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Euro area CDS spreads in the crisis: The role of open market operations and contagion

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Euro area CDS spreads in the crisis: The role of open market operations and contagion

Petra Gerlach-Kristen*

Abstract: This paper studies euro area CDS spreads during the financial crisis. We examine the impact of the crisis on both commercial banks and sovereigns, and focus on two questions. First, have the ECB's open market operations reduced market stress? It seems that large repo volumes, especially if credited to banks the same day, helped initially, and that the announcement of the Securities Market Programme also calmed markets. Asset purchase volumes do not seem to matter directly. Second, was there contagion among and between banks and sovereigns? We find evidence for both. Interestingly, sovereign CDS spreads appear immune after April 2010. We argue that this might reflect the ECB's efforts to stop contagion during the euro crisis.

Key words: CDS spreads, ECB, sovereign debt crisis, open market operations, contagion

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Euro area CDS spreads in the crisis: The role of open market operations and contagion

1. Introduction

On 9 August 2007 BNP Paribas announced that it would suspend three of its funds because problems in the US subprime market prevented their proper valuation. The financial crisis that followed spread from subprime funds to money markets, triggering on 15 September 2008 the collapse of Lehman Brothers, and from there to international bank and government bond markets. The euro area debt crisis first affected Greece, which sought its initial bailout from the IMF/European Commission/ECB-Troika in May 2010; a second bailout followed in July 2011. Ireland received assistance in November 2010, and Portugal in May 2011, and Spain the promise of support if requested in June 2012.

The European Central Bank responded to the crisis by slashing interest rates from October 2008 onwards and by offering more liquidity to market participants through its standard auctions of repurchase agreements (repos). It then changed the conditions under which liquidity was made available, by extending the contract length of some of the repo operations and by adopting full allotment. Lengthening contracts was a first step towards more permanent liquidity provision.

From the middle of 2009 onwards, the ECB engaged in outright purchases, thus providing permanent funds to market participants. Initially, the ECB bought covered bonds when the transmission of policy rate changes to market rates seemed impaired. The first Covered Bond Purchase Programme (CBPP) lasted from June 2009 to June 2010. When the sovereign debt crisis spread, the ECB decided in May 2010 to purchase government bonds alongside private debt under the Securities Market Programme (SMP). Covered bonds purchases have been made again under a second Covered Bond Purchase Programme (CBPP2) since November 2011. Outright Monetary Transactions (OMT) were announced in September 2012 (though at the time of writing no actual purchases have been made under this scheme). Their introduction marked the end of the SMP.

A number of papers have examined the impact of the liquidity provision through repos and related temporary transactions money market interest rates.[1] A second strand of the literature has studied the impact of asset purchase programmes on longer-term government bond yields.[2] Thus, papers tend to focus on one type of measure and on the effect on the borrowing costs of either banks or governments.

In this paper, we look simultaneously at the response of commercial bank and sovereign CDS spreads to allow for direct comparisons. We do so using five-year credit default swap spreads, which

[1] See Čihák et al. (2009) on long-term ECB repos, McAndrews et al. (2008), Wu (2008) and Taylor and Williams (2009) for the Federal Reserve and Aït-Sahalia et al. (2012), Frank and Hesse (2009), IMF (2009) and Gerlach-Kristen and Kugler (2012) for international comparisons.

[2] See Stroebel and Taylor (2009) the effectiveness of the Fed's purchase of mortgage-backed securities and Gagnon et al. (2011), Bauer and Rudebusch (2011) and Krishnamurthy and Vissing-Jorgensen (2011) its Large-Scale Asset Purchases. Meier (2009), Joyce et al. (2010) and Daines et al. (2012) study the impact of quantitative easing in the UK. IMF (2010) compares the effect of asset purchase programmes in the US, the UK and the Euro area, and Meaning and Zhu (2011) study the impact in the US and the UK.

are readily available for bank and government debt. We concentrate on the CDS spreads of Germany, Greece, Ireland, Italy, Portugal and Spain, and of two commercial banks from each of these countries. These spreads are related to market participants' expectations as to how likely it is that a commercial bank or a government will default on its loans. A high CDS spread thus reflects that markets believe that a debtor is in serious difficulties. A further advantage of CDS spreads is that, in contrast to government bond yields, there is no direct flight-to-safety effect. If investors decide that the default probability of, say, Ireland increases, the Irish sovereign CDS spread and the bond yield rise. At the same time, investors that have sold Irish bonds are looking for a substitute asset to invest in and are likely to turn to a safer, e.g. German, bond. German bond yields decline as a consequence. German CDS spreads, by contrast, remain largely unaffected. [3]

Using CDS data, we ask two broad sets of questions. The first concerns the impact of ECB open market operations on spreads. How successful have they been in reducing market stress? Are repos, which are temporary liquidity injections, more or less successful than asset purchases, which inject liquidity permanently? What features of the repos matter: volume, contract length, or settlement speed? How important were the announcements of the asset purchase programmes?

The second set of questions revolves around contagion. Do commercial bank CDS spreads respond to one another? We examine whether the CDS spread of one bank responds to those from the previous day of the other banks in our data set, controlling for open market operations and other measures of market stress and rescue operations. Do commercial bank spreads react if the market believes the default probability of sovereigns has increased? Is contagion from the own sovereign particularly large? And we ask the same questions for sovereigns: is there contagion between them, is there contagion from commercial banks, and do domestic banks have a particularly large impact?

Our main findings are that early in the crisis, repos indeed reduced commercial bank CDS spreads. In particular, large volumes that were transferred fast seemed to reduce stress during the liquidity crisis. Later on, the announcement of the Securities Market Programme drove down spreads of both banks and sovereigns. Regarding contagion, there is ample evidence of contagion among banks. Sovereign spreads tend to influence those of both other sovereigns and commercial banks. Interestingly, after the onset of the euro crisis sovereign CDS spreads appear to have been immune to one another and to bank spreads. It is possible that this reflects ECB bond purchases to prevent contagion.

The rest of the paper is structured as follows. Section 2 presents the data. We first discuss how CDS spreads over the course of the crisis and then review the ECB open market operations. Section 3 presents the regression setup. Section 4 discusses the impact ECB open market operations seem to have had on CDS spreads. Section 5 reports the results on contagion. Section 6 concludes.

[3] CDS data of course have disadvantages, too. First, liquidity was low before the crisis and may have been boosted by speculators since then. Second, the European Parliament has restricted the purchase of sovereign CDSs to investors who hold the underlying bonds, or closely related bonds, and the introduction of this restriction may have caused gyrations in CDS spreads. The restrictions came into force on 1 November 2012 and reduced liquidity in some market segments. The estimations therefore end on 1 August 2012. Finally, in the Greek default discussions, a lot of attention was given to how triggering CDS payout clauses could be avoided, and this also may have caused swings in CDS spreads.

2. Data

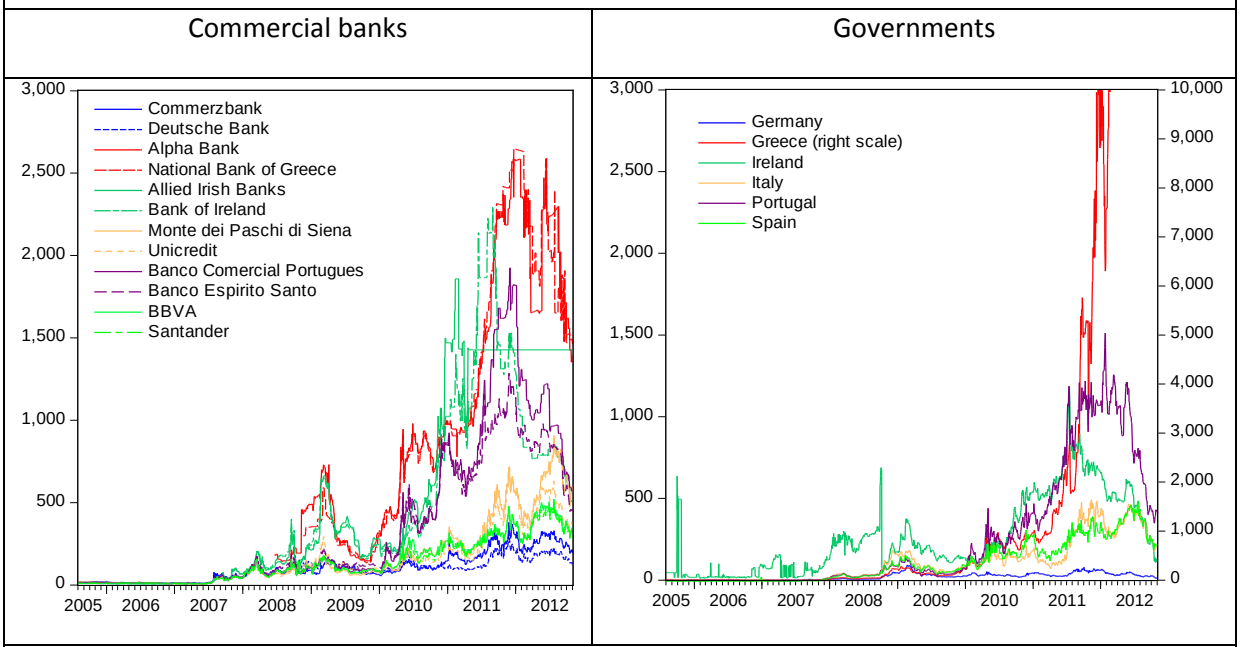
2.1 CDS spreads

We use daily data spanning 1 August 2005 to 1 August 2012. Figure 1 shows in the left panel the CDS spreads for twelve commercial banks. We choose two banks per country and concentrate on some of the best known. For Germany, we use Commerzbank and Deutsche Bank, for Greece Alpha Bank and National Bank of Greece, for Ireland AIB and Bank of Ireland, for Italy Monte dei Paschi di Siena and Unicredit, for Portugal Banco Comercial Português and Banco Espírito Santo, and for Spain BBVA and Santander. The right panel shows the CDS spreads for the six governments.

