate channel is the most important channel for the euro area. Thus, knowledge about the ability of monetary policy to influence bank retail rates is of particular interest for the European Central Bank (ECB).

There exists a large literature on the effect changes in monetary policy rates have on bank retail rates, i.e. the interest rate pass-through (IP).[1] Stylized facts about the IP for the euro area before the outburst of the global financial crisis are that retail rates reacted sluggishly to changes in market rates; transmission used to be complete in the long run only for some retail products, for example short-term lending rates to non-financial corporations.

In mid-2007, the US sub-prime mortgage crisis started to impair the European financial system.[2] Money markets dried up due to a loss of confidence within the banking system, leading to renewed interest especially in the first part of the IP, the transmission from policy rates to money market rates (see, e.g., Čihák, Harjes and Stavrev (2009), Abbassi and Linzert (2012)). These studies find that, while the transmission from conventional monetary policy and monetary policy expectations to money market rates weakened, unconventional measures were effective in reducing money market rates.

The transmission from market rates to bank retail rates gained attention in the course of the sovereign debt crisis, starting with the near default of the Greek government in April 2010. With lending rates increasing sharply in some peripheral countries despite policy rate cuts (see also Figure 1(d)), the ECB concluded that the transmission mechanism was hampered (ECB (2012), ECB (2013)).[3] Other studies (e.g. Aristei and Gallo (2014),

[1] For the euro area, see i.a. Aristei and Gallo (2014), Banerjee, Bystrov and Mizen (2013), Belke, Beckmann and Verheyen (2013), de Bondt (2005), von Borstel (2008), Darracq Paries, Moccera, Krylova and Marchini (2014), ECB (2009), ECB (2013), Hofman (2006), Hristov, Hülsewig and Wollmershäuser (2014), Sander and Kleimeier (2004), Sørensen and Werner (2006).

[2] See Lenza, Pill and Reichlin (2010) and Aristei and Gallo (2014) for a detailed description of the crisis evolution and the ECB's policy response.

[3] This becomes clear from the following statements of the ECB Governing Council when announcing first the SMP and then the OMT.

"The Governing Council of the European Central Bank (ECB) decided on several measures to address the severe tensions in certain market segments which are hampering the monetary policy transmission mechanism and thereby the effective conduct of monetary policy towards price stability in the medium term *[...]*." (10 May 2010)

"*[...]* Exceptionally high risk premia are observed in government bond prices in several countries and financial fragmentation hinders the effective working of monetary policy *[...]*." (2 August 2012)

Moreover, Jean-Claude Trichet, at the time president of the ECB, stated in Vienna in 31 May 2010: "We reduced our key interest rates to unprecedented low levels and introduced a series of nonstandard measures to support credit provision by banks to the euro area economy. This was essential at a time when *[. . .]* severe problems in the money market were hampering the transmission of lower key ECB interest

ECB (2013), Hristov et al. (2014) and Illes and Lombardi (2013)) also find that monetary policy has become less effective in influencing lending rates during the crisis, especially in peripheral countries (in the case of ECB (2013) and Illes and Lombardi (2013) in the sense that other factors such as sovereign risk, macro and borrowers' risk and bank risk dominated monetary policy).

Most studies so far use money market rates as an approximation to the monetary policy stance. However, money market rates were near the zero lower bound (ZLB) and did not move much since August 2012. Unconventional measures which were undertaken instead and which could potentially also have affected bank lending rates are not captured by most of these studies.

We investigate the IP in the euro area over the sovereign debt crisis period and compare it to the IP prior to the crisis. We include the monetary policy interest rate together with a dummy variable capturing important unconventional monetary policy announcements in a factor-augmented vector autoregressive model (FAVAR) together with latent factors extracted from a large set of bank lending rates of individual euro-area countries and components of the IP. The latter capture sovereign risk, banks' funding risk (other than sovereign risk) and markups over funding costs charged by banks. The FAVAR we use can account for possible nonstationarity and cointegration in the data.

We estimate a monthly FAVAR for the sovereign debt crisis period (2010 to 2013), and compare the results with those from a FAVAR estimated over the pre-crisis period (2000 to mid-2007) (which we use as a benchmark and which obviously does not include the unconventional monetary policy announcement dummy). We then look at the effects of changes in money market rates to bank lending rates of individual euro-area countries and their components. We exclude the period from mid-2007 to 2009 (global financial crisis) from our baseline analysis as it has been quite different from the sovereign debt crisis. While interruptions in money markets during the global financial crisis likely led to changes in the transmission from policy rates to unsecured longer-term money market rates, the link between banks' funding costs and retail rates was seen as a major problem during the sovereign debt crisis (Beirne (2012), ECB (2013), Illes and Lombardi (2013)). The period between our two samples is not long enough to be modeled separately in our framework, but we experiment with a longer crisis sample period starting in 2007 in the robustness section further below.

We then assess the effects of unconventional monetary policy on bank lending rates. In our baseline model those are captured by shocks to the unconventional monetary policy announcement dummy, but we also experiment with other unconventional monetary policy shock measures, such as central bank assets, measures computed from (high frequency) asset price movements within a narrow window around announcements (Rogers,

rates to money market and bank lending rates.", which makes clear that the ECB has also been concerned about the IP.

Scotti and Wright (2014)) and measures derived from shadow/ZLB Gaussian Affine Term Structure Models (the shadow short rate and the "effective monetary stimulus" measure; see Krippner (2013*a*), Krippner (2014)).

Our main findings are as follows. The transmission of conventional monetary policy to retail lending rates has not changed during the sovereign debt crisis compared to the pre-crisis period, which differs from previous findings in the literature. However, the composition of the IP has changed. Easy conventional monetary policy reduced sovereign risk in peripheral countries and longer-term bank funding risk in peripheral and core countries, but was not effective in lowering spreads between lending rates and banks' funding costs. This was not, or not as much, the case prior to the crisis. Reasons for the altered transmission to banks' markups could be higher borrower risk (or banks' risk perception), lower competition among banks as a consequence of crisis-induced mergers or insolvencies or the break down in cross-border banking, credit supply constraints, less risk taking due to a stricter regulatory environment or the ZLB which may have been binding at least for the core countries. We leave it to future research to explore in depth the underlying mechanisms.

Unconventional monetary policy had comparable effects on bank lending rates (and the components of the IP) as conventional monetary policy. The effects can be explained with relatively large shocks rather than a strong transmission.

The remainder of the paper is organized as follows. In Section 2, we relate our study to the IP literature and discuss our main contributions. In Section 3 we explain the methodologies to estimate the FAVAR and to decompose the IP. In Sections 4 and 5 we present our data and the results on the transmission of shocks to the monetary policy interest rate to bank lending rates, respectively. In Section 6, we aim at understanding differences in the IP across periods and countries by assessing the transmission to components of lending spreads in (i.a. sovereign risk, bank funding risk other than sovereign risk, banks' margins). In Section 7 we investigate effectiveness of unconventional monetary policy. We finally conclude in Section 8.

2 Contributions to the interest rate pass-though literature

We make three major contributions to the fast growing IP literature.

The first contribution is the use of a FAVAR, which has, to our knowledge, not been applied so far in the IP literature. Using a FAVAR has several advantages. The dynamics of a large number of variables (i.e. interest rates and spreads) can be assessed simultaneously in a consistent framework. Spillovers across markets and countries are accounted for. Also, the FAVAR is an ideal framework for analyzing the transmission of a common driving force (such as euro-area monetary policy) to individual countries and variables.[4] Our

[4] Conventional monetary policy transmission in the euro area has been analyzed before in a factor model

baseline model comprises only interest rates and spreads (to resemble what is typically done in the IP literature). We assess the robustness of our results in Section 5.2 by including factors explicitly accounting for macroeconomic and other developments in the model. The model is very flexible and goes beyond approaches used previously in the literature. The standard IP literature typically explores monetary policy effectiveness in small-scale error correction models (i.e. single equation models or bivariate models which include one retail rate and the policy rate). Exceptions for the euro area are Sørensen and Werner (2006), who use panel estimation techniques, and Hristov et al. (2014)) who use a Bayesian panel VAR and assess the effects of identified monetary policy as well as aggregate supply and demand shocks. Error-correction models, however, neglect the potential interaction between interest rates and cross-country spillovers, whereas panel VARs only allow for a very limited amount of heterogeneity and cross-country dependence, which clearly mattered during the sovereign debt crisis (e.g. Arezki, Candelon and Sy (2011), Beirne and Fratzscher (2013)).

We use a modification of the traditional FAVAR. We adopt the approach of Bai and Ng (2004) to obtain consistent estimates of the factors driving the large set of possibly non-stationary interest rates and spreads, no matter whether the idiosyncratic components are I(1) or I(0). This differs from empirical studies using FAVARs which are typically applied to stationary data.[5] The assumption of interest rates being I(1) is consistent with the IP literature.

Second, we do not only analyze the effects of monetary policy on lending rates but also decompose the spread between lending rates and the policy rate into various stages of the pass-through process, capturing the term spread, sovereign risk, banks' funding risk (other than sovereign risk) and banks' price setting behavior, which is driven, i.a., by credit risk or risk perceptions by banks and competition in the banking sector. Previous studies (e.g. ECB (2013), Illes and Lombardi (2013)) have accounted for factors capturing different types of risk in IP models. However, they investigate the importance of those factors relative to monetary policy and find them to have dominated in peripheral euro-area countries in recent years, but they do not explore how monetary policy has affected those factors.

Third, we analyze not only the effects of conventional monetary policy but also of unconventional monetary policy on bank lending rates. We use several measures for unconventional monetary policy which have been considered in the literature. In our baseline model, we include as a crude measure a dummy variable capturing important monetary policy announcements (as described in Table 2). We also consider central bank assets, high-frequency asset price movements around monetary policy announcements taken from

setup, for example, by Eickmeier and Breitung (2006) and Barigozzi, Conti and Luciani (2014).

[5]Exceptions are Eickmeier (2009), Barigozzi et al. (2014), Banerjee, Marcellino and Masten (2014).

Rogers et al. (2014) (henceforth RSW) as well as the shadow short rate (SSR) and the "effective monetary stimulus" measure (EMS), which are derived from a shadow/ZLB Gaussian Affine Term Structure Model (GATSM). The latter three measures summarize both conventional and unconventional monetary policy. More details are provided in Section 7.

Most other studies analyzing the IP for the crisis period (as for example Hristov et al. (2014) and Illes and Lombardi (2013)) rely on money market rates such as the Eonia (Euro OverNight Index Average) as a measure for monetary policy, neglecting the effects of unconventional monetary policy. One exemption is Creel, Hubert and Viennot (2013) who make use of SMP volumes.

3 Methodology

3.1 Estimating the interest rate pass-through using a FAVAR

The analysis starts with an N-dimensional vector X_t, which includes a large number of bank retail rates and spreads from individual euro-area countries. We assume that X_t is driven by r common factors $F_t = (F_{1t}, \ldots, F_{rt})'$. Following Bernanke, Boivin and Eliasz (2005) the r-dimensional vector of factors F_t can be broken down into an M-dimensional vector of observed factors G_t and an $r - M$-dimensional vector of unobserved (or latent) factors H_t, i.e. $F_t = (G_t', H_t')'$. In our baseline pre-crisis model G_t comprises the monetary policy rate, and in our baseline crisis model it includes the unconventional monetary policy dummy and the monetary policy rate. Due to its preferable time series properties, we apply the Eonia as an approximation to the monetary policy rate, as it is usually done in the IP literature. However, results are very similar when we use the rate for the main refinancing operations (MRO) directly. Hence, $M = 1$ (for the pre-crisis model) or 2 (for the crisis model). H_t will thus reflect factors (other than monetary policy) driving X_t (which can be either I(1) or I(0)). It is assumed that the dynamics of the monetary policy instrument(s) and the latent factors can be described using a VAR(p) model:

$$F_t = c + B_1 F_{t-1} + \ldots + B_p F_{t-p} + w_t, \quad E(w_t) = 0,\ E(w_t w_t') = W. \tag{3.1}$$

The common factors F_t are related to X_t through an approximate dynamic factor model (Bai and Ng (2002), Stock and Watson (2002), Bai and Ng (2004)):

$$X_t = \Lambda' F_t + e_t, \tag{3.2}$$

where $e_t = (e_{1t}, \ldots, e_{Nt})'$ denotes a vector of variable-specific (or idiosyncratic) components, which can be either I(0) or I(1). The matrix of factor loadings is $\Lambda = (\lambda_1, \ldots, \lambda_N)$, where λ_i is an r-dimensional vector whose elements capture the effect of each factor on variable i, $i = 1, ..., N$. The number of common factors is generally well short of the number of variables contained in the dataset, i.e., $r << N$. In addition, F_t may contain dynamic factors and their lags. To that extent, equation (3.2) is not restrictive.

We note that equation (3.2) resembles the simple and intuitive models typically estimated in the IP literature in which lending rates are assumed to be functions of the monetary policy instrument(s) and controls. As noted, our model, in addition, allows for the comovement between different interest rates and spreads in different countries, as reflected in the common factors F_t.

The model can be estimated in three steps. First, we extract H_t from the large dataset. Applying principal components to the data in levels (X_t) bears the risk of inconsistent factor estimation. The reason is that interest rates (and spreads) may be I(1) (consistent with the assumption typically adopted in the IP literature), and it cannot be ruled out that not only the factors are I(1) - which would pose no problem for the principal component estimation, as shown by Bai (2004) - but also the idiosyncratic components. In their "PANIC" (Panel Analysis of Nonstationarity in Idiosyncratic and Common components) approach, Bai and Ng (2004) suggest differencing I(1) series, estimating the factors with principal components applied to the differenced data and re-cumulating those estimated factors. Doing so results in consistent estimates of the factors driving the levels.[6] We therefore apply the Bai and Ng (2004) procedure to our large interest rate and spread dataset, i.e. we estimate factors with principal components, h_t, from (demeaned and standardized) $x_t = X_t - X_{t-1}$.[7] Cumulating $\widehat{h}_t$ yields estimates of latent factors driving X_t, $\widehat{H}_t$.[8]

To determine the dimension of H_t, i.e. the number of common latent factors driving X_t, we adopt an informal criterion and look at the variance share explained by the common factors driving x_t. It turns out that $r - M = 3$ latent factors are sufficient to explain at least 50 percent of the variation in x_t over the pre-crisis period. We need 5 latent factors to explain at least 50 percent over the crisis period.[9] This suggests that there is more heterogeneity in the interest rate and spread dynamics over the crisis period, consistent with ECB (2013) and Illes and Lombardi (2013).

[6]Bai and Ng (2004) argue that, even if some of the (true) idiosyncratic components driving the level series are I(0) and this procedure would lead to overdifferencing, none of the conditions for the consistent estimation of the factors (and the number of factors) would be violated.

[7]Panel unit root tests (as described in Levin, Lin and Chu (2002), and Im, Pesaran and Shin (2003) as well as Fisher-type tests using ADF- and PP-tests as in Maddala and Wu (1999) and Choi (2001)) suggest that most interest rates, but also some of the spreads, are non-stationary.

[8]We slightly deviate from Bai and Ng (2004) in the following respect. The authors difference the data, demean the differenced data, estimate the factors from that transformed dataset with principal components, and ultimately cumulate the factor estimates. We instead apply an OLS detrending to our original data, which does not have the (undesired) property that starting and ending values of the cumulated factors are 0.

[9]More precisely, 3 (5) factors explain 56 (54) percent of the variation in x_t before (during) the crisis. The fourth (sixth) factor accounts for only 7 (5) percent. We show that results are robust when we augment the number of factors.

In the second step, we model the dynamics of $\widehat{F}_t = (G_t', \hat{H}_t')'$ with the aid of a VAR model. The lag lengths have been chosen for the pre-crisis period to be 2 and for the crisis period to be 1 based on the BIC.

Third, we regress each element of x_t, x_{it}, on $\widehat{h}_t$ and stationary versions of G_t (i.e. the first difference of the Eonia for the baseline crisis model and the unconventional monetary policy dummy and the first difference of the Eonia for the baseline pre-crisis model) to obtain estimates of the loadings. Impulse responses of x_{it} to the monetary policy shocks are, hence, computed as linear combinations of impulse responses of the latent and observed factors.

We apply a Cholesky decomposition of the VAR residual covariance matrix where we order the monetary policy instrument(s) first. Hence, we allow the latent factors H_t to respond on impact to unexpected changes in monetary policy. This assumption that monetary policy is predetermined with respect to lending rates is standard in the IP literature and provides us with an upper bound of the monetary policy effects on interest rates and spreads. We emphasize that we do not attempt to seriously identify fully structural monetary policy shocks, which would involve more complex (and debatable) identification schemes. Following the IP literature, we are interested in the pass-through of changes in monetary policy to lending rates, no matter whether they are driven by monetary policy or other shocks. Nevertheless we control, further below, for other factors summarizing macroeconomic and other developments to assess robustness of our results.

