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Transmission of liquidity shocks: Evidence on cross-border bank ownership linkages ☆

Yifei Cao [1], Ian Gregory-Smith, Alberto Montagnoli *

Department of Economics, University of Sheffield, UK

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ABSTRACT

This study examines whether a liquidity shock to a banking system could be transmitted to other economies through a network of bank ownership. Firstly we construct cross-border ownership networks for banks located in European countries. We then exploit the 2010 European debt crisis as a natural experiment. The analysis shows that subsidiary banks located outside of Greece, Ireland, Italy, Portugal and Spain (GIIPS) but with ownership linkages to these countries have a lower loan growth rate during the crisis period. This suggests that the liquidity shock experienced by GIIPS countries was indeed transmitted to those banks through ownership linkages. Larger subsidiary banks and those subsidiaries that were more profitable are found to be more resilient to the shock. We also find that the parent bank's characteristics affect the transmission of the shock, supporting the notion of an internal capital market operating within these banks.

1. Introduction

This study provides empirical evidence on whether foreign bank ownership linkages can transmit external liquidity shocks. The past two decades has witnessed extensive globalisation of the financial sector. Banks from one country to the next are increasingly connected by cross-border interbank lending relationships and ownership ties. Additionally, there has been a large increase in the presence of foreign-owned banks in a typical domestic banking system. The overall share of domestic banking assets held by foreign banks has increased from 15% in 1995 to 23% in 2005 (International Monetary Fund, 2007). As a result, the role of foreign banks and foreign-owned domestic banks in the banking system has become more important, in both developed countries and emerging markets.

Yet the implications of increasing foreign banks are not well understood in literature. On one hand, access to foreign banking capital may intensify the competition of the domestic banking sector, thereby stimulating financial innovation, and the efficiency of domestic companies (Claessens et al., 2001; Sturm and Williams, 2004). Such 'spillovers' can help establish a modern financial system in developing countries and led to better financial regulations (Lensink and Hermes, 2004). On the other hand, a large proportion of foreign owned banks in the domestic banking system could increase a country's expo-

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* Corresponding author.
E-mail addresses: ycao13@sheffield.ac.uk (Y. Cao), i.gregory-smith@sheffield.ac.uk (I. Gregory-Smith), a.montagnoli@sheffield.ac.uk (A. Montagnoli).
[1] Address: Department of Economics, 10 Mappin Street, Sheffield S1 4DT, UK.

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sure to an international liquidity shock. If so, micro-prudential policies should be designed in order to limit the potential contagion so that the financial stability of the domestic banking system is preserved.

The European sovereign debt crisis that began in 2010 provides an excellent quasi-natural experiment to test possible contagion effects. This shock generated a liquidity crisis in Greece, Ireland, Italy, Portugal, Spain (GIIPS). We show how this shock was propagated to the other European countries through ownership linkages of banks and their subsidiaries. The contribution of this paper is twofold. First, our paper provides cross-country bank-level evidence that liquidity shocks from certain countries could be transmitted to other countries through bank ownership linkages. Papers in the literature have explored shocks from a single country (Peek and Rosengren, 2000), or a global shock transmitted to a single country (Aiyar, 2012; Schnabl, 2012). However, evidence from cross-country analysis is scarce (noting Cetorelli and Goldberg, 2011) and crucially, we exploit information on ownership to identify the transmission mechanism. This is the main novelty and contribution of the paper. Additionally, our paper provides new evidence based on the 2010 European sovereign debt crisis. While other papers in the literature have used the 2008 global financial crisis (Aiyar, 2012; Cetorelli and Goldberg, 2011) or the Japanese financial crisis in 1990s (Peek and Rosengren, 2000) or the Russian default in 1998 (Schnabl, 2012), the European sovereign debt crisis is unique in many ways. In particular, it generated severe liquidity shocks in several countries which required international financial support. As such our paper provides important information on the effect of financial integration of European countries over the past two decades.

We make use of subsidiary bank level data to construct ownership networks for banks located in all European countries. The exposure to the liquidity crisis in GIIPS countries is constructed for each international banking group (network) as measured by the proportion of their total banking assets in GIIPS countries. Then the banking group level exposure is assigned to each bank within the network. For example, we classify a bank as highly exposed to the crisis if the proportion of its group's total assets in GIIPS countries is high.[2]

Our working hypothesis is drawn from the theory of capital markets developed by Morgan et al. (2004). Their analysis predicts that banks exposed to a sovereign crisis will reduce their lending during the crisis period in order to support their parent or subsidiary banks. In our case, it will be the subsidiary banks in non-GIIPS countries with higher exposure to GIIPS countries through their ownership linkages who will reduce their lending. We label this as the contagion effect and estimate using the difference-in-differences (DID) method. The baseline results from the DID regressions imply that a bank's lending growth rate would reduce by 5.75 percentage points if the bank's exposure increases by 1 percent. The results support the hypothesis that highly exposed banks' lending performance is negatively affected by the foreign liquidity shock due to the cross-border ownership linkages.

The rest of the paper proceeds as follows. We review the related literature on banking networks and the potential for shocks to work through the banking system. In Section 3 we describe the empirical framework, including how we use the information on ownership and exposure to the sovereign crises. Section 4 presents descriptive statistics before explaining the DID method in Section 5 which generates the results in Section 6. Section 7 aims to establish robustness before Section 8 concludes.

2. Literature review

The banking literature has explored the role of the internal capital market within a banking group. This literature provides a theoretical grounding as to why a liquidity shock can be transmitted through bank ownership linkages. Using US bank data provided by the Federal Reserve Y-9 tapes and the Federal Reserve Reports of Income and Condition (Call Report) from 1986 to 1989, Houston et al. (1997) suggest that there is an internal capital market established by the bank holding company allocating scarce capital resources among the subsidiary banks. Morgan et al. (2004) examine the effect of the integration of the US banking system during economic volatility. The empirical results support the idea of an internal capital market, through which inter-state banks smooth business cycles. Furthermore, there is evidence for multinational banks; for instance, Cetorelli and Goldberg (2008) suggest that the parent bank and its foreign subsidiary often borrow and lend through their internal capital market; they show that large global-oriented banks in the US use the internal capital markets with their foreign subsidiaries to smooth domestic liquidity shocks. De Haas and Van Lelyveld (2010) construct a network for 45 large multinational banks and their foreign subsidiaries. They support the hypothesis that there exists an internal capital market within international banking groups, and that there is a positive relationship between a parent bank's financial strength and a subsidiary bank's loan growth.

