Abstract

We study spillovers from bank to sovereign risk in the euro area using difference specifications around the European Central Bank's release of stress test results for 130 significant banks on October 26, 2014. We document that following this information release bank equity prices in stressed countries declined. Surprisingly, bank risk in stressed countries was not absorbed by their sovereigns but spilled over to non-stressed euro area sovereigns. As a result, in non-stressed countries, the co-movement between sovereign and bank risk increased. This suggests that market participants perceived that bank risk is shared within the euro area.

Keywords: bank-sovereign nexus, risk spillovers, stress test, European Central Bank, Comprehensive Assessment.

JEL classification: C68, F34.

Non-technical summary

The sovereign debt crisis that erupted in 2010 in the euro area highlighted that bank risk and sovereign risk are closely intertwined. A growing literature points towards a close connection between banks and the sovereign within a country. Domestic bank risk can weaken a country's public finances in case troubled banks require government support, while domestic sovereign risk can weaken bank balance sheets through banks' holdings of government debt. The feedbacks between bank and sovereign risks can lead to a 'doom loop', as a result of which both banks and their sovereigns can end up in a crisis simultaneously.

Bank risk and sovereign risk can also be transmitted across countries. One channel is through risk transmission from foreign to domestic banks, for example due to cross-border exposures and financial contagion. Similarly, contagion can cause risk transmission across sovereigns. Such cross-border bank-to-bank and sovereign-to-sovereign risk transmission can worsen the domestic doom loop. Furthermore, foreign sovereign risk can be transmitted to domestic banks directly through banks' holdings of distressed government bonds.

In this paper, we document that there is an additional channel of bank-sovereign risk transmission across countries, whereby *banking sector risk* in *stressed* countries can affect the credit risk of *non-stressed* sovereigns in the euro area. Our study exploits variation from a negative information shock associated with the release of the European Central Bank's (ECB) Comprehensive Assessment (CA) results in October 2014. The CA was of a year-long examination of the resilience of the 130 largest banks in the euro area, which consisted of a backward-looking Asset Quality Review (AQR) and a forward-looking supervisory stress test (ST) of the examined banks. The CA covered bank assets of €22 trillion, which represented more than 80% of total banking assets in the euro area. The ECB carried out the CA together with 26 national supervisors from November 2013 to October 2014, involving a total of approximately 6000 people.

The completion of the CA on October 26, 2014 was a major milestone in the ECB's preparation for the Single Supervisory Mechanism (SSM), the newly created cross-border

banking supervisor within the euro area. The SSM became operational on November 4, 2014, two weeks after the release of the CA results. The SSM is a key pillar of the European 'Banking Union.' The Banking Union is a set of legislation that was ratified by the European Council and the European Parliament in successive steps between 2012 and 2014. It ensures a consistent application of EU banking rules, thereby reducing risks in the banking sector related to, for example, exposure of national banking systems to their sovereigns; see, for instance, European-Commission (2012) and Constâncio (2014). Indeed, as a result of the crisis, the need to break the negative feedback loops between national banking systems and their sovereigns, and to deepen risk-sharing in the monetary union were recognized as essential elements for a successful Economic and Monetary Union in the long run (see the Five Presidents' Report, Juncker et al. (2015)).

We document that following the publication of the CA results on October 26, 2014, bank equity prices declined by about 12 percent after the arrival of adverse news about bank risk in stressed euro area countries. We show that the banking sector risk in stressed countries was not absorbed by their sovereign, but spilled over to non-stressed euro area sovereigns.

We rationalize these findings by pointing towards risk-sharing through cross-country mechanisms, such as the European Stability Mechanism (ESM). Such cross-border risk-sharing mechanisms allow insurance against idiosyncratic, country-level shocks at a low cost and thereby make the euro area as a whole more resilient.

1   Introduction

The sovereign debt crisis that erupted in 2010 in the euro area highlighted that bank risk and sovereign risk are closely intertwined. A growing literature points towards a close connection between banks and the sovereign within a country (e.g., Acharya et al. (2014), Farhi and Tirole (2018), and Acharya and Steffen (2015)). Domestic bank risk can weaken a country's public finances in case troubled banks require government support, while domestic sovereign risk can weaken bank balance sheets through banks' holdings of government debt. The feedbacks between bank and sovereign risks can lead to a 'doom loop', as a result of which both banks and their sovereigns can end up in a crisis simultaneously.

Bank risk and sovereign risk can also be transmitted across countries. One channel is through risk transmission from foreign to domestic banks, for example due to cross-border exposures and financial contagion (e.g., Degryse et al. (2010), Tressel (2010)). Similarly, contagion can cause risk transmission across sovereigns, and was arguably present during the most severe phases of the euro area sovereign debt crisis (e.g., Lucas et al. (2014), Benzoni et al. (2015), Kallestrup et al. (2016), or Augustin et al. (2018)). Such cross-border bank-to-bank and sovereign-to-sovereign risk transmission can worsen the domestic doom loop. Furthermore, foreign sovereign risk can be transmitted to domestic banks directly through banks' holdings of distressed government bonds (e.g., Beltratti and Stulz (2015) and Kirschenmann et al. (2016)).[1]

In this paper, we document that there is an additional channel of bank-sovereign risk transmission across countries, whereby *banking sector risk* in *stressed* countries can affect the credit risk of *non-stressed* sovereigns in the euro area.[2]

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[1] More generally, Kallestrup et al. (2016) document that domestic bank risk - and, consequently, domestic sovereign risk - are also strongly influenced by bank total foreign asset holdings, of which claims on the foreign private sector are an important part.

[2] Throughout the paper, we refer to Greece, Ireland, Italy, Portugal, and Spain (GIIPS) as stressed countries, and to Austria, Belgium, France, Germany, and the Netherlands as non-stressed countries. Non-stressed countries were less affected by the sovereign debt crisis between 2010–2012. For an identical grouping of countries see, for example, Acharya and Steffen (2014), Fratzscher and Rieth (2015), and Eser and Schwaab (2016), among others.

Our study exploits variation from a negative information shock associated with the release of the European Central Bank's (ECB) Comprehensive Assessment (CA) results on October 26, 2014. Bank equity prices declined by about 12 percent after the arrival of adverse news about bank risk in stressed euro area countries. We show that the banking sector risk in stressed countries was not absorbed by their sovereign, but spilled over to non-stressed euro area sovereigns.

We rationalize these findings by pointing towards risk-sharing through cross-country mechanisms, such as the European Stability Mechanism (ESM).[3] Such cross-border risk-sharing mechanisms allow insurance against idiosyncratic, country-level shocks at a low cost and thereby make the euro area as a whole more resilient. This interpretation is also in line with Fratzscher and Rieth (2015). Using euro area data between 2003 and 2013, they document that the link between banks and their respective sovereign was typically tighter, the larger the banking sector bailout package was. But in the stressed countries whose sovereign was bailed out (Ireland, Greece, and Portugal), this bank-sovereign link was broken because bank risk was, at least partly, forwarded to other sovereigns.

The CA was of a year-long examination of the resilience of the 130 largest banks in the euro area, which consisted of a backward-looking Asset Quality Review (AQR) and a forward-looking supervisory stress test (ST) of the examined banks. The CA covered bank assets of €22 trillion, which represented more than 80% of total banking assets in the euro area. The ECB carried out the CA together with 26 national supervisors from November 2013 to October 2014, involving a total of approximately 6000 people. The completion of the CA on October 26, 2014 was a major milestone in the ECB's preparation for the Single Supervisory Mechanism (SSM), the newly created cross-border banking supervisor within the euro area. The SSM became operational on November 4, 2014, two weeks after the release of the CA results. The SSM is a key pillar of the European 'Banking Union.' The Banking

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[3]The ESM is a support facility established in September 2012 and is backed by euro area sovereigns according to their share in the ECB's equity capital. In late 2014, the ESM had approximately €80 bn in equity, allowing it to raise debt to achieve a total size of approximately €700 bn. Germany (27.0%) and France (20.2%) together contributed approximately half of the ESM's equity.

Union is a set of legislation that was ratified by the European Council and the European Parliament in successive steps between 2012 and 2014, with the main objective of reducing risks for taxpayers and breaking the remaining links between national banking-systems and their sovereigns; see, for instance, European-Commission (2012) and Constâncio (2014).

Quantifying the transmission from bank risk to sovereign risk usually suffers from the strong two-way dependence between these two sectors. On the one hand, banks depend on their own sovereigns because they hold large amounts of sovereign debt. On the other hand, sovereigns provide a fiscal backstop to their banking sectors, particularly in times of financial crisis. Fortunately, the variation in bank risk after the announcement of the CA allows us to isolate the risk transmission from banks to sovereigns. Changes in sovereign CDS spreads after the announcement of the CA results appear to be plausibly triggered by the arrival of adverse news about the health of the banking sector, rather than new information about sovereign risk.

We first establish that the CA release revealed significant new information to market participants beyond what was anticipated.[4] A priori, it is not entirely obvious that the information released on October 26 would be a surprise, for two reasons: First, banks have had ample time to respond to the likely result by raising enough equity capital between January 2014 and October 2014 to avoid shortfall; indeed, the participating banks raised a total of €57.1 bn in bank capital during that time; see ECB (2014a). Second, two confidential documents were leaked in the two weeks preceding the announcement of the CA results on October 26, revealing that 25 banks will 'fail' the CA. As this information leakage was not bank- or country-specific, sovereign CDS spreads increased in all euro area countries in the days preceding October 26. When the CA results were released on October 26, we find no evidence that suggests that the market was surprised about the euro area-wide, headline results of the AQR. However, we find that market participants were taken by surprise that out of 25 banks that failed the CA, 20 banks and the majority of capital shortfalls were

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[4]Recent literature investigates whether stress tests provides information that is new to investors; see e.g. Petrella and Resti (2013), Sahin and de Haan (2016), and Goldstein and Leitner (2016).

concentrated in stressed countries.[5] It is this information surprise that our regression analysis will exploit.