We show median impulse responses and 90% confidence bands to shocks to the monetary policy rate (and further below to the unconventional monetary policy dummy and other unconventional measures). The confidence bands are constructed using the bootstrap-after-bootstrap methodology proposed by Kilian (1998) with 500 replications. In the bootstrap, we neglect the uncertainty involved with the (latent) factor estimation following Bernanke et al. (2005) because of the large cross-section dimension.

3.2 Decomposing the interest rate pass-through

Within the framework described in the previous subsection, we first analyze the pass-through from monetary policy rates r_{policy} to bank lending rates r_{retail}, as it is typically done in the IP literature. However, in order to understand the effectiveness of the IP, we will then move on to analyze the reaction of individual components of the difference between bank lending rates and policy rates to unexpected changes in monetary policy, which reflect the different stages within the IP mechanism. The IP is decomposed as follows (see also Illes and Lombardi (2013)):

$$(r_{retail} - r_{policy}) = (r_{retail} - r_{bank}) + (r_{bank} - r_{gov}) + (r_{gov} - r_{rf\_long}) + (r_{rf\_long} - r_{policy}). \quad (3.3)$$

This decomposition captures the transmission from:

1. short-term policy rates to longer-term risk free rates ($r_{rf\_long} - r_{policy}$),
2. longer-term risk free rates to sovereign funding costs ($r_{gov} - r_{rf\_long}$),
3. sovereign funding costs to bank funding costs ($r_{bank} - r_{gov}$),
4. bank funding costs to lending rates for retail customers ($r_{retail} - r_{bank}$).

The first stage of the decomposition ($r_{rf\_long} - r_{policy}$) is related to the Rational Expectations Hypothesis of the Term Structure (REHTS), which states that the spread between a long rate and a short rate should equal the weighted average of expected future changes in the short rate, see Sargent (1972).

The second stage ($r_{gov} - r_{rf\_long}$) gives us insights into the pricing of sovereign risk during the crisis and how sovereign risk reacts to monetary policy. This "sovereign-bank nexus" has gained importance during the sovereign debt crisis (Ejsing and Lemke (2011), Fratzscher and Rieth (2015)), as sovereign risk affected banks' balance sheets. Banks hold domestic sovereign bonds, and sovereign debt serves as liquidity reserves, as collateral for financial transactions, or as an alternative investment opportunity. Hence, during the crisis an increase in sovereign risk caused valuation losses, solvency problems, and lower collateral values for banks (van Rixtel and Gasperini (2013)).

With the third stage ($r_{bank} - r_{gov}$), we consider the effect monetary policy has on bank funding costs besides spillovers from government bond markets and capital or money market conditions. This term mostly reflects banks' risks as perceived by market participants. The effect is ambiguous. After a monetary policy loosening, balance sheets of firms and households improve, leading to reduced loan loss provisions by banks (Bernanke, Gertler and Gilchrist (1999)). Three additional channels through which monetary policy can affect bank risk are discussed in Dell'Ariccia, Laeven and Marquez (2014).[10] Monetary easing lowers bank lending rates, which reduces the return on assets and, hence, the incentive for banks to monitor. This increases bank risk ("pass-through channel"). Through the "risk-shifting channel", a monetary easing lowers the costs of banks' liabilities, which increases banks' profits and, hence, lowers bank risk.[11] Finally, risk increases because of an agency problem: banks with limited liability take on excessive risk since they do not internalize losses they impose on depositors and bondholders in case of failure. Capital serves as a commitment device. Hence, if banks are highly capitalized, depositors demand a lower premium. A reduction in interest rates reduces agency costs and, hence, the need

[10] See also Angeloni and Faia (2009).

[11] Banks typically face a maturity mismatch between assets and liabilities, with maturities of the bank's assets exceeding those of its liabilities, as in Ho and Saunders (1981). At least for countries for which variable-rate loan contracts are less important and securitisation plays a minor role, this leads to an increase in profits after a monetary policy easing and therefore to a decrease in bank risk. Hence, taking different maturities into account, the "risk-shifting" channel dominates the "pass-through channel". See Entrop, Memmel, Ruprecht and Wilkens (2012) for evidence for Germany.

to hold capital. Therefore, banks optimally choose to increase leverage after a loosening of monetary policy, which also increases risk (Adrian and Shin (2011)).

The last stage of the IP ($r_{retail} - r_{bank}$) involves the price setting behavior of banks with respect to their customers, as described e.g. in Freixas and Rochet (1997). It mainly reflects credit risk or risk perceptions by banks, banks' risk-taking behavior as well as bank's efficiency and strategic considerations. The sign of the reaction of lending margins after changes in monetary policy is also unclear *a priori*. A decrease in interest rates lowers the probability of default within the real sector, as in the classical balance sheet channel (Bernanke et al. (1999)). Furthermore, especially in periods of ongoing low interest rates, banks risk appetite increases, as described in Borio and Zhu (2012). Both factors should lead to a compression in margins charged by banks over funding costs. However, margins can also rise after expansionary monetary policy. This might be the case if bank lending rates are adjusted sluggishly due, for example, to market power. Also, if (positive) credit demand effects dominate (positive) credit supply effects, lending rates over funding costs may rise.

4 Data

Within the baseline FAVAR framework, we jointly model the Eonia, the unconventional monetary policy dummy, bank lending rates, and different components of the transmission process as described above.

Plots of the underlying series can be found in Figure 1(a) to (n). Figure 1(a) shows Eonia and ECB's assets for the period January 2000 to December 2013, together with important crisis events and selected announcements of unconventional monetary policy by the ECB. In both periods (January 2000 – June 2007 and January 2010 – December 2013) market rate increases and decreases occur nearly equally frequently. However, it becomes clear that from summer 2012 onwards, money market rates have been close to the zero lower bound. Unconventional measures gained importance. The ECB's total assets, however, already increased markedly after the change in tender procedure to fixed rate full allotment in October 2008 and with the Very Long Term Refinancing Operations (VLTRO) in December 2011 and February 2012. Due to early repayments of VLTROs, ECB's assets strongly declined in the course of 2013.

Bank lending rates included in the model are short-term rates (interest rate fixation periods of less than one year) to firms and private households for the euro area as a whole as well as for 11 member states: Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, the Netherlands and Portugal. Luxembourg is not considered due to missing data. The same holds for countries that joined the EMU after 2002.

We concentrate on lending rates to non-financial corporations as well as on housing loans to private households due to their economic importance, resulting in 24 bank lending rates in the model. Pricing of consumer lending seems to depend more on customers characteristics than on funding costs, which makes it difficult to establish valid IP relationships even before the global financial crisis (see von Borstel (2008) and Aristei and Gallo (2014)). As consumer lending only accounts for roughly 10 percent of lending to private households in the euro area, we exclude consumer lending rates from our analysis. Furthermore, as our main attention will be on the transmission in peripheral countries, only short-term interest rate fixation periods are considered here, representing the typical loan contract in those countries, especially in housing markets, see ECB (2006). However, we will examine the effect on longer-term lending rates in our robustness section.

Lending rates are taken from the harmonized Monetary Financial Institutions Interest Rates (MIR) Statistics. Firm lending rates are aggregated by new business volumes across small-scale and large-scale contracts. As the harmonized data are only available from 2003 onwards, we make also use of non- harmonized data taken from the Retail Interest Rate (RIR) Statistics for the period January 2000 to December 2002 in order to cover an entire interest rate cycle.[12] The pre-crisis sample, hence, covers the period January 2000 to June 2007. For the sovereign debt crisis period, observations from January 2010 to December 2013 are considered. Plots of all retail rates can be found in Figures 1(c) to (f). It is obvious that heterogeneity increased during the sovereign debt crisis especially among firm loan rates.[13]

In addition to the lending rates we include proxies for the components of the IP process, as explained in Section 3.2. Table 1 gives an overview of how the components are calculated.

For the term spread ($r_{rf\_long} - r_{policy}$) the difference between the 10-year OIS rate and the Eonia is taken into account. Due to the single monetary policy, the term spread as a measure for expected monetary policy rates is not country-specific. For the government bond spread ($r_{gov} - r_{rf\_long}$), we calculate the difference between 10-year government bond rates and 10-year euro OIS rates. As counterparty risk is present in 10-year OIS rates, these rates slightly exceeded government bond yields in the pre-crisis period. Thus, German government bond yields are considered instead as the longer-term risk-free rate before the onset of the global financial crisis. During the crisis period, however, German yields have been distorted by safe haven flows, see von Hagen, Schuknecht and Wolswijk (2011). Therefore, OIS rates were used instead. Government bond yields in the core countries (peripheral countries) are shown in Figures 1(g) and (h), respectively.

Longer-term bank funding costs apart from sovereign risk ($r_{bank} - r_{gov}$) are approximated by 5-year CDS-premia for systemically important institutions, see Figures 1(f) and

[12] For short-term lending rates, the combined time series are provided by the ECB. For firm loans, we aggregate the rates on small and large scale loans backwards using the first observed volumes in January 2003 as fixed weights for the whole period January 2000 to December 2002.

[13] Before its accession to EMU in 2001, Greek lending rates strongly diverted from all other rates in our sample due to the still ongoing convergence process.

(g). Simple averages are constructed for each country under consideration. CDS series for Finland could not be included due to missing data. Greece has not been taken into account, as liquidity in bank CDS markets during the sovereign debt crisis has not been high enough to ensure meaningful prices. The spreads between banks' and government funding costs are calculated by adding the 5-year euro-area OIS rates to the CDS premia and subtracting 10-year government bond benchmark yields (corrected for the term-spread between 5- and 10-year OIS rates). The maturity mismatch results from the fact that 5-year contracts represent the benchmark contract in CDS markets, with highest liquidity and most reliable prices, whereas 10-year contracts are typically more relevant in government bond markets. Bank CDS data are available only from January 2003 onwards.

To capture not only longer-term bank funding costs, rates on retail deposits are included as well. We consider deposit rates for overnight deposits, savings deposits, and time deposits for firms and private households, aggregated by new business volumes (see Figures 1(k) and (l)). All rates are taken from the harmonized MIR statistics.[14] Due to the short average interest rate fixation period within these deposit contracts, spreads are calculated with respect to the 3-months OIS rate.[15]

For the last part of the pass-through, the difference between banks' funding costs and retail rates ($r_{retail} - r_{bank}$), overall banks' funding costs are calculated as the weighted average of short-term and long-term funding costs. A similar approach has been applied by Illes, Lombardi and Mizen (2015). Country-specific weights are taken from the respective balance sheet relations in the Balance Sheet Items (BSI) statistics. As a proxy for the costs related to interbank liabilities, the Eonia is considered here.[16] As a price for deposits in banks' balance sheets, the volume-weighted average of all deposits in the MIR statistics is used. For the period January 2000 to December 2002 deposit rates are extended backwards by the RIR data. The costs of securities are approximated by the 5-year CDS spreads for systemically important institutions plus the 5-year OIS rate. These rates are only available from 2003 onwards. For the period January 2000 to December 2002, the bank funding costs index therefore is calculated neglecting the capital market funding of euro-area banks. The price of equity is approximated by a long-term equity premium, which is assumed to equal 5 percent, in addition to the 5-years risk free rate (euro OIS rate), because including real stock market prices would lead to undesirable volatility within the

[14] Aggregating overnight deposits, fixed time deposits and savings deposits for the period January 2000 to December 2002 we used the weights observed in January 2003, similar to the way we aggregated the firm lending rates. For Finland, Ireland and Portugal, not all deposit categories have been reported in the RIR statistics. Our aggregated series, thus, rely on the available deposit categories only.

[15] Since we consider both longer-term and short-term funding cost in our empirical setup, the different stages of the IP will not add to the difference between bank lending rates and policy rates.

[16] It can be argued, that especially for banks in peripheral countries the Eonia does not reflect relevant interbank lending costs. However, to our knowledge, there is no information publicly available on the pricing of interbank loans in peripheral countries. As such, one has to bear in mind that funding costs are presumably underestimated by our index for these countries. This is especially true for Greek banks, as their funding during the sovereign debt crisis has been increasingly relying on ECB's financing.

bank funding indicator in case of asset price bubbles. The assumed long-term equity premium of 5 percent is taken as a rough average of required equity premia calculated for Europe (Fernandez (2006)). The resulting costs are shown in Figures 1(m) and (n).

Policy rates, EONIA, the 10-year euro-area government benchmark rate as well as all macro data we are using below, and data from the MIR, RIR and BSI statistics are taken from the ECB. Longer-term capital market rates as the 5- and 10-year OIS rates and country-specific 10-year government bond rates are obtained from Bloomberg and Datastream respectively. CDS premia were collected from Markit.

Overall, the large dataset to which we apply our baseline model includes 81 variables (interest rates and components). Series on bank CDS for Austria only start in July 2003. We use the expectation maximization algorithm (Stock and Watson (2002)) to convert the (stationary) imbalanced dataset of the first sample period into a balanced one.

5 The pass-through of conventional monetary policy to lending rates

In this section we analyze the effects of conventional monetary policy, i.e. shocks to the Eonia, over the crisis sample period. We compare the transmission over that period with the one over the pre-crisis period, which serves as a benchmark. We focus on normalized shocks which have an instantaneous negative effect on the Eonia of 1 percentage point. This allows us to compare the transmission in the two periods.

We next present results on the transmission to the Eonia itself, to bank lending rates and - further below in Section 6 - the IP components. Throughout the paper, we provide impulse responses for unweighted averages of countries in the core and the periphery of the euro area. For bank lending rates and our baseline model, we also present individual country results. For the IP components we make those results available upon request. In the text, we discuss, however, individual country dynamics whenever they differ notably from the dynamics of the country averages.

5.1 Baseline results

Figure 2 shows impulse response functions of the Eonia to its own shock for the two sample periods. The shock changes the Eonia temporarily, and confidence bands for the two periods overlap, which suggests that differences are not statistically significant. Confidence bands have become somewhat narrower over time. We note that the shock size, measured as the impact effect on the Eonia of a one standard deviation shock, has slightly declined over time, from 0.10 percentage points before the crisis to 0.08 percentage points during the crisis.[17]

Figure 3 shows that bank lending rates to same-sized Eonia shocks decline in both periods. The pass-through does not seem to have changed over time. This holds for housing and business lending rates in the core and in the periphery.[18] Exceptions are the reaction of Greek and Irish housing lending rates. The transmission to the former has become larger over time, whereas the transmission to the latter has become weaker. We shed light into possible reasons in the next section. But overall, there is surprisingly little heterogeneity in the IP across countries, which contrasts with cross-country evidence for the euro area provided by Banerjee et al. (2013), Sørensen and Werner (2006), Darracq Paries et al. (2014). One reason might be that these studies rely on a mixture of short- and long-term interest rate fixation periods within the aggregate bank retail rates. However, within the euro area large differences with respect to consumer's preferences regarding interest rate fixation periods can be observed. As a consequence, resulting retail rates very much differ in their underlying maturity structure. In our baseline model, we decided to stick to short-term lending rates with comparable interest rate fixation periods across countries. Results for longer-term lending rates can be found in the robustness section.

5.2 Robustness checks

In this section we apply an extensive robustness analysis to our baseline crisis model. For the sake of space, we do not show results here, but make them available upon request.

First, we model the latent interest rate and spreads factors as well as the monetary policy instruments together with four latent "macroeconomic factors" in the VAR model. The macroeconomic factors are estimated from a large dataset including macroeconomic variables (industrial production, unemployment rates, consumer and producer price inflation), fiscal variables (such as public debt, the primary public balance and a summary measure of rescue payments which have been received by euro area countries from the euro area rescue vehicles (European Financial Stability Facility and European Stability Mechanism) and the IMF), housing and business loans for individual euro-area countries as well as the euro-area stock market volatility index (VSTOXX), all suitably transformed if necessary. The fiscal series are meant to capture, i.a., rescue measures for banks undertaken during the sovereign debt crisis. The VSTOXX is included to control for financial and uncertainty shocks, which may have mattered especially during the crisis (Gambacorta, Hofmann and Peersman (2014)). The series enter in levels or log levels, and the PANIC approach is applied to this macroeconomic dataset as well. For details on the variables,

[17] These figures seem small, but are broadly consistent with previous work analyzing the monetary policy transmission in the euro area for a recent period (e.g. Soares (2011)).

[18] We have also included small-scale firm loan rates (volumes of less than 1 million) as an approximation to small and medium enterprise (SME) lending in our model. Results are very similar to the results for total loans and thus not reported here.

see Table 1. We add four factors, which explain at least 30 percent of the variation in the (stationary version of) the macroeconomic dataset. We add them to our benchmark FAVAR and order them before the monetary policy instruments and the latent interest rate/spread factors H_t, which reflects the fact that macroeconomic factors are slow moving relative to interest rates. This modification of the baseline model allows us to test whether our latent factors H_t capture indeed all relevant drivers of lending rates (excluding monetary policy) and whether taking them explicitly into account changes our results. The model which includes the macroeconomic factors also embeds more explicitly an interest rate rule, and, hence, allows us to get closer to structurally identified "monetary policy shocks".[19]

Second, we clean the variables in the large dataset from the observable factors prior to estimating the FAVAR as follows. Each variable of the large interest rate and spread dataset (in differences) is regressed on the first difference of the Eonia and the unconventional monetary policy announcement dummy. We then re-run the entire analysis using the residuals.