Along side these benefits of being part of a bank network, there is the risk that the foreign subsidiary banks are too dependent on its parent, especially for subsidiaries located in emerging markets where capital is relatively scarce and expensive, and alternative funding sources are more difficult to find. In this case, a liquidity shock received by a parent bank can be ultimately transmitted to its vulnerable foreign subsidiaries through an internal lending channel. Using the Japanese banking crisis in 1990s as a quasi-natural experiment, Peek and Rosengren (2000) show that Japanese banks in the US significantly reduced loan supply during the crisis and this loan supply shock had a negative real effect on economic activities since

[2] This is an appropriate measure because banks located in a GIIPS country are those most affected by the sovereign shock. Indeed, banks hold more domestic government debts rather than foreign debts on their balance sheet, a phenomenon known as home bias. If there is a sovereign credit event, domestic banks as government bond holders are directly affected.

demand for loans cannot easily be fulfilled with alternative forms of financing. Looking at the recent global financial crisis, Aiyar (2012) uses UK quarterly bank-level data from the Bank of England to show that an external funding shock had a significant and substantial impact on domestic lending activities. Specifically, the evidence suggests that subsidiaries and branches of foreign banks tighten their credit supply more than domestic banks during the crisis.

Popov and Udell (2010) examine whether the recent global financial crisis which erupted in advanced economies was transmitted to central and eastern Europe through foreign banks. They construct an index to measure the level of financial distress in the 14 countries in the region and exploit the data on SMEs provided by the 2008 Business Environment and Enterprise Performance Survey. The results of this study imply that SMEs in central and eastern Europe would have a higher probability of rejection on their loan applications if the banking system was dominated by foreign banks. Another study on Eastern European countries by Ongena et al. (2015) support these results. It is shown that during the recent financial crisis, internationally-borrowing local banks and subsidiaries of foreign banks reduce their loans more than locally funded banks, while lending by banks with more retail deposits are relatively stable no matter whether the banks are foreign-owned or borrowing internationally.

Schnabl (2012) exploits the 1998 Russian default to examine how a liquidity shock received by international banks was transmitted to Peru. Taking advantage of detailed interbank lending databases provided by the central bank of Peru, the author shows that the liquidity shock was transmitted through an international interbank lending channel. Compared with locally funded banks, both internationally borrowing banks and foreign owned banks are affected more by this channel. Specifically, foreign owned banks perform relatively better than those borrowing abroad, since international banks reduce their interbank lending to these banks more than their foreign subsidiaries. Anginer et al. (2014) examine the association of default risk between international parent banks in developed countries and their subsidiaries in emerging economies during the recent financial crisis, rather than transmission channels of the liquidity shock. Controlling for different financial regulation across different countries, they show a significant and positive correlation between a parent's and a subsidiary's default risk. Moreover, it shows that the default risk of subsidiaries with higher capital, retail deposits, profitability and independency is less correlated with the parents' default risk.

The above papers focus on a liquidity shock in a single country transmitted into another country (Peek and Rosengren, 2000), or a global liquidity shock transmitted to a single country (Aiyar, 2012). We build on these papers by providing evidence at the level of the banks and their subsidiaries on the operation of an internal capital market with a cross-country setting. A prior cross-country analysis (Cetorelli and Goldberg, 2011) examines whether a liquidity crisis in advanced economies could be transmitted to emerging markets through foreign banks at country level. Our paper adds to this work, by including both developed and developing economies in our sample and testing at the bank level whether bank ownership linkages across Europe can serve as a vehicle to transmit liquidity shocks. This proposition has yet to be tested in the literature.

3. Empirical setting

3.1. The crisis as an experiment

In December 2009, Fitch, Moody's, and S&P downgraded the rating for Greek sovereign credit when they perceived that the Greek government was suffering from public deficit difficulties. During April 2010, Greek bonds were downgraded to junk status by S&P. This event is typically regarded as the start of the sovereign debt crisis in Europe. Immediately after, Moody's downgraded the rating for the Irish sovereign debt, and Spain lost its top credit rating. The crisis further deepened in 2011 when Portuguese and Italian sovereign debt rating were downgraded.

Fig. 1 depicts the CDS (Credit Default Swap) spread of GIIPS countries' 5-year sovereign debt, along with the CDS spread of German 5-year bond as a comparison. A CDS is a financial arrangement by which the buyer of the CDS will be protected by the seller in the event of credit default. Thus, the CDS spread for sovereign indicates the default risk of the sovereign debts, so Fig. 1 describes the evolution of the sovereign debt crisis.

Banks holding downgraded bonds may begin to suffer liquidity issues. As Popov and Van Horen (2015) and De Marco (2013) suggest, there may be two channels through which the valuation haircut on the GIIPS sovereign debts have a negative effect on a bank's liquidity and thus lending activities. These are the 'funding channel' and 'capital channel'. Banks are likely to be affected by a sovereign credit event through the funding channel because the value reduction of the sovereign debt directly weakens the asset side of the bank's balance sheet, and also affects the bank's borrowing capacity in the interbank lending market due to the fact that banks often use sovereign debt as collateral. They are also likely to be shocked through the capital channel because the capital loss due to the devaluation of sovereign debt may drive a bank's capital ratio below the regulatory ratio. In response, the bank reduces lending to maintain their capital ratio. Therefore, the sovereign debt crisis can be seen as a liquidity shock for banks who were holding a relatively large amount of impaired sovereign debts in their portfolio. Since banks usually tend to hold more domestic sovereign debts rather than foreign government bonds (an effect known as home bias), the GIIPS sovereign debt crisis represents a severe liquidity shock to banks located in GIIPS countries.

Fig. 2 shows the overall GIIPS sovereign debt holdings for 21 EU banking systems, as recorded by the European Banking Authority (EBA) stress test in 2010, 2011 and 2014. The tests selected banking groups to cover at least 50% market share of a country's banking system. Though it is not a complete survey for all the banks in the sampled countries, the result is the best