To show how banking sector risk is transmitted to foreign sovereigns, we proceed in two steps. First, we study changes in the magnitude of sovereign-bank risk dependence *within countries* based on difference and difference-in-differences regression specifications. Surprisingly, we find no significant increase in the dependence between sovereign and bank risk for stressed countries despite the spike in bank risk within these countries. This is in line with a second fiscal backstop that provides an additional source of fresh equity to banks in stressed countries, for example through cross-border risk-sharing facilities, including the ESM. Such insurances reduce the credit risk borne by bank debt holders, independent from the financial health of their sovereign; see Geeroms and Karbownik (2014) and Farhi and Tirole (2018).[6] While there is no increase in risk dependence in stressed countries, sovereign-bank dependence within non-stressed countries becomes significantly positive after the announcement of the CA results. This indicates that through the completion of the CA and a progressing Banking Union, risk was transferred across borders to non-stressed sovereigns and, as a result, their interdependence with domestic banks increased. This notion is consistent with theoretical work by Acharya et al. (2014) and Leonello (2017), who argue that an adverse shock to either banks or sovereign increases the risk of a 'doom loop'.

Second, we study changes in cross-border risk dependence by relating the sovereign CDS spreads of non-stressed countries to changes in bank risk for banks located in stressed countries. We find that non-stressed sovereigns appear to take on the banking sector risk from stressed countries. Before the announcement of the CA results, there was no significant

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[5]Changes in bank-level equity prices ranged from -38.6% in the case of Banca Monte dei Paschi di Sienna (Italy), to +10.1% for Erste Bank (Austria) around the announcement of the CA results. Indeed, the highest AQR asset value adjustments were imposed on banks located in Cyprus, Greece, Italy, Portugal, and Slovenia; see ECB (2014, p. 5).

[6]To our knowledge, the theoretical literature on the sharing of banking sector risks across sovereigns in the context of a monetary union is sparse. The most related economic modeling framework is Farhi and Tirole (2018) who comment on, but do not explicitly model, cross-country sovereign-bank risk dependence subject to international risk-sharing facilities. Theoretical asset pricing frameworks that allow for shocks to investors' information sets are more abundant, and include King and Wadhwani (1990), Veldkamp (2006), and Pavlova and Rigobon (2007).

dependence between stressed countries' banking sectors and non-stressed countries sovereign credit risk. After the announcement, the shock to the equity valuation of banks located in stressed countries spilled over to non-stressed sovereigns, controlling for changes in domestic banks' CDS spreads, common factors, as well as other confounding effects. These findings are robust to plausible variations in the econometric approach, data frequency, as well as to variations in the length of the data sample.

The remainder of the paper is organized as follows. Section 2 reviews the literature. Section 3 discusses the CA and the announcement of the CA results. Section 4 presents the data and summary statistics. Section 5 outlines our methodology and conceptual framework. Section 6 presents our empirical results and discusses which risk transmission channels are likely to be important for explaining our findings. Section 7 presents evidence from a time-varying parameter model. Section 8 concludes. A supplementary External Appendix contains additional data statistics and empirical results.

2   Related literature

Our paper relates to several strands of literature examining risk transmission between banks and their sovereign within a country, as well as risk transmission of bank and sovereign risk across borders.

Within a country, banking sector risk and sovereign risk may interact and amplify each other, due to the so-called bank-sovereign nexus.

On the one hand, the deteriorating banking sector health may weaken domestic public finances and sovereign debt sustainability when the banking sector requires a bailout (e.g., Acharya et al. (2014), Leonello (2017)) or when the government holds bank securities such as in the aftermath of the global financial crisis (Beck et al. (2010)).

On the other hand, deteriorating sovereign health can weaken bank balance sheets, pri-

marily via banks' holdings of domestic government debt. There are many reasons highlighted in the recent literature for why banks may choose to hold bonds issued by their sovereign.[7] For example, banks hold government bonds for risk-, liquidity- and collateral-management purposes (e.g., Bolton and Jeanne (2011), Gennaioli et al. (2014), Farhi and Tirole (2018)). Also, they may be holding sovereign debt for investment purposes, and to minimize their capital cost as other assets carry higher risk-weights. Additionally, banks may choose to hold government bonds for strategic purposes. For instance, banks may engage in search for yield, acquiring risky domestic bonds to earn high returns in good times, while neglecting default risk in bad times when both bank and sovereign default risks are high. Or, the banking system may want to maximize its chance of being bailed-out by their sovereign (Cooper and Nikolov (2018), Koetter and Popov (2018)). An additional mechanism leading banks to hold domestic government debt is moral suasion whereby government coerces banks to keep purchasing domestic sovereign bonds at times of fiscal stress when no other private investors would do so (Becker and Ivashina (2018)).

Bank and sovereign risks are also interconnected and amplified through the macro-economy. For example, rises in sovereign risk can lead to de-leveraging and reduced bank lending, and harm the macro-economy (e.g., Acharya et al. (2018), Bocola (2016)). Altavilla et al. (2017), Gennaioli et al. (2016), and Ongena et al. (2016) all report evidence that a country's banking sector increased holdings of local public debt during the European sovereign debt crisis, which amplified the negative effects of the crisis. Vice versa, bad macroeconomic shocks may increase default risks of banks and their sovereign, both directly - through their negative impact on the economic activity and on the fiscal revenues - and indirectly, as an initial fall in the price of public debt hurts the net worth of banks and their investment, increasing the chance of a government bail-out and amplifying the doom-loop (Farhi and Tirole (2018)).

Across countries, risk transmission may occur via banks, via sovereigns, and via bank-

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[7]See, e.g., Buch et al. (2016) for an analysis of determinants of sovereign bond holdings of German banks and the implications of such holdings for bank risk.

sovereign interconnectedness across borders.

Across banks, risk transmission can operate through cross-border interbank market linkages (as in, e.g, Niepmann and Schmidt-Eisenlohr (2013) who build on the classic model of Allen and Gale (2000)) or through information contagion whereby a bank's risk increases due to adverse news on other banks because of, e.g., correlated investments (Acharya and Yorulmazer (2008)) or contagious bank runs (Chen (1999)). Recent empirical evidence on cross-border contagion through interbank linkages includes Degryse et al. (2010) and Tressel (2010), while information contagion channel was analyzed by Lang and Stulz (1992), Jorion and Zhang (2007), Jorion and Zhang (2009), and Helwege and Zhang (2016).[8]

Across sovereigns, a lack of fiscal discipline in one country may lead financial markets to lower their expectations about fiscal consolidation efforts in other countries. As a result, those other countries also begin to face costs in terms of significantly increased interest rates on their government debt. Such negative market sentiment can be self-fulfilling and can drive countries into bad equilibria (see, e.g., Corsetti and Dedola (2016) for a theoretical framework and De Grauwe and Ji (2013) for an empirical analysis).

Another strand of literature - spurred in part by the euro area sovereign debt crisis - highlights risk transmission from a sovereign in one country to banks in another country or vice versa.

One transmission channel operates through holdings of foreign government debt by domestic banks (e.g., Beltratti and Stulz (2015) and Kirschenmann et al. (2016)).

While holdings of foreign bank securities by the domestic government are not common,

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[8]When companies file for bankruptcy, other firms in the same industry often suffer as a result. Lang and Stulz (1992) conclude that rivals' stocks drop in response to the news because investors learn about future industry cash flows from the filing. Consistent with this result, Jorion and Zhang (2007) report that credit default swap (CDS) premiums typically rise for firms in an industry after a default in that industry. Theocharides (2007), Hertzel and Officer (2012), and Boissay and Gropp (2012) present evidence of similar patterns for corporate bonds, bank loans, and trade credit, respectively. In addition, Helwege and Zhang (2016) find that both counterparty risk transmission and information transmission have significant effects on other financial firms' stock prices.

the link between foreign banks and domestic government can operate indirectly, e.g., through cross-border risk-sharing mechanisms such as the ESM or the ECB policies in the context of the European Monetary Union. Several recent papers present theoretical analyses of cross-border risk-sharing. For example, Niepmann and Schmidt-Eisenlohr (2013) study contagion between two countries that occurs through international balance sheet connection and characterize a government's bank bail-out policy when the bank's bankruptcy has adverse effects across borders. They show that efficient risk-sharing requires that the healthy country should finance a larger fraction of the bailout of the distressed country's banks than the distressed country does. Uhlig (2014) considers a model in which banks can use sovereign bonds for repurchase agreements with a common central bank and argues that regulators in risky countries have an incentive to allow their banks to hold domestic bonds and risk defaults, effectively shifting the risk of potential sovereign default losses on the common central bank. Farhi and Tirole (2018) provide a rationale for supranational banking supervision based inter alia on the argument that other countries may have an incentive to bail out a country or its banks so as to prevent spillovers on their own economy and society. Eijffinger et al. (2015) present a theory to explain the behavior of sovereign bond spreads in Southern Europe between 1998 and 2012. Their key theoretical argument is related to the bail-out guarantees provided by a monetary union. The existence of (implicit) risk-sharing guarantees can help rationalize the empirical findings in our paper whereby following the CA's release of bad news about banks in stressed euro area countries, bank risk spilled over to the credit risk of non-stressed euro area sovereigns. In the next section, we provide more details on the goals and results of the ECB's CA.

3 The ECB's Comprehensive Assessment

In this section, we first discuss the main goals, results, and the communication of the ECB's CA. Then, we argue that the announcement of the CA results was a relevant event allowing us to study the impact of an increase in bank risk on sovereign risk.

3.1 Aims and results of the CA

The CA started in November 2013 to ensure that when the ECB became the euro area's single supervisor (SSM) by late 2014, banks' assets and risks were evaluated according to the same rules across all countries. The assessment consisted of a backward-looking Asset Quality Review (AQR) and a forward-looking supervisory stress test of the euro area's most significant banks. Bank assets under review amounted to €22 trillion representing 82 percent of the euro area's total banking assets. The assessment was carried out by the ECB together with 26 national supervisors during the 12 months between November 2013 and October 2014, involving approximately 6000 people.