Third, we carry out the analysis alternatively with seven/nine (rather than five) latent factors, which explain at least 60/70 percent of the variation in x_t.

Fourth, we construct heteroscedasticity-robust confidence bands by means of a wild boostrap where we only resample the signs of the residuals rather than the residuals themselves (Wu (1986), Liu (1988)).[20]

Fifth, we re-estimate the model in levels and apply simple principal components rather than the differencing-and-cumulating ("PANIC") approach.

Sixth, we replace our unconventional monetary policy announcement dummy with central bank assets as a control for unconventional monetary policy.

None of those changes alters our key results.

Seventh, we add to the large interest rate and spread dataset business and housing lending rates with longer interest rate fixation periods (more than 5 years and more than 10 years, respectively) (see Table 1 for a description of the data). While our finding from our baseline for the core countries is confirmed, we find a weaker pass-through to lending rates during the crisis in the peripheral countries. However, those results should be taken with care as longer-term lending rates do not represent typical loan contracts in these countries. Well-behaved series for longer-term retail rates could only be obtained for Italy (Spain and Italy) in the case of business (housing) loan rates, see Table 1.

Finally, we modify the crisis and the pre-crisis sample periods. When we include the

[19] We also looked at the effects of macroeconomic variables to unexpected changes in the Eonia and found that economic activity and prices were somewhat stimulated during the crisis, whereas loans barely moved.

[20] As shown in Monte Carlo simulations by Eickmeier, Lemke and Marcellino (2014), factors can be estimated very precisely with principal components even when there is notable time variation in the factor innovation volatilities.

global financial crisis period in our crisis sample (which then runs from July 2007 to December 2013), the transmission to bank lending rates does not change compared to the shorter crisis sample. However, we detect changes in the transmission to individual components of the IP, which we will discuss in the next section. The fact that we find changes over time confirms the choice of the shorter crisis sample period as our benchmark.

As a final check, we shorten the pre-crisis sample period and begin in January 2003, following most recent IP studies for the euro area (Aristei and Gallo (2014), Belke et al. (2013), von Borstel (2008), Darracq Paries et al. (2014), Hristov et al. (2014)). Relying on this shorter sample allows us to use only harmonized MIR data rather than the combined series of harmonized and non-harmonized data. A drawback, however, of this shorter period is that the pre-crisis sample has mostly been characterized by policy tightenings (i.e. an increase in the EONIA, Figure 1(a)) and, hence, does not capture a full interest rate cycle, unlike the crisis and the longer pre-crisis sample periods. As such, the result of a weakened loan rate pass-through from the pre-crisis to the crisis period might be partly driven by asymmetries, as reported for the euro area among others by Kleimeier and Sander (2006). The IP turns out to be much stronger when estimated based on the period 2003-2007 compared to 2000-2007 and, hence, also much stronger compared to the crisis sample period. This is driven by the fact that also the shock is estimated to be more persistent, i.e. the effect of the shock to the Eonia itself is much longer lasting. This result is very interesting and explains why previous studies typically find that the IP has weakened in the sovereign debt crisis. Relying on a longer pre-crisis sample period, we do not confirm this finding.

Overall we conclude from this section that the pass-through of conventional monetary policy to bank lending rates does not seem to have changed with the crisis. This finding is robust against a large number of alterations to the model. It differs from that of previous studies which tend to find a weakening of the IP during the crisis, possibly because they rely on a pre-crisis sample period which does not cover an entire interest rate cycle. We also find that there is little heterogeneity in the IP across countries. This does not contradict previous results in the literature that there is considerably more heterogeneity in the dynamics during the crisis. We also find that more factors are needed to explain the same share of interest rate rate and spread variation than prior to the crisis.

6 Understanding changes in the pass-through of conventional monetary policy

While we found that the aggregate effects on lending rates are not different in the two periods, we analyze in this section whether the effects on the individual components of lending rates over the policy rate, as described in Section 3.2, have changed over time. We only show results for the country group averages (core and periphery) and make individual country results available upon request.

6.1 Effects on the term spread

Figure 4 reveals that in both periods the risk-free long rate declines by slightly less than the Eonia after the conventional monetary policy shocks, which is in line with the REHTS. The effects are very similar in the two periods.

6.2 Effects on sovereign risk

Sovereign risk was basically not affected in any of the countries before the crisis after a monetary policy loosening (Figure 5). By contrast, we observe a strong and statistically significant decline during the sovereign debt crisis in the peripheral countries, which can be due to either signaling effects or lower funding costs for sovereigns.

Looking at individual country results, sovereign risk decreases particularly strongly in Greece (by about 10 percentage points), which can possibly explain our finding in the previous section that the aggregate effects on bank lending rates have become stronger in Greece. Strong declines are also found in all other peripheral countries (by 1 to 4 percentage points). Sovereign risk in the core countries slightly declines as well during the crisis, driven by developments in Austria, Belgium and France. It increases mildly in Germany. Those results are consistent with findings by Rogers et al. (2014) and Altavilla, Giannone and Lenza (2014) for unconventional monetary policy announcements by the ECB. According to the authors, government bond rates decreased notably in peripheral countries, while they increased slightly in Germany (in case of the latter study only for longer maturities).

The differential response in the core vis-à-vis the peripheral countries may be due to a risk transfer from governments in peripheral countries to governments in core countries, especially in Germany. Safe haven flows from peripheral to core countries after a monetary policy tightening might be an alternative explanation. Given that our model is symmetric, safe haven flows would result in an increase in government bond yields in the core and a decline in the periphery of the euro area after a loosening. When we compare the effects on sovereign risk over the sovereign debt crisis period with those over the extended crisis period starting in 2007, we do not find that Eonia shocks significantly affect sovereign risk in the longer crisis period. Hence, the reduction in sovereign risk is - unsurprisingly - confined to the sovereign debt crisis.

6.3 Effects on banks' funding risk (other than sovereign risk)

CDS spreads corrected for sovereign risk slightly declined prior to the crisis. During the crisis, they declined by more in both core and peripheral countries (Figure 6). Confidence bands resulting from the crisis model are wide. An explanation for the observed changes might be that, due to changes in capital regulation, banks were unable or less able to increase leverage during the crisis after a monetary policy easing (Dell'Ariccia et al. (2014)). Hence, other channels which led to a decline in bank risk dominated. Again, the reduction in CDS spreads is only found for the sovereign debt crisis period, but not for the extended (global financial crisis+sovereign debt) crisis period.

Deposit spreads rose in both periods with similar effects across countries. This finding is in line with the standard IP literature, showing that deposit rates adapt sluggishly to changes in market rates, see e.g. Sørensen and Werner (2006) or von Borstel (2008). The increase in deposit spreads is larger on impact during the crisis pointing to greater sluggishness, but confidence bands overlap thereafter.

6.4 Effects on banks' margins

Figure 7 finally presents impulse responses of banks' margins, i.e. lending rates over bank funding costs. Loose monetary policy brought lending margins down prior to the crisis, although, in the case of housing lending rates, not significantly. While core countries' business loan margins moved similarly during the crisis, peripheral countries' business and core and peripheral countries' housing loan margins increased during the crisis. The business loan margins' reactions for the periphery are driven by Ireland, Italy, Portugal and Spain, but not by Greece where margins declined during the crisis. Housing loan margins' increases are found for all countries but Finland and, again, Greece.[21]

There are several possible explanations for the decline in the transmission to margins. The first explanation is a decline in competition in the banking sector due to crisis-induced mergers and insolvencies and the break down of cross-border banking activities.[22] In a recent study for the euro area, Leroy and Lucotte (2014) show that less competition leads to higher lending rates and a less effective transmission of monetary policy impulses.

Second, monetary policy may have been simply less effective in improving the situation of households in some countries and of non-financial firms because of high unemployment or balance sheet problems, see e.g. ECB (2013).[23]

[21]Results for Greece should be interpreted with care as Greek banks were forced due to lost confidence to substitute on a large scale market and deposit funding by central bank funding (including also emergency liquidity assistance programs) during the sovereign debt crisis. With market and policy rates close to the ZLB, our calculation of the bank funding costs presumably understates funding costs especially for Greek banks. To our knowledge, no better data is available on their true funding costs.

[22]As a consequence, the sum of market shares of the 5 largest banks within each country increased from 49 percent (on average over the years 2000-2006) to 57 percent (2010-2013) averaged across the five peripheral countries considered here. The same holds for the country-specific Herfindahl indices (defined as the sum of squared market shares), which increased from 0.07 (2000 to 2006) to 0.09 (2010 to 2013). Both are measures for concentration (data source: ECB, Structural Financial Indicators).

[23]Unemployment rates in the five peripheral countries considered throughout the analysis doubled from almost 8 percent during the pre-crisis period compared to 16 percent during the sovereign debt crisis (Source: ECB). Similarly, debt to income ratios (after taxes) of non-financial firms rose from 669 percent

Third, excessive risk taking, which would have lowered spreads after a monetary policy loosening, was probably less relevant during the crisis because of (anticipated) regulatory measures undertaken (Basel III). This is supported by Eickmeier, Metiu and Prieto (2015) who find evidence for risk taking in low but not in high financial volatility periods.

Fourth, credit supply constraints during the crisis may have put upward pressure to the spreads after monetary policy loosening shocks. Negative demand effects may, in addition, explain the reaction of loans during the crisis. For example, substitution of non-financial firms away from bank loans to other forms of finance in an effort to become less bank dependent may have played a role in the core countries. See Deutsche Bundesbank (2012) for evidence for Germany.

Fifth, the ZLB mechanically might have led to greater sluggishness in the adjustment of lending rates (although it seems that there was still room, in particular in peripheral countries, to lower lending rates (Figures 1(d) and 1(f)). It is beyond the scope of this paper to explore in depth the underlying mechanisms, and we leave it to future research.

To summarize, while the aggregate effects of conventional monetary policy on lending rates do not seem to have changed, we found that the composition of the IP has changed with the crisis. Monetary policy was unable to lower markups charged by banks over funding costs especially in peripheral countries. At the same time, conventional monetary policy lowered sovereign risk in peripheral countries and bank funding risk (other than sovereign risk) in peripheral and core countries. We note that the robustness checks we discussed for the effects on lending rates carry through to the components of the IP.

7 Effects of unconventional monetary policy on bank lending rates

We proceed by assessing the effects of unconventional monetary policy on bank lending rates. No consensus has been reached in the literature on which measure to use. Moreover, a difficulty is that it is hard to compare the effectiveness of conventional monetary policy prior to the crisis to the effectiveness of overall (conventional and unconventional) monetary policy during the crisis, or even to compare the effectiveness of conventional monetary policy with the effectiveness of unconventional monetary policy during the crisis.

We adopt a broad approach and consider various measures that have been considered in the literature. The measures capture different aspects, ranging from pure monetary policy announcements, central bank balance sheet changes to changes in other risk-free interest rates at longer maturities triggered by monetary policy measures. Some measures cover

(on average between 2002 and 2006, no data available before 2002) to 824 percent (on average between 2010 and 2012, latest data available). Debt to income ratios of households increased from 101 to 130 percent for the same period (Source: Eurostat, Greece not included due to missing data).

unconventional monetary policy in isolation, but we consider also combined conventional and unconventional measures. Some of the latter measures can be compared across the two periods.

Let us introduce the measures we will use.

First, we will look at shocks to our crude measure of unconventional monetary policy included in our baseline, i.e. the dummy capturing announcements of unconventional monetary policy.

Second, we will replace the dummy with the logarithm of ECB's central bank assets, which we order as well before the Eonia.[24] Central bank assets should influence longer-term interest rates by affecting the supply and demand for assets, leading to changes in prices and portfolio rebalancing effects ("portfolio balance channel"). They have previously been used as a measure of unconventional monetary policy, e.g., by Gambacorta et al. (2014) and Boeckx, Doosche and Peersman (2014).

Third, we will replace both the Eonia and the dummy in our baseline with a monetary policy measure proposed by RSW, which is available over the crisis sample period.[25] It relies on the idea of Gurkaynak, Sack and Swanson (2005), measuring monetary policy surprises directly from high-frequency asset market data. For the euro area, the RSW data reflects movements of the spread between 10-year Italian and German government bond yields within a 30 minutes window around conventional and unconventional monetary policy announcements. The authors argue that the ECB's unconventional monetary policy was addressed to influence sovereign bond spreads.

Fourth and fifth, we will use as the only monetary policy instrument in the FAVAR either the SSR or the EMS. The SSR and the EMS are derived from a shadow/ZLB GATSM (Black (1995), Krippner (2012), Krippner (2013*a*), Krippner (2013*b*), Krippner (2014)). The SSR is the short rate in absence of physical currency and can be negative at the ZLB. The EMS is the integral of expected SSR over all horizons, truncated at zero, versus the neutral rate. It reflects the actual monetary policy stimulus and is inversely related to interest rates. The EMS contains information not only about actual monetary policy, but also about future monetary policy as expected by market participants. It has been pointed out for the euro area by Banerjee et al. (2013), Hofman and Mizen (2004), Kleimeier and Sander (2006) and Kwapil and Scharler (2010) that against the background of adjustment costs for bank retail products, expectations about future monetary policy rates matter for the speed and completeness of the IP. Moreover, at the ZLB, when conventional instruments are no longer available, influencing interest rate expectations by announcing unconventional measures remains one of the possible means to stimulating the economy

[24]We also switched the ordering between central bank assets and the Eonia. Results remain similar, although the central bank asset shocks have slightly weaker and less statistically significant effects on lending rates.

[25]We are grateful to Jonathan Wright for providing us with the measure.

("signaling channel" (Bauer and Rudebusch (2011)).[26] The EMS also overcomes some of the weaknesses of the SSR, as recently pointed our by Krippner (2014), such as lack of robustness with respect to the specific term structure modeling choice. More details on the concepts of the SSR and the EMS and the precise measures we use in our analysis are provided in the Appendix.

An advantage of the SSR and the EMS is that they represent measures of monetary policy that are consistent over the two periods. Before the crisis the SSR captures conventional monetary policy. During the crisis, it captures both conventional and unconventional monetary policy to the extent that the unconventional policy moved the yield curve. The EMS captures over the pre-crisis period current and future expected conventional monetary policy. In the crisis period it embeds, in addition, current and future expected unconventional monetary policy. The influences are translated via the term structure into a common metric, which renders them comparable across periods.

We first use the latter two measures and re-estimate the models including those measures over the two sample periods. We look at impulse responses of lending rates to expansionary SSR and EMS shocks which changes the measures by 1 percentage point in each period, as we did before for the Eonia shocks. Results are presented in Figures 8 and 9. It seems that the transmission has become weaker over time. We find, as for the Eonia shocks, no notable differences between core and peripheral countries. We also compute the size of the shocks (i.e. the impact effects of one standard deviation shocks on the SSR and the EMS themselves) and find that SSR and EMS shocks over the crisis period are about 1.5 times as large as over the pre-crisis period.

As the next step, we provide in Figure 10 the effects on lending rates between 2010 and 2013 to "typical", one standard deviation, shocks to all unconventional and combined (unconventional and conventional) measures, in comparison to one standard deviation shocks to the Eonia from our baseline model. We find that all shocks lead to - at least marginally - significant declines in bank lending rates. This holds for business and housing lending rates and for core and peripheral countries. Given that central bank assets and the dummy represent only unconventional monetary policy shocks, we can conclude that unconventional monetary policy exerted some additional effect on bank lending rates. Shocks to the unconventional and the combined measures tend to trigger weaker reactions of lending rates than Eonia shocks. However, confidence bands overlap with those of impulse responses to Eonia shocks. We finally do not show here, but note that the effects of the measures including unconventional monetary policy on the IP components are qualitatively very similar to the Eonia shock effects presented in Section 6. Most importantly, expansionary unconventional monetary policy has also been unable to lower banks' margins or even raised them.

[26] These considerations presumably led the ECB to introduce formal forward guidance in July 2013.

Overall, we conclude that unconventional monetary policy complemented conventional monetary policy and helped lowering lending rates. This was, however, mainly driven by large unconventional monetary policy shocks, whereas the propagation of unconventional monetary policy over the crisis has probably been weaker than the propagation of conventional policy.

8 Conclusion

We analyze the interest rate pass-through within the euro area, capturing a variety of interactions between different retail rates, market rates and countries. We look at the pass-through of conventional as well as unconventional monetary policy before the global financial crisis and during the sovereign debt crisis.

We find that the aggregate (conventional) pass-through, i.e. the effects of conventional monetary policy to bank lending rates, has not changed during the crisis compared to prior to the crisis. This finding is robust against a large number of alterations to the model. It differs from previous studies which tend to find a weakening of the IP during the crisis, possibly because they rely on a pre-crisis sample period which does not cover an entire interest rate cycle. We also find that there is little heterogeneity in the IP across countries. This does not contradict previous results in the literature that there is considerably more heterogeneity in the dynamics during the crisis. We also find that more factors are needed to explain the same share of interest rate rate and spread variation than prior to the crisis, which supports that literature.