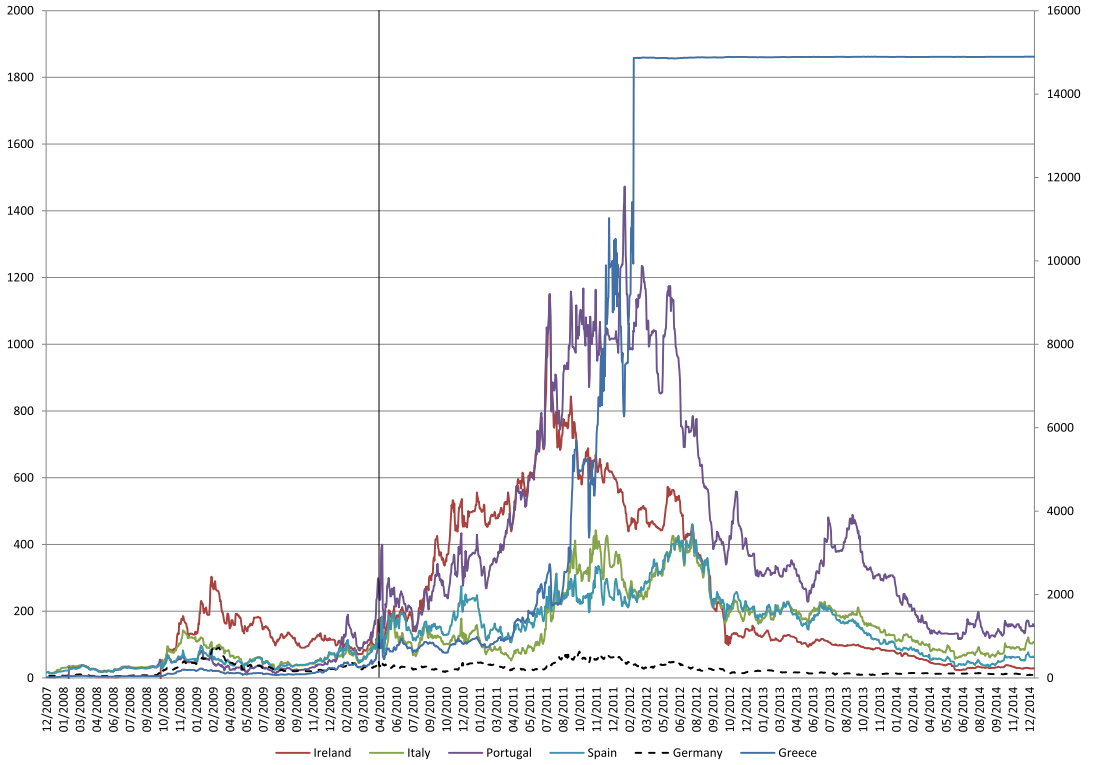

Fig. 1. CDS spread of GIIPS sovereign debts (5 Year), by country. *Notes:* This figure depicts the CDS spread of GIIPS sovereign debt which captures the default risk of the government, thus describes the evolution of the sovereign debt crisis. The unit for Greek debt's CDS spread is depicted by the vertical axis to the right. As it shows, after the Greek bond was downgraded to junk status in April 2010, the sovereign crisis formally erupted and the CDS spread of all GIIPS countries started to scramble up, while the CDS spread of German bonds remained low and stable during the whole period. *Source:* Datastream.

proxy available for the European banking system. As the figure shows, excluding GIIPS Countries, Austria, Belgium, Cyprus and Luxembourg had a relative high exposure to GIIPS sovereign debts in 2010. Significantly, banks in these countries reduced their GIIPS debt holdings during the crisis. Meanwhile, the portfolio of GIIPS banks contains a consistent home bias over the same period. Thus if the valuation haircut of sovereign debt has a negative effect on a bank's liquidity, it is very likely that banks in GIIPS country had received the strongest liquidity shock due to the crisis.

Fig. 3 illustrates the trend of bank credit supply in GIIPS countries and Germany during the crisis period. The growth rate of bank lending fell sharply during the 2008 and 2009 due to the global financial crisis. This can be interpreted as a common trend before the sovereign debt crisis. At the beginning of 2010, banks in all countries show a recovery of their credit supply. However, the trends start to diverge when the sovereign shock comes in April 2010. The growth rate of bank lending in GIIPS country shrinks again during the crisis while German banks increase their lending with a low but stable growth rate. It is worth noting that the poor performance of German banks might also be partly due to the crisis in GIIPS countries. In addition, Fig. 4 shows the interest spread on the policy rate for new loans for the same countries from 2007 to 2014. The story is similar, the trends started to diverge as the crisis occurs. Overall, the evidence shows that banks in GIIPS countries appear to have suffered from liquidity problems during the crisis period, and this can be attributed to the sovereign debt crisis.

3.2. Network construction and exposure measurement

Ownership networks connect banks in GIIPS countries with banks in other European economies not directly exposed to the impaired sovereign debts. An effective ownership linkage between a parent and a subsidiary bank is defined by a control stake where the parent bank holds 50% or more of the subsidiary bank's total equity. Fig. 5 provides an illustration of the three possible scenarios of the network. Scenario 1 shows the case that both the parent bank P_1 and the subsidiary bank S_1 are located outside of GIIPS countries, so this banking group has no linkages with banks in GIIPS countries thus they do not have any direct exposure to the liquidity crisis in the GIIPS banking system. In scenario 2, one of the two subsidiary banks S_4 is located in a GIIPS country, thus there is a possibility that the liquidity shock received by S_4 could be transmitted to the parent bank P_2 and the other subsidiary S_2. The last possible scenario is that the parent bank is located in GIIPS country. As scenario 3 shows, the parent bank P_3 and subsidiary bank S_5 are located in GIIPS countries while the other subsidiary bank S_3 is located in other economies. In this scenario, it is plausible that the liquidity shock in GIIPS countries may have an effect on S_3 since it has a relatively large exposure.