The objectives of the CA were threefold. First, to strengthen banks' balance sheets by repairing any problems uncovered; second, to enhance transparency by improving the quality of information available on the health of the individual banks; and third, to build confidence by assuring that, on completion of the required remedial actions, all banks would be soundly capitalized; see ECB (2014a). The CA concluded with the release of the overall results and recommendations for subsequent supervisory measures, on October 26, 2014. In addition to the CA's headline results, the ECB also disclosed detailed bank-level balance sheet information on a dedicated website. These bank-level templates were only partially available on October 26, 2014, and became fully available in the days immediately following the announcement of the CA results.

As the CA's headline result, a total capital shortfall of €25 billion was identified, at 25 banks. Of these 25 banks, 20 were located in stressed countries, nine of which were located in Italy, and four in Greece. Twelve out of these 25 banks had already covered their capital shortfall by increasing their capital during 2014 (near-pass), leaving 13 banks that fell short (near-fails or fails). The 13 failing banks were required to prepare capital plans within two weeks of the announcement of the CA results, and were given up to nine months to cover their capital shortfall. If the required new equity could not be raised in private markets, the respective sovereign was called upon to provide a fiscal backstop by purchasing the remaining

number of shares. This procedure was known ex-ante, and connected the health of the banks to that of their respective sovereign. In case the respective sovereign were unable to provide a sufficient public sector backstop, the ESM was made available as a second backstop for both sovereigns and banks.[9]

The AQR was a point-in-time assessment of the valuation of banks' assets as of December 31, 2013 and provided a starting point for the stress test. The AQR audits revealed that banks' non-performing exposures needed to be adjusted upwards by €136 billion (to a total of €879 billion). This value adjustment was economically significant, as it corresponded to approximately 1.3% of 2014 euro area GDP of €10.1 trn.[10] In addition, the end-of-2013 book values of banks' assets needed to be adjusted downwards by a total of €48 billion.

The stress test provided a forward-looking examination of the resilience of banks' solvency to a baseline and a stress scenario, also reflecting the new information arising from the AQR. Based on the AQR results, the stress test suggested that the macro-financial stress scenario would deplete banks' loss-absorbing CET1 capital by about €263 billion. This would decrease the median CET1 ratio by approximately 4 percentage points from 12.4% to 8.3%. This reduction was substantially higher than those found in earlier exercises, such as the stress tests previously undertaken by the European Banking Authority between 2010–2013. The relative harshness of the test likely contributed to a perception that, this time, the results were more credible.

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[9]The direct recap option of the ESM was introduced by euro area head of states on June 29, 2012. The respective announcement clarified that the ESM can be used to *i*) support countries who get into economic difficulties, for example following adverse banking sector outcomes, and *ii*) to directly recapitalize banks, provided that the Banking Union (single supervision) is in place by then. The experience during the peak of the euro area sovereign debt between 2010–2012, however, may have also taught market participants that such rules can change over the course of a weekend, if deemed necessary. We do not consider an event study around the June 29, 2012 announcement because it is unclear to what extent the statement was unexpected, and how it would have generated country-specific banking sector risk.

[10]Source: http://ec.europa.eu/eurostat/.

3.2 The ECB's CA as a relevant event

The announcement of the CA results was a relevant event for our identification because, (i), the CA led to a significant adverse information shock and, (ii), banks facing negative surprises were located in stressed countries. Consequently, bank risk in stressed countries was substantially reassessed.

This section discusses the CA's communication timeline and significant news prior to the official announcement of the results. Figure 1 plots the chronology of the ECB communication and news up to the announcement of the CA results. The ECB announced on October 10, 2014 that the final CA results would be published in about two weeks' time, on October 26, 2014. Following this statement, media attention turned towards the CA. News coverage of the upcoming CA was particularly intense during these two weeks leading up to the CA announcement. Indeed, news reports and rumors were so frequent, and the resulting market movements so volatile, that the ECB offered a press release on October 22 stating that "any media reports on the outcome of the tests are ... highly speculative." Arguably, two news reports stand out. Both reports appear to have had a significant impact on financial markets. First, a Bloomberg News report on Tuesday, October 14 quoted from a leaked confidential ECB document, dated October 6, that some banks "need to fail" to prove the exam's credibility; see Bloomberg (2014). A pressing worry was that the exam would not "reveal big enough capital shortfalls to prove its rigor," according to the leaked document. Second, a Bloomberg News report on Friday, October 24, again based on a leaked ECB document, stating that exactly 25 banks had failed the ST, the correct number. No report contained bank-level information, such as bank identities, or accounting data. As a result, the news was perceived as euro area-wide news.

To ensure a reliable quantification of the different effects over time, we distinguish three periods for our empirical study: (i) a baseline pre-announcement period (Pre-CA, September 29 - October 10), (ii) a soft information period in which some information was involuntarily released to financial markets through leaked confidential documents (Soft Info, October 13

– 24), and (*iii*) a post-announcement period during which all hard information about the CA results became available to all market participants (Post-CA, October 27 - November 4).[11] Our two-week post-CA period also accounts for the fact that the bank-level data templates were only partially available on the ECB's website on Sunday, October 26, 2014. The templates became fully available only during the first days after the announcement of the CA results.

The CA announcement released not only information about individual banks, with some passing the bar and others not, but it also revealed whether the new euro area wide banking supervision differs from the one of the national supervisors. On October 26, 2014, the ECB released the results of the CA suggesting that the rules of the new single supervision are significantly stricter than those of the national supervisor in stressed countries.

Figure 2 plots the cumulative log-changes in bank equity prices on average over the period from September 29 to November 7, 2014. The solid vertical line marks the announcement of the CA headline results on October 26, 2014. The figure also distinguishes between non-stressed countries (solid line), and stressed countries.

Equity prices for banks located in stressed countries dropped sharply after the CA, by about 12 percent. By contrast, bank equity prices remained approximately unchanged in non-stressed countries. If anything, bank equity prices in non-stressed countries *increased* slightly from Friday October 24 to one week later. On average, there was no effect of the information shock on bank risk for non-stressed countries. Finally, we note the parallel trend in equity prices before the release of the CA results. The parallel trend suggests that bank equity prices across the euro area were driven by common factors before October 26.

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[11]Sahin and de Haan (2016) study announcement effects of the ECB's CA based on a narrow window around October 26 and find little variation in market prices around the event. More variation is found based on wider windows. The gradual leakage of confidential information during our Soft Info period explains this outcome.

4 Data

In this section, we discuss data and summary statistics for our sample period.

4.1 Data sources

We consider standard equity and CDS data for our study. Bank equity data are taken from Bloomberg for all listed CA banks. Stock returns are based on daily closing prices, and are available at a daily frequency. CDS spreads are obtained from the Credit Market Analysis (CMA) database via Thomson/Reuters Datastream. All CDS refer to a 5-year maturity, and are subject to a full-restructuring credit event clause. Bank and sovereign CDS are subject to pre-determined and comparable contractual (ISDA) agreements. This comparability permits a consistent measurement of point-in-time credit risk perceptions for both banks and sovereigns. The CA results are publicly available from the ECB's website[12]; see also ECB (2014a).

In general, price formation in derivative markets can potentially be disrupted during times of financial distress; see e.g. Augustin et al. (2014). In addition, the depth of corporate CDS markets could be time-varying. We account for CDS market liquidity-related concerns in two ways. First, we exclude from our analysis CDS spreads that exhibit two or more zero returns in at least one of our three 10-day periods. Second, we accommodate contract-specific differences in liquidity by allowing for bank (contract)-specific fixed effects in our panel specifications.

4.2 Summary statistics

Table 1 lists statistics for banks with liquid CDS spread or equity data. Banks are sorted according to the change in their market capitalization from the pre-CA period (average) to

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[12]https://www.bankingsupervision.europa.eu/banking/comprehensive/.

the post-CA period (average). For banks that do not have a stock listing, we sort according to CDS spread changes, with the largest increase first.

Most of the banks that suffered stock market valuation losses around October 26, 2014 announcement were located in countries affected by the euro area sovereign debt crisis between 2010–2012, such as Greece, Ireland, Italy, Portugal, and Spain (stressed countries); see Table 1. Of the top 20 worst performers in terms of changes in equity market valuation, 18 banks were located in the stressed countries' group. Conversely, banks located in non-stressed countries tended to receive a clean bill of health. Of the bottom ten entries, referring to banks with the most positive changes in equity valuation, seven are located in non-stressed countries. Bank-level equity surprises range from -38.6% in the case of Banca Monte dei Paschi di Siena (Italy), to +10.1% for Erste Bank (Austria).[13]

Typically, the relationship between CDS spread and equity market valuation is negative so one would expect that the worst performers in terms of changes in equity market valuation would also suffer the largest CDS spread increases. However, Table 1 documents that this is not the case in our sample. Indeed, the relationship is *positive* for some banks in stressed countries. For example, Permanent TSB (Ireland) suffered an equity valuation decline of 15.3% and also a decline in CDS spread of 1.4%; or Banca Popolare (Italy) showed an equity valuation decline of 7.1% and a decline in CDS spread of 4.0%. This suggests, as discussed earlier, that equity holders suffered a loss while bond holders benefited from risk sharing among euro area countries.[14]

The final column of Table 1 indicates the headline result of the CA. Four outcomes were possible. Pass (P) if the bank met the 5.5% CET1 ratio requirement under the adverse

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[13]The External Appendix A reports descriptive statistics distinguishing the Pre-CA, Soft Info, and Post-CA period.