While the aggregate effects do not seem to have changed, the composition of the IP is found to have changed. This is investigated by decomposing the spreads between lending and policy rates into the different stages of the pass-through process. We find that easier monetary policy during the crisis period reduced sovereign risk spreads in the euro-area periphery as well as longer-term banks' funding risks (other than sovereign risk) in both the core and the peripheral economies. However, monetary policy was not able to reduce the markup over funding costs charged by banks. This has not, or not as much, been the case prior to the crisis. Credit supply constraints, increased perceptions of non-financial private sector risks by banks in the peripheral countries, decreased competition due to crisis-induced mergers and insolvencies and the break-down of cross-border banking, or the fact that lending rates were close to the ZLB in the core countries during the sovereign debt crisis, could have mattered.

We finally investigate how effective unconventional monetary policy has been. We find that unconventional monetary policy complemented conventional monetary policy and helped lowering lending rates. This was, however, mainly driven by large unconventional monetary policy shocks, whereas the propagation of unconventional monetary policy over the crisis has probably been weaker than the propagation of conventional policy.

We are now ready to derive some policy conclusions. First, the aggregate IP has not been hampered during the crisis. We note, however, that the IP is only one - although important - aspect of the monetary transmission mechanism which the ECB's policy intended to repair. Second, however, the transmission to banks' margins, one component of the IP, seems to have been distorted. It seems important to adopt policies which help reduce credit supply constraints and borrower risk and which help re-establish competition in the banking sector. Unconventional monetary policy does not seem to be the right tool (just as conventional monetary policy, which is also not available anymore), as it has also been unable to lower margins during the crisis.

9 Appendix: Shadow Short Rate and Effective Monetary Stimulus

In this section we present the Shadow Short Rate (SSR) and the Effective Monetary Stimulus (EMS) measure we use in our analysis to quantify monetary policy.

The measures are derived from an estimated shadow/ZLB Gaussian Affine Term Structure Models (GATSM). Shadow/ZLB-GATSMs have become popular recently as a means of representing the yield curve in environments when the ZLB is a material constraint.

To provide an overview relevant to this paper, shadow/ZLB-GATSMs are based on the Black (1995) mechanism:

$$\underline{\mathrm{r}}(t) = \max\{0, \mathrm{r}(t)\}$$

where $\underline{\mathrm{r}}(t)$ is the actual short rate and $\mathrm{r}(t)$ is the shadow short rate (SSR), which can take on negative values. Specifying a GATSM process for $\mathrm{r}(t)$ therefore defines both the shadow term structure and the ZLB term structure simultaneously. We refer readers to the ZLB papers we cite for details on the general framework, but we provide an overview of the key elements of our specific framework below.

The SSRs obtained from shadow/ZLB-GATSMs have been proposed as a measure of the stance of monetary policy; e.g. see Krippner (2012), Krippner (2013*a*), Wu and Xia (2014) and Lombardi and Zhu (2014). The proposal has intuitive appeal because the estimated SSR can evolve to negative levels even while the actual policy rate (or its proxy) is constrained by the ZLB. Therefore, a negative SSR can give an indication of whether the overall stance of monetary policy, including the policy rate and longer-horizon policy rate expectations that are more influenced by unconventional policy measures, is more stimulatory than just a zero policy rate setting. For example, Figure 1(b) shows that the estimated SSR for the euro area became negative around February 2010 and reached its minimum of -2.7 percent in December 2012, while the deposit facility already was set to 0 in July 2012.[27]

[27] After the introduction of the fixed rate full allotment tender policy by the ECB in August 2008, the

The estimate for the SSR we use in our analysis and show in Figure 1(b) is based on a two-level term structure model. We also estimated the SSR from a three-factor model term structure model. However, while the resulting SSR basically remains at zero at the ZLB, the SSR derived from the two-level model displays strongly negative developments at the ZLB, which we think are more meaningful given the additional stimulus from unconventional monetary policy. The estimated confidence interval of the two-factor SSR estimates is a maximum of +/- 29 basis points over our sample period.

From a practical quantitative perspective, SSRs have been shown to be sensitive to the practical choices underlying their estimation, in particular the number of state variables (or factors) used to represent the shadow term structure; see, for example, Christensen and Rudebusch (2014), Christensen and Rudebusch (2013), Bauer and Rudebusch (2014), and Krippner (2013*a*).[28] Moreover, from a theoretical economic perspective, negative SSRs are not an actual interest rate faced by economic agents, who will continue to face current and expected interest rates based on the actual ZLB-constrained rates (with appropriate margins). As such, SSRs are not fully comparable across conventional/non-ZLB and unconventional/ZLB environments. In other words, a decline in the SSR when it is already negative need not deliver the same stimulus as a same-size decline in the actual policy rate during conventional periods, because short-maturity rates on the actual yield curve have no scope to move lower in the ZLB environment.

The EMS measure improves on the SSR by directly summarizing the current and expected actual short rate relative to a neutral interest rate. Specifically, the shadow yield curve is specified to be an arbitrage-free Nelson-Siegel model, as popularized by Christensen, Diebold and Rudebusch (2011), the nominal neutral rate is the estimated Level component of the shadow/ZLB-GATSM, and the expected path of the actual short rate is obtained from the non-Level components (i.e. Slope and Curvature in the three-factor model) subject to truncation at the ZLB. The truncation demarks the component of the SSR and its expectations that is "effective", i.e. that delivers rates of zero or above which therefore are passed through to actual interest rates along the yield curve. The EMS is then the integral of the difference between the expected actual short rate and the neutral rate over the time horizon from zero to infinity. We refer readers to Krippner (2014) for additional details on how the EMS is calculated from the estimated state variables and parameters for a shadow/ZLB-GATSM, but Figures 11(a) and (b) provide the essential intuition for two yield curve examples.

Figure 11(b) shows that in ZLB periods short rate expectations will initially include a period of zero followed by a non-zero path that converges to the prevailing nominal neutral

deposit facility can be regarded as the relevant policy rate due to excess reserves, see Beirne (2012) for a very detailed discussion. Consequently, in Figure 1(a) and (b), the policy rate is depicted by the main refinancing operations (MRO) up to August 2008 and the deposit facility (DF) afterward.

[28]Krippner (2013*a*) also shows that the maturity span of the data and the estimation method can also cause material variation in the estimated SSRs.

rate estimate. Figure 11(a) shows that in non-ZLB periods the expected path of the short rate is entirely non-zero as it converges to the prevailing nominal neutral rate estimate. However, in both regimes, the EMS measure aggregates expected short rates relative to the prevailing nominal neutral rate, with both obtained from the single shadow/ZLB-GATSM that is estimated consistently across both regimes. Hence, the EMS measure is directly comparable between ZLB and non-ZLB periods. The estimated confidence interval of the two-factor EMS estimates is a maximum of +/- 150 basis points over our sample period.

For ease of interpretation, we highlight two aspects of the EMS. First, we have defined it so that a larger value of the EMS indicates easier overall monetary policy. Specifically, as in the cross-sectional Figures 11(a)-(b), a larger value indicates a larger gap between expectations of the actual policy rate and the neutral rate. Second, the unit of the EMS is percentage points, as is the gap between expectations of the actual policy rate and the nominal neutral rate. However, a one percentage point change in the EMS should not be taken as being approximately equal to a one percentage point change in the policy rate. The reason is that the EMS, being the entire area of the gap between expectations of the actual policy rate and the nominal neutral rate, also accounts for the expected persistence of any given policy rate change and any influence a policy rate change may have on future expected changes in the policy rate.

The EMS measure we use in our baseline model is obtained via a shadow/ZLB-GATSM that is based on the two-factor (i.e. Level and Slope) arbitrage-free Nelson-Siegel model. The data are monthly averages of daily yields on fixed income instruments with maturities of 0.25, 0.5, 1, 2, 3, 5, 7, 10, 15, 20, and 30 years obtained from Bloomberg. The sample period is January 1999 to December 2014. We use euro overnight indexed swap (OIS) rates from January 2006 (when it first became available), and German government bond data prior to that as a proxy for OIS rates.[29] To improve the estimates of the nominal neutral rate, the long-horizon surveys of inflation plus real output growth from the ECB Survey of Professional Forecasters have been used to supplement the yield curve data. Note that these survey data produce a long-horizon neutral rate estimate that is more akin to Wicksellian natural rate, and which is therefore more stable over time compared the more cyclical neutral rates obtained from small-scale structural models. The estimated EMS for the euro area is shown in Figure 1(b), together with the SSR and the Eonia. The figure reveals that increases in the EMS typically coincide with declines in policy rates or increases in central bank assets.

We note that the EMS we use in our baseline model also includes term premia (i.e. the Q measure; see Krippner (2014)). One reason is that unconventional monetary policy has been found to have an effect via both expected short-term interest rates and term premia (e.g. Rogers et al. (2014)). Another, perhaps more important, reason is the general

[29] Our choice of German government bond data for the early part of the sample was based on our finding that it had a better correlation with OIS rates in the period from 2006 compared to alternatives we tested.

result that term premia are imprecisely estimated from term structure models when only yield curve data is used for the estimation. Therefore, removing term premia explicitly from the EMS involves a notable amount of uncertainty. For example, the estimated confidence interval for the EMS under the physical P measure (i.e. without risk premia) from the shadow/ZLB term structure model estimated for the present paper is more than 20 percentage points, and is also very asymmetric, so it would not be suitable to use as data. Supplementing the estimation with non-yield curve data could potentially improve the precision of the P-measure EMS and risk premia, and we note this avenue for future research.

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Table 1: Data sources and variable transformations

Variables	Data description	Countries	Sources
Baseline model			
Firm loan rates	Firm lending rate with interest rate fixation periods of less than one year, aggregated over different size of loans by new business volumes.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	ECB
Housing loan rates	Housing loan rate with interest rate fixation periods of less than one year.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	ECB
Government bond spreads	Difference between 10-year government bond yields and 10-year Euro swap rates.	AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	Datastream
	Difference between euro area 10-year benchmark government bond yield and 10-year Euro swap rate.	EA	Datastream, ECB
Deposit spreads	Spread between aggregate deposit rate (overnight deposits, savings deposits and time desposits) for private households and firms, aggregated by new business volumes, and 3-months OIS rate.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	Datastream, ECB
CDS spreads	Spread between average of 5-year bank CDS rate for systemically important institutions and 10-year government bond yields (corrected for term premium measured by the difference between 5 and 10-year euro swap rates).	EA, AT, BE, DE, ES, FR, IE, IT, NL, PT	Datastream, ECB, Markit
Bank funding cost index	The bank funding cost index is calculated as the weighted average (weights taken by aggregate national bank balance sheet data), where interbank liabilites are weighted by the EONIA, non-MFI deposits by the aggregate deposit rate, securites by 5-year bank CDS-premia plus 5-year Euro swap rates, equity by 5-year Euro swap rate plus assumed long-term equity-premium of 5 percent.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	Datastream, ECB, Markit
Markup on firm loans	Difference between aggregate firm lending rate and bank funding cost index.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	Datastream, ECB, Markit
Markup on housing loans	Difference between housing loan rate and bank funding cost index.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	Datastream, ECB, Markit

Variables	Data description	Countries	Sources
Robustness checks			
Macroeconomic data	Logarithms of industrial production index, differences of the logarithms of the harmonized index of consumer prices (HICP) and producer price index (PPI), standardised unemployment rate. All macroeconomic series have been seasonally adjusted by Census X12.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	ECB
Fiscal data	Logarithm of general government debt (stocks at nominal value) over GDP in percentage points, and deficit/surplus in percentage points. All fiscal series were interpolated from quarterly to monthly by the cubic-spline method and seasonally adjusted by Census X12.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	ECB
Rescue dummy	Log-differences of rescue payments made by EFSF/ESM, EFSM and IMF for countries within the euro area.	EA	IMF, EFSF, ESM, European Comission
VSTOXX	Square root of implied variance of EURO STOXX 50 realtime options of a given time to expiration.	EA	VSTOXX
Firm loan volumes	Differences of the logarithms of outstanding amounts of loans to non-financial corporations denominated in Euro, divided by country-specific price developments (HICP). Seasonally adjusted by Census X12.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	ECB
Housing loan volumes	Differences of the logarithms of outstanding amounts of loans to households and non-profit institutions serving households denominated in Euro, divided by country-specific price developments (HICP). Seasonally adjusted by Census X12.	EA, AT, BE, DE, ES, FI, FR, GR, IE, IT, NL, PT	ECB
Long-term firm lending rates	Aggregate firm lending rates with interest rate fixation periods of more than 5 years, aggregated over different size of loans by new business volumes.	EA, AT, BE, DE, FR, IT, NL	ECB
Long-term housing loan rates	Housing loan rates with interest rate fixation periods of more than 10 years.	EA, AT, BE, DE, ES, FI, FR, IT, NL	ECB

Notes: Data on deposit rates and long-term lending rates have been extended backwards for the period January 2000 to December 2002 by means of the non-harmonized RIR statistics.

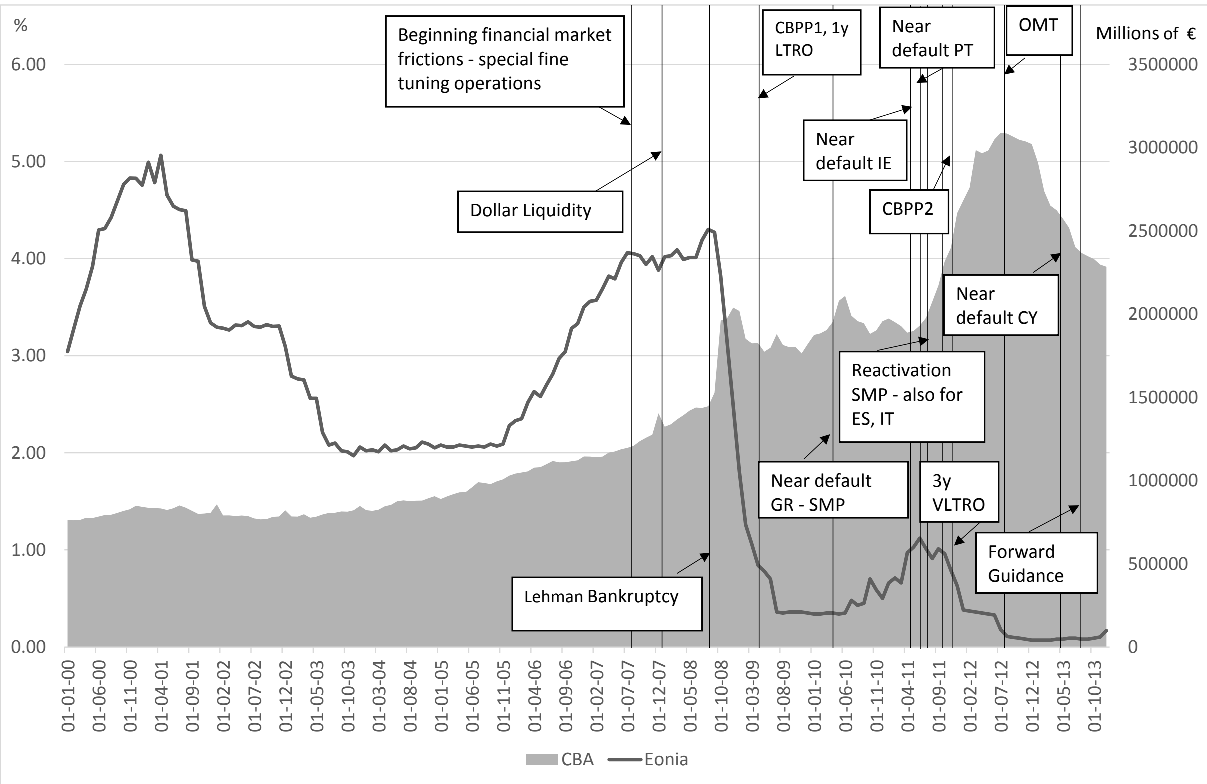
Table 2: Main events covered by the unconventional monetary policy announcement dummy

Date	Event
August 2007	Special fine-tuning operations, supplementary Long Term Refinancing Operations (LTRO)
December 2007	Dollar liquidity
March 2008	6 months LTRO
October 2008	Full allotment
May 2009	1-year LTRO and Covered Bonds Purchase Program (CBPP)
May 2010	Securities Market Program (SMP) and change in collateral requirements (issued or guaranteed by Greek government)
May 2011	Change in collateral requirements (issued or guaranteed by Irish government)
July 2011	Change in collateral requirements (issued or guaranteed by Portuguese government)
August 2011	Reactivation of SMP
October 2011	CBPP2
December 2011	Announcements of 3-year very long term refinancing operations (VLTRO), results of first 3-year VLTRO
February 2012	Results of second 3-year VLTRO
July 2012	"Whatever it takes"-speech in London
August 2012	Announcement Outright Monetary Transactions (OMT)
March 2013	Change in collateral requirements (government guaranteed bank bonds)
May 2013	Change in collateral requirements (issued or guaranteed by Cypriot government)
July 2013	Forward Guidance