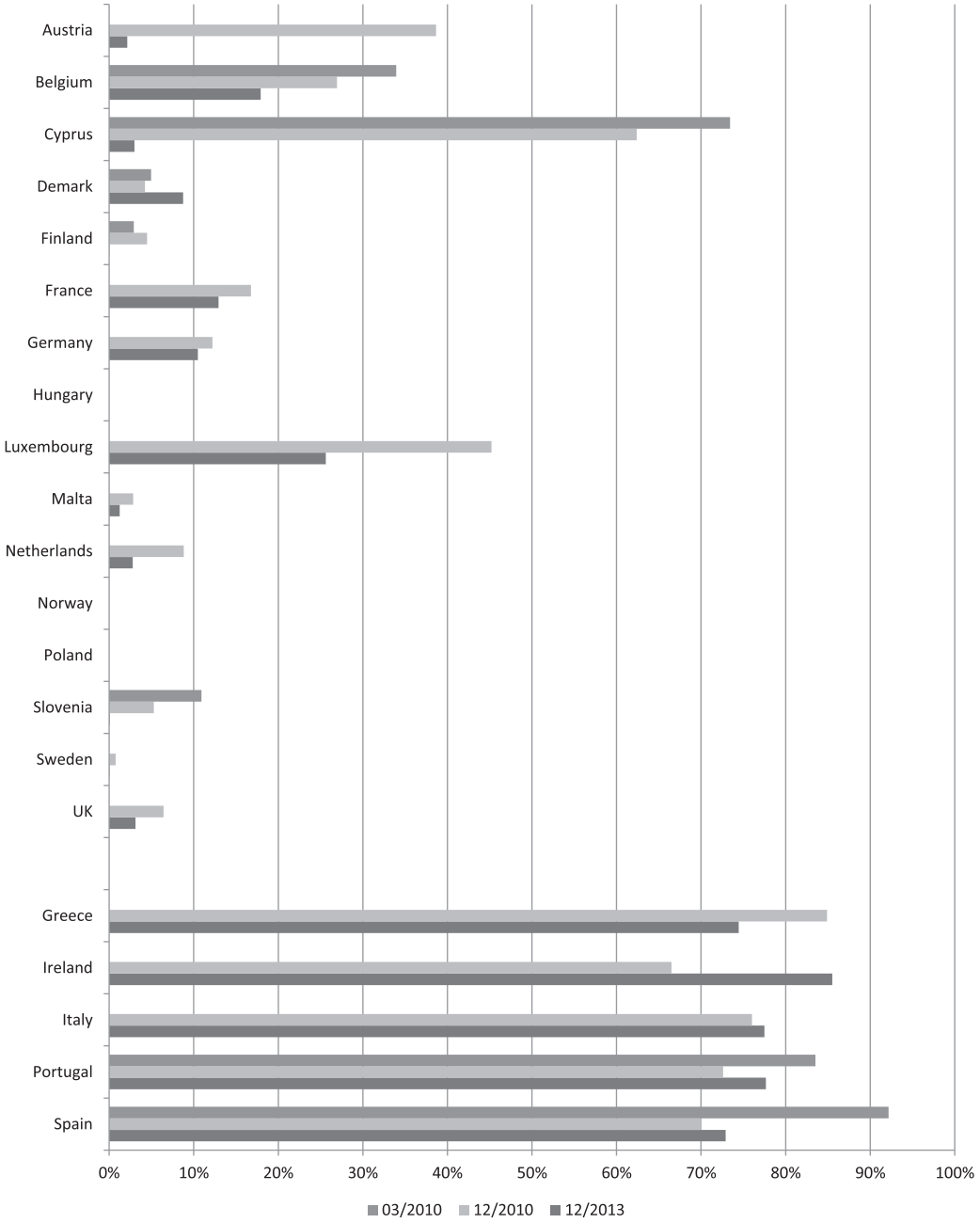

Fig. 2. GIIPS sovereign debt exposure, by country. *Notes:* This figure shows to what extent a banking system of a EU country was exposed to GIIPS sovereign debts, which is revealed by the EBA stress tests. As it shows, despite GIIPS countries, banks in Austria, Belgium, Cyprus and Luxembourg were highly exposed to the GIIPS debts in 2010. However, those banks significantly reduced their GIIPS debt holding during the crisis. Meanwhile, the sovereign debt portfolio of banks in GIIPS countries performed a consistent home bias. Data for Austria, Germany, France, UK, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Poland, and Sweden in March 2010 is missing. *Source:* European Banking Authority, Stress Test 2010, 2011 and 2014.

The main objective of this study is to test whether the liquidity shock received by either S_4, S_5 or P_3 would be transmitted to S_2 and S_3, respectively, through cross-border ownership linkages. In other words, it focuses on whether subsidiary banks S_1, S_2 and S_3 behave differently during the crisis due to the ownership linkages with banks in GIIPS countries.

It is necessary to identify the degree of exposure to the crisis based on the identified cross-country bank ownership networks. In order to do this, we create an exposure measurement for the banking groups, indicating the extent to which the subsidiary banks are exposed to the crisis. The measurement can be given by the equation below

$$Exposure_{it} = \sum_{k} \frac{Assets_{ikt}}{Total\ Assets_{it}} \times CDS_{kt}$$

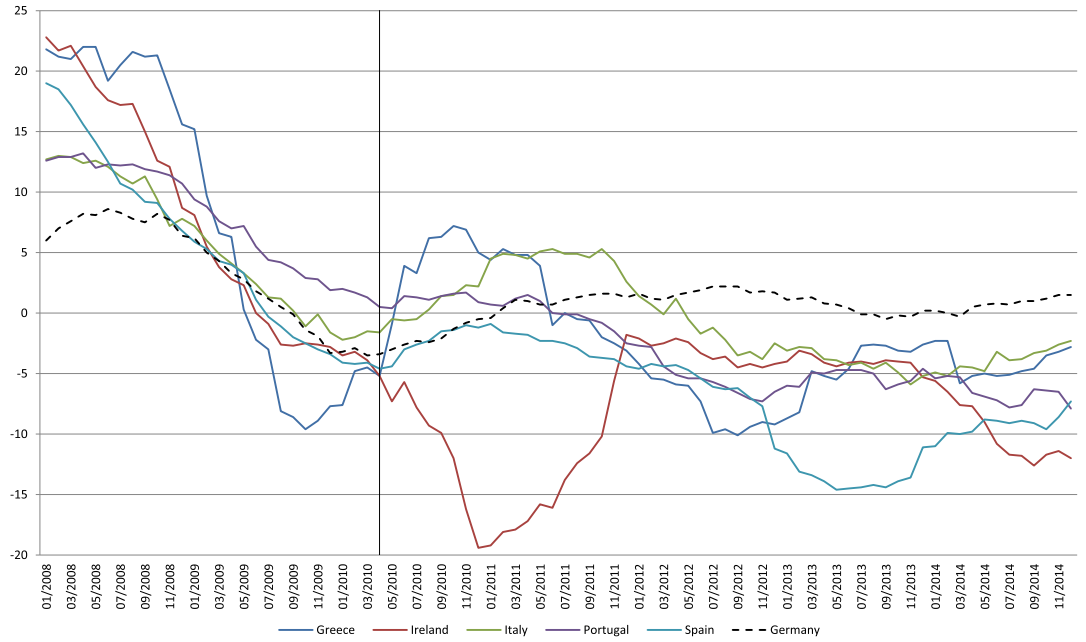

Fig. 3. Growth rate of loans to domestic non-financial corporations, by country. *Notes:* This figure presents the loan growth rate to domestic non-financial companies for GIIPS countries and Germany. Banks in all GIIPS countries and also Germany reduce their lending significantly during the global financial crisis in 2008. In the beginning of 2010, banks in all countries tend to recover their credit supply. However, the trends start to diverge when the sovereign shock comes up in April 2010. Growth rate of bank lending in GIIPS country shrinks again during the crisis while German banks increase their lending with a low but stable rate. *Source:* European Central Bank Data Warehouse.