Before the onset of the financial crisis, CDS spreads were low. After the announcement of Paribas' difficulties in August 2007, commercial banks' CDS spreads started increasing, and they rose further after the collapse of Lehman Brothers. Then the crisis spread, and from late 2008 onwards, government CDS spreads began rising as well. It is notable how closely sovereign and corporate CDS spreads are correlated between countries. The exception is Greece, where sovereign CDS spreads (plotted on a separate scale) rose much faster than commercial bank CDS spreads after March 2011.

In the analysis below, we use the CDS spreads in levels. While tests do not reject the hypothesis of a standard root, we accommodate potential unit root behaviour by estimating simple level equations that include lags of the dependent variable. We hence allow for a random walk process and avoid a spurious regression problem. The estimates we thus obtain are consistent, and hypothesis tests have standard asymptotic distributions (see Hamilton, 1994, and Sims, Stock and Watson, 1990).

Figure 1: Credit default swap spreads (in basis points)



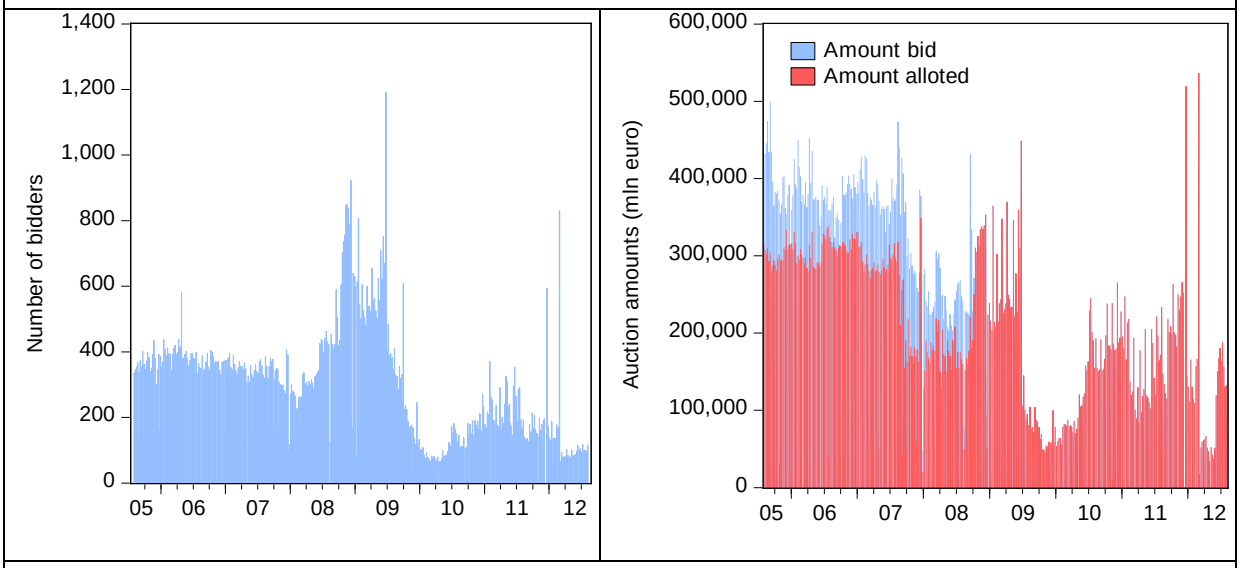
Note: Five-year CDS spreads, in basis points. Data for National Bank of Greece only from November 2008, Source: Datastream.

2.2 Open market operations

At the root of the financial crisis lay a realisation on part of investors that risks had been underestimated, causing liquidity to dry up in a variety of markets. Illiquidity in many cases was seen as signalling potential insolvency, and CDS spreads reflected this. Central banks tried to ease liquidity squeezes by stepping in as provider of funds where counterparties had withdrawn.

For the euro zone, banks' need for liquidity can be gauged from the information on the ECB's open market operations. Figure 2 shows in the left panel the number of bidders in the repo auctions. Participation numbers almost doubled in the fall of 2008 but have since fallen below pre-crisis level. A large number of banks also submitted bids in the long-term repo operations in late 2011 and early 2012.

Figure 2: Bidding behaviour

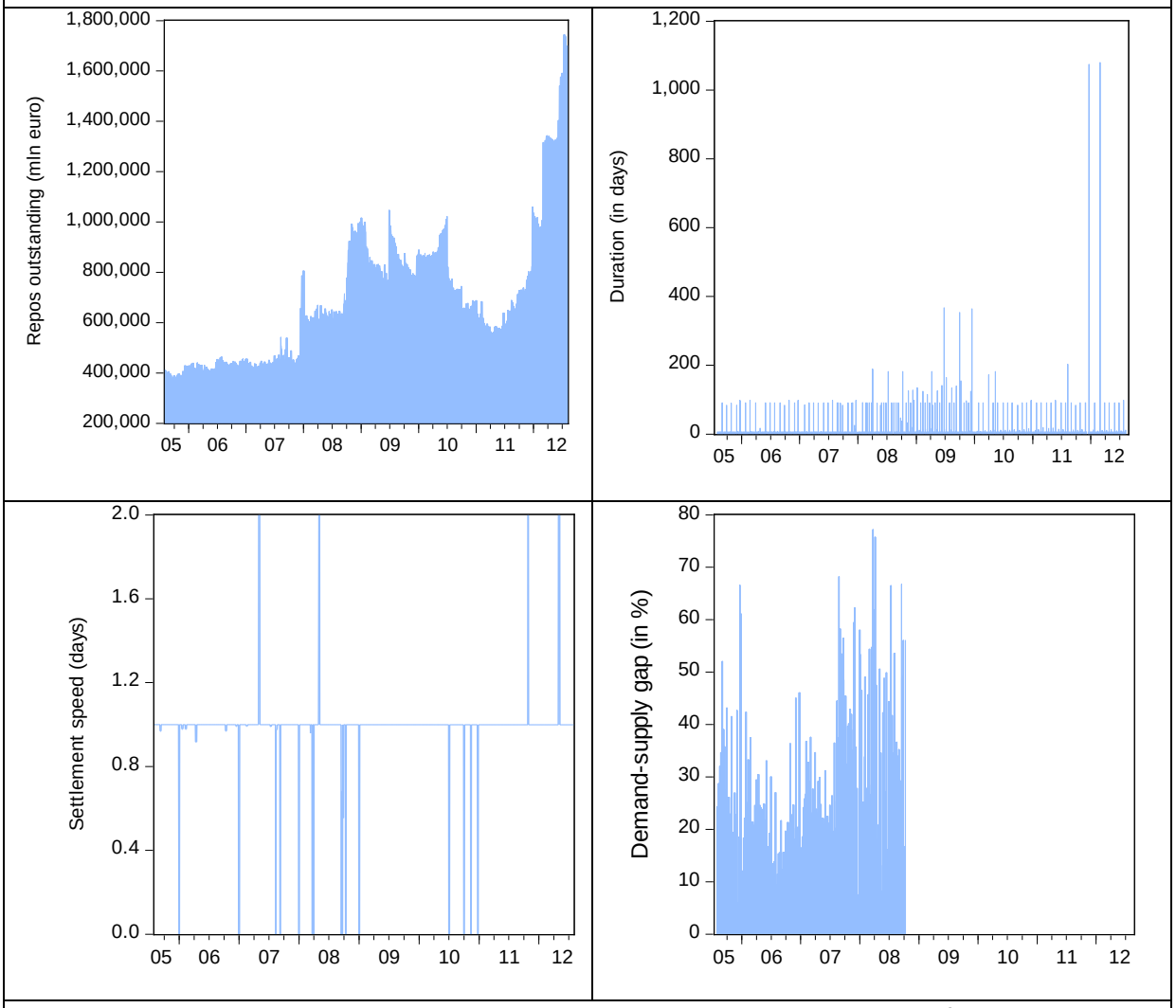


Note: Euro repo auctions only. Amounts in million euros. Source: ECB website

The right plot of the same figure shows the sum of the bids submitted (in blue) and the liquidity allotted by the ECB (in red). Before the fall of 2008, the ECB tended to allot liquidity amounting to about three quarters of the bids it received. Liquidity provision reflected the ECB's internal assessment of liquidity needs in the markets. In September 2008, the sum of bids increased sharply, and in October the ECB switched to a fixed-rate full-allotment (FRFA) policy. This policy change meant that repo demand was fully accommodated and that variable-rate tenders gave way to fixed-rate tenders.[4]

[4] The ECB had originally offered liquidity at the same rate for all auction participants, pro rata. However, banks tended to bid for very large amounts, presumably to cut competitors off from their access to liquidity. The ECB therefore switched in mid-2000 to a variable-rate procedure, which implied that banks had to pay high interest if they wanted to secure a large amount of liquidity. The marginal interest rate, which captures what the last bank whose demand the ECB meets pays in interest, lay on average 4.5 basis points above the minimum bid rate between June 2000 and September 2008. On 8 October, it rose to 111 basis points above the minimum bid rate, indicating that banks were

Figure 3: Repo supply



Note: Liquidity outstanding counts euro repo auctions only, securities held are securities of euro area residents denominated in euro. Source: ECB website, author's calculations.