[14]Deutsche Bank AG (row 9) is an outlier in Table 1. It is a large bank located in a non-stressed country with a negative equity return of approximately -8% from the Pre-CA to the Post-CA period. Deutsche Bank suffered substantial litigation losses related to mortgage miss-selling and alleged Libor rigging. These litigation losses were communicated on October 29, 2014, three days after the CA announcement and within our Post-CA period. For our main analysis, we keep Deutsche Bank in the sample, which makes our estimates more conservative.

scenario and also met the 8% ratio under the baseline scenario. Near-pass (NP) if the bank did not meet both required ratios, but had already covered its capital shortfall before October 26, 2014. Near-fail (NF) if the bank did not meet both ratios and had not covered the shortfall, but its plans to raise capital were deemed adequate. Fail (F) if the capital ratio requirements were not met and no adequate repair measures were underway.

Whether a bank (near-)passed or (near-)failed the CA was not necessarily surprising. Recall that banks were evaluated on data only up to December 2013. Consequently, banks had the chance to anticipate and correct a potentially weak capital ratio. This is why, to measure the information shock, we focus on the changes in equity valuation from before to after the release of the CA results, rather than on the pass/fail announcement.

Having established that there was an information shock to bank risk in stressed countries, we now turn towards a more detailed discussion of the bank CDS spreads throughout our sample period. Figure 3 reports debt-weighted averages of CDS spreads for both banks and sovereigns.[15] Each panel plots average CDS spreads for both banks (solid line) and sovereigns (dashed line). The top and bottom panels refer to non-stressed countries (i.e., Austria, Belgium, France, Germany, and the Netherlands) and stressed countries (Greece, Ireland, Italy, Portugal, and Spain), respectively.

There are several takeaways from these graphs and summary statistics. First, sovereign CDS spreads increased in all euro area countries during the Soft-Info period. In particular, debt-weighted sovereign CDS spreads in non-stressed countries increased by approximately 6 bps, from 33 bps to 39 bps. CDS spreads in stressed countries rose by about 40 bps, from 140 bps to 180 bps. This increase in CDS spreads happened around the leaking of information about the CA by the media. In particular, the Bloomberg News report on October 14 stating that the ECB worries that not enough banks would fail the stress test led to an increase

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[15]The respective unweighted averages are reported in the supplementary External Appendix B. Unweighted averages are similar to Figure 3. Sovereign CDS spreads are weighted by total government debt as reported by Eurostat as of end-2013. Banks' CDS spreads are weighted by total bank liabilities in December 2013. Bank liabilities are taken from the CA templates.

in sovereign CDS spreads.[16] Non-euro area countries located in Europe's single market were not perceived as more risky (see External Appendix A for summary statistics). This is noteworthy, as the latter countries do not have an equity stake in the ESM. Therefore, non-euro area countries would be less likely to be affected by euro area bank risk.

Second, while sovereign CDS remained elevated after the spike during the Soft-Info period, bank CDS declined again and remained only somewhat higher in comparison to the Pre-CA levels. These changes in bank CDS spreads are in line with the changes in the corresponding bank equity prices (exhibiting a negative relationship) during the Pre-CA and Soft-Info period. However, the release of the CA results on October 26 breaks this relationship: bank equity prices in stressed countries drop, while the corresponding CDS remained on the approximately the same level (recall Figure 2). This suggests that market participants did not perceive any additional default risk for bank debt in stressed countries because of the release of the CA results. Perhaps, it was deemed that sufficient government and ESM funds were available for all stressed countries in case the necessary equity recapitalizations could not be accomplished with private sector funds only. Mandatory bail-in rules in the euro area that would have affected debt holders as well came into effect only in January 2016.

Third, banking sector CDS spreads were mostly below the sovereign CDS spread before and after the announcement of the CA results in stressed countries. This might seem odd given that banks are considered to be closely linked to their sovereign, for example through holdings of domestic sovereign debt (see ECB (2014b)), or given that holdings of domestic debt had increased significantly during the euro area sovereign debt crisis after the ECB's three-year LTROs in 2012 (see Acharya and Steffen (2015)). The observation that some bank CDS spreads from stressed countries traded below the CDS spread of their respective sovereign also suggests that markets perceived that bank risk is shared.

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[16]The spike in sovereign CDS is visible on October 15 in Figure 3 because our CDS spread data is sampled business-daily in the early afternoon around 2pm.

5 Methodology and conceptual framework

This section discusses our methodology and conceptual framework.

5.1 Methodology

Our empirical analysis proceeds in two steps. First, we study changes in sovereign-bank dependence, pairing domestic banks with their respective sovereign. This allows us to test whether within-country risk dependence changes from before to after the announcement of the CA results. Second, we test for changes in cross-border dependence by relating the sovereign CDS spreads of non-stressed countries to changes in bank risk for banks located in stressed countries.

We first test cross-sectional differences with a simple panel regression setup:

$$
\begin{aligned}
\Delta \mathtt{cds}_{j(i),t}^{s} \;=\;& \alpha_0 + \alpha_1 \cdot \mathtt{S}_j \cdot \Delta \mathtt{cds}_{i,t}^{b} + \alpha_2 \cdot \Delta \mathtt{cds}_{i,t}^{b} \\
& + \;\; \gamma_t + \delta_i + \varepsilon_{i,t},
\end{aligned}
\tag{1}
$$

where $\Delta \mathtt{cds}_{j(i),t}^{s}$ is the daily log-change in CDS spread for sovereign $j(i)$ in which bank i is located, $\Delta \mathtt{cds}_{i,t}^{b}$ is the daily log-change in CDS spread for bank i at time t, and $\mathtt{S}_j$ is a dummy variable that takes the value of one for stressed countries and zero for non-stressed countries. Bank fixed effects δ_i eliminate the influence of unobserved bank- (or CDS contract-) specific characteristics (such as differences in market liquidity) on sovereign-bank risk dependence. Time fixed effects γ_t control for unobserved changes that are common to all sovereign CDS, possibly including some hard-to-measure financial frictions like changes in overall CDS market liquidity. Coefficient α_1 is expected to be positive if the bank-sovereign nexus is stronger in stressed countries, and vice versa. Coefficient α_2 is expected to be positive if bank risk is positively associated with sovereign risk. We estimate the parameters in Equation (1) for the three sub-periods - the Pre-CA, Soft-Info, and Post-CA periods -

separately.

The panel regression (1) contains repeated CDS spread values on the left-hand side if multiple banks i are located in country $j(i)$. Repeated left-hand side values allow us to control for bank-specific fixed effects δ_i, and ensure sufficient cross-sectional variation ($N = 48$; see Table 1). Repeated left-hand-side values may, however, affect inference because of cross-sectional dependence in the error terms $\varepsilon_{i,t}$ at the country level. We take this issue into account when constructing standard errors.[17]

Second, we consider a difference-in-differences specification. This specification allows us to study country-group differences in sovereign-bank risk dependence before and after the ECB's announcement of the CA results. Specifically, we estimate:

$$
\begin{aligned}
\Delta\mathtt{cds}^s_{j(i),t} \;=\; & \alpha_0 + \alpha_1 \cdot \mathtt{S}_j \cdot \mathtt{P}_t \cdot \Delta\mathtt{cds}^b_{i,t} + \alpha_2 \cdot \mathtt{S}_j \cdot \Delta\mathtt{cds}^b_{i,t} \\
& +\; \alpha_3 \cdot \mathtt{P}_t \cdot \Delta\mathtt{cds}^b_{i,t} + \alpha_4 \cdot \mathtt{S}_j \cdot \mathtt{P}_t \\
& +\; \alpha_5 \cdot \Delta\mathtt{cds}^b_{i,t} + \delta_i + \gamma_t + \varepsilon_{i,t},
\end{aligned}
\tag{2}
$$

where $\Delta\mathtt{cds}^s_{j(i),t}$, $\Delta\mathtt{cds}^b_{i,t}$, and $\mathtt{S}_j$ remain as explained in Equation (1). The additional dummy variable $\mathtt{P}_t$ distinguishes the Pre-CA, Soft Info, and Post-CA periods. As in Equation (1), daily time fixed effects γ_t absorb the influence of common macroeconomic and financial factors, and bank fixed effects δ_i eliminate the impact of unobserved bank heterogeneity. Two coefficients of interest are α_1 and α_3. If sovereign-bank risk dependence in stressed

---

[17]We experimented with three alternative approaches to make sure our inference is robust. All approaches yielded similar results. First, we clustered error terms at the country level, and bootstrapped the standard errors to mitigate the drawback from having a small number of country clusters (ten). This approach may not work well if between-cluster error terms are dependent. This might be the case in our sample of countries that share the same monetary policy and exchange rate. Second, we employed a non-parametric bootstrap. Here, residuals are drawn from the cross-section without country or group clusters. This approach is appropriate provided the cross-sectional dependence is approximately similar across the N different country-bank pairs. Finally, we computed Driscoll and Kraay (1998) standard errors. These standard errors are robust to arbitrary cross-sectional and time series dependence. They are valid, however, only asymptotically as both N and T go to infinity. In addition, Driscoll and Kraay standard errors are inconsistent when daily time fixed effects are included. Each of the three approaches is substantially more conservative than standard OLS standard errors that assume cross-sectionally independent error terms. We report t-statistics based on non-parametrically bootstrapped standard errors (the second approach) in the remainder of the paper.

countries (the 'experimental group') changes by less than in non-stressed countries (the 'control group'), then α_1 is negative, and vice versa. If, in addition, the completion of the CA increases sovereign-bank dependence in non-stressed countries, then α_3 is positive.