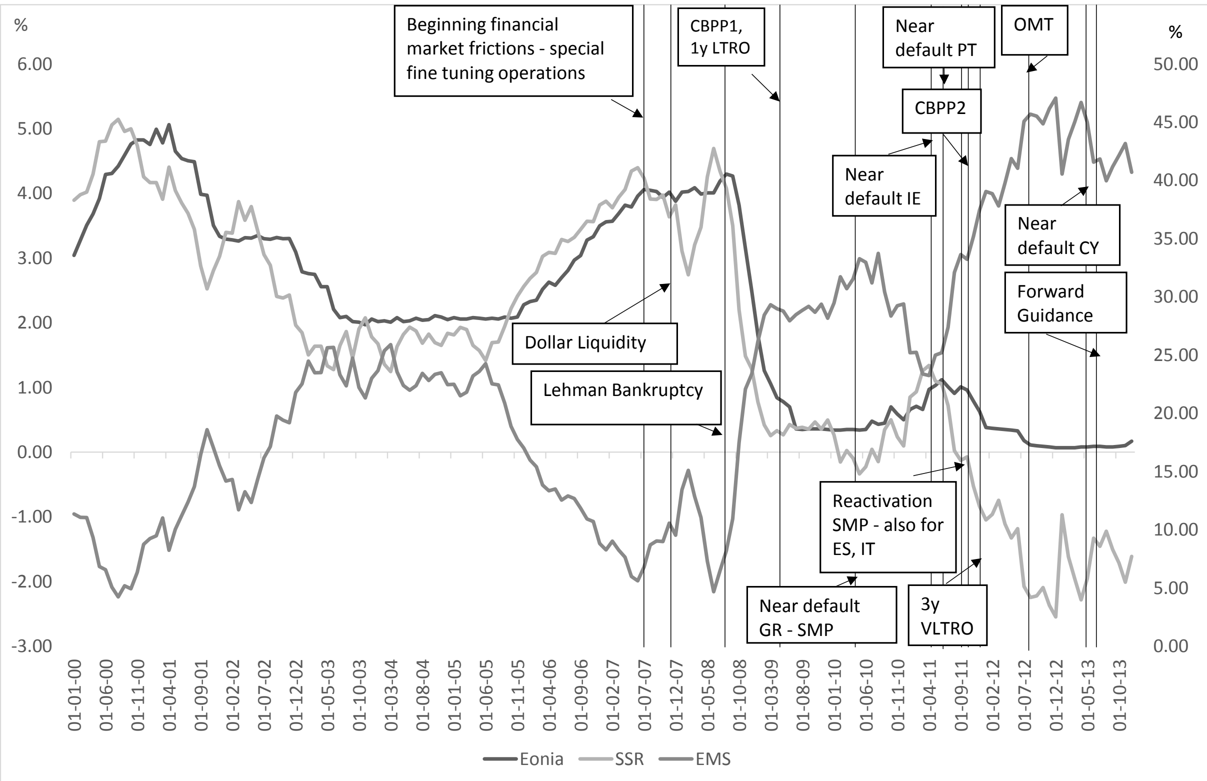
Notes: Selection based on own considerations according to ECB announcements (www.ecb.europa.eu/press/html/index.en.html) and Rogers et al. (2014).

Figure 1: Selected monetary policy measures and country-specific interest rates

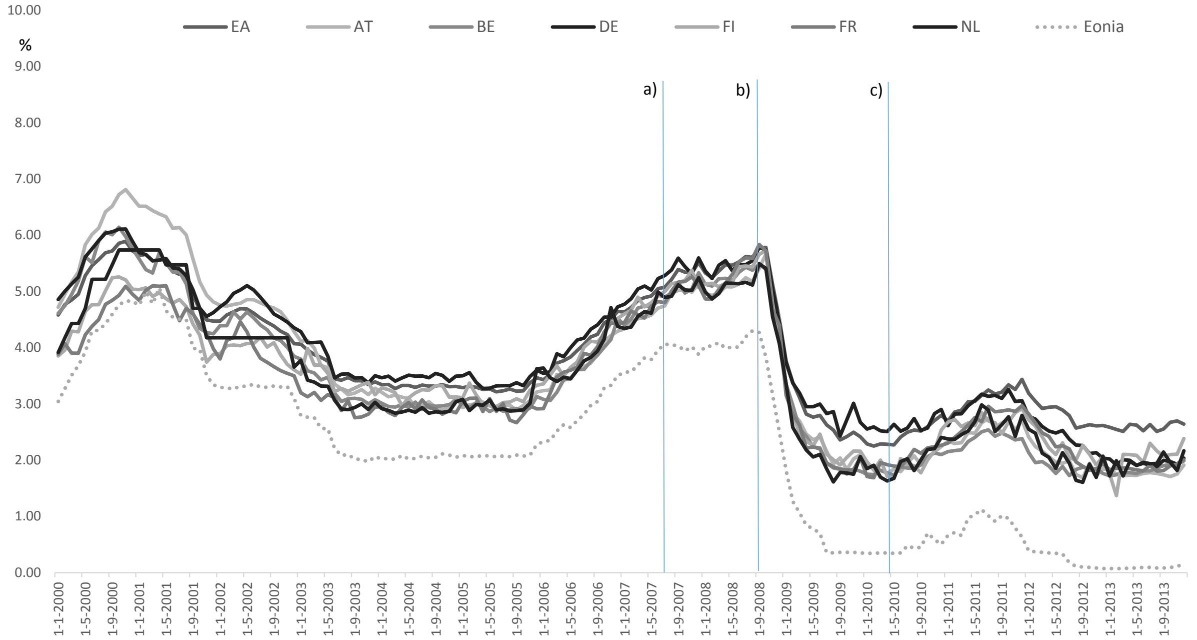
(a) Eonia, central bank assets, main crisis events and policy announcements



(b) Eonia, the Shadow Short Rate (SSR) and the Effective Monetary Stimulus (EMS)

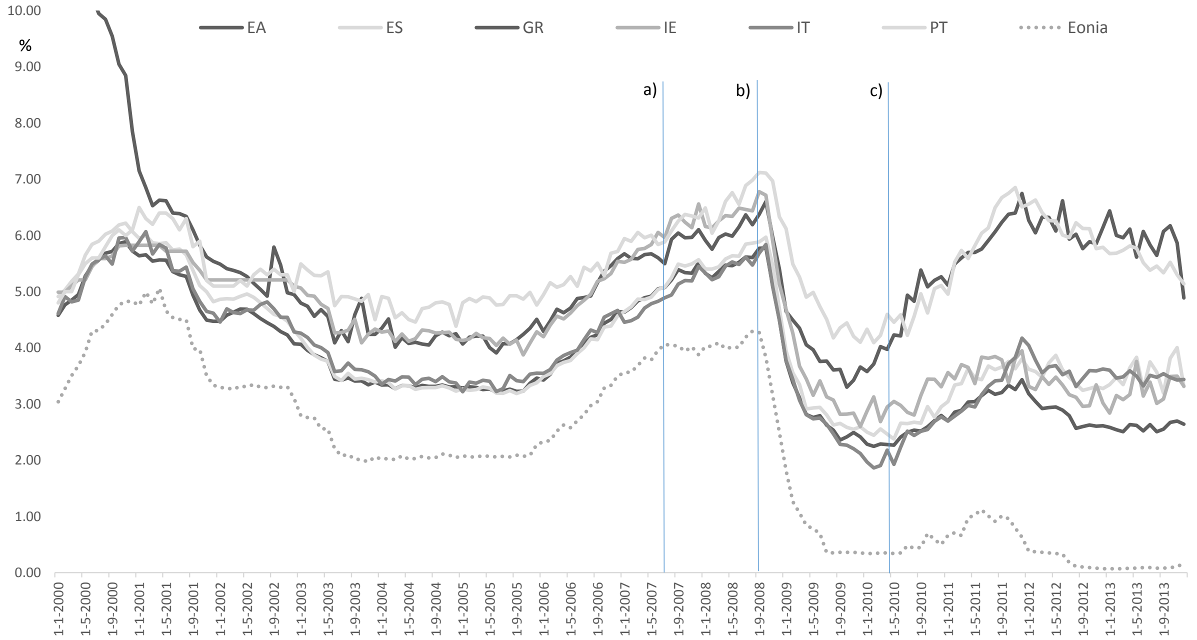


(c) Short-term firm lending rates in the euro area and selected core countries



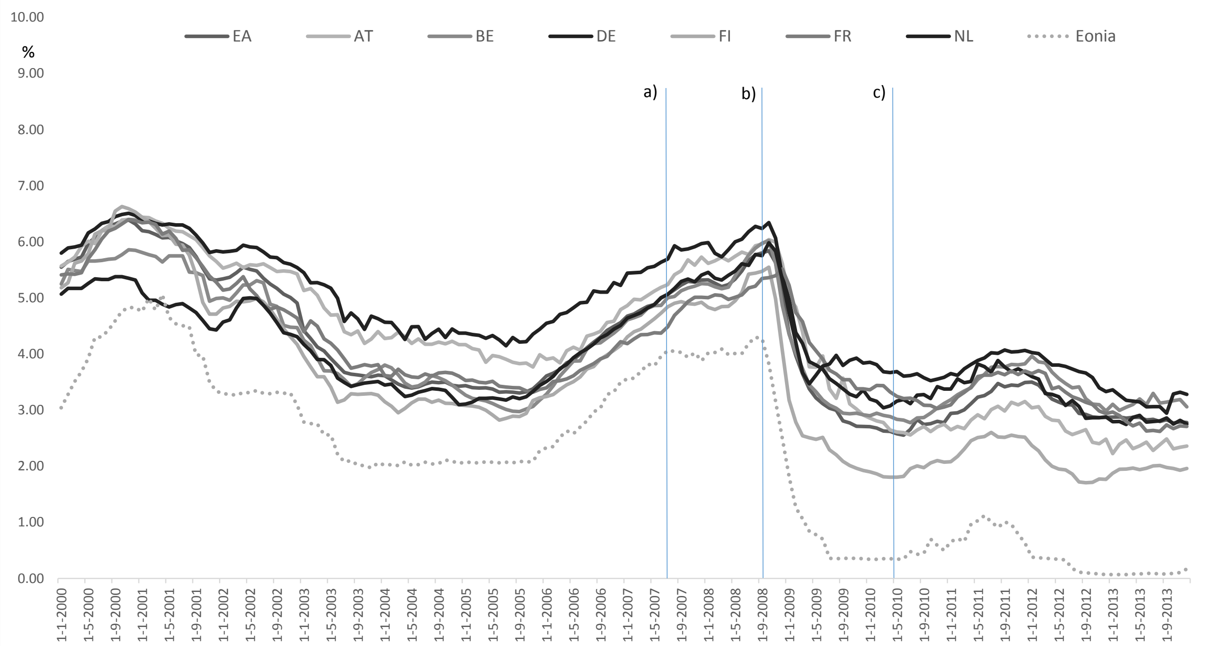
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(d) Short-term firm lending rates in the euro area and selected peripheral countries

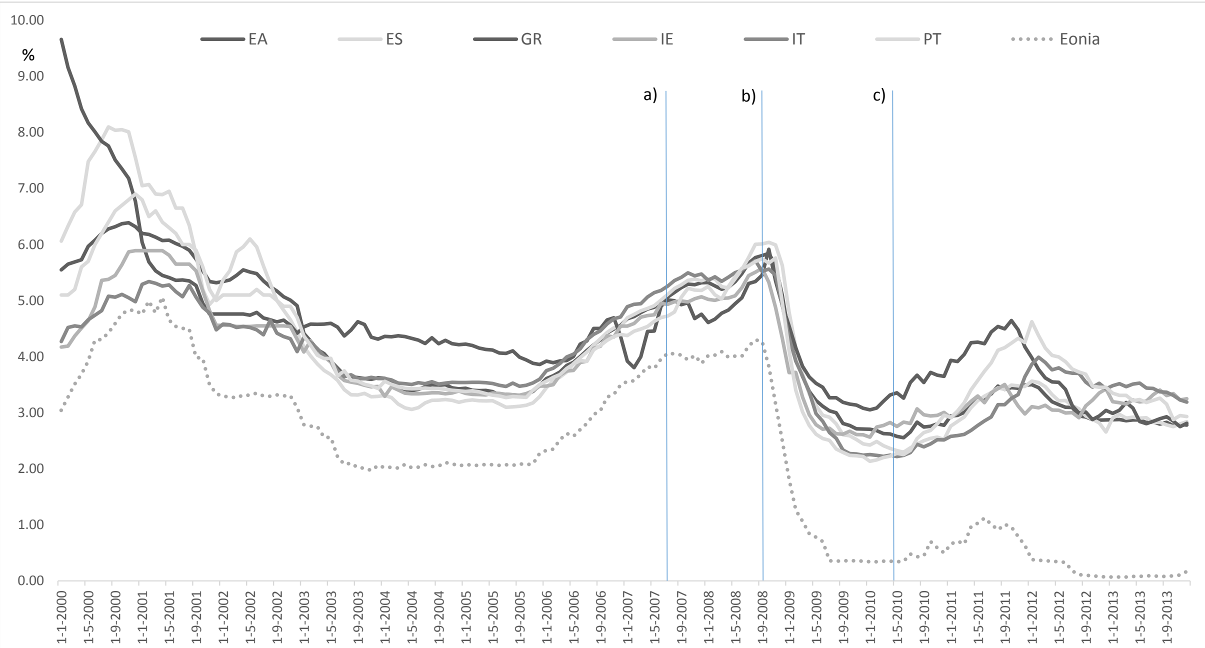


a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

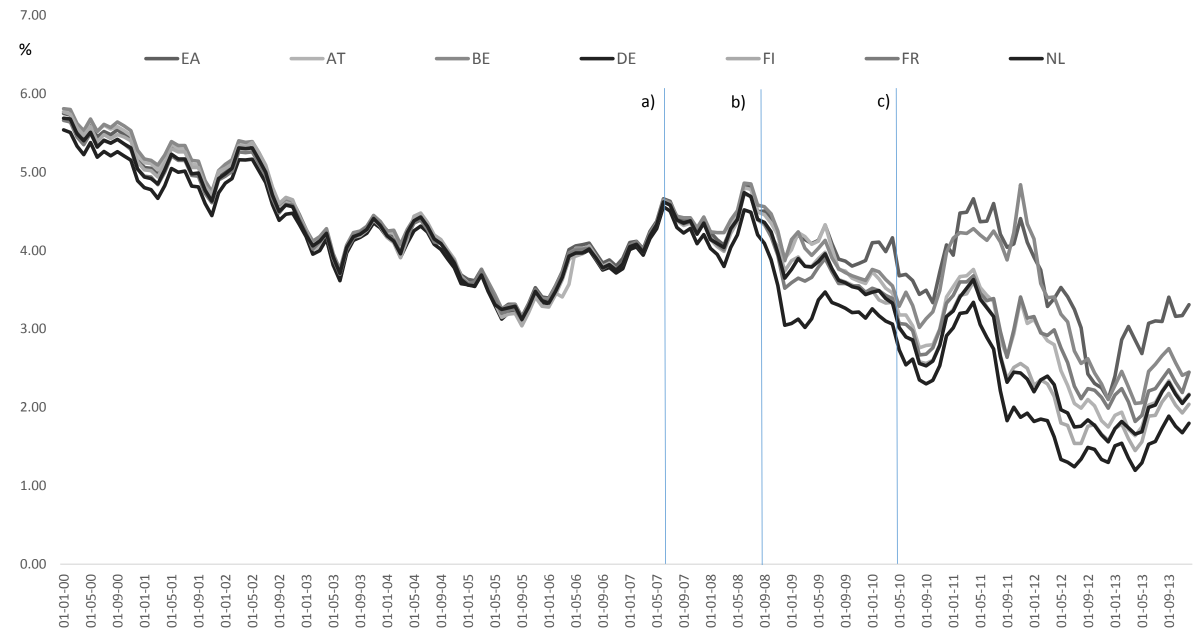
(e) Short-term housing loan rates in the euro area and selected core countries



(f) Short-term housing loan rates in the euro area and selected peripheral countries