Figure 3 provides details on the repos. Liquidity provision through repos, in the top left panel, increased in several steps.[5] There was a first rise at the end of 2007, when worries about end-of-the-year effects in commercial banks' balance sheets were widespread. The ECB raised the amount of liquidity outstanding after the collapse of Lehman Brothers in September 2008. Since that October, the FRFA policy has meant that how much liquidity is made available is determined by banks' demand. There was a decline in outstanding liquidity in mid-2010, but since the second half of 2011, it has increased sharply and beyond levels seen before. This rise may be related to banks' unwillingness to lend across intra-euro zone borders, which has further added to the ECB's role as

urgently looking for liquidity. The ECB only once returned to a variable-rate tender (on 28 April 2010, when there were hopes that the financial crisis was coming to an end), but then immediately reverted to full allotment.

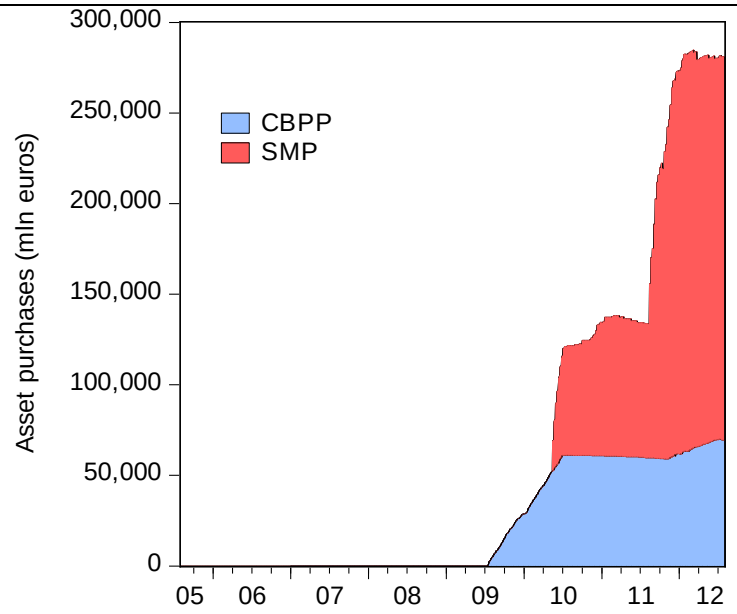
5 We show only liquidity provided through repos and in euros. We record a change in liquidity on the day of settlement of the repo, not on the day of the auction (preliminary regressions suggested the settlement date performed better), and we do not deduct the liquidity parked in ECB deposits, since deposits follow a pattern that depends on maintenance periods and complicate the picture.

intermediary. The rise in commercial banks' deposits with the ECB, which passed 1 trillion euros in the first quarter of 2012, supports this notion.

A comparison of the outstanding liquidity and the length for which the ECB offers funds to commercial banks, shown in the top right graph, suggests that when repos were offered over a long period demand was particularly high. Before the crisis, the ECB offered funds for typically two weeks and three months. Since 2008, it has repeatedly lengthened the duration of its repo contracts. The longest contract has been three years.[6]

The bottom left panel shows that repo auctions were typically settled after one day, though there were quite a number of fast tenders in 2007 and 2008.[7] The demand-supply gap, shown in the bottom right panel as percentage of demand, started increasing when the crisis began (see also Gerlach-Kristen and Kugler, 2012). This indicates that supply did not keep up with demand. The gap closed on 8 October 2008, when the ECB adopted the FRFA policy.

Figure 4: Asset purchases



Note: CBPP volumes from the ECB's liquidity analysis, SMP volumes constructed from ECB sterilisation announcements. Source: ECB website.

Turning from the temporary liquidity provision to the ECB's outright asset purchases, we show in Figure 4 the securities purchased under the Covered Bond Purchase Programmes (CBPP) and the

[6] It should be noted that there sometimes were several auctions on one day. For those cases, we compute the length of the repo contracts for that day (and any other non-volume variables) as weighted average, with the weights given by the volumes of the different repo auctions. For those days when the ECB did not conduct repo operations, we use the lagged value for those variables. We also estimated the model using only data from repo auction days. The results were similar to those provided in the text.

[7] We do not distinguish between fast and standard tenders. Preliminary regressions showed this difference to be unimportant.

Securities Market Programme (SMP). The first CBPP ran from 4 June 2009 to 30 June 2010, the SMP from 10 May 2010 to 6 September 2012, and CBPP2 began on 3 November 2011. The CBPP volumes are from the ECB's daily liquidity analysis, while the size of the SMP purchases is taken from the ECB announcements on the resulting sterilising operations, which are made weekly. All these data are available from the ECB's website.

2.3 Contagion

To examine the role of contagion, we study the interaction between CDS spreads. Since there are eighteen different spreads in our sample, we refrain from including them all individually in the regressions. Instead, we construct summary measures.

There are three hypotheses we would like to test. First, we want to test for existence of contagion within a group (i.e. among commercial banks and among sovereigns). To do so, we proceed as follows. For Commerzbank, the first commercial bank in our sample, we construct a summary measure of all other commercial bank CDS spreads. This measure is given by the first principal component of all commercial bank CDS spreads apart from that of Commerzbank.[8] We include the lagged value of this measure in the regression for the Commerzbank spread. This allows us to assess whether a common movement in the other banks' CDS spreads on the previous day impacts on the Commerzbank spread today. To test for within-sovereign contagion, we construct e.g. for Germany the first principal component of the other five sovereign spreads and use the lagged value of this variable in the regression.

Second, we would like to examine if there was contagion between groups. I.e., if commercial bank CDS spreads increase, does that cause a rise in sovereign spreads the following day? To test this hypothesis, we construct one principal component of all commercial bank spreads and another first principal component from all sovereign CDS spreads. The lag of the commercial bank principal component is then included in the regression for the different sovereign CDS spreads. If we find a significant positive impact in e.g. the German equation, this suggests that the German CDS spread tends to rise if perceived default risk increases in the banking sector. Correspondingly, the lagged sovereign principal component is included in the individual commercial bank regressions, and a significant coefficient would indicate that sovereign default risk raises the same risk of individual banks.

Third, we would like to test whether contagion within a country is stronger than across borders. To test for domestic contagion, we include in the Commerzbank and Deutsche Bank regressions the lagged German CDS spread, and in the regression for Germany the lagged spreads of both Commerzbank and Deutsche Bank. If we identify a significant positive impact, this implies that domestic contagion is particularly strong and detectable beyond the common movements identified by the first principal component.

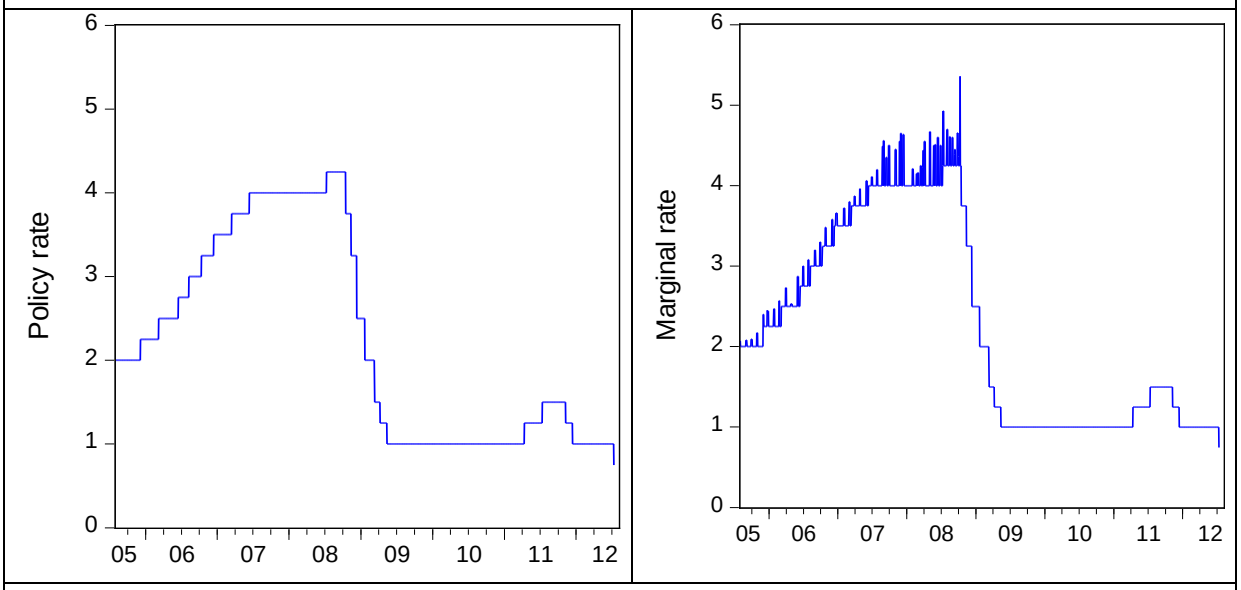
[8] We construct the loadings for the principal components using the correlation, rather than the covariance, matrix of the different CDS spreads. This avoids attaching a dominating weight on the most volatile CDS spreads (i.e. Greece). We ensure that the loadings are normalised such that the first principal component increases in times of market stress.

2.4 Other explanatory variables

To account for other forces that drive CDS spreads, we include a number of controls in our regressions. The first of these are ECB interest rates. Figure 5 shows the policy rate and the marginal rate.

The policy rate is set by the Governing Council and affects a commercial bank's default probabilities positively or negatively, depending on the bank's interest-rate exposure and hedging. The policy rate was moreover the minimum bid rate for auctions that were conducted under flexible-rate tenders. The marginal rate was determined mechanically as the rate payable by the last bank whose bid the ECB accepted. When the ECB adopted full allotment, the policy rate became the repo rate for all banks partaking in the auction.

Figure 5: ECB interest rates (in %)



Source: ECB website

To capture the rescue packages granted to Ireland, Greece, Portugal and Spain, we construct a series of bailout dummies that take the value of unity the day a Troika bailout was agreed and thereafter. For Greece, this variable takes the value 2 after the second bailout. The default dummy is set to unity after the Greek sovereign CDS spread reached 10,000 basis points. We also include a dummy for the nationalisation of Anglo Irish Bank on 15 January 2009, which pushed Irish government finances into turmoil. This might be reflected in the Irish sovereign CDS spread.