To test for spillovers across borders, we use bank equity and CDS as measures of bank risk in stressed countries and estimate the following model:

$$
\begin{aligned}
\Delta\mathtt{cds}^{s,ns}_{j(i),t} \quad &= \alpha_0 + \alpha_1 \cdot \mathtt{P}_t \cdot \Delta\overline{\mathtt{eq}}^{b,st}_t + \alpha_2 \cdot \Delta\overline{\mathtt{eq}}^{b,st}_t \\
&\quad + \alpha_3 \cdot \mathtt{P}_t \cdot \Delta\overline{\mathtt{cds}}^{b,st}_t + \alpha_4 \cdot \Delta\overline{\mathtt{cds}}^{b,st}_t \\
&\quad + \alpha_5 \cdot \Delta\mathtt{cds}^{b,ns}_{i,t} + \kappa' f_{t-1} + \delta_i + \gamma_w + \varepsilon_{i,t},
\end{aligned}
\tag{3}
$$

where $\Delta\mathtt{cds}^{s,ns}_{j(i),t}$ are daily log-changes in the CDS spread of a non-stressed (ns) sovereign (s) $j(i)$ at time t, $\Delta\mathtt{cds}^{b,ns}_{i,t}$ are log-changes in the CDS spread of bank i located in a non-stressed country $j(i)$, $\Delta\overline{\mathtt{eq}}^{b,st}_t$ is the log-change of a weighted average of banks' equity prices in stressed countries, and $\overline{\mathtt{cds}}^{b,st}_t$ is a weighted average of CDS spreads for banks in stressed countries; $\kappa' f_{t-1}$ allows for common (market) factors, and γ_w are weekly time fixed effects.

We weigh the relative importance of stressed countries' banks by their assets as of December 2013. Changes in foreign banks' credit risk are measured by their equity returns and CDS spreads. As bank equity holders (not debt holders) are diluted by the required equity recapitalization following the CA, we would mostly expect spillovers through stressed banks equity. We use weekly time fixed effects since daily effects would absorb $\Delta\overline{\mathtt{eq}}^{b,st}_t$ due to multicollinearity. Parameters α_1 and α_3 allow us to test whether cross-border risk dependence increases following the announcement of the CA results. Parameters α_2 and α_4 capture Pre-CA risk dependence between sovereigns and banks across borders, controlling for domestic banks' credit risks.

5.2 Conceptual framework

In this section we present a conceptual framework which will help interpreting our empirical results. Following King and Wadhwani (1990), we imagine a setting in which two assets — stressed (s) and non-stressed (ns) — are traded with the following terminal payoff structure (denoted by v):

$$
\begin{aligned}
v^s &= \beta^s F + \epsilon^s \\
v^{ns} &= \beta^{ns} F + \epsilon^{ns}
\end{aligned}
$$

where $F \sim (0, \sigma_F^2)$ is a systematic factor, and $\epsilon^s, \epsilon^{ns}$ are idiosyncratic terms.[18]

In such a setting, most models of information transmission (e.g., Kodres and Pritsker, 2002; Yuan, 2005; Veldkamp, 2006; Pasquariello, 2007; Pavlova and Rigobon, 2007) will yield the following equilibrium pricing relationship (P) between these two assets:

$$
\begin{aligned}
\Delta P^s &= b^s \Delta P^{ns} + g^s \Delta \epsilon^s \\
\Delta P^{ns} &= b^{ns} \Delta P^s + g^{ns} \Delta \epsilon^{ns},
\end{aligned}
$$

where Δ denotes time (e.g., daily) differences, and the reduced-form equilibrium slope coefficients are given by

$$
\begin{aligned}
b^i &= b^i \left(\beta^s, \beta^{ns}, \sigma_F^2, \sigma_{\epsilon_s}^2, \sigma_{\epsilon_{ns}}^2, \text{frictions} \right), i = ns, s, \\
g^i &= g^i \left(\beta^s, \beta^{ns}, \sigma_F^2, \sigma_{\epsilon_s}^2, \sigma_{\epsilon_{ns}}^2, \text{frictions} \right), i = ns, s.
\end{aligned}
$$

In other words, the equilibrium relationship between price dynamics in stressed and non-stressed assets will depend on the structural relationship between their fundamentals ($\beta^s, \beta^{ns}, \sigma_F^2$), and on idiosyncratic shocks (with variances $\sigma_{\epsilon_s}^2, \sigma_{\epsilon_{ns}}^2$). Unobserved frictions to

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[18] Our empirical analysis involves multiple stressed and non-stressed assets in a panel. The intuition developed here carries over to a more general case.

investors' trading activity ('frictions') may also be present. Such frictions could be due to, for example, time-varying risk aversion, changes in funding liquidity, noise trading, adverse selection, information asymmetries, and so on.

The variation in bank risk is most simply thought of as a negative shock to stressed banks ($\Delta\epsilon^s < 0$), while leaving non-stressed banks approximately unaffected ($\Delta\epsilon^{ns} \approx 0$). Sovereign CDS spreads are affected only through sovereigns' exposure to banks. In addition, parameters may break due to a structural change in the economy (like the move towards a banking union). Sections 6 and 7 document a change in panel correlation (slope) parameters, controlling for other effects, from b^i before the CA announcement to, say, $b^{i\prime}$ thereafter. We take such changes $b^i \rightarrow b^{i\prime}$ as indicative of increased cross-border risk dependence.

6 Empirical results and spillover channels

This section presents our empirical results and discusses which spillover channels are likely to be most relevant for rationalizing them.

6.1 Empirical results

In this subsection, we first present estimates of the effect of the CA release on the co-movement between banks and their sovereign. Second, we present estimates of spillovers of bank risk across borders, from stressed countries to non-stressed sovereigns.

Table 2 reports the regression estimates on the co-movement of banks and sovereigns (model specifications (1) and (2)). In columns 1–6, we test country-group differences within each subperiod (Pre-CA, Soft Info, and Post-CA). Then, we study event country differences in columns 7–8.

For stressed countries, our results suggest that there is no significant dependence between the CDS spreads of sovereigns and banks. The sovereign-bank risk dependence coefficient for

stressed countries is given by the sum of α_1 and α_2; see Equation (1). This sum is small and statistically insignificant in all three subperiods; see columns 2, 4, and 6. For example, risk dependence in the Pre-CA period is -0.101 + 0.168 = 0.067 and is not significant (column 2). Risk dependence remains insignificant following the announcement of the CA results, despite stressed countries' exposure to considerable AQR losses and adverse stress test results.

For non-stressed countries, risk dependence between sovereigns and banks increased significantly after the release of the CA results. The sovereign-bank risk dependence coefficient for non-stressed countries is given by α_2. The coefficient is negative and insignificant in the Pre-CA period (columns 1 and 2), but turns positive and significant in the Post-CA period (columns 5 and 6). The coefficient α_2 captures the increase by 0.39 from before to after the announcement of the CA results (column 8, row 3). This is surprising because, on average, there was no adverse news for banks located in non-stressed countries. We conjecture that the bank risk revealed by the CA in the stressed countries fed into the non-stressed countries' sovereign risk and thus affected the bank-sovereign dependence in those countries. Below, we test explicitly for such cross-border spillovers from the stressed countries into the non-stressed bank-sovereign dependence.

In sum, despite adverse news about bank risk in stressed countries, there is no change in risk correlations between banks and sovereigns in stressed countries. However, risk dependence between non-stressed sovereigns and their banks increases. Therefore banking sector risk from stressed countries is likely to have spilled over to non-stressed countries.

To see whether the bank risk in stressed countries spilled over to non-stressed countries, we study changes in risk dependence across countries in Table 3. Here, our model specification is Equation (3). Columns 1–3 and 4–6 refer to observations from the Pre-CA and Post-CA periods, respectively.[19] Columns 7 and 8 refer to event country difference estimates.

We include domestic banks' CDS spreads, lagged changes in the Euro Stoxx non-bank

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[19]The Soft-Info period is in line with Table 2 and omitted for brevity.

equity index, bank CDS contract fixed effects, and weekly time fixed effects as controls.[20] Bank equity and CDS averages are both weighted by bank assets as of December 2013.

Our findings are as follows. First, there is a significant bank-sovereign risk dependence across borders after the release of the CA results on October 26, 2014. While the coefficient on the weighted bank-equity index from stressed countries is not significant during the Pre-CA period, it becomes strongly significant Post-CA (columns 4–6). A 1% decline in bank equity in stressed countries is associated with a 0.33% increase in sovereign CDS in non-stressed countries. Similarly, the relationship between non-stressed countries' bank CDS spreads and their respective sovereign CDS is not significant before the CA, but becomes positive Post-CA, as already shown in Table 2.

Second, we test for spillovers from bond holders of banks located in stressed countries - as measured by the average bank CDS spreads - to sovereigns in non-stressed countries (Column 8). The bank risk uncovered by the CA in stressed countries was affecting primarily equity holders due to the potential equity recapitalization after the stress test. We would therefore expect a less pronounced spillover effect from debt holders. In fact, bank debt holders may even benefit if bank debt becomes safer following a recapitalization. Indeed, our results suggest that there was no significant risk spillover from bank CDS spreads in stressed countries to sovereign CDS in non-stressed countries.

6.2 Spillover channels

Our paper documents that banking sector risk in stressed euro area countries spilled over to the credit risk of non-stressed euro area sovereigns. In this subsection, we revisit the various channels through which sovereign and bank risks interact as outlined in Section 2, and discuss which channels are likely to be important for explaining our empirical findings. We argue that the most important channel is the cross-border risk-sharing channel while the

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[20]We experimented with other controls such as, for instance, the VSTOXX or the VIX. The results remain robust. We report results with the more stringent and relevant non-bank Euro Stoxx index.

other channels are less relevant in our case as we look at the relationship between sovereign and bank credit risk around the window immediately surrounding the release of the CA results.

We document that the CA revealed adverse news about bank risk in stressed countries. There was no simultaneous shock to stressed sovereigns or adverse macroeconomic shocks that would affect both banks and sovereigns across the euro area. Therefore, potentially relevant spillover channels for our analysis are: 1) from banks in stressed countries to their own domestic sovereigns (within-country bank-sovereign nexus); 2) from banks in stressed countries to banks in non-stressed countries; and 3) from banks in stressed countries to non-stressed sovereigns, either through direct linkages or indirectly through risk-sharing mechanisms within a monetary union.