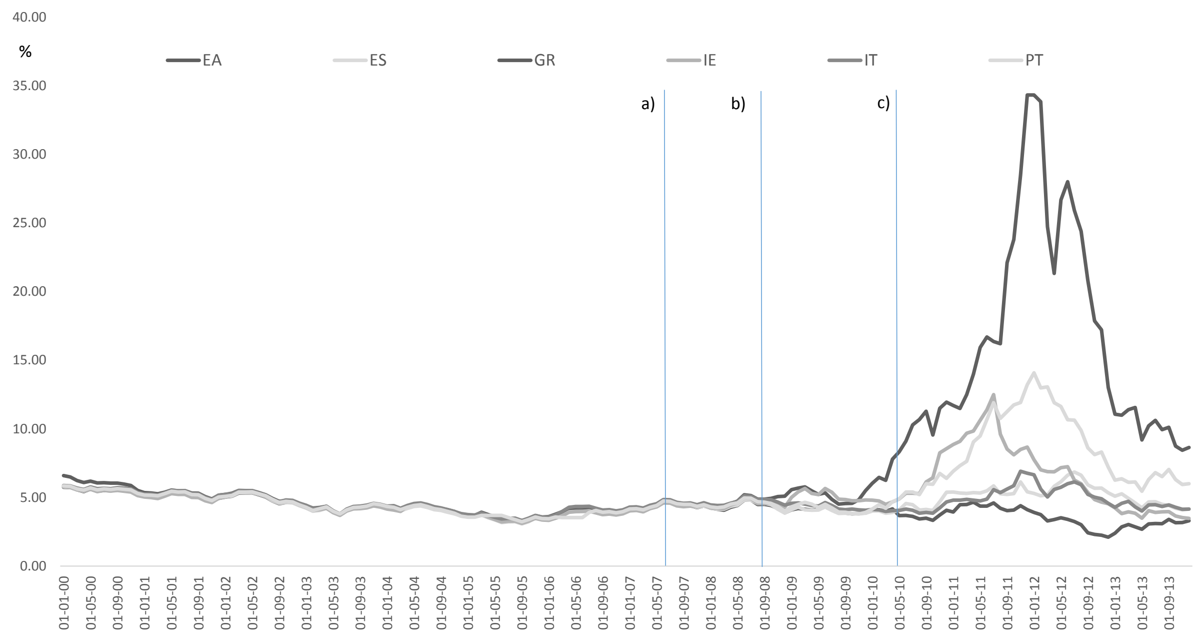


(g) 10-year government bond rates in the euro area and selected core countries



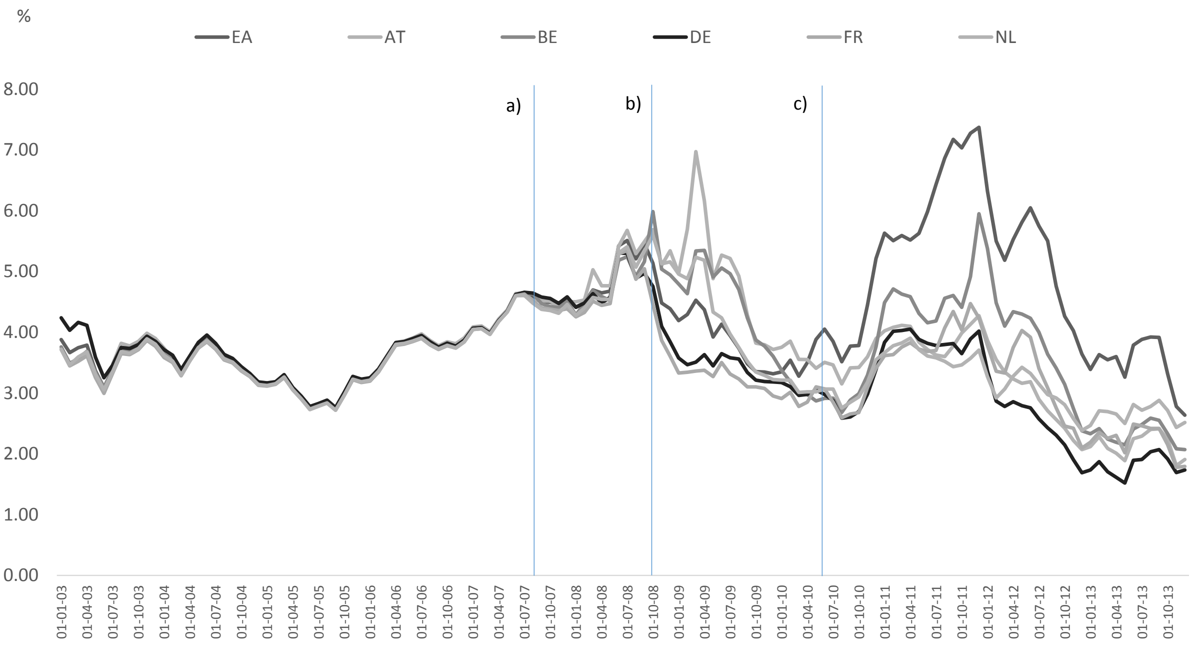
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(h) 10-year government bond rates in the euro area and selected peripheral countries



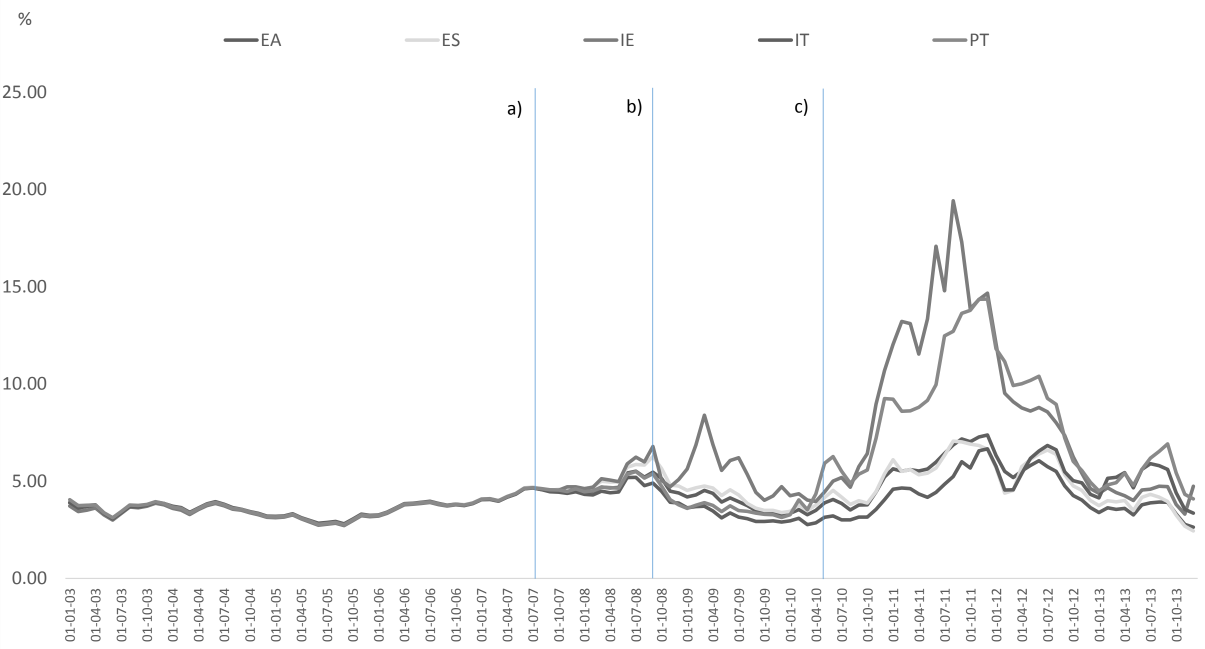
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(i) 5-year bank CDS yields (plus 5-year OIS euro swap rates) in the euro area and selected core countries



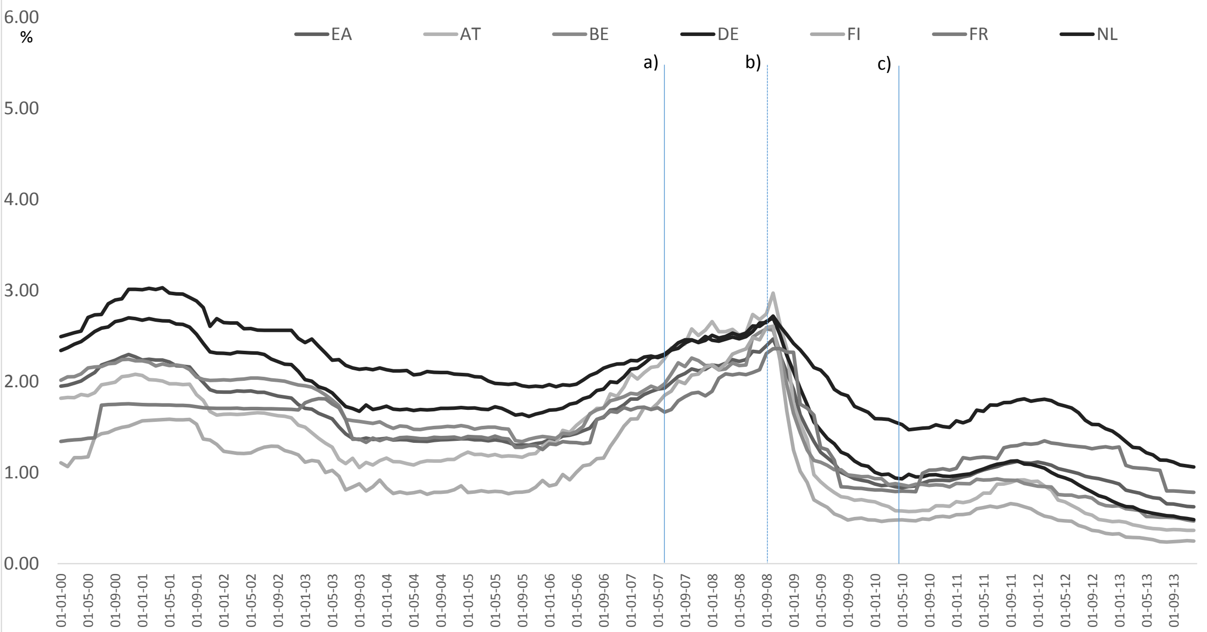
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(j) 5-year bank CDS yields (plus 5-year OIS euro swap rates) in the euro area and selected peripheral countries



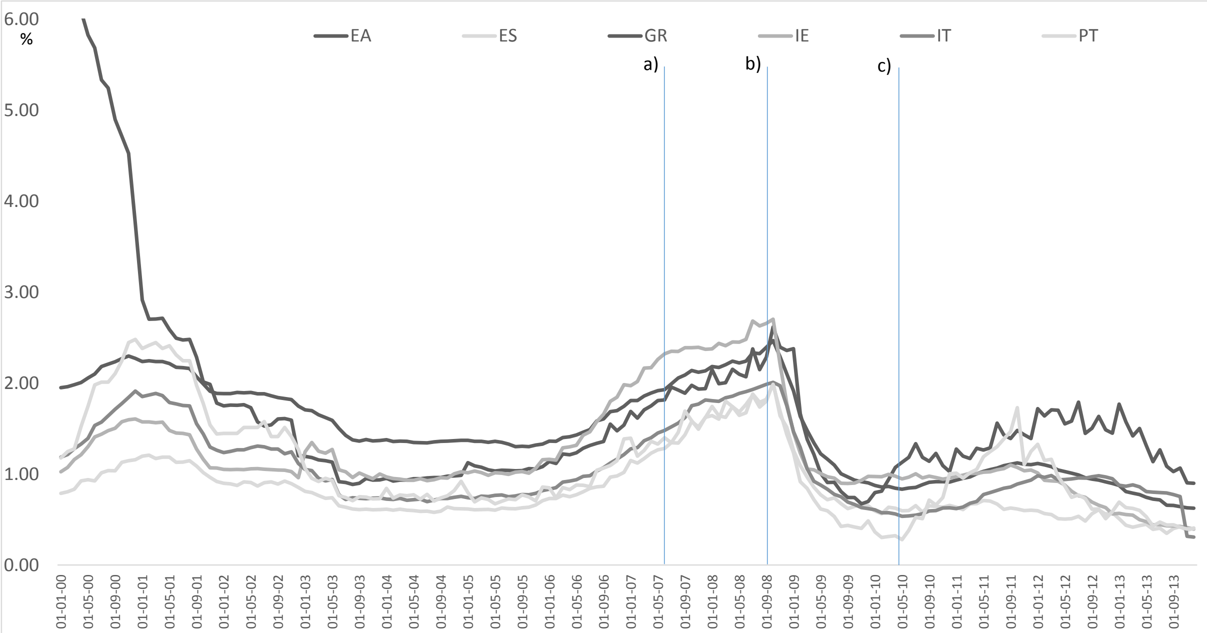
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(k) Deposit rates in the euro area and selected core countries



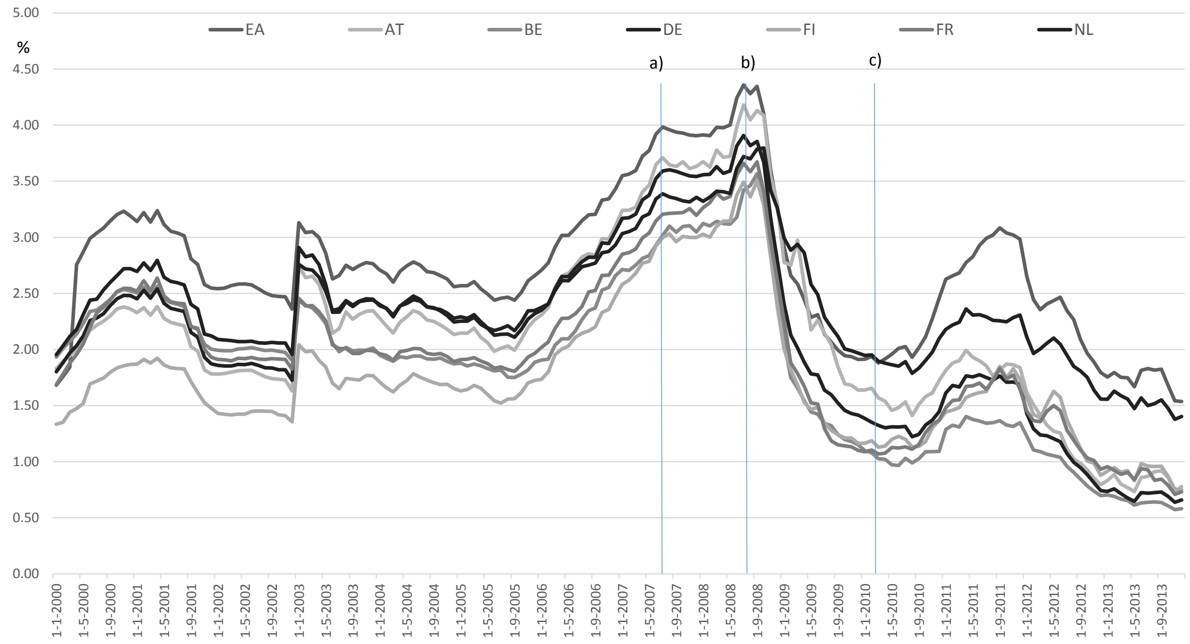
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(l) Deposit rates in the euro area and selected peripheral countries



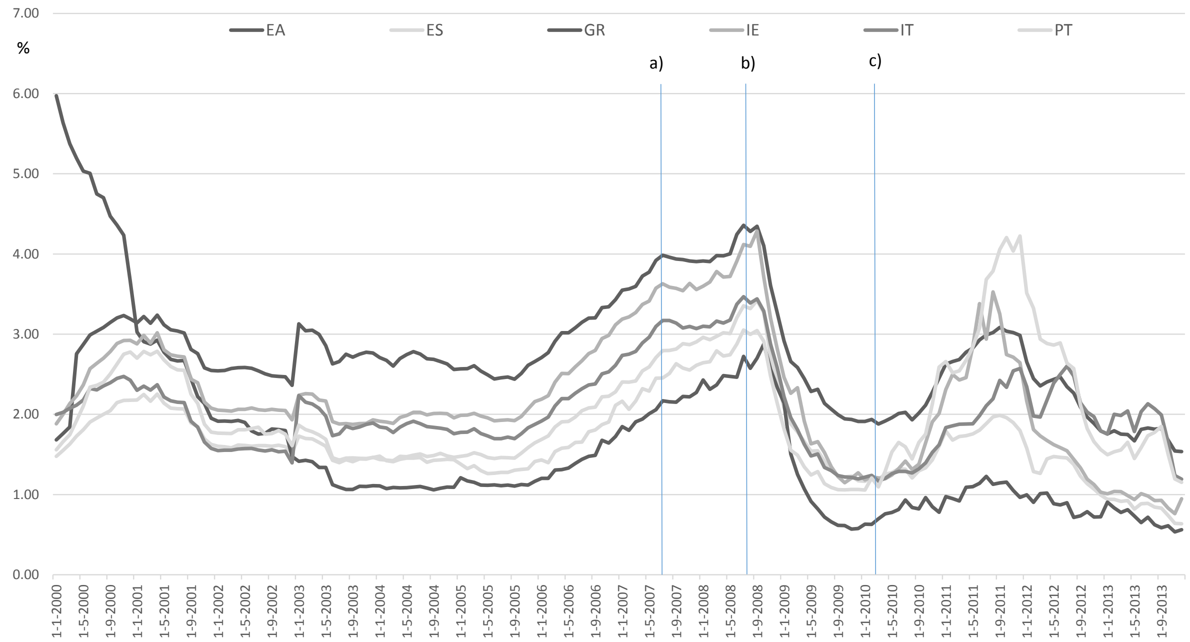
a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(m) Bank funding cost index in the euro area and selected core countries



a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

(n) Bank funding cost index in the euro area and selected peripheral countries



a) Beginning of the **global financial crisis**, ECB's reaction: i.a. 3m-LTROs (Aug 2007) and Dollar liquidity (Dec 2007)
b) **Lehman bankruptcy**, ECB's reaction: i.a. full allotment (October 2008), 1y-LTROs and CBPP1 (May 2009)
c) Beginning of the **sovereign debt crisis**, ECB's reaction: i.a. SMP (May 2010), VLTROs (Dec 2011, Feb 2012), OMT (Aug 2013), Forward guidance (Jul 2013)

Notes: Bank funding cost indices for Finland and Greece are calculated neglecting securities, only covering deposits, interbank borrowing and equity. Finish (and Greek) data on bank CDS rates are not included, as liquidity in this market segment (during the sovereign debt crisis) has not been high enough to ensure meaningful prices.