We capture calendar effects using an end-of-quarter dummy, general market volatility using the VIX, and any other euro-area developments not reflected in the previous variables using the euro-dollar exchange rate. Any further influences on the CDS spreads, and there are certainly many, are subsumed in the residual. We estimate our equations in systems to allow for the fact that shocks may be correlated across banks and sovereigns. We now turn to the estimation.

3. Regression setup

In this section we present the regression setup. Sections 4 and 5 discuss the estimates by topic, focussing first on the ECB's open market operations and then on contagion. We model CDS spreads in two systems of equations. For commercial CDS spreads we fit for each bank

$$
\begin{aligned}
CDS_{j,t} = {} & a_j + a_{j,1} CDS_{j,t-1} + a_{j,2} CDS_{j,t-2} \\
& \left.\begin{aligned}
& + a_{j,repo} repo_t + a_{j,repo,1} repo_{t-1} + a_{j,length} length_t \\
& + a_{j,settle} settlement_t + a_{j,dsg} dsg_t \\
& + a_{j,CBPP_ann} CBPP_ann_t + a_{j,CBPP2_ann} CBPP2_ann_t \\
& + a_{j,CBPP} CBPP_t + a_{j,CBPP,1} CBPP_{t-1} \\
& + a_{j,SMP_ann} SMP_ann_t + a_{j,SMP} SMP_t + a_{j,SMP,5} SMP_{t-5}
\end{aligned}\right\} \text{Open market operations} \\
& \left.\begin{aligned}
& + a_{j,Banks} pcBanks_{j,t-1} + a_{j,Sovs} pcSovs_{t-1} \\
& + a_{j,ownSov} ownSov_{t-1}
\end{aligned}\right\} \text{Contagion} \\
& \left.\begin{aligned}
& + a_{j,prate} prate_t + a_{j,mrate} mrate_t \\
& + a_{j,GR} bailoutGR_t + a_{j,IE} bailoutIE_t + a_{j,PT} bailoutPT_t \\
& + a_{j,SP} bailoutSP_t + a_{j,dGR} defaultGR_t + a_{j,Anglo} Anglo_t \\
& + a_{j,q} quarter_t + a_{j,VIX,1} VIX_{t-1} + a_{j,VIX,2} VIX_{t-2} \\
& + a_{j,USD,1} USD_{t-1} + a_{j,USD,2} USD_{t-2} + e_{j,t}
\end{aligned}\right\} \text{Other controls}
\end{aligned}
$$

The first two terms capture the autoregressive component of the CDS spreads and account for potential unit root behaviour.

The next block of variables captures the ECB open market operations. We first include variables on the liquidity provision through repos, starting with the outstanding repo liquidity today and yesterday. We include the lag because it might be either the stock or the flow of this variable that affects CDS spreads. Besides the repo volume, we also analyse whether the length of the contract helped reduce financial stress, the settlement speed and the demand-supply gap.[9] Next follow variables covering the ECB's purchases. We include a dummy that takes the value of unity on the day a programme was announced (and -1 when the CBPP was stopped), and two variables recording the total volumes of assets bought under the two programmes. Again, we include the current value as well as the lag to account for the possibility that it is the flow, rather than the stock, of purchases that matters. While the CBPP data are available daily, the SMP data are weekly basis. We therefore use as lag of five working days for the SMP.

The next block of variables captures contagion. We first control for contagion between commercial banks. To do so, we construct the first principal component of the CDS spreads of all commercial banks but the one studied and include this in the regression. The next variable is the first principal

[9] In early regressions, we also included dummies for those days on which the collateral rules were changed. However, they were almost always insignificant, and we have therefore excluded them.

component of all sovereign CDS spreads. If doubts about government finances affect commercial banks' outlook, as they might well if a bank holds government bonds, this variable should be significant. To account for the possibility that the own sovereign is particularly important, be this because the bank is biased towards domestic government bonds or because the state's capacity for support matters for a bank's CDS spread, we include the domestic sovereign CDS spread as a separate variable. We lag the variables capturing contagion to avoid simultaneity.

Finally, there are other controls. The first of these are ECB interest rates. It is not clear what effect they should have on CDS spreads.[10] Bailout, default and the Anglo dummies should in principle reduce market stress and thus bring down spreads. However, if the measures threaten the finances of the rescuers, there might be the opposite effect for some of the sovereign CDS spreads. The quarter dummy might increase some bank spreads, and the VIX should generally be associated with higher spreads. The dollar exchange rate, finally, is defined as EUR/USD, so that an increase captures a depreciation of the euro. To the extent that depreciation helps restore competitiveness, a rise in the exchange rate should be correlated with falling sovereign spreads. Note that we lag the exchange rate and the VIX to avoid simultaneity.

We estimate the CDS spread equation simultaneously for all twelve commercial banks using seemingly unrelated regression techniques. [11] This approach lets us take advantage of the fact that banks' CDS spreads probably were exposed to much the same shocks.

We estimate essentially the same regression for sovereign CDS spreads,

$$
\begin{aligned}
CDS_{j,t} = {} & a_j + a_{j,1} CDS_{j,t-1} + a_{j,2} CDS_{j,t-2} \\
& \left.\begin{aligned}
& + a_{j,repo} repo_t + a_{j,repo,1} repo_{t-1} + a_{j,length} length_t \\
& + a_{j,settle} settlement_t + a_{j,dsg} dsg_t \\
& + a_{j,CBPP_ann} CBPP_ann_t + a_{j,CBPP2_ann} CBPP2_ann_t \\
& + a_{j,CBPP} CBPP_t + a_{j,CBPP,1} CBPP_{t-1} \\
& + a_{j,SMP_ann} SMP_ann_t + a_{j,SMP} SMP_t + a_{j,SMP,5} SMP_{t-5}
\end{aligned}\right\} \text{Open market operations} \\
& \left.\begin{aligned}
& + a_{j,Sovs} pcSovs_{j,t-1} + a_{j,Banks} pcBanks_{t-1} \\
& + a_{j,Bank1} Bank1_{t-1} + a_{j,Bank2} Bank2_{t-1}
\end{aligned}\right\} \text{Contagion} \\
& \left.\begin{aligned}
& + a_{j,prate} prate_t + a_{j,mrate} mrate_t \\
& + a_{j,GR} bailoutGR_t + a_{j,IE} bailoutIE_t + a_{j,PT} bailoutPT_t \\
& + a_{j,SP} bailoutSP_t + a_{j,dGR} defaultGR_t + a_{j,Anglo} Anglo_t \\
& + a_{j,q} quarter_t + a_{j,VIX,1} VIX_{t-1} + a_{j,VIX,2} VIX_{t-2} \\
& + a_{j,USD,1} USD_{t-1} + a_{j,USD,2} USD_{t-2} + e_{j,t}
\end{aligned}\right\} \text{Other controls}
\end{aligned}
$$

[10] On the one hand, higher interest rates make the situation for borrowers such as commercial banks and governments more expensive. On the other hand, banks are lenders as well and might benefit from higher rates. Since the impact of interest rates is not the focus of this paper, the ambiguity of the expected sign on interest rates does not matter for the main analysis.

[11] We do not impose equality constraints across equations since preliminary tests tended to reject.

The only difference is that for contagion, we include the two first principal components of all other sovereigns and of all commercial banks, as well as the CDS spreads of the two domestic banks. Again, the inclusion of the latter accounts for the possibility of especially strong spill-overs within a country.

In the estimation, we use daily week-day data and consider four subsamples, to allow for the possibility that CDS spreads responded differently to different measures and events over time. The first is the pre-crisis sample, runs from 1 August 2005 to 8 August 2007, the day before the Paribas announcement. The Paribas phase ends on 12 September 2008. Lehman Brothers collapsed on 15 September 2008, and the Lehman phase covers data up to 21 April 2010. The next day, the Greek CDS spread crossed 500 basis points, and we choose this as the onset of the euro-area debt crisis.

Tables 1 to 4 present the results for these four subsamples for commercial bank CDS spreads, Tables 5 to 8 show the results for sovereign spreads. In discussing the results, we first concentrate on the effect of open market operations and then turn to the issue of contagion. Within each of these sections, we discuss commercial bank CDS spreads and sovereign spreads in turn.

4. ECB open market operations and CDS spreads

This section examines how the ECB's open market operations reduced market pressure as captured by CDS spreads. Given the degree of detail the ECB publishes on its operations, we are able to ask quite detailed questions, such as the following. Did the repo auctions mainly improve commercial banks' financial situation, who are the ECB's counterparties in the tenders, or was there also an indirect impact on sovereign CDS spreads? Did it matter for how long liquidity was provided for, and how fast? How did asset purchases help? Were the CBPPs or the SMP more effective in driving down spreads?

One important issue in this analysis is endogeneity. After all, the ECB is likely to increase liquidity supply when CDS spreads rise. The analysis addresses this issue in two ways. First, the CDS spreads used in the estimation were recorded at the end of the trading day, i.e. after the open market operations. The ECB operations thus were not based on the CDS values recorded for that day. Second, we include lagged values in the analysis. Obviously, the ECB's operations reflected the general level of market stress in a particular period, so that there is a longer-run link between the operations and the CDS spreads. The presence of lags in the analysis allows for a long-run relationship between the level of CDS spreads and the volume of open market operations. From this perspective, our regressions can be thought of as reformulated error-correction equations.

Another issue that must be mentioned is that for the temporary open market operations, only commercial banks, but not sovereigns, were ECB counterparties. Therefore, if we detect and impact of repo auctions on sovereign CDS spreads, this captures an indirect effect stemming from changes in the health of the financial sector. The same is true for purchases under the CBPP. By contrast, the SMP had a direct impact on sovereign CDS spreads, since under this programme also government bonds were bought. Presumably, these operations should affect the discount at which new government debt is issued.