First, within stressed countries, our analysis suggests that bank risk in stressed countries was not absorbed by their own sovereign as the correlations between banks and sovereigns in stressed countries did not change. This may be because sovereigns in stressed countries did not have spare fiscal capacity to absorb the bank shock at this point.

Second, spillovers from banks in stressed countries to banks in non-stressed countries (e.g., due to direct exposures or information contagion) do not appear to play a major role in our event as there is no adverse reaction of bank equity or CDS prices in non-stressed countries. Prices do not change even for larger, more international banks.

Third, our analysis suggests that there was a significant bank-sovereign risk spillover across borders after the release of the CA results as a decline in bank equity in stressed countries was associated with an increase in sovereign CDS in non-stressed countries. It is unlikely that this spillover operated through a direct channel as we are not aware of substantial holdings, by the non-stressed governments, of securities issued by banks in stressed countries. Therefore, our analysis is suggestive that the most likely channel is an indirect spillover channel operating through the risk-sharing mechanisms within the European Mon-

etary Union. Indeed, the completion of the CA coincided with a significant move towards the European Banking Union. Other mechanisms of cross-country risk-sharing may operate through the ESM. Consistent with risks being transferred across borders through such indirect channels, we find that the increase in correlation between bank risk in stressed countries and sovereign risk in non-stressed countries is persistent (see Section 7 below).

7   Robustness: Evidence from a time-varying parameter model

This section presents a time-varying parameter model that allows us to draw inference on the time-variation in risk dependence parameters directly. We find that our cross-border findings are robust to plausible variations in the econometric approach, and to the use of weekly data outside of the 30 business-day period studied so far.

We consider the panel regression model with time-varying parameters:

$$\Delta \mathsf{cds}_{j(i),t}^{s,ns} = \alpha_{1,t} \cdot \Delta \mathsf{cds}_{i,t}^{b,ns} + \alpha_{2,t} \cdot \Delta \overline{\mathsf{eq}}_t^{b,st} + \delta_i + \gamma_t + \epsilon_{i,t}, \tag{4}$$

where $\Delta \mathsf{cds}_{j(i),t}^{s,ns}$ denotes the weekly difference in the log CDS spread of non-stressed (ns) sovereigns (s), $\Delta \mathsf{cds}_{i,t}^{b,ns}$ is the weekly difference in the log CDS spread of bank i located in a non-stressed country $j(i)$, $\Delta \overline{\mathsf{eq}}_t^{b,st}$ is a weekly equity return associated with banks located in stressed countries, δ_i is a bank fixed effect, $\gamma_t \sim \mathrm{NID}(0, \sigma_\gamma^2)$ is a serially uncorrelated time effect, and $\epsilon_{i,t}$ is an idiosyncratic error term. We are most interested in estimating the time-varying cross-country effect $\alpha_{2,t}$ controlling for the time-varying domestic banks' risks via $\alpha_{1,t}$.

To accommodate an extended T-dimension, we allow for time-variation in the measurement error variances in Equation (4), according to:

$$\epsilon_t = (\epsilon_{j(1),t}, \ldots, \epsilon_{j(N),t}) \sim \mathrm{NID}\left(0, H_t\right), \tag{5}$$

where the covariance matrix is specified as $H_t = \mathrm{diag}\left(h_{j(1),t}, \ldots, h_{j(N),t}\right)$, $h_{j(i),t} = \sigma_\epsilon^2 \cdot$ $\mathrm{CDS}_{j(i),t-1}^{s,ns} \geq 0$, σ_ϵ^2 is a single parameter to be estimated, and $\mathrm{CDS}_{j(i),t-1}^{s,ns}$ is the lagged CDS spread of the non-stressed sovereign $j(i)$ in which bank i is located. As a result, all measurement error variances are serially correlated and are higher during more stressful times; see Feldhütter and Lando (2008) and Eser and Schwaab (2016) for related specifications. While somewhat restrictive, (5) is parsimonious and sufficiently flexible to allow us to test the key economic hypotheses at hand.

The time-varying parameters $\alpha_{1,t}$ and $\alpha_{2,t}$ capture the elasticities of (log-changes in) non-stressed sovereigns' CDS spreads with respect to (log-changes in) the risk of domestic and foreign banks, respectively. The parameters evolve over time as

$$\alpha_t = (\alpha_{1,t}, \alpha_{2,t})' = \alpha_{t-1} + \eta_t; \qquad \eta_t \sim \mathrm{NID}\left(0, Q\right), \tag{6}$$

where η_t is a two-dimensional error term, and Q a positive definite covariance matrix. Non-zero off-diagonal elements in Q allow the two time-varying parameters to be correlated. Coefficients α_t are initialized as uninformative $\alpha_1 \sim \mathrm{N}(0, \upsilon I)$, with $\upsilon \to \infty$; see Durbin and Koopman (2012, Chapter 5).

Model (4)–(6), together with its initial condition, is a standard linear Gaussian model in state space form. The log-likelihood is obtained from a single run of the Kalman Filter; see Durbin and Koopman (2012). Filtered estimates of the time-varying parameters and their standard errors are also provided by the Kalman Filter.

Figure 4 plots the conditional mean estimates of time-varying parameters $\alpha_{1,t}$ and $\alpha_{2,t}$ in Equation (4). Parameters are reported at a weekly frequency from April 1 to November 30, 2014.

We focus on two findings from this medium-term study. First, the time variation in both risk elasticity parameters is initially small. Both risk parameters are not statistically different from zero for most weeks in 2014. As a result, our ten-day Pre-CA period appears to be

representative of the weeks and months leading up to the ECB's CA. Put differently, our Pre-CA regression estimates approximately reflect a broader baseline dependence relationship.

Second, both risk sensitivity parameters change significantly in October 2014, and stay approximately unchanged in the weeks that follow. The loading on domestic banks' CDS spreads α_1 becomes significantly positive and increases to approximately 0.20. This is in line with the regression coefficient of approximately 0.32 in Table 3. The cross-border elasticity α_2 decreases to approximately -0.51 in October 2014, in line with the shorter window of our baseline model.

We conclude that the time differences reported in Section 6 are robust to adopting a different econometric approach (time-varying parameter model instead of moments-based estimation), data frequency (weekly instead of daily), as well as to variations in the length of the data sample.

8 Conclusion

We documented spillovers of bank risk across countries in the euro area around the European Central Bank's release of the Comprehensive Assessment (CA) results for 130 significant banks on October 26, 2014. Surprisingly, bank risk uncovered by the CA in stressed countries was not absorbed by their sovereigns, but spilled over to non-stressed countries.

Our findings point to the existence of risk-sharing across borders in the euro area in 2014, which enhanced the resilience of the euro area as a whole to idiosyncratic shocks. Going forward, such cross-border risk-sharing should primarily take place through private rather than public institutions. Shortly after the results of the CA were released, Mario Draghi, the ECB President, observed that "... when a shock hits ..., we need other ways [than exchange rate adjustments] to help spread those costs. ... In a monetary union like ours, there is a particular onus on private risk-sharing to play this role. Indeed, the less public-sector risk-sharing we want, the more private sector risk-sharing we need." (Draghi, 2014).

Greater private sector risk-sharing can be achieved through deepening integration of financial and capital markets combined with the necessary common backstops. We conjecture that endowing the relevant European authorities with a sizable bank resolution fund, funded by risk-sensitive contributions from banks, could contribute to a shift in risk dependence away from the public sector to the private sector (i.e., towards bank shareholders). According to current plans, the common European bank resolution fund is scheduled to achieve a modest size of approximately €55 billion in 2022, eight years after its inception in 2014. Other tools such as bail-in rules should further contribute to limiting public sector involvement.

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Figure 1: Communication timeline

A timeline of official communication and news reports. We distinguish a Pre-CA (September 29 – October 10), Soft-Info (October 13 – 24), and Post-CA (October 27 – November 04) period. During the Soft-Info period, official ECB communication is printed above the timeline and news reports are printed below.

Pre-CA

Soft-Info

Post-CA

October 13:
ECB and the national central banks start talking about the CA results.

October 22:
ECB press release: "Until … [October 26] any media reports on the outcome of the tests are by their nature highly speculative."

October 10:
ECB announces that the CA results will be published on October 26, 2014.

October 26:
Official results are released by the ECB.

time

October 13-24:
Media reports on potential outcomes of the ECB's CA, mainly based on estimates provided by various investment banks.

October 14:
First Bloomberg News report based on a leaked document stating that banks would need to fail the stress test to prove the exam's rigor.
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October 24:
Second Bloomberg News report based on a leaked document stating that 25 banks failed the stress test.

October 26-28:
Bank-level data templates are published.