Figure 2: Impulse response of the Eonia to its own shock (solid: point estimates to a shock normalized to lower the Eonia by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

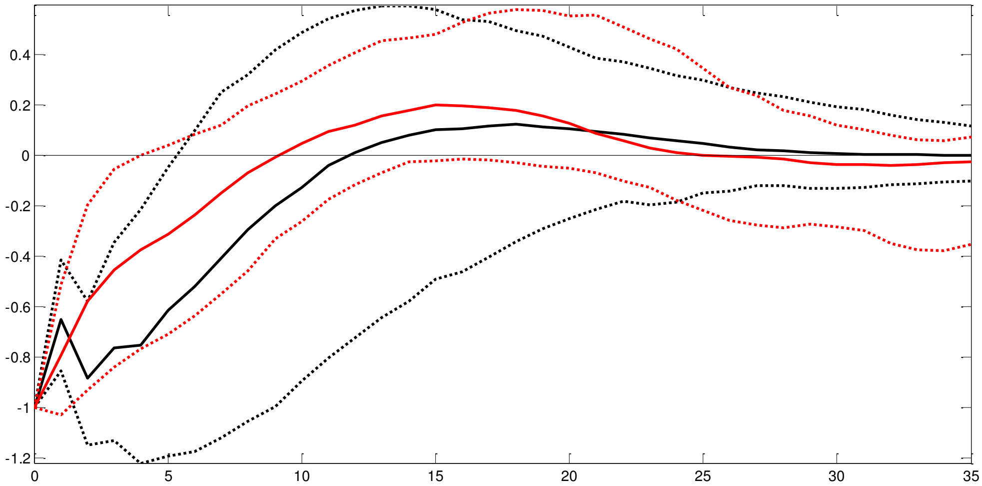
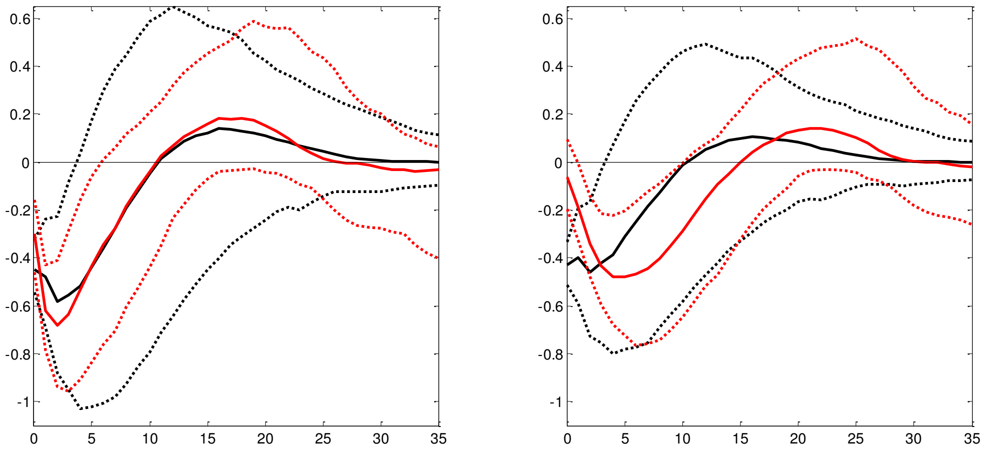
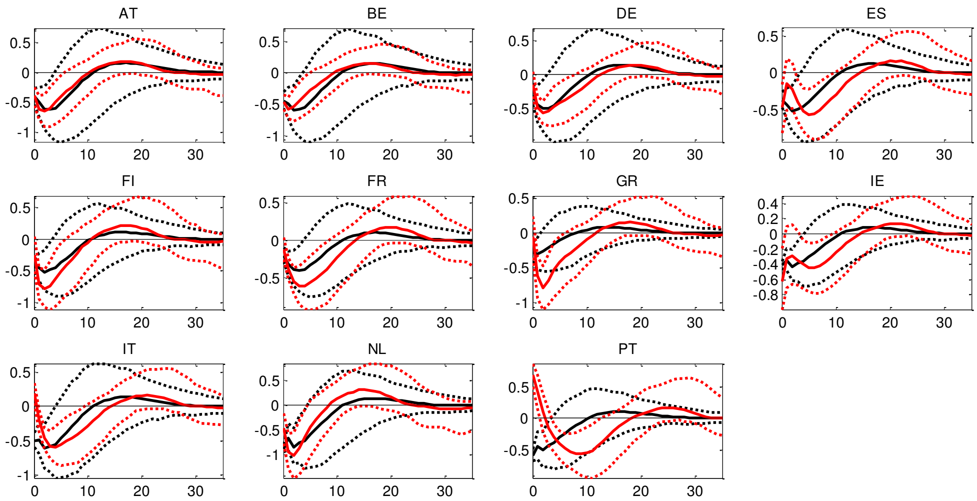


Figure 3: Impulse responses of business and housing lending rates to Eonia shock (solid: point estimates to a shock normalized to lower the Eonia by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

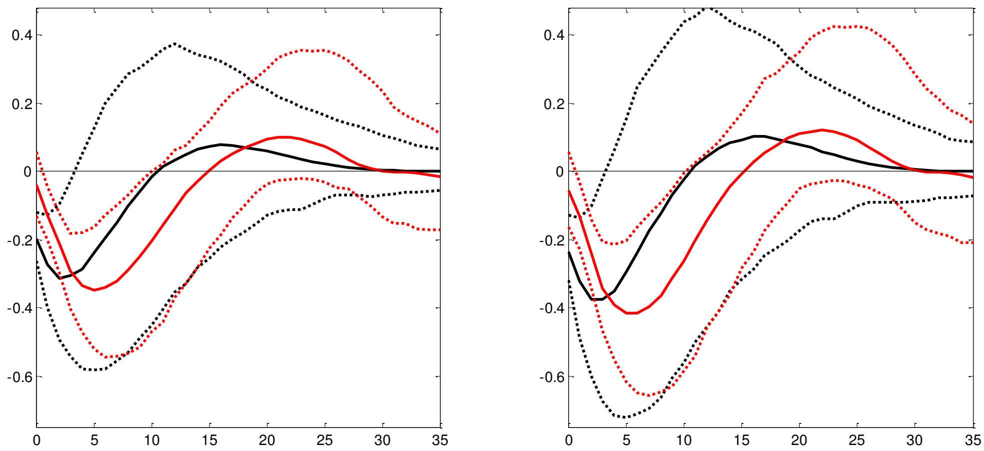
(a) Business lending rates – core vs. periphery



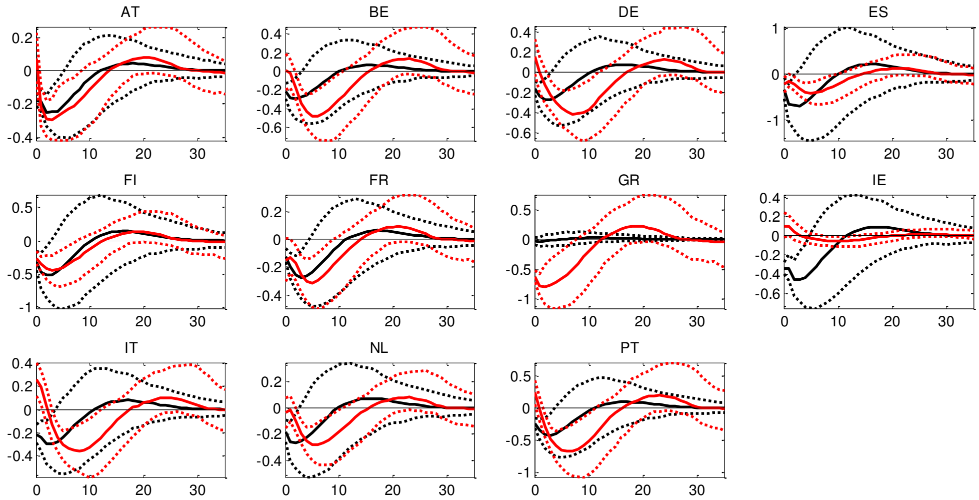
(b) Business lending rates – individual countries



(c) Housing lending rates – core vs. periphery



(d) Housing lending rates – individual countries



Notes: Impulse responses of “core” and “periphery” are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

Figure 4: Impulse responses of the term spread to Eonia shock (solid: point estimates to a shock normalized to lower the Eonia by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

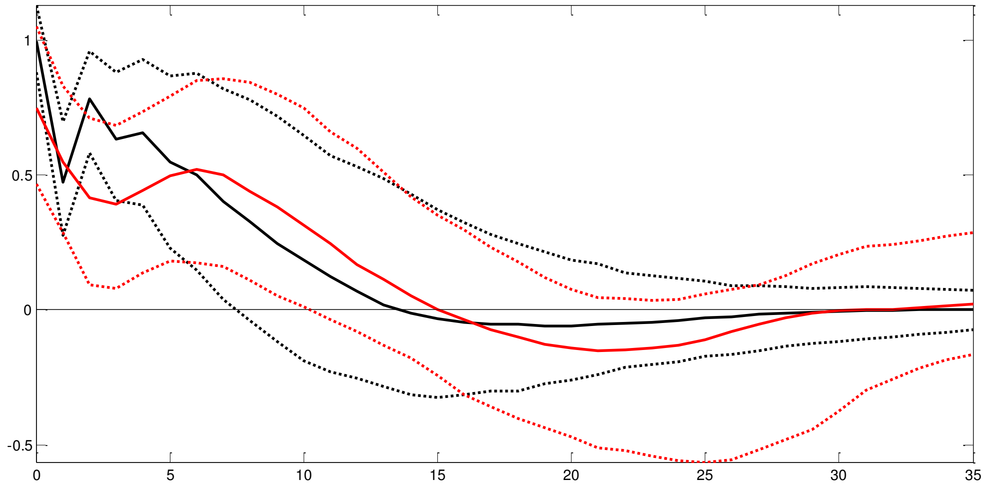
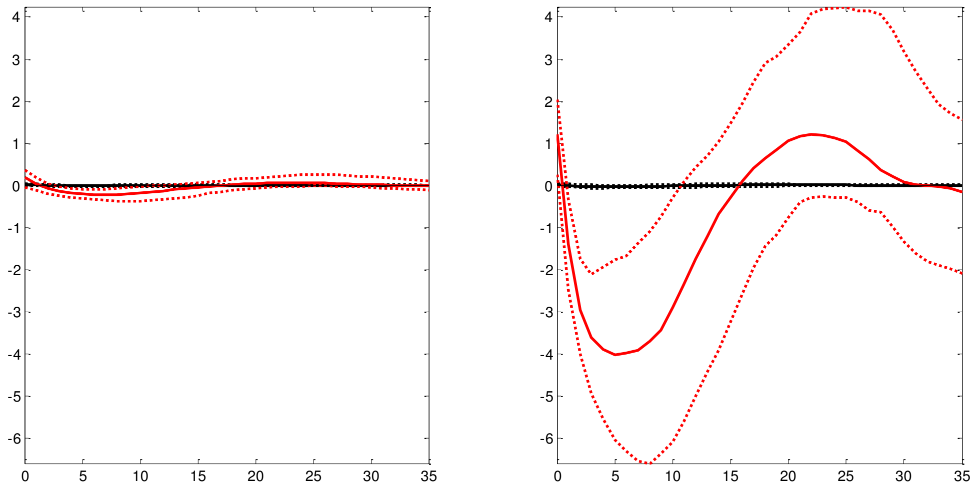


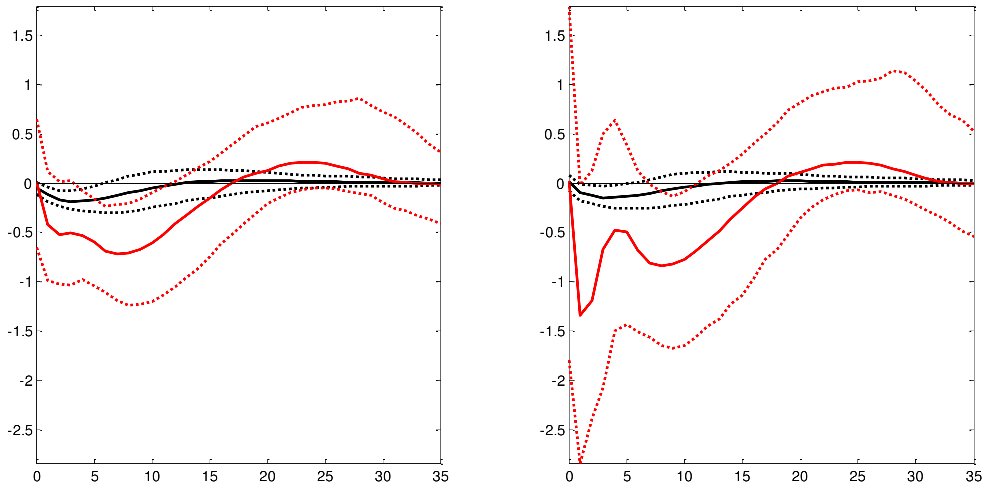
Figure 5: Impulse responses of sovereign risk to Eonia shock – core vs. periphery (solid: point estimates to a shock normalized to lower the Eonia by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)



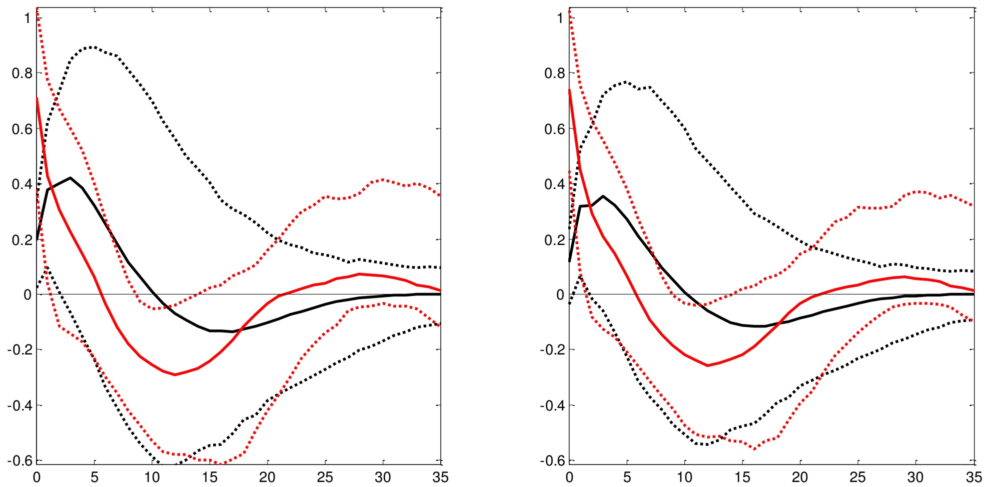
Notes: Impulse responses of “core” and “periphery” are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

Figure 6: Impulse responses of bank funding risk (CDS spreads corrected for sovereign risks, and household and firm deposit spreads) measures to Eonia shock (solid: point estimates to a shock normalized to lower the Eonia by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

(a) CDS spreads – core vs. periphery



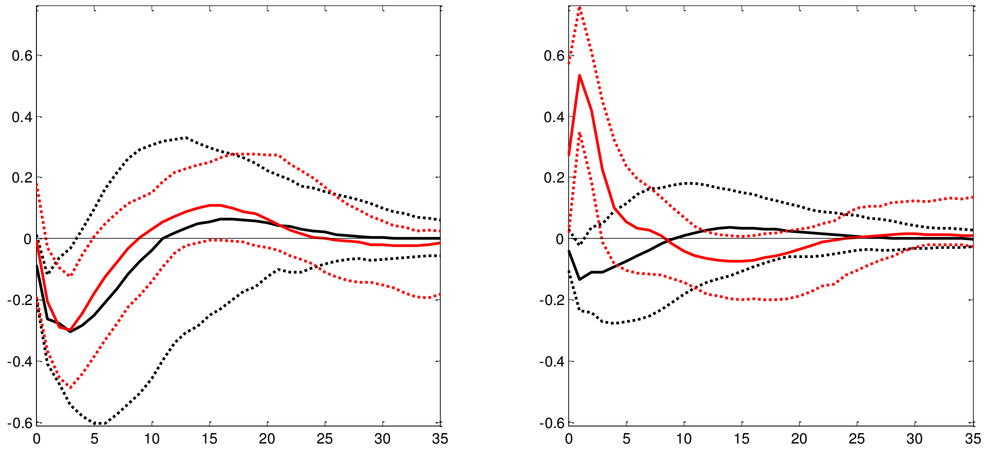
(b) Deposit spreads – core vs. periphery