With these qualifications in mind, we now turn to analysing the regression output.

Table 1: Impact on commercial bank CDS spreads, pre-crisis phase (1 August 2005 to 8 August 2007)

	Commerz-bank	Deutsche Bank	Alpha Bank	National Bank of Greece	AIB	Bank of Ireland	Monte dei Paschi di Siena	Unicredit	Banco Comercial Português	Banco Espírito Santo	BBVA	Santander
AR1	0.583***	0.663***			0.788***	0.763***	0.711***	0.703***	0.378***		0.670***	0.711***
AR2	0.184***	0.258***			0.016	0.167***	0.153***	0.123***	0.156***		0.151***	0.138***
ECB open market operations												
Repo	0.011	0.008			-0.008	-0.002	-0.005	0.003	-0.017**		0.002	0.003
$Repo_{-1}$	-0.012	-0.006			0.009	0.002	0.005	-0.006	0.010		0.002	0.003
Length	0.017**	0.010**			0.002	-0.000	0.006*	0.004	0.002		0.004	0.003
Settle	0.112	-0.096			-0.195	0.032	0.039	0.245	0.200		0.164	0.213
dsg	-0.005	0.009			0.012	0.006	0.006	0.002	-0.002		0.002	-0.001
Contagion												
pcBanks	15.707***	0.445			7.967***	3.221***	6.670***	7.537***	23.706***		6.819***	5.176***
pcSovs	-0.181	-0.066			-9.762***	-2.684	-0.031	-0.092	-0.547**		-0.330	-0.303
ownSov	0.142	-0.008			0.017***	0.005	0.024	0.163***	-0.119***		-0.012	-0.012
Other controls												
Prate	3.321*	2.863**			1.032	0.210	1.469	1.380	0.164		1.301*	0.537
Mrate	-2.858	-2.512*			-0.810	0.050	-1.697*	-0.858	-0.312		-0.946	-0.346
Quarter	-0.554	0.004			-0.081	0.034	0.138	0.196	0.302		0.027	-0.046
VIX_{-1}	0.752***	0.473***			0.169***	0.160***	0.371***	0.323***	0.166***		0.262***	0.309***
VIX_{-2}	-0.635***	-0.318***			-0.129***	-0.128***	-0.287***	-0.272***	-0.141***		-0.214***	-0.228***
USD_{-1}	-19.118	-3.579			-2.493	2.566	2.033	0.718	7.821		-3.048	1.471
USD_{-2}	11.746	-1.167			3.344	-3.325	-3.426	-2.756	-6.585		2.378	-2.610
Adj R^2	0.900	0.900			0.943	0.958	0.963	0.935	0.961		0.950	0.944

Note: 527 observations, SUR estimates. Impact of open market operations per billion euro. No data available to Alpha Bank, National Bank of Greece and Banco Espírito Santo. */**/*** denotes significance at the 10/5/1 percent level.

Table 2: Impact on commercial bank CDS spreads, Paribas phase (9 August 2007 to 12 September 2008)

	Commerz-bank	Deutsche Bank	Alpha Bank	National Bank of Greece	AIB	Bank of Ireland	Monte dei Paschi di Siena	Unicredit	Banco Comercial Português	Banco Espírito Santo	BBVA	Santander
AR1	0.785***	0.860***	0.607***		0.907***	0.911***	0.773***	0.828***	0.816***	0.804***	0.611***	0.690***
AR2	0.126***	0.064*	0.073		0.047	0.029	0.001	0.081**	-0.012	-0.030	0.079***	0.004
ECB open market operations												
Repo	-0.018	-0.013	-0.051		-0.010	-0.002	-0.004	-0.011	-0.017*	-0.003	-0.019*	-0.013
$Repo_{-1}$	0.006	0.005	0.135***		0.010	0.011	-0.000	0.003	0.007	0.008	0.010	0.010
Length	0.022*	0.017	NA		-0.001	-0.021	0.006	0.020	0.010	-0.007	0.007	0.013
Settle	-3.038**	-1.171	-0.000		-1.200	0.341	-1.260	-0.552	-0.520	-1.312	-0.531	0.389
Dsg	-0.032	-0.008	0.035		-0.058**	-0.021	0.003	0.012	-0.007	0.007	0.009	0.004
Contagion												
pcBanks	0.910	-0.763	12.375**		7.100***	8.779***	7.989***	0.121	6.332***	6.406*	9.833***	10.100***
pcSovs	13.383***	11.694***	-10.411		-10.613	-22.319**	8.262**	8.791*	12.171***	18.119**	22.379***	16.545***
ownSov	-0.449**	-0.302	-1.166**		0.024	0.056*	-0.005	-0.018	-0.016	0.108	-0.190**	-0.105
Other controls												
Prate	-9.860**	-3.989	0.530		11.223**	17.270**	-11.135***	-3.459	0.111	2.257	-0.140	3.381
Mrate	-2.466	-3.130	-0.621		0.360	3.347	-1.682	-4.629**	-2.236	1.355	-2.909	-3.760*
Quarter	1.816	1.651	2.626		1.848	1.646	2.899	2.153	1.315	3.006	2.566	2.540
VIX_{-1}	1.148***	1.083***	0.054		0.812***	0.858***	0.886***	1.065***	0.826***	0.919***	0.887***	1.006***
VIX_{-2}	-1.159***	-1.042***	-0.324		-0.926***	-0.979***	-0.939***	-1.051***	-0.843***	-1.226***	-0.859***	-0.919***
USD_{-1}	-11.772	16.153	97.785*		-9.695	58.149	-28.318	0.387	3.766	47.788	7.933	-0.202
USD_{-2}	-1.261	-23.138	-98.333		-3.710	-68.764	20.556	-6.548	-22.984	-56.313	-20.012	-14.859
Adj R^2	0.960	0.959	0.915		0.986	0.987	0.970	0.951	0.975	0.958	0.969	0.970

Note: 287 observations (61 for Alpha Bank, 104 for Banco Espírito Santo), SUR estimates. Impact of open market operations per billion euro. No data available to National Bank of Greece. */**/*** denotes significance at the 10/5/1 percent level.

Table 3: Impact on commercial bank CDS spreads, Lehman phase (15 September 2008 to 21 April 2010)

	Commerz-bank	Deutsche Bank	Alpha Bank	National Bank of Greece	AIB	Bank of Ireland	Monte dei Paschi di Siena	Unicredit	Banco Comercial Português	Banco Espírito Santo	BBVA	Santander
AR1	0.711***	0.836***	0.887***		0.916***	0.908***	0.766***	0.735***	0.867***	0.986***	0.801***	0.799***
AR2	0.159***	0.045	0.039		0.032	0.025	0.126***	0.101***	0.001	-0.088**	0.099***	0.057*
ECB open market operations												
Repo	0.027**	0.042**	0.012		0.002	0.001	0.015	-0.031**	-0.004	-0.004	0.004	0.000
$Repo_{-1}$	-0.031***	-0.395**	-0.036		-0.039	-0.036	-0.022**	0.011	-0.008	-0.011	-0.014	-0.012
Length	0.000	0.001	0.006		-0.005	0.002	0.000	0.002	0.001	0.002	0.000	0.002
Settle	3.605*	7.995***	5.466		11.238**	13.793**	4.466**	9.155***	4.437*	2.517	3.033	2.424
Dsg	0.154*	0.306***	-0.039		0.572***	0.474**	0.273***	0.061	0.197**	0.245***	0.210***	0.183**
CBBP_ann	0.503	-1.027	-3.180		-7.191	-4.991	0.186	1.120	6.823	0.741	0.041	-2.397
CBPP	-2.052	-0.871	-5.657		1.746	1.291	-0.789	-0.804	-1.950	-0.185	-1.275	-1.487
$CBPP_{-1}$	1.927	0.800	5.703		-2.108	-1.816	0.773	0.707	1.924	0.132	1.290	1.500
Contagion												
pcBanks	1.617	0.547	0.015		-5.923	-1.693	-4.086***	0.383	1.074	-1.043	-1.568	-0.585
pcSovs	1.254	0.511	10.382**		18.919***	21.548***	5.186***	9.321***	-1.004	1.457	2.228*	2.075
ownSov	-0.051	0.038	0.065		-0.047***	-0.071***	0.027*	-0.010	0.126***	0.088***	0.050**	0.074***
Other controls												
Prate	7.589	40.061***	11.359		-2.102	-3.281	11.296*	14.878*	7.116	11.245*	12.599**	8.331
Mrate	-8.605	-39.909***	-7.414		-2.597	2.693	-12.634**	-14.167*	-8.012	-12.781**	-13.516**	-8.485
Anglo	-10.603*	-11.355*	27.127		-21.451	-17.818	-7.742	-11.944	-9.153	-14.819**	-11.725**	-13.328**
Quarter	2.922	5.599**	1.202		4.450	4.692	-0.454	-1.747	-0.003	0.489	-1.954	-2.227
VIX_{-1}	0.253**	0.499***	-0.574		0.646***	0.194	0.494***	0.395***	0.371***	0.530***	0.512***	0.525***
VIX_{-2}	-0.372***	-0.499***	0.510		-0.636***	-0.504*	-0.450***	-0.364***	-0.443***	-0.615***	-0.511***	-0.528***
USD_{-1}	-30.318	-57.963**	-31.920		-54.220	-87.810	-48.107*	-77.997**	-12.289	-38.072	-39.750	-30.350
USD_{-2}	6.511	49.128*	3.486		59.630	96.698	42.352	88.574***	0.822	30.952	26.650	19.952
Adj R^2	0.929	0.920	0.983		0.986	0.986	0.942	0.956	0.966	0.969	0.945	0.937

Note: 418 observations, SUR estimates. Impact of open market operations per billion euro. No data available to National Bank of Greece. */**/*** denotes significance at the 10/5/1 percent level.