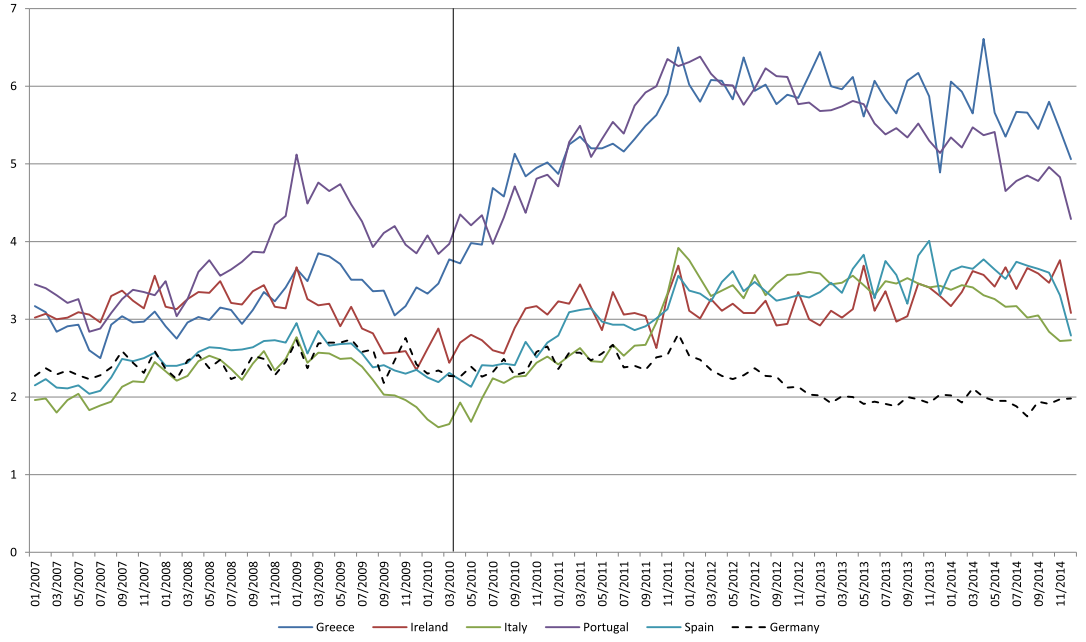

Fig. 4. Interest spread (on ECB deposit facility) for new loans to non-financial corporations, by country. *Notes:* As this figure shows, the interest spread in GIIPS countries start to rise up after the shock while the spread in Germany is relatively low and stable during the crisis period. Together with Fig. 4, evidence shows that there is a liquidity squeeze in banking system of GIIPS countries during the sovereign debt crisis. *Source:* European Central Bank Data Warehouse.

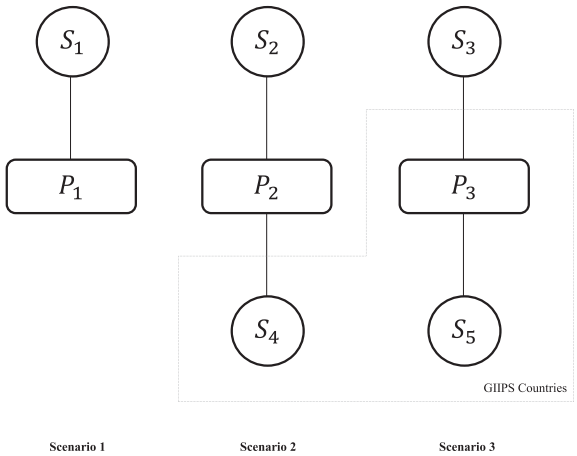

Fig. 5. 3 scenarios of bank ownership network. *Notes:* This figure illustrates 3 possible scenarios of bank ownership network in this study. P_i stands for parent banks and S_i stands for subsidiary banks. Scenario 1 is the case that both parent banks and subsidiary bank are located in non-GIIPS countries thus this banking group is not exposed to the crisis. Scenario 2 shows that one subsidiary of the banking group is located in GIIPS country thus there is a possibility that the liquidity shock received by S_4 could be transmitted to the parent bank P_2 and the other subsidiary bank S_2. The last possible scenario is that the parent bank is located in GIIPS country. In this case, it is very likely that the liquidity shock received by the parent bank would be transmitted to S_3 through the ownership linkage.

where i identifies the banking group, t denotes time point and k stands for each GIIPS country. $TotalAssets_{it}$ is the total assets of the parent banks of the banking group. The first term captures the extent to which the banking groups are involved with the business in GIIPS countries, thus the exposure of the banking group to the crisis. The second term, CDS_{kt} captures the intensity of the crisis in different countries. Therefore the exposure of each subsidiary bank outside of the GIIPS countries is given by the calculated exposure of the banking group.

Fig. 6 illustrates an example of a simple bank ownership network across European countries, as in scenario 2. The parent bank of this banking business group is located in a non-GIIPS European country, say France, while it has two subsidiaries in GIIPS countries, S_2 in Greece (GR) and S_3 in Italy (IT). There are also two subsidiary banks S_1 and S_4 located in non-GIIPS countries, which could be both domestic subsidiaries in France or foreign subsidiaries in countries like Germany or the UK. The exposure to the crisis for S_1 and S_4 at time t are then given by the exposure of this banking group X at time t:

$$Exposure_{Xt} = \frac{Assets_{S_2 t} \times CDS_{GRt} + Assets_{S_3 t} \times CDS_{ITt}}{Total\ Assets_{Xt}}$$

where $Total\ Assets_{Xt} = Assets_{Pt} + \sum_{i=1}^{4} Assets_{S_i t}$.

3.3. Theory and hypothesis

Holmstrom and Tirole (1997) propose an incentive model for financial intermediation. This model suggests that the moral hazard problem of firms as a borrower can be alleviated by monitoring from banks, but banks as financial intermediators can neglect to monitor and thus also generate a moral hazard problem to depositors (indirect investors). In this case, banks' loanable funds and firms' investment spending are determined by the stock of bank capital and firm collateral. Both a credit crunch caused by a capital shock on banking system and a collateral squeeze in the real economy can reduce the loanable funds and investment spending. Morgan et al. (2004) extend this model to a two-state version to analyse the effect of interstate banking on economic volatility in the US during the bank integration process after 1978. The model shows that the effect of a credit crunch in a state can be dampened under the interstate banking regime while a collateral squeeze will be amplified through the internal capital market between banks.

This conceptual framework can easily be extended to the context of multinational banks where there is some non-negative degree of capital mobility between host countries. The application of this model for explaining the effect of multinational banks during the European debt crisis is illustrated in Fig. 7, with two classical demand-supply diagrams. The X-axis denotes the loan quantity and Y-axis denotes loan rate or bank capital return. Consider country 1 as one of the five GIIPS countries and country 2 as a non-GIIPS European country. The valuation haircut of the GIIPS debts may reduce the liquidity of banks in country 1 through both the capital channel and the funding channel, which shifts the bank credit supply curve to the left, resulting in a lower amount of bank lending and a higher interest rate. This process is supported by the trend of loan growth and interest spread depicted in Figs. 3 and 4.

If there is no multinational banking, the story would end here and nothing would happen in country 2. However, country 1 and country 2 are connected by bank ownership networks. Observing higher capital return in country 1, the bank holding company or headquarters will reallocate their banking assets across countries, by reducing their lending in country 2 and

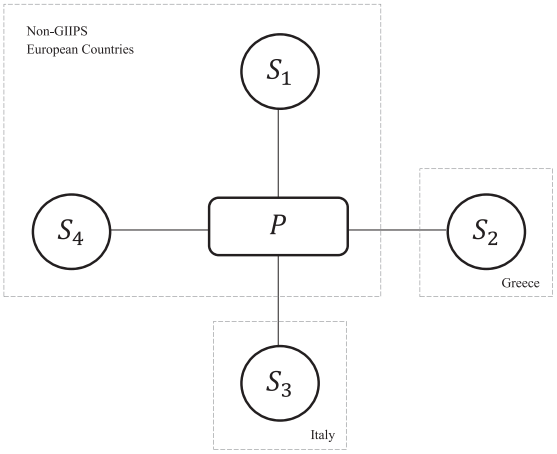

Fig. 6. Example of a simple network *Notes:* This figure illustrates an example of a simple network in scenario 2 where the parent bank *P* is located in non-GIIPS country.