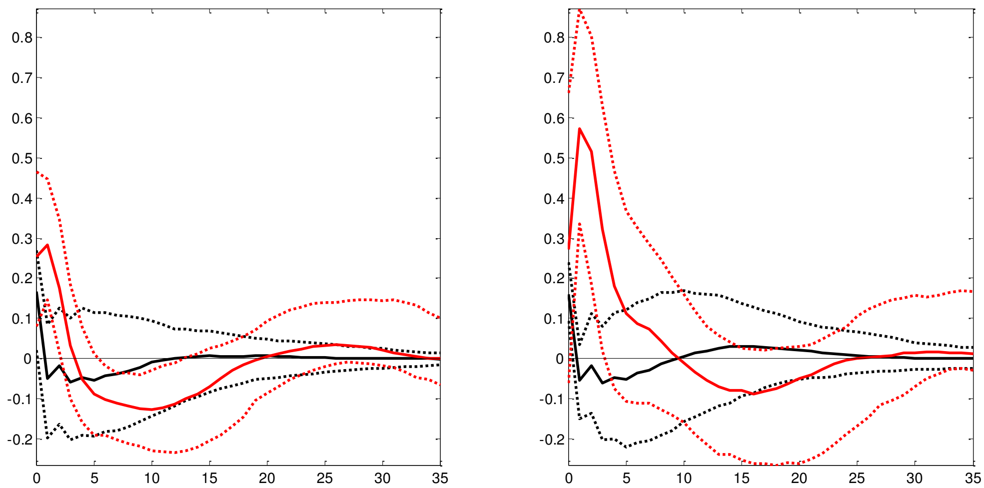
Notes: Impulse responses of “core” and “periphery” are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

Figure 7: Impulse response of business and housing lending margins to Eonia shock (solid: point estimates to a shock normalized to lower the Eonia by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

(a) Business lending margins – core vs. periphery



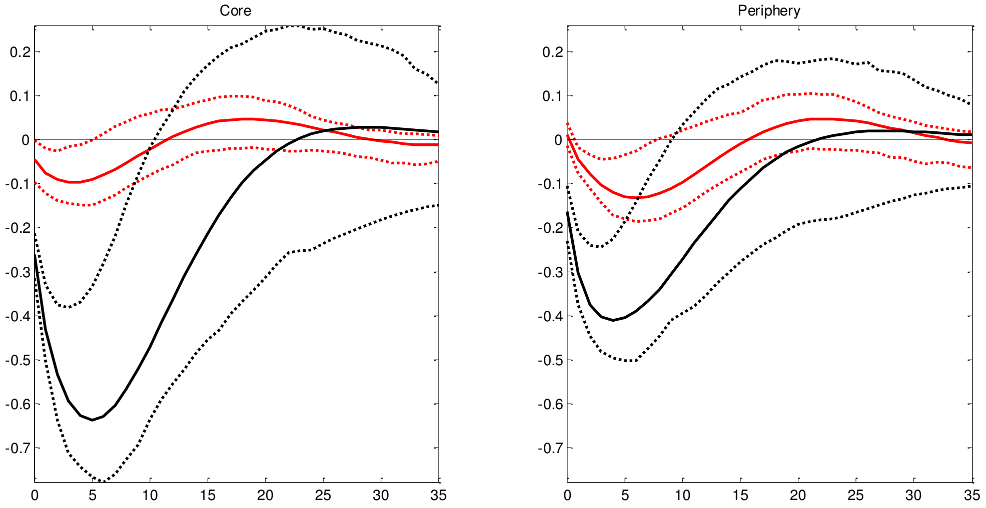
(b) Housing lending margins – core vs. periphery



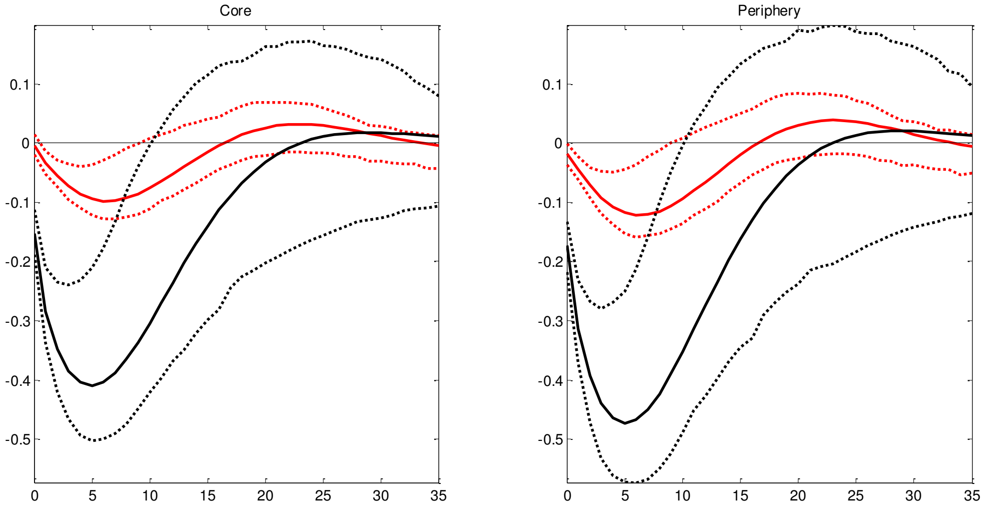
Notes: Impulse responses of “core” and “periphery” are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

Figure 8: Impulse responses of business and housing bank lending rates to SSR shock (solid: point estimates to a shock normalized to lower the SSR by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

(a) Business lending rates – core vs. periphery



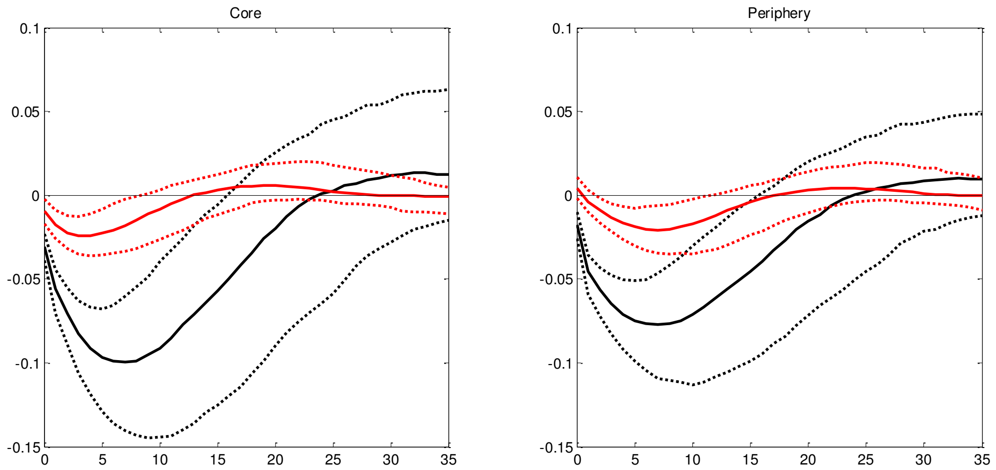
(b) Housing lending rates– core vs. periphery



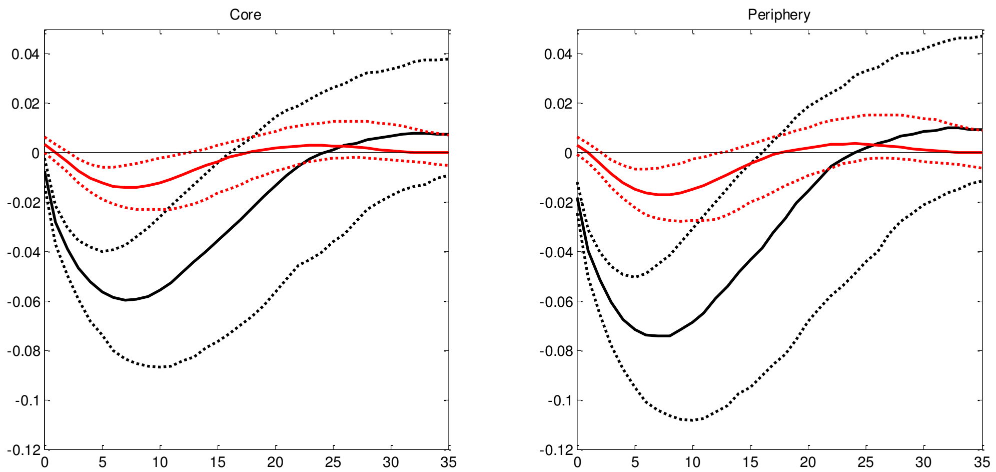
Notes: Impulse responses of "core" and "periphery" are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

Figure 9: Impulse responses of business and housing bank lending rates to EMS shock (solid: point estimates to a shock normalized to increase the EMS by 1 percentage point on impact; dotted: 90% confidence bands; black: pre-crisis, red: crisis)

(a) Business lending rates – core vs. periphery

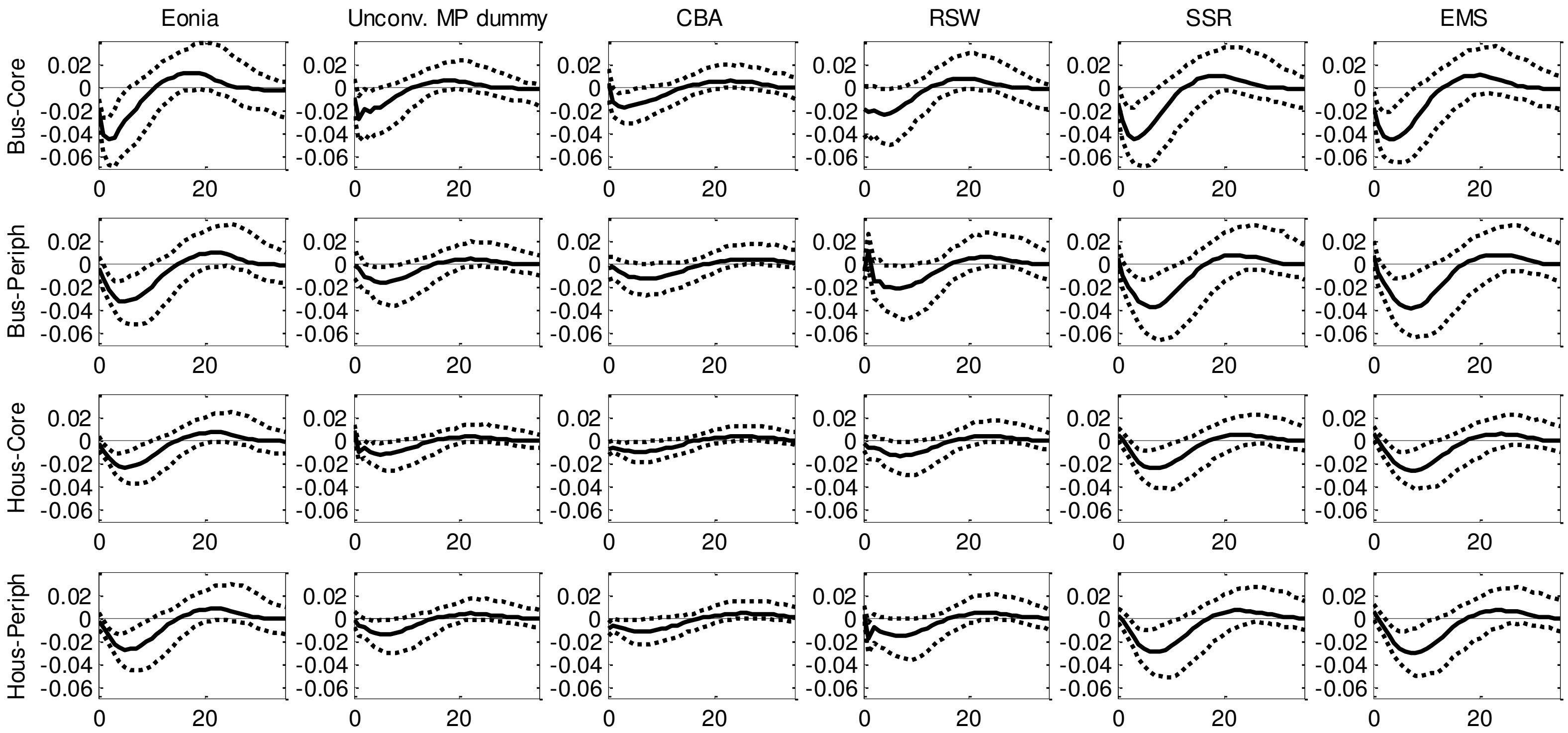


(b) Housing lending rates – core vs. periphery



Notes: Impulse responses of "core" and "periphery" are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

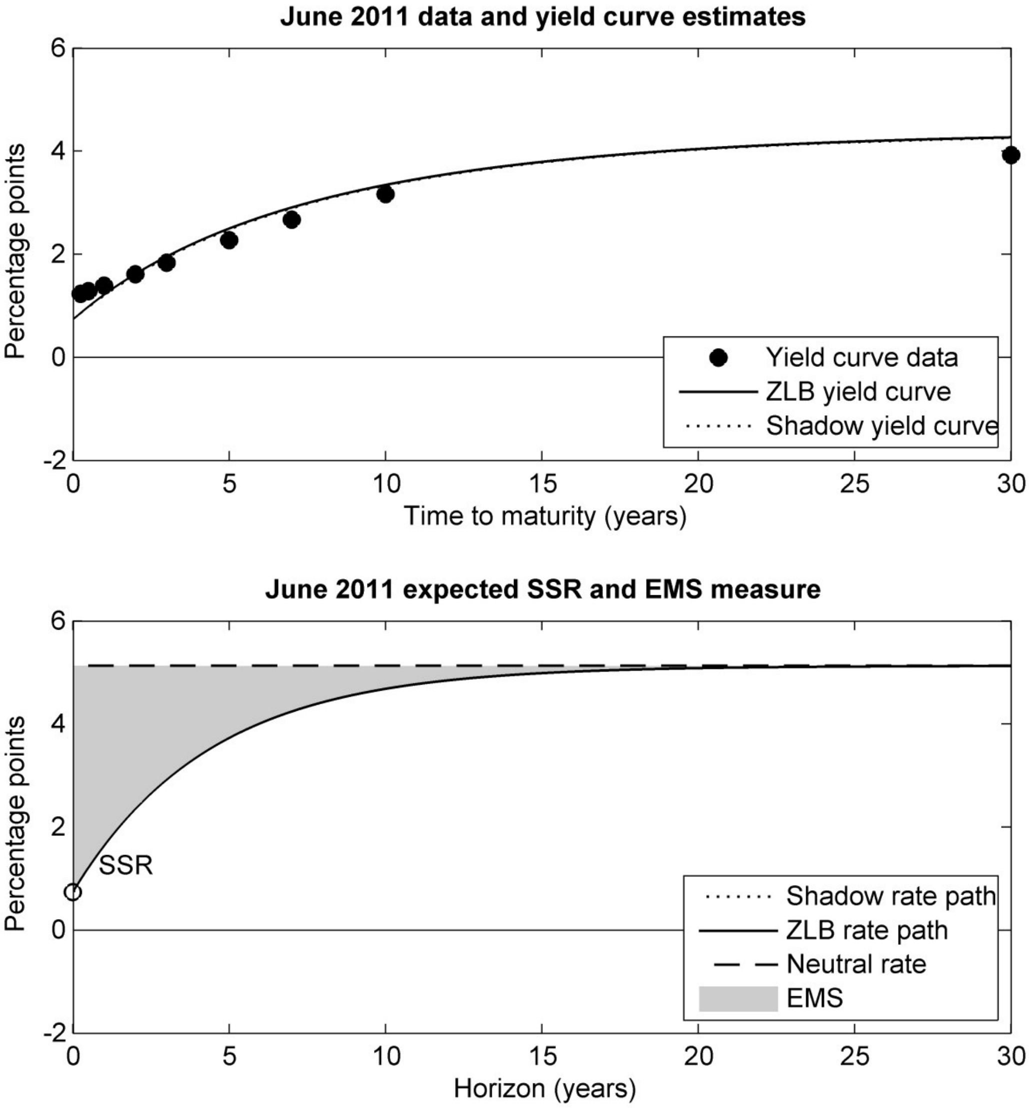
Figure 10: Impulse responses of business and housing lending rates to 1 standard deviation expansionary conventional, unconventional and combined (conventional and unconventional) monetary policy shocks during the crisis period (solid: median; dotted: 90% confidence bands)



Notes: Impulse responses of “core” and “periphery” are computed as unweighted averages across countries; periphery: GR, IT, IE, ES, PT; core: all others.

Figure 11: Euro-area yield curve data, estimated two-factor yield curves, and the associated shadow short rate and EMS measures

(a) Example illustrating the EMS in a non-ZLB-constrained environment. The ZLB and shadow yield curve estimates are in the first panel; the SSR and the EMS measure, which is represented by the shaded area, from the shadow yield curve is in the second panel.



(b) Example illustrating the EMS in a ZLB-constrained environment. The ZLB and shadow yield curve estimates are in the first panel; the SSR and the EMS measure, which is represented by the shaded area, from the shadow yield curve is in the second panel.