Table 4: Impact on commercial bank CDS spreads, euro-crisis phase (22 April 2010 to 1 August 2012)												
	Commerz-bank	Deutsche Bank	Alpha Bank	National Bank of Greece	AIB	Bank of Ireland	Monte dei Paschi di Siena	Unicredit	Banco Comercial Português	Banco Espírito Santo	BBVA	Santander
AR1	0.883***	0.884***	0.676***	0.571***	1.025***	0.846***	0.926***	0.937***	0.991***	1.051***	0.844***	0.834***
AR2	-0.005	-0.051*	0.246***	0.273***	-0.075*	0.041	0.026	-0.022	-0.067*	-0.127***	-0.049*	-0.030
ECB open market operations												
Repo	-0.013	-0.006	0.165	-0.329***	0.014	0.033	-0.027	-0.015	0.002	0.007	0.016	0.007
$Repo_{-1}$	0.021	0.013	-0.188*	0.290**	0.001	-0.052	0.025	0.012	-0.027	-0.012	0.005	0.010
Length	-0.004	-0.004	-0.000	0.042**	-0.002	0.006	-0.008	-0.007	0.002	-0.004	-0.006	-0.007*
Settle	-2.781	-1.499	4.535	13.228	-1.001	-5.644	-3.120	-2.065	2.831	0.227	-3.149	-2.437
CBPP_ann	3.701	1.648	-27.992	36.297	-1.699	-20.487	6.545	0.998	-4.681	5.937	-4.034	0.853
CBPP2_ann	-13.115	2.123	-97.631*	-7.720	2.749	1.768	-18.520	-17.391	7.360	-3.615	-10.820	-7.758
CBPP	-3.414	-3.916	-21.107	17.936	6.692	9.158	-6.457	-8.270	-22.061*	-8.657	-5.601	-5.234
$CBPP_{-1}$	2.952	2.662	17.769	-22.471	-6.128	-7.373	5.951	7.596	19.661*	7.498	5.313	4.351
SMP_ann	-36.355***	-52.270***	-202.273***	-6.859	-83.376**	-88.813*	-80.242***	28.792**	-159.184***	-149.846***	-81.293***	-83.038***
SMP	-0.040	0.156	0.624	1.114	0.153	-0.001	-0.066	0.170	0.684	0.399	-0.051	-0.137
SMP_{-5}	0.044	-0.099	-0.115	-0.096	-0.130	-0.725	0.030	-0.151	-0.559	-0.414	0.039	0.146
Contagion												
pcBanks	4.303***	2.440***	6.910	-10.063*	3.230	15.722***	2.131	4.378***	3.761	-0.219	6.868***	6.030***
pcSovs	-3.407**	-1.115	12.833*	37.909***	-2.990	-10.301	-5.749**	-5.452***	9.465*	8.679**	-5.690***	-4.661***
ownSov	0.151***	-0.024	-0.004	-0.001	0.024	0.074	0.072***	0.084***	0.009	0.005	0.092***	0.078***
Other controls												
Prate	6.926	0.200	-1.776	36.479	26.209	-14.106	0.101	3.782	-12.221	-14.332	6.499	-0.891
Bailout GR	4.354	1.988	-11.215	-8.979	3.862	36.516**	8.457*	3.221	-0.995	-4.526	1.410	3.326
Bailout PT	-0.696	-3.617**	-19.768*	-2.518	28.283***	29.944**	2.335	-2.504	2.902	12.331**	-1.070	2.650
Bailout IE	0.808	-0.624	24.125	41.028***	-13.052	57.999***	4.372	2.915	1.851	3.990	0.511	0.594
Bailout SP	-0.623	2.354	24.547	13.606	-6.315	-5.336	5.807	-0.974	3.175	1.179	-9.439**	-4.132
Default GR	4.812	3.329	19.043	-27.645	-6.608	-19.105	10.777**	10.248**	-2.004	-3.535	8.544**	8.625**
Quarter	-4.565	-3.088	6.658	8.057	-25.714**	-9.927	-7.800	-5.243	1.949	2.592	-6.323	-5.928
VIX_{-1}	0.485**	0.574***	-0.254	2.029*	-1.284*	-1.604	0.578*	0.674**	0.338	0.635	0.404	0.405
VIX_{-2}	-0.685***	-0.324**	0.162	-1.899	0.399	0.699	-0.820**	-1.006***	0.072	-0.551	-0.535**	-0.438*
USD_{-1}	-125.002***	-98.461***	-609.216**	162.230	-214.672	-98.670	-242.973***	-155.125**	-247.369*	-201.359**	-108.661*	-95.874*
USD_{-2}	132.710***	100.118***	545.926**	-289.929	221.621	262.138	250.195***	165.296***	289.394**	213.476**	112.450**	120.681**
Adj R^2	0.982	0.975	0.993	0.994	0.993	0.990	0.993	0.993	0.995	0.992	0.981	0.984

Note 595 observations (AIB 260), SUR estimates. Impact of open market operations per billion euro. */**/*** denotes significance at the 10/5/1 percent level.

ECB operations and commercial bank CDS spreads

Table 1 shows that before the financial crisis, commercial banks' CDS spreads did not respond clearly to liquidity provision. The CDS spread of Banco Comercial Português is the only spread that significantly decreased in response to larger repo volumes. Otherwise, we find for the two German banks and Banca Monte dei Paschi di Siena an apparent rise in CDS spreads when repos were available for longer periods. Before the crisis, the ECB offered three-month funds monthly to help banks meet their reserve requirements, and the movements in CDS spreads seem to be connected with this.[12]

During the Paribas phase, the results shown in Table 2 suggest that increased liquidity provision through repos seems to have reduced CDS spreads. We estimate a significant negative impact on CDS spreads for Banco Comercial Português and BBVA.[13] Once Lehman Brothers collapsed, we identify in Table 3 a clear impact of settlement speed and the demand-supply gap on commercial bank CDS spreads. Fast settlement tended to drive down spreads, which is not surprising given that in this phase money markets had dried up. Similarly, CDS spreads apparently declined when the ECB supplied much liquidity relative to demand. The impact of large repo volumes per se is unclear.[14]

After the bankruptcy of Lehman Brothers, the ECB adopted the CBPP. Neither its announcement nor the actual purchases have a significant impact on CDS spreads. By contrast, Table 4 shows that the announcement of the SMP apparently reduced spreads drastically, by up to 200 basis points. Actual volumes do not appear to matter, though this part of the analysis is hampered by the fact that we only have weekly SMP data. Temporary open market operations have no clear impact during the euro-crisis phase.

ECB operations and sovereign CDS spreads

Turning next to the impact of open market operations on sovereign CDS spreads, we see in Table 5 that before the crisis, large repo volumes apparently drove up markets' belief that government finances might be negatively affected in Germany and Italy. This might be related to the role of liquidity providers German and Italian banks seem to have had in money markets.

Once the financial crisis began, we find in Table 6 no clear impact of temporary open market operations on sovereign CDS spreads anymore. The Italian spread apparently declined in the

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[12] Perhaps related to this, we find that German bank CDS spreads seemed to rise when the marginal rate was close to the policy rate, which happened when the ECB accommodated most of the liquidity demand. It is possible that the German banks tended to provide liquidity to others, so that their business model suffered when the ECB offered long-term and cheap liquidity.

[13] The coefficient on the lagged repo volume is negative, though insignificant, indicating that it might be the flow of liquidity, not the outstanding stock, that affects CDS spreads. We also find a significant lagged coefficient for Alpha Bank.

[14] We again find that German spreads apparently increased when much liquidity is offered. By contrast, the CDS spread of Unicredit seemed to decline.

Paribas phase if the flow of repos was large.[15] Of course, government were not a party in the repo tenders. What we detect here therefore must be an indirect effect. Presumably, it relates to the notion that the ECB's actions would help stabilise the economy and therefore government finances. This indirect impact makes it difficult to interpret some of the findings on temporary open market operations. For instance, we find that fast settlement seems to have reduced the Irish CDS spread, but to have raised the German spread. After the collapse of Lehman Brothers, the only impact temporary open market operations seem to have had on sovereigns was on Irish spreads. In Table 7, fast settlement, again, and a small demand-supply gap appear to have reduced Irish spreads.

While permanent open market operations also do not involve the government as a transaction party, at least under the SMP government bonds were purchased. Since the bond price rises and yields falls when the ECB government bonds and since primary auction participants take account of such market signals, it should be expected that sovereign CDS spreads declined after SMP purchases. Also, the announcement of programmes might reduce spreads.

Table 7 shows that in the Lehman phase, the announcement of the first CBPP has no significant effect on sovereign CDS spreads. We find that a large flow of purchases seems to have helped drive down the Spanish CDS spread.[16] When the SMP was announced, we find in Table 8 again a massive drop in spreads. The announcement of CBPP2 does not seem to have had any impact. Last settlement seems to have raised CDS spreads in Greece and Spain, which may indicate that markets took speedy liquidity provision as a crisis sign.

[15] We find the same signs for Ireland, though only the lagged repo volume is significant.

[16] Interestingly, these coefficients are rather large. An additional one million of purchases under the CBPP apparently lowered Spanish spreads by 4.2 basis points. For comparison, the effect of an additional million provided through repos seems to have lowered Italian CDS spreads in the Paribas phase by a mere 0.004 basis points.