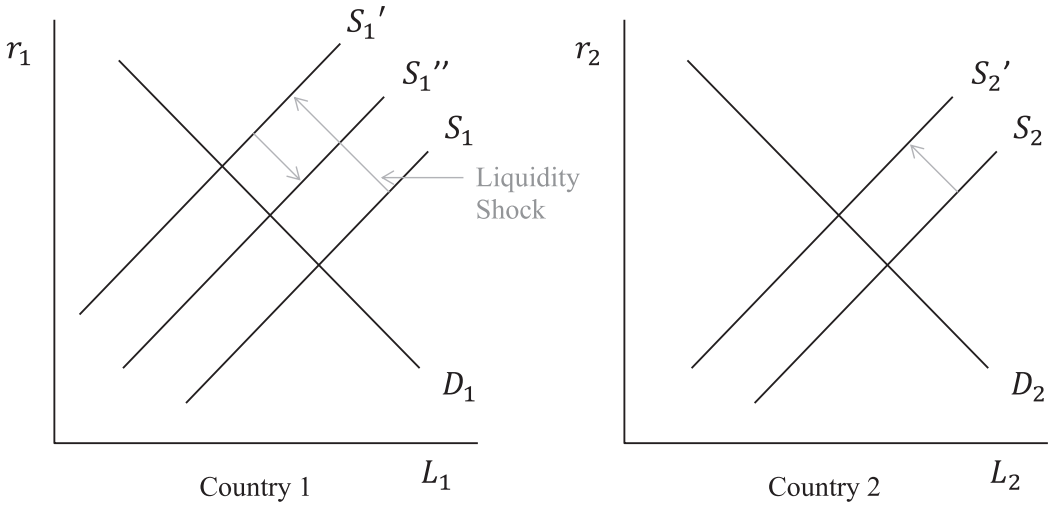

Fig. 7. Internal capital market hypothesis. *Notes:* In the left panel, a liquidity shock at the banking system of Country 1 lead to a lower level of loan supply and a higher loan interest rate. If Country 2 is connected with Country 1 by bank ownership networks, the model predicts that the shock will be alleviated in Country 1 but transmitted to Country 2 in the right panel, through the channel of banking group's internal capital market.

increasing credit supply in country 1. The mitigation of the liquidity shock in country 1 due to the internal capital market is called the 'support effect' by De Haas and Van Lelyveld (2010), and we call the credit contraction in country 2 the 'contagion effect', since the liquidity shock spills over through the internal capital market. The major objective of this study is thus to identify the contagion effect in the banking system of non-GIIPS countries during the European sovereign debt crisis.

4. Data and descriptive statistics

In Section 3.2, a bank is defined as a parent bank's subsidiary if 50% or more of its total equity are directly held by the parent bank. 50% is the natural cutoff which gives the parent bank absolute control over its subsidiary and hence plausibly part of the internal capital market. In order to identify banks ownership ties, we extract banks' shareholder information from Bankscope and then link parent banks with their subsidiaries.[3] Finally we construct bank ownership networks across European countries by using banks' shareholder information in the year of 2010, which is the starting point of the sovereign debt crisis.

Table 1 shows the sample of countries used in this study and the number of parent banks and subsidiary banks in each country that could be identified from the data. The data records information for 8872 banks from which we could observe

[3] Some banks' shareholders are also owned by other European banks. In this case, these banks are all defined as the subsidiaries of the ultimate parent banks.

Table 1
Sample country, parent banks and subsidiary banks.

Western Europe			Eastern Europe		
Countries	Parent	Subsidiary	Countries	Parent	Subsidiary
Andorra	1	2	Albania	1	8
Austria	25	42	Belarus	1	7
Belgium	6	16	Bosnia and Herzegovina	0	9
Cyprus	4	7	Bulgaria	1	11
Denmark	12	21	Croatia	1	11
Finland	3	6	Czech Republic	2	9
France	30	91	Estonia	0	4
Germany	35	71	Hungary	2	13
Gibraltar	0	0	Kosovo	0	1
Greece	5	–	Latvia	0	9
Iceland	2	1	Lithuania	1	3
Ireland	2	–	Macedonia	0	8
Italy	15	–	Moldova	0	4
Liechtenstein	1	1	Montenegro	0	3
Luxembourg	7	53	Poland	3	27
Malta	0	2	Romania	1	16
Monaco	1	0	Russia	26	65
Netherlands	11	20	Serbia	0	12
Norway	8	10	Slovakia	0	6
Portugal	3	–	Slovenia	2	6
San Marino	0	1	Ukraine	2	22
Spain	3	–			
Sweden	7	9			
Switzerland	27	46			
Turkey	9	7			
United Kingdom	21	49			
Total	238	455	Total	43	254

Notes: This table shows the sample country for this study and the number of parent banks and subsidiary banks in each country that could be identified from the database thus included into the ownership network. The categorisation between Eastern and Western European countries is classified by Bankscope. Initially Bankscope records information for 8872 banks in the sample countries, from which we could only observe shareholder information for 709 subsidiary banks belonging to 281 banking groups. Subsidiary banks in GIIPS countries are not included in the sample since this study focus on subsidiary banks in non-GIIPS countries only.

shareholder information for 709 subsidiary banks belonging to 281 banking groups. We limit our sample to include four types of banks: commercial banks, cooperative banks, mortgage banks, and saving banks. Bank holding companies are initially included in the sample in order to construct the ownership network, as the holding company is the most important node in a ownership network. Once the networks are constructed, we drop bank holding companies from our sample because they do not function as the other four types of banks that collect deposit and originate loans.

As Table 1 shows, 455 subsidiary banks are located in Western European countries while 254 subsidiary banks are based in Eastern Europe. In terms of parent banks, there are 238 banks from Western Europe and 43 banks are located in Eastern European countries. Subsidiary banks in GIIPS countries are not included in the sample since this study focus on subsidiary banks in non-GIIPS countries only. However, subsidiary banks are allowed to be owned by parent banks in GIIPS country, in which case the banking group would be in scenario 3 according to our taxonomy.

Banks' balance sheet data are also obtained from Bankscope. We collect bank-level unconsolidated data for 709 subsidiary banks and 281 parent banks, from 2008 to 2013, resulting in an unbalanced panel dataset. We also collect GDP growth rate and unemployment rate data for the sample banks' host and home countries from the World Bank DataBank. Table 2 presents the summary statistics for the variables that used in our econometric analysis.