Figure 2: Cumulative bank equity returns in the euro area

Cumulative log-changes in closing prices for bank equities. We distinguish banks located in non-stressed countries (solid line), stressed countries (dashed line). Equity prices are from September 29, 2014 to November 7, 2014. The dashed vertical line marks the beginning of the Soft Info period, while the solid vertical line marks the Monday close following the announcement of the CA results.
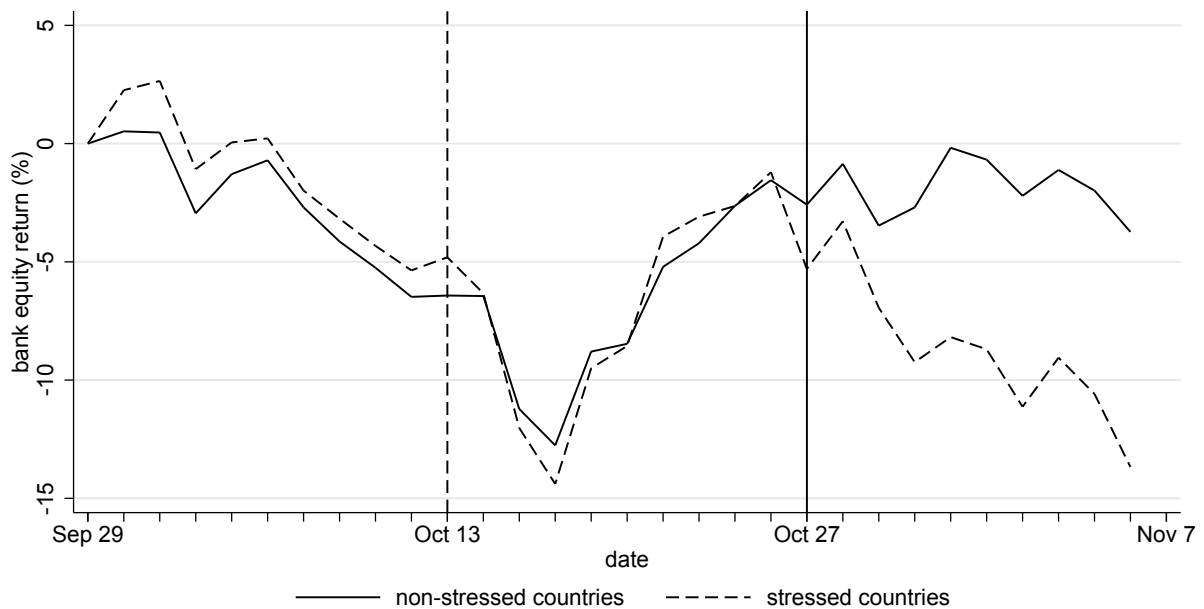
Figure 3: Weighted averages of bank CDS and sovereign CDS spreads in the euro area

Weighted averages of CDS spreads for both banks and sovereigns in the euro area from September 29, 2014 to November 7, 2014. Weights are given by the respective levels of total government debt for sovereign CDS, and bank-specific total liabilities for bank CDS, on December 31, 2013. In each panel the dashed vertical line marks the start of the Soft Info period, while the solid vertical line marks the Monday close following the Sunday announcement of the CA results. The top panel plots average CDS levels for non-stressed countries' banks' CDS (solid line) and non-stressed countries' sovereign CDS (dashed line). The bottom panel plots average CDS levels for stressed countries' banks' CDS (solid line), and stressed countries sovereign CDS (dashed line).
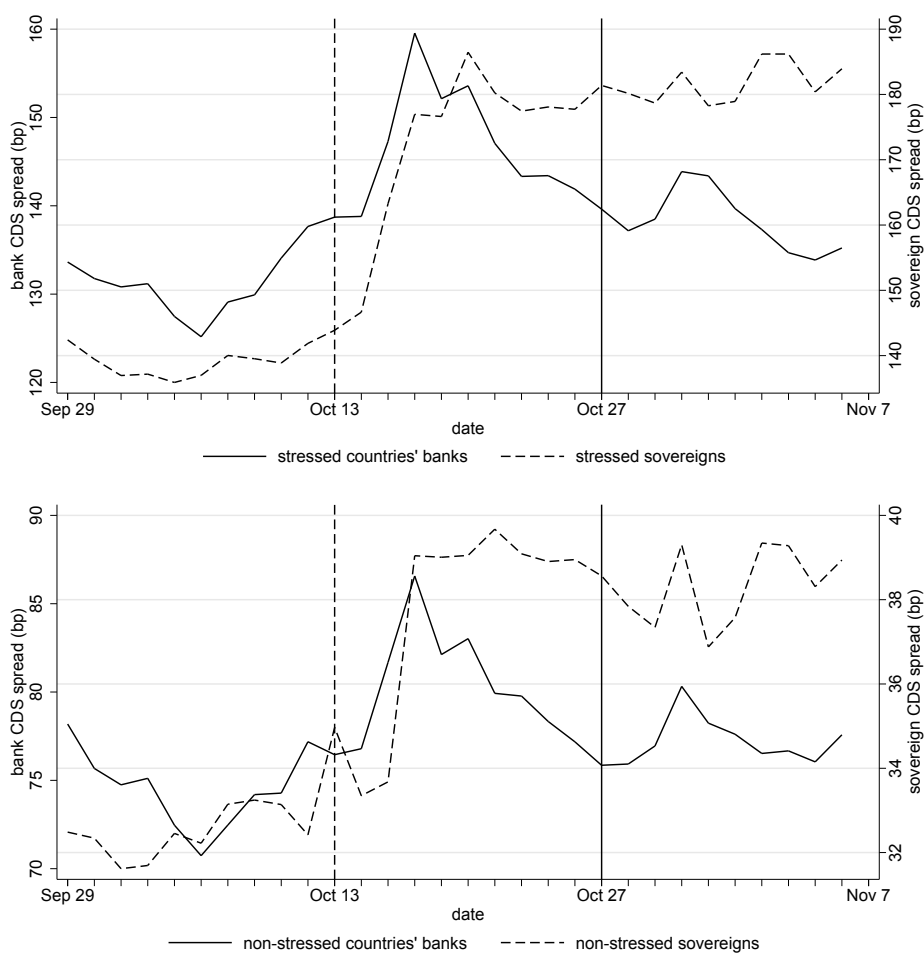
Figure 4: Time-varying parameter estimates

Filtered estimates of time-varying parameters $\alpha_{1,t}$ and $\alpha_{2,t}$ for the panel specification given in Equation (4). Static parameters are estimated based on weekly panel data from January 01, 2009 to November 30, 2014. Standard error bands are reported at a 95% confidence level. Coefficient estimates are at a weekly (Friday-on-Friday) frequency and are reported between April 1, 2014 and November 30, 2014. Vertical lines mark the boundaries of the Pre-CA, Soft Info, and Post-CA periods.
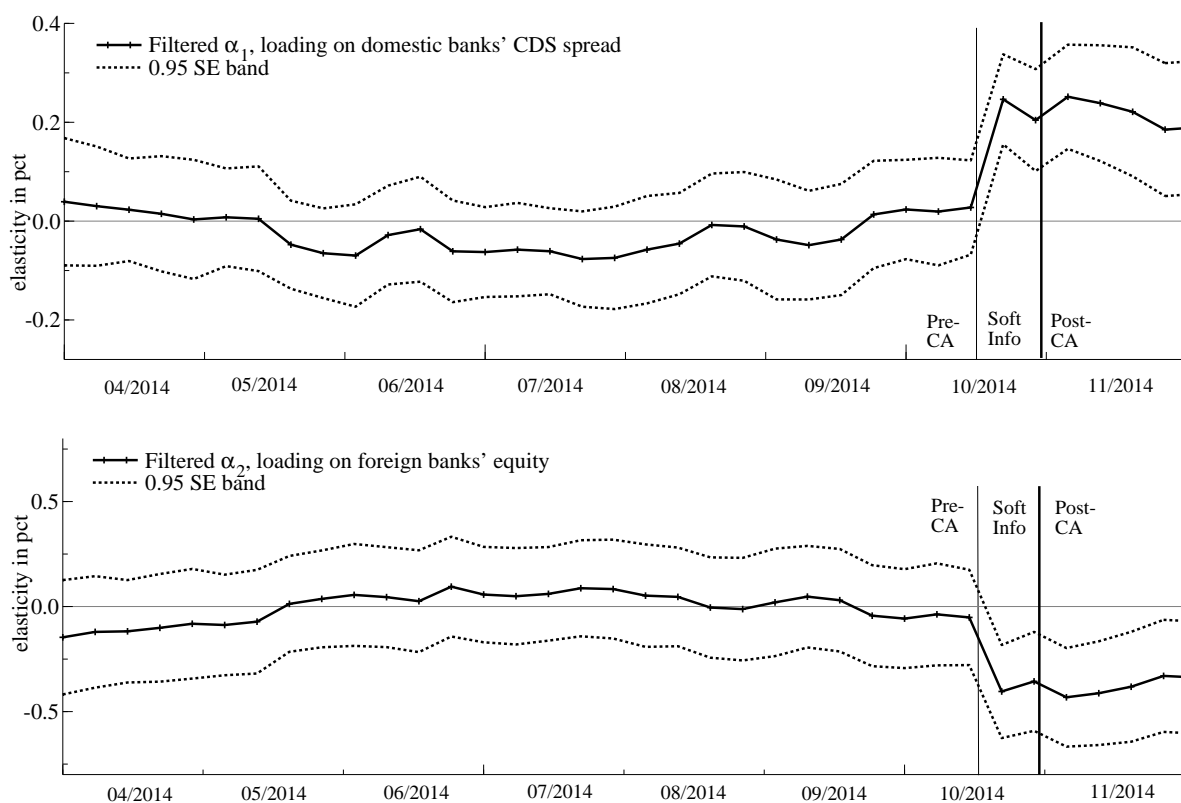
Table 1: Bank-level outcomes

Banks are sorted by their respective change in equity market valuation from the Pre-CA to the Post-CA period (in ascending order). When equity prices are missing, banks are sorted by their respective change in CDS spread (in descending order). The third and fourth columns report the increments between Pre-CA and Post-CA average prices. The last column refers to the headline CA result: pass (P), near-pass (NP), near-fail (NF), and fail (F). Stressed countries are highlighted in blue.