Table 5: Impact on sovereign CDS spreads, pre-crisis phase (1 August 2005 to 8 August 2007)						
	Germany	Greece	Ireland	Italy	Portugal	Spain
AR1	0.565***	0.672***	0.714***	0.834***	0.600***	0.676***
AR2	0.245***	0.250***	0.096**	0.094**	0.314***	-0.150***
ECB open market operations						
Repo	0.004*	0.004	-0.199	0.006**	0.005	0.003
$Repo_{-1}$	-0.003	0.001	-0.264	-0.003	-0.002	0.005
Length	0.001	0.001	0.087	0.001	-0.002	-0.007*
Settle	0.027	-0.178	5.500	-0.128	0.154	-3.299***
Dsg	0.005**	-0.001	0.199	0.000	-0.001	0.013
Contagion						
pcSovs	0.035	-0.069	56.980	-0.137	-0.197*	0.420
pcBanks	-1.532	0.267	17.418	1.479	0.729	2.016
ownBank1	0.017	NA	-0.846	-0.045***	-0.006	0.022
ownBank2	0.006	NA	-0.011	0.015	NA	-0.033
Other controls						
Prate	0.438*	-0.002	49.200	0.007	-0.724**	-1.170
Mrate	-0.470*	-0.379	-36.385	-0.467*	0.541*	0.967
Quarter	0.034	-0.146	79.379***	0.157	0.234*	2.300***
VIX_{-1}	0.008	0.004	1.491	0.039***	0.046***	0.026
VIX_{-2}	-0.013	0.003	-0.295	-0.023*	-0.037**	-0.079
USD_{-1}	-2.653	0.626	223.931	3.733*	4.722*	2.406
USD_{-2}	3.246*	-0.821	-259.135	-2.485	-5.033*	4.842
Adj R^2	0.679	0.982	0.704	0.972	0.953	0.595

Note: 527 observations, SUR estimates. Impact of open market operations per billion euro. */**/*** denotes significance at the 10/5/1 percent level.

Table 6: Impact on sovereign CDS spreads, Paribas phase (9 August 2007 to 12 September 2008)						
	Germany	Greece	Ireland	Italy	Portugal	Spain
AR1	0.928***	0.524***	0.482***	0.952***	0.720***	0.707***
AR2	-0.058	0.310***	0.220***	0.003	0.038	0.082
ECB open market operations						
Repo	0.000	0.009	-0.057	-0.004*	-0.001	0.001
Repo-1	0.000	0.003	0.065*	0.006**	0.001	0.003
Length	-0.001	-0.001	-0.057	-0.003	-0.003	-0.003
Settle	-0.253*	NA	12.407**	0.346	0.319	0.153
Dsg	-0.001	0.013	-0.151	-0.006	0.004	-0.002
Contagion						
pcSovs	0.319	9.592**	120.687***	2.927***	5.235***	3.827***
pcBanks	0.302	-0.806	-2.046	-0.722	1.543	1.531*
ownBank1	-0.005	0.004	-0.194	0.009	0.001	0.059**
ownBank2	0.004	NA	0.247	0.016	-0.003	-0.045*
Other controls						
Prate	-0.0169	-4.504**	3.806	0.879	1.115	0.953
Mrate	0.091	0.423	10.083	0.054	0.230	0.736
Quarter	-0.148	1.986***	1.439	0.162	-0.658	0.095
VIX_{-1}	0.012	0.074	1.475**	0.088**	0.107**	0.021
VIX_{-2}	-0.005	-0.081	-0.876	-0.069**	-0.010	-0.043
USD_{-1}	-1.325	-7.557	228.620*	6.454	12.781	12.092
USD_{-2}	0.424	5.995	-194.514	-8.693	-14.104*	-9.040
Adj R^2	0.955	0.959	0.966	0.995	0.980	0.993

Note: 287 observations (Greece 62), SUR estimates. Impact of open market operations per billion euro. */**/*** denotes significance at the 10/5/1 percent level.

Table 7: Impact on sovereign CDS spreads, Lehman phase (15 September 2008 to 21 April 2010)						
	Germany	Greece	Ireland	Italy	Portugal	Spain
AR1	1.073***	0.991***	0.759***	0.968***	1.006***	0.816***
AR2	-0.138***	-0.075*	0.003	-0.021	-0.038	0.132***
ECB open market operations						
Repo	-0.002	0.017	0.008	-0.008	-0.004	-0.008
$Repo_{-1}$	0.001	-0.012	-0.052	0.006	-0.002	0.000
Length	0.000	0.008	-0.001	0.004	0.000	0.006*
Settle	-0.148	0.381	102.983***	-1.498	1.141	1.210
Dsg	-0.010	0.130	1.400***	-0.017	-0.001	0.044
CBPP_ann	1.679	11.071	2.813	1.986	1.910	2.201
CBPP	0.061	-5.091	-7.884	-2.999	-2.815	-4.163**
$CBPP_{-1}$	-0.098	5.508	7.274	3.025	2.872	4.219**
Contagion						
pcSovs	1.967***	5.380**	14.543***	2.535**	1.816*	3.056***
pcBanks	0.711	-9.012***	18.381**	-5.179***	-3.450***	-3.494**
ownBank1	-0.028***	0.019***	-0.164**	0.021	0.006	0.039
ownBank2	-0.019**	NA	0.124*	0.021	0.003	-0.055
Other controls						
Prate	-6.968***	9.200	28.336	4.152	5.280	-3.367
Mrate	6.573***	-9.757	-17.625	-4.056	-4.383	2.684
Anglo	-0.012	13.091	18.977	-0.580	-0.091	-0.847
Quarter	0.228	4.198	43.900***	1.970	1.455	-0.928
VIX_{-1}	0.112***	0.229	0.901	0.242***	0.136	0.194**
VIX_{-2}	-0.108***	-0.216	-0.969*	-0.202**	-0.210**	-0.155*
USD_{-1}	-11.406	-96.731**	-231.385*	-42.761*	-54.286**	-70.959***
USD_{-2}	4.317	68.228	296.497**	29.083	40527*	60.025***
Adj R^2	0.990	0.986	0.897	0.983	0.981	0.964

Note: 418 observations, SUR estimates. Impact of open market operations per billion euro. */**/*** denotes significance at the 10/5/1 percent level.

Table 8: Impact on sovereign CDS spreads, euro-crisis phase (22 April 2010 to 1 August 2012)						
	Germany	Greece	Ireland	Italy	Portugal	Spain
AR1	0.866***	0.719***	1.139***	1.094***	1.097***	1.072***
AR2	0.002	0.257***	-0.214***	-0.164***	-0.166***	-0.134***
ECB open market operations						
Repo	0.003	0.549	-0.003	-0.040	-0.105	-0.007
$Repo_{-1}$	-0.003	-0.503	0.000	0.051*	0.084	0.024
Length	-0.001	-0.250**	0.001	-0.005	0.008	-0.004
Settle	-0.634	-158.400**	-2.293	-3.709	-12.006	-5.301*
CBPP_ann	-0.287	-12.035	4.881	20.548	17.921	7.999
CBPP2_ann	-0.602	-36.824	-15.004	-21.218	-28.194	-4.620
CBPP	-1.618	159.341	-5.753	-7.435	-3.052	-6.315
$CBPP_{-1}$	1.253	-169.958	6.439	6.503	-0.583	5.823
SMP_ann	-10.207***	-339.652	-62.639***	-82.717***	-195.415***	-71.071***
SMP	-0.013	1.465	0.141	-0.042	0.387	0.118
SMP_{-5}	0.014	1.779	-0.172	-0.006	-0.059	-0.122
Contagion						
pcSovs	-0.096	-49.552	2.101	-2.392	3.788	-2.738
pcBanks	1.449***	23.611	0.500	2.156	1.320	0.833
ownBank1	-0.006	-0.077	0.003	0.001	-0.033*	-0.012
ownBank2	-0.025**	-0.035	0.006	-0.005	-0.026	0.003
Other controls						
Prate	1.998	-88.873	9.655	16.882**	20.176	13.231
Bailout GR	2.052***	16.023	-6.393	11.049***	11.094	9.578**
Bailout PT	-0.708	-19.630	2.017	-2.909	15.546**	2.884
Bailout IE	-1.490**	113.624	8.823*	0.233	23.885***	1.822
Bailout SP	-1.585**	NA	-4.360	-0.005	-10.486	-1.819
Default GR	-0.198	NA	-3.802	1.108	4.611	0.700
Quarter	0.026	24.660	-6.981	-6.225	-2.145	-5.894
VIX_{-1}	0.147**	3.068	0.174	0.178	0.581	-0.117
VIX_{-2}	-0.163***	-1.703	-0.393	-0.468	-0.998	-0.226
USD_{-1}	-27.335**	-2514.323	-153.188*	-120.227*	-129.267	-94.563
USD_{-2}	16.930	2782.045*	206.421**	107.036*	112.267	87.982
Adj R^2	0.961	0.996	0.990	0.989	0.992	0.979

Note: 595 observations, SUR estimates. Impact of open market operations per billion euro. */**/*** denotes significance at the 10/5/1 percent level.

Summary open market operations

Table 9 provides a summary of the findings just discussed. We code as zero instances when there was at most one significant coefficient estimated for the variable in question in the respective subsamples. If there were significant negative and positive estimates, we denote this by a question mark, unless there were at least two more significant positive (negative) coefficient estimates, in which case we report a "+" ("-"). Obviously, if there were only significant positive (negative) estimates, this is recorded as a "+" ("-"), too.

It can be seen that temporary open market operations successfully lowered commercial bank CDS spreads during those phases of the crisis when liquidity concerns dominated. Early on, sheer volume seems to have mattered, but after the collapse of Lehman Brothers, large supply relative to demand and fast settlements were most effective. During the euro crisis, however, fast settlement seems to have been taken as a negative signal for sovereigns.

For permanent open market operations, we are unable to identify a clear volume effect. That said, the announcement of the SMP drove down both commercial bank and sovereign CDS spreads, and this massively, by up to 200 basis points.