The key variable of interest in this study is the subsidiary bank's exposure to the crisis. In order to scale the bank's exposure according to the intensity of the crisis, we collect CDS spread data for GIIPS country's 5-year senior debts from DataStream.[4] We take the average level of sovereign debt CDS spread in December each year to scale the bank's exposure. As a result, exposure becomes a time-varying variable though the ownership network is constant. Since the magnitude of the CDS spread varies remarkably (as the trends in Fig. 1 suggest), the magnitude of the calculated exposure also varies, hence we take the log of the final exposure variable in order to harmonise the data. Fig. 8 depicts the distribution of exposure data for banks with positive exposure to the crisis. Grey bars show the exposure distribution for subsidiary banks in scenario 2 where the parent banks are located in non-GIIPS countries, while black bars show the distribution for banks in scenario 3 where their parent banks are located in GIIPS countries. Clearly, banks in scenario 3 tend to have higher exposure than banks in scenario 2, which suggests that the exposure measurement works well because banks in scenario 3 are expected to be more exposed to the crisis compared with scenario 2 banks.

[4] The trend of the CDS spread for other types of sovereign debts are highly correlated thus we use the CDS spread for 5-year senior debt as the indicator for the crisis intensity.

Table 2
Summary statistics for main variables.

Variable	Bank Type	Mean	Std. Dev.	Min	Max	Observation
Bank level						
Loan growth	*Subsidiary*	10.70	54.97	−100.00	900.00	3001
	Parent	10.68	54.56	−100.00	796.81	822
Size	*Subsidiary*	14.61	2.17	4.22	21.63	3210
	Parent	16.35	2.23	8.65	21.86	955
Deposit	*Subsidiary*	57.57	31.86	0.00	100.00	3004
	Parent	53.11	28.20	0.00	100.00	793
Liquidity	*Subsidiary*	28.70	23.33	0.01	100.00	3205
	Parent	21.33	17.05	0.00	89.37	909
Capital	*Subsidiary*	11.96	13.36	0.25	100.00	3199
	Parent	22.33	28.93	0.00	100.00	944
Interest Margin	*Subsidiary*	3.05	3.76	−3.95	61.49	3080
	Parent	2.28	3.04	−25.20	35.20	862
Profitability	*Subsidiary*	0.31	4.62	−94.33	98.21	3195
	Parent	−0.54	13.62	−233.42	35.56	946
Country Level						
GDP Growth	*Host Country*	0.77	3.40	−17.95	10.20	4235
	Home Country	0.47	3.11	−14.80	10.20	1672
Unemployment	*Host Country*	8.07	4.72	2.60	47.50	4095
	Home Country	7.21	3.29	2.60	27.30	1634

Notes: This table presents the summary statistics for the variables that used in our econometric analysis. Bank level data are obtained from Bankscope while country level data are collected from World Bank. *Loan growth* is the annual growth rate of gross loans, including net loans and also loan loss reserves. This variable is used as the performance indicator for bank's lending activities. *Size* is log of a bank's total assets, which is a typical measurement for bank size. *Deposit* is a bank's customer deposit divided by its total assets. *Liquidity* is a bank's liquid assets over total assets, while *Capital* is a bank's total equity over total assets. *Interest Margin* is a bank's net interest margin indicating the bank's capability in its core business. *Profitability* is indicated by bank's return on total assets. *GDP Growth* is the annual growth rate of GDP while *Unemployment* is the unemployment rate for each country in our sample.

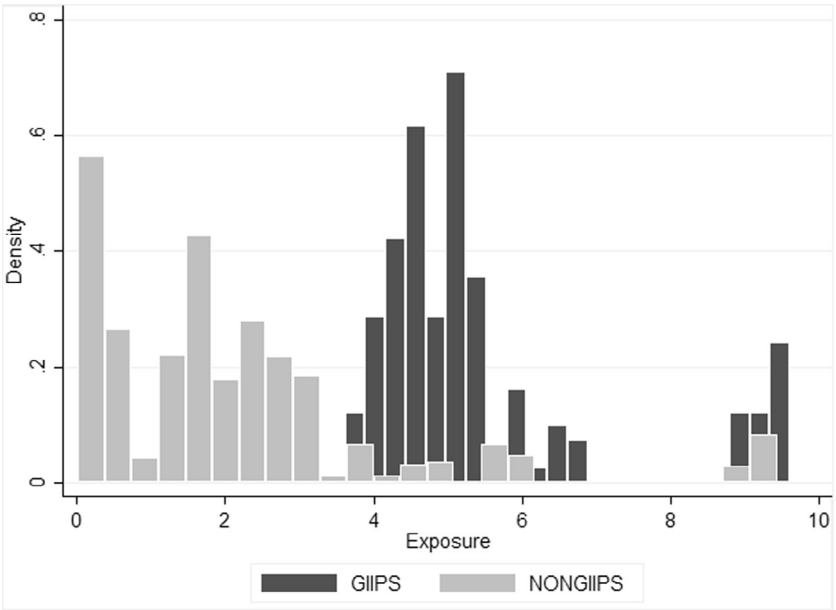

Fig. 8. Exposure distribution. *Notes:* This figure depicts the distribution of exposure data for banks with positive exposure to the crisis. Grey bars show the exposure distribution for subsidiary banks in scenario 2 where the parent banks are located in non-GIIPS country, while black bars show the distribution for banks in scenario 3 where their parent banks are located in GIIPS country. It clearly shows that banks in scenario 3 tend to have higher exposure than banks in scenario 2, which suggests that the exposure measurement works well since banks in scenario 3 are expected to expose more to the crisis compared with scenario 2 banks.

Fig. 9 shows the trends of average loan growth rate for banks in different level of exposure. In our final sample, 525 banks have no exposure to the crisis, thus these banks are in scenario 1. For positive exposure, 97 banks are categorised into low exposure group while 85 banks are categorised into high exposure group, based on the exposure data in 2010. As the figure shows, the lending activity of banks in all 3 types collapsed between 2007 and 2009 due to the global financial crisis, and this dynamic can be interpreted as a common trend. However, in the year of 2010, which is the first year of the European debt

Fig. 9. Trend of loan growth rate, by exposure group. *Notes:* This figure shows the trends of average loan growth rate for banks with different level of exposure. In the final sample, 525 banks have 0 exposure to the crisis (scenario 1 banks). For those who have positive exposure, 97 banks are categorised into low exposure group while 85 banks are categorised into high exposure group, base on the exposure data in 2010. As the figure shows, the lending activity of banks in all 3 types collapsed between 2007 and 2009 due to the global financial crisis. In 2010, which is the first year of the European debt crisis, banks in scenario 1 and banks with lower exposure experienced a strong recovery in their lending growth while highly exposed banks did not recover to the same extent. The average lending growth rate for banks with higher exposure continues to drop in 2011 with the further deterioration of the European debt crisis, and there is no sign of recovery until 2014. Though lending growth for both scenario 1 banks and lower exposed banks has been recovered since 2010, the performance of lower exposed banks is much more volatile than scenario 1 banks during the crisis period.

crisis, banks in scenario 1 and banks with lower exposure experienced a strong recovery in their lending growth while highly exposed banks did not show the same level of recovery. More importantly, the average lending growth rate for banks with higher exposure continues to drop in 2011 with the further deterioration of the European debt crisis, and there is no sign of recovery until 2014. Another thing to be noticed here is that though lending growth for both scenario 1 banks and lower exposed banks has been recovered since 2010, the performance of lower exposed banks is much more volatile than scenario 1 banks' during the crisis period. This suggests that the stability of banks' lending activity would also be affected even they are just marginally exposed to the crisis. We also explored whether the decline in loan growth observed over the sample period varied at points in the distribution other than the mean, but the decline is at all percentiles.