Bank name	Country	Equity change	CDS change	CA outcome
Banca Monte dei Paschi di Siena SpA	IT	-38.60%	3.79%	F
Banca Carige SpA	IT	-35.23%		F
Permanent TSB plc	IE	-15.30%	-1.44%	F
Alpha Bank SA	GR	-13.33%	20.98%	P
Banco Comercial Português SA	PT	-12.22%	6.89%	F
National Bank of Greece SA	GR	-12.13%	20.98%	NF
Eurobank Ergasias SA	GR	-10.90%	20.96%	NF
Piraeus Bank SA	GR	-8.59%	11.33%	NP
Deutsche Bank AG	DE	-8.21%	10.67%	P
Liberbank SA	ES	-8.18%		NP
Banca Popolare Di Milano Scarl	IT	-7.14%	-4.03%	F
Banco Santander SA	ES	-7.03%	6.85%	P
UniCredit SpA	IT	-6.77%	4.78%	P
Unione Di Banche Italiane Scpa	IT	-6.33%	2.24%	P
Banco Bilbao Vizcaya Argentaria SA	ES	-5.62%	6.78%	P
Banca Popolare di Sondrio Scpa	IT	-4.77%		NP
Société Générale	FR	-3.78%	6.20%	P
Banca Popolare Dell'Emilia Romagna SC	IT	-3.60%		NP
Banca Piccolo Credito Valtellinese SC	IT	-3.47%		NP
Banco de Sabadell SA	ES	-3.36%	-12.70%	P
Banco Popular Español SA	ES	-3.14%	-16.70%	P
BNP Paribas	FR	-2.96%	7.66%	P
Bankinter SA	ES	-2.83%	-9.85%	P
Intesa Sanpaolo SpA	IT	-1.93%	0.09%	P
KBC Group NV	BE	-1.05%	5.59%	P
Banco BPI SA	PT	-0.77%	14.78%	P
Groupe Crédit Agricole	FR	-0.19%	8.16%	P
Raiffeisen Zentralbank AG	AT	0.61%	-11.67%	P
Banco Popolare SC	IT	0.73%	-13.13%	NP
IKB Deutsche Industriebank AG	DE	0.76%	-7.28%	P
ING Bank NV	NL	0.88%	-3.58%	P
Aareal Bank AG	DE	1.62%		P
The Governor and Company of the Bank of Ireland	IE	2.09%	-4.68%	P
Mediobanca - Banca di Credito Finanziario SpA	IT	2.80%	4.50%	P
Commerzbank AG	DE	5.93%	-2.39%	P
Erste Group Bank AG	AT	10.07%	-13.95%	P
Dexia NV	BE		13.01%	NF
Caixa Geral de Depósitos SA	PT		6.79%	P
C.R.H.	FR		0.19%	NP
Allied Irish Banks plc	IE		-1.04%	P
Banque PSA Finance	FR		-1.46%	P
Landesbank Baden-Württemberg	DE		-1.94%	P
ABN AMRO Bank NV	NL		-2.07%	P
Coöperatieve Centrale Raiffeisen-Boerenleenbank B.A.	NL		-2.10%	P
Landesbank Hessen-Thüringen Girozentrale	DE		-2.14%	P
Bayerische Landesbank	DE		-2.61%	P
Norddeutsche Landesbank Girozentrale	DE		-2.83%	P
BAWAG P.S.K.	AT		-2.84%	P
RCI Banque	FR		-2.86%	P
HSH Nordbank AG	DE		-2.89%	P
SNS Bank NV	NL		-2.95%	P
AXA Bank Europe SA	BE		-3.72%	NP
The Royal Bank of Scotland NV	NL		-14.24%	P
DZ Bank AG	DE		-16.46%	P

Table 2: Bank-sovereign dependence

This table reports results from cross-sectional difference regressions. Tests of cross-sectional differences for the Pre-CA, Soft Info, and Post-CA are separately shown in columns 1–2, 3–4, and 5–6, respectively. Columns 7 and 8 report difference-in-differences estimates of the following model:

$$\Delta cds^s_{j(i),t} = \alpha_0 + \alpha_1 \cdot S_j \cdot P_t \cdot \Delta cds^b_{i,t} + \alpha_2 \cdot S_j \cdot \Delta cds^b_{i,t} + \alpha_3 \cdot P_t \cdot \Delta cds^b_{i,t} + \alpha_4 \cdot S_j \cdot P_t + \alpha_5 \cdot \Delta cds^b_{i,t} + \delta_i + \gamma_t + \varepsilon_{i,t},$$

where $\Delta cds^s_{j(i),t}$ is the daily log-change in CDS spread for sovereign $j(i)$ in which bank i is located, $\Delta cds^b_{i,t}$ is the daily log-change in CDS spread for bank i at time t, P_t distinguishes the Pre-CA, Soft Info, and Post-CA periods, and S_j is a dummy variable that takes the value of one for stressed countries and zero for non-stressed countries. Bank fixed effects δ_i eliminate the influence of unobserved bank– (or CDS contract–) specific characteristics (such as differences in market liquidity) on sovereign-bank risk dependence. Time fixed effects γ_t control for unobserved changes that are common to all sovereign CDS such as overall CDS market liquidity. Each column indicates whether the regression contains time (Time FE) and bank (Bank FE) fixed effects. Standard errors are bootstrapped.

Dep. Var.: $\Delta cds^s_{j(i),t}$	(1) Pre-CA	(2) Pre-CA	(3) Soft Info	(4) Soft Info	(5) Post-CA	(6) Post-CA	(7) Diff-Diff (4)-(2)	(8) Diff-Diff (6)-(2)
$S_j \cdot P_t \cdot \Delta cds^b_{i,t}$							0.129	-0.451***
							(0.148)	(0.124)
$S_j \cdot \Delta cds^b_{i,t}$	0.161**	0.168**	0.276**	0.292**	-0.298***	-0.290**	0.157**	0.163**
	(0.081)	(0.074)	(0.126)	(0.146)	(0.095)	(0.118)	(0.075)	(0.071)
$P_t \cdot \Delta cds^b_{i,t}$							-0.109	0.389***
							(0.123)	(0.125)
$P_t \cdot S_j$							0.000	-0.002
							(0.005)	(0.004)
$\Delta cds^b_{i,t}$	-0.093	-0.101	-0.185*	-0.211*	0.298***	0.289**	-0.088	-0.097
	(0.073)	(0.071)	(0.095)	(0.123)	(0.095)	(0.122)	(0.071)	(0.069)
S_j	0.005*		0.005		0.003			
	(0.003)		(0.005)		(0.003)			
Observations	480	480	480	480	480	480	960	960
R-squared	0.2515	0.2732	0.4253	0.4381	0.5326	0.5489	0.4095	0.4487
	-	-	-	-	-	-	-	-
Bank FE	NO	YES	NO	YES	NO	YES	YES	YES
daily Time FE	YES	YES	YES	YES	YES	YES	YES	YES
	-	-	-	-	-	-	-	-
Bootstrapped SE	YES	YES	YES	YES	YES	YES	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Bank risk spillovers across borders

This tables tests spillovers across borders for the Pre-CA, and Post-CA in columns 1–3, and 4–6, respectively. Columns 7 and 8 report difference estimates of the following model:

$$\Delta \mathbf{cds}_{j(i),t}^{s,ns} = \alpha_0 + \alpha_1 \cdot P_t \cdot \Delta \overline{\mathbf{eq}}_t^{b,st} + \alpha_2 \cdot \Delta \overline{\mathbf{eq}}_t^{b,st} + \alpha_3 \cdot P_t \cdot \Delta \overline{\mathbf{cds}}_t^{b,st} + \alpha_4 \cdot \Delta \overline{\mathbf{cds}}_t^{b,st} + \alpha_5 \cdot \Delta \mathbf{cds}_{i,t}^{b,ns} + \kappa' f_{t-1} + \delta_i + \gamma_w + \varepsilon_{i,t},$$

where $\Delta \mathbf{cds}_{j(i),t}^{s,ns}$ are daily log-changes in the CDS spread of a non-stressed (ns) sovereign (s) $j(i)$ at time t, $\Delta \mathbf{cds}_{i,t}^{b,ns}$ are log-changes in the CDS spread of bank i located in a non-stressed country $j(i)$, $\Delta \overline{\mathbf{eq}}_t^{b,st}$ is the log-change of a weighted average of banks' equity prices in stressed countries, and $\overline{\mathbf{cds}}_t^{b,st}$ is a weighted average of CDS spreads for banks in stressed countries; $\kappa' f_{t-1}$ allows for common (market) factors, and γ_w are weekly time fixed effects. Each column indicates whether the regression contains time (Time FE) and bank (Bank FE) fixed effects. Standard errors are bootstrapped.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. Var.: $\Delta \mathbf{cds}_{j(i),t}^{s,ns}$	Pre-CA	Pre-CA	Pre-CA	Post-CA	Post-CA	Post-CA	Diff-Diff (5)-(2)	Diff-Diff (6)-(3)
$P_t \cdot \Delta \overline{\mathbf{eq}}_t^{b,st}$							-0.282***	-0.328***
							(0.059)	(0.067)
$P_t \cdot \Delta \overline{\mathbf{cds}}_t^{b,st}$								-0.065
								(0.067)
$\Delta \overline{\mathbf{eq}}_t^{b,st}$	-0.042	-0.042	-0.005	-0.255***	-0.254***	-0.273***	0.021	0.065
	(0.047)	(0.070)	(0.065)	(0.043)	(0.049)	(0.042)	(0.045)	(0.057)
$\Delta \overline{\mathbf{cds}}_t^{b,st}$			0.055			-0.046		0.066
			(0.045)			(0.062)		(0.041)
$\Delta \mathbf{cds}_{i,t}^{b,ns}$	0.045	0.044	0.026	0.436***	0.443***	0.470***	0.277***	0.265***
	(0.078)	(0.082)	(0.074)	(0.108)	(0.112)	(0.126)	(0.083)	(0.066)
$\Delta \ln(\text{Euro Stoxx non-bank})_{t-1}$	-0.718***	-0.718***	-0.846***	-1.546***	-1.544***	-1.560***	-1.198***	-1.276***
	(0.212)	(0.208)	(0.184)	(0.299)	(0.304)	(0.236)	(0.184)	(0.146)
Observations	260	260	260	260	260	260	520	520
R-squared	0.1643	0.1984	0.2029	0.2825	0.2990	0.3005	0.2354	0.2372
Bank FE	NO	YES	YES	NO	YES	YES	YES	YES
Weekly Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Bootstrapped SE	YES	YES	YES	YES	YES	YES	YES	YES

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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