Table 9: Summary open market operations

	Pre-crisis (Aug05-Aug07)		Paribas phase (Aug07-Sep08)		Lehman phase (Sep08-Apr10)		Euro crisis (Apr10-Aug12)	
	Banks	States	Banks	States	Banks	States	Banks	States
Temporary open market operations – Repos								
Volume	0	+	-	0	?	0	0	0
Length	+	0	0	0	0	0	?	0
Settlement speed	0	0	0	?	+	0	0	-
Demand-supply gap	0	0	0	0	+	0	NA	NA
Permanent open market operations – Asset purchases								
CBPP announcements	NA	NA	NA	NA	0	0	0	0
CBPP volume	NA	NA	NA	NA	0	0	0	0
SMP announcement	NA	NA	NA	NA	NA	NA	-	-
SMP volume	NA	NA	NA	NA	NA	NA	0	0

Note: We record a zero impact for variables that are significant in at most one equation per subperiod. Question marks denote variables for which we found roughly equally many significant positive and negative coefficients across banks/sovereigns within one subperiod.

Overall, it is difficult to provide overwhelming evidence of the effectiveness of ECB open market operations in reducing CDS spreads throughout the crisis. Repos seem to have helped initially, while asset purchases appear to have had no discernible effect. That said, we have examined mainly quantitative measures. The finding that the announcement of the SMP mattered so much suggests that qualitative measures underlining the ECB's willingness to act may have been more important. Communication also has played an important role in the ECB's attempts to limit contagion, and this is what we turn to next.

5. Contagion

Since the crisis has spread first from subprime mortgages and banks active in this field to broader money markets and then to sovereigns, contagion between financial institutions and states has been a major issue since 2007. This section assesses the existence and presence of contagion in European CDS spreads. It documents how contagion has spread among commercial banks and among sovereigns and examines whether there are linkages between the two groups. Special attention is paid to domestic contagion, i.e. from banks within one country to that same sovereign, or vice versa.

Contagion in commercial bank CDS spreads

Before the financial crisis, commercial banks' CDS spreads moved together. Table 1 shows for instance that the spread for Commerzbank significantly increased if the day before, the first principal of the other commercial banks in our data set had risen. This finding suggests that market participants' doubts about the health of banks spread from one to the other. Turning to the first principal component of sovereign CDS spreads, we find for this phase a negative impact of sovereign spreads for AIB, Unicredit and Banco Comercial Português. For those three banks, we also identify an effect of the own sovereign (positive for AIB and Unicredit, negative for BCP). There seems to be no obvious explanation for this pattern.

In the first phase of the financial crisis, the contagion across commercial banks remains a robust finding (Table 2). We now also identify a clear effect of sovereign CDS spreads, with higher spreads driving up commercial bank spreads. Presumably, this reflects an effect on back of information on the general state of the economy contained in the sovereign CDS spread, rather than a direct role of the government's default probability. The impact of the own sovereign CDS spread mitigates this effect for Commerzbank, Alpha Bank and BBVA, but strengthens it for Bank of Ireland.

Contagion between banks seems temporarily less pronounced after the collapse of Lehman Brothers, while the common component of sovereign CDS spreads apparently matters for banks in all countries but Germany and Portugal. Table 3 shows these results. Again, this may be related to the state of the economy reflected in government CDS spreads, though it seems likely that over time, the sovereign default probability started to matter directly. In Portugal, the sovereign CDS spread seems to have affected banks' spreads, as was the case in Spain. This may reflect that commercial banks hold government bonds on their portfolio, which implies a major impact of a sovereign default on banks.

It is interesting to contrast the findings for Portugal and Spain with the Irish case. For Ireland, we find that increases in the Irish sovereign CDS spread seem to have reduced Irish banks' CDS spreads. It seems likely that this is the effect of the bank guarantee made by the Irish government on 30 September 2008 and the subsequent capital injections. These measures effectively shifted the risk of bankruptcy from the banks to the state. In this connection, it is noteworthy that the announcement on 15 January 2009 that Anglo Irish Bank would be nationalised does not appear to impact on the Irish bank or sovereign CDS spreads, but that it significantly reduces those of both German bank, of Banco Espírito Santo and both Spanish banks. It seems probable that this reflects markets' belief that banks outside Ireland were heavily exposed to Anglo and that they were the main beneficiaries of the nationalisation.

For the phase of the euro crisis, shown in Table 4, we find contagion within the bank group, while the impact of the principal component of sovereigns sometimes yields a positive and sometime a negative sign. Rises in the own sovereign's CDS spread drive up CDS spreads of Italian and Spanish banks, suggesting clear contagion here.

Contagion in sovereign CDS spreads

Before the crisis, there are few signs of contagion effects both within the group of sovereigns and from banks. The Portuguese CDS spread apparently declined if the spread of other sovereigns increased, and the Italian CDS spread decreased if the spread of Banca Monte di Paschi di Siena rose (Table 5). Then, after the Paribas announcement, there is evidence of contagion among sovereigns. For all countries but Germany does Table 6 report an increase in CDS spreads a day after the first principal component of the other sovereign spreads has risen. This early in the crisis, it seems likely that the effect is due to information contained in sovereign CDS spreads on the general state of the economy, and not to sovereign default risk. For Spain, there also is a positive impact of the first principal component of all banks. The CDS spread of BBVA seems to have had an additional effect in the same direction, while the impact of Santander was weaker.

Table 7 shows that contagion appears to have been pronounced in the phase after the collapse of Lehman Brothers. The first principal component of sovereign CDS spreads is significant for all countries. This may reflect contagion through real trade links, but it may also mirror the realisation that the rescue measures taken by individual countries or the Troika would have cross-border effects on government finances.

The effect of bank spreads is unclear. The Irish CDS spread apparently increased if commercial bank spreads rose (with the effect being even stronger for AIB but weaker for Bank of Ireland), while the sovereign CDS spreads in the other euro-crisis countries tended to decline when bank spreads across Europe rose. Moreover, the German sovereign CDS spread apparently moved in the opposite direction from that of the German commercial banks, while increases in the spread of Alpha Bank seems to have driven up further the Greek sovereign CDS spread.

Finally, during the euro crisis there seems to have been little contagion among sovereign CDS spreads. We only find three significant coefficients in Table 8, one showing a positive impact of bank spreads on the German CDS spread, one of Deutsche Bank (with a negative sign) also on the German spread and one of Banco Comercial Português on the Portuguese sovereign spread (also with a negative sign). It is surprising at first glance to find so little evidence of contagion during the euro area debt crisis. However, it is possible that the ECB's asset purchases under the SMP were successful in breaking the contagion links that had manifested themselves in the Lehman phase.

Summary contagion

Table 10 summarises the findings on contagion. We find contagion from banks to banks in all subsamples but the Lehman phase, and from sovereigns to sovereigns in the Paribas and Lehman phase. During those two subsamples, banks also responded to the principal component of sovereign CDS spreads, which probably captured information on the state of the economy in general. In the opposite direction, there is no evidence of contagion from banks to sovereigns. If anything, we find that sovereign CDS spreads decline in the Lehman sample when bank CDS spreads rise.

The evidence on domestic contagion is mixed. Regarding the impact of the own sovereign CDS spread, we find that it tends to offset the effect of the first principal component during the Paribas phase. Thereafter, a higher domestic sovereign CDS spread has tended to increase the spread of domestic banks in Italy, Portugal and Spain. This may reflect the presence of government bonds in those banks' portfolios, or the worry that constrained government finances imply less room for rescue measures and a higher default probability of banks. In Ireland, where the state took over large parts of the banking system, bank spreads by contrast declined as the sovereign CDS spread increased.

Table 10: Summary contagion

	Pre-crisis (Aug05-Aug07)		Paribas phase (Aug07-Sep08)		Lehman phase (Sep08-Apr10)		Euro crisis (Apr10-Aug12)	
	Banks	States	Banks	States	Banks	States	Banks	States
Contagion from banks	+	0	+	0	0	-	+	0
Contagion from states	-	0	+	+	+	+	?	0
Domestic contagion	?	0	-	?	+[1)]	?	+	-

Note: We record a zero impact for variables that are significant in at most one equation per subperiod. Question marks denote variables for which we found roughly equally many significant positive and negative coefficients across banks/sovereigns within one subperiod. [1)] Negative impact for Irish banks.

The most striking finding in Table 10 is that sovereign CDS spreads do not appear to respond to one another and to stress in the banking system during the euro crisis phase. This is surprising given the scale and spread of this crisis. However, it may reflect that the ECB used SMP purchases as a means of preventing problems in one country from spilling over to other countries and thus successfully stopped contagion.

6. Conclusions

This paper examines euro area CDS spreads during the financial crisis. CDS data allow us to analyse how the crisis affected both commercial banks, which were at the centre of attention in 2007 to 2009, and sovereigns, to which the focus has shifted since.

We try to answer to two questions. First, how effective have the ECB open market operations been in reducing CDS spreads and thus markets' expectations about the default probability of banks and sovereigns? And second, how important has contagion among and between banks and sovereigns been?

For the open market operations, we find that in the early part of the crisis, large repo volumes, both in absolute terms and relative to demand, as well as speedy settlement helped reduce commercial bank CDS spreads. Since the beginning of the euro crisis, only the announcement of the Securities Market Programme has had a clear-cut effect in bringing down both bank and sovereign CDS spreads.

We detect contagion among banks in three of our four subsamples, and contagion among sovereigns in the aftermath of the collapse of Lehman Brothers. During that period, there

also is evidence that increasing sovereign CDS spreads have tended to raise bank spreads. Arguably, the most interesting finding on contagion is, however, that sovereign CDS spreads have appeared immune to general movements in bank spreads and in the spreads of other sovereigns since the onset of the euro crisis. This may indicate that the ECB asset purchases have successively prevented contagion.

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