5. Econometric method

We use the method of difference-in-differences (DID) to identify whether the liquidity crisis in GIIPS country's banking system due to the European sovereign debt crisis could be transmitted to other European countries through bank's cross-border ownership linkages. A conventional DID setting requires two groups: control group and treatment group; and two periods: pre-treatment period and post-treatment period. Two dummy variables will be created to indicate whether an observation gets the treatment or not before and after the implementation of the treatment; and whether this observation is in pre-treatment period or post-treatment period. It tests the difference in the difference between the treated group and control group in the two periods. Thus a significant difference in difference would suggest a significant treatment effect.

Specifically, the treated groups in our DID analysis are the non-GIIPS-based banks exposed to the liquidity crisis in a GIIPS country, due to their ownership linkages with banks in a GIIPS banking system. The control group is represented by banks without an ownership link with banks in the GIIPS countries (e.g. scenario 1). The year of 2010 is used as the cut-off between the pre- and post-period, since early 2010 is considered the sating of the debt crisis. In terms of grouping, in the control group there are 525 (scenario 1), while in the treated sample there are 172 banks with positive exposure (scenario 2 or 3). Note that exposure here is a continuous variable so we can measure the intensity of the shock.

The specifications of the regression model are illustrated by the equations below. We first apply the conventional DID method to find the treatment effect. As Eq. (1) shows, the DID method is implemented by the interaction term between bank's exposure (treatment) and the dummy variable for post-period. The estimated coefficient on the interaction term,

$\hat{\alpha}_2$, will examine our hypothesis that the subsidiary banks with higher exposure to the crisis would reduce their lending growth more than those with lower exposure during the crisis.

$$\Delta L_{i,j,t} = \alpha_1 + \alpha_2 Expo_{j,t} * Post_t + \sum_{k=3}^{m} \alpha_k X_{i,t} + \sum_{k=m+1}^{n} \alpha_k X_{j,t} + \gamma_t + \gamma_i + \xi_{i,j,t} \quad (1)$$

$$\Delta L_{i,j,t} = \beta_1 + \sum_{k=2}^{p} \beta_k Expo_{j,t} * Year_t + \sum_{k=p+1}^{q} \beta_k X_{i,t} + \sum_{k=q+1}^{s} \beta_k X_{j,t} + \gamma_t + \gamma_i + \epsilon_{i,j,t} \quad (2)$$

where i is each subsidiary bank in the sample and j is each parent bank/banking group, t denotes each year in the sample, ranging from 2008 to 2013. $\Delta L_{i,j,t}$ is loan growth rate of subsidiary bank i in banking group j at time t and $Expo_{j,t}$ is banking group j's exposure to the crisis at time t. $Post_t$ is a dummy variable for post-period which takes value 1 if the time is in between 2010 and 2013; otherwise 0. $Year_t$ is a set of time dummy variables, which indicate each year in the sample, ranging from 2008 to 2013; $X_{i,t}$ is a set of control variables for subsidiary bank i at time t. $X_{j,t}$ is a set of control variables for parent bank j at time t and γ_t is a set of time dummy variables controlling for year effect. γ_i controls for bank level fixed effects for subsidiary bank i. $\xi_{i,j,t}$ is the error term for bank i in group j at time t.

Our analysis also applies the dynamic DID method in the robustness check section. The conventional DID with two periods can only identify whether the treatment has a effect in the post period, while the dynamic DID allows us to see the impact of treatment as it evolves over the years in the post period. In other words, the advantage of dynamic DID method is that it is able to show when the treatment becomes effective and when the effect dies out. As Eq. (2) shows, the dynamic DID method is implemented by introducing a interaction term between bank's exposure and year dummy variables. The estimated coefficient on this term shows the effect of a bank's exposure on bank lending activity in each year over the sample period. Moreover the assumption of common trends before the shock can be inspected.

The dependent variable, *Loan growth*, is the annual growth rate of gross loans, including net loans and also loan loss reserves. As suggested by De Haas and Van Lelyveld (2010), it captures the changes in loan that is due to changes in loan loss provisions. This variable is used as the performance indicator for bank's lending activities. Finally, we include the following variables to control for both subsidiary and parent characteristics. *Size* is log of a bank's total assets, which is a typical measurement for bank size. *Deposit* is a bank's customer deposit divided by its total assets. This variable indicates bank's funding stability by capturing to what extent the bank is funded by stable customer deposits. *Liquidity* is a bank's liquid assets over total assets, while *Capital* is a bank's total equity over total assets. *Liquidity* and *Capital* measure a bank's risk aversion and solvency. A higher liquidity/capital ratio indicates that the bank is taking less risk and is more solvent. *Interest Margin* is a bank's net interest margin indicating the bank's capability in its core business. *Profitability* is indicated by bank's return on total assets. Summary statistics for the variables is presented in Table 2.

6. Empirical results

6.1. Baseline result

The baseline results of this study are presented in Table 3. Columns (1)–(3) show the results from the conventional DID regressions. In the first specification we do not include any control variables while the second and third specifications include controls for the subsidiary's characteristics and for the parent's characteristics respectively. The number of observations decreases as we include more control variables into the model. The estimated coefficient on *Exposure* is positive and statistically significant, suggesting that banks with higher exposure tend to have a higher lending growth rate during the whole sample period. However, this effect is not significant once we control for the characteristics of subsidiary or parent banks, as shown in columns (2) and (3). *Post* dummy has a negative coefficient, indicating that the lending activity of all banks are negatively affected during the crisis, though again it is not significant once we include control variables for both subsidiary and parent banks. The interaction between *Exposure* and *Post* dummy is the key term in the conventional DID regressions and the estimated coefficient on this term shows the main result of our study. The coefficient is negative and statistically significant and is consistent across the each specification. Taking the estimate from column (3) as an example, the estimated coefficient implies that if a bank's exposure increases by 1 percent, the bank's lending growth rate would decrease by 5.756 percentage points. The subsidiary bank's exposure is calculated based on the bank's ownership linkages with banks located in GIIPS country where there is a liquidity crisis, thus it captures to what extent the subsidiary bank is exposed to the crisis due to its ownership ties. The regression results then show that the ownership linkages between banks in GIIPS country and bank in Non-GIIPS EU countries transmit the liquidity crisis. In other words, we cannot reject the hypothesis that the liquidity crisis in GIIPS country was transmitted to other European countries through bank ownership networks.

Our estimates include a rich set of control variables. These are presented in the second and third columns of Table 3. They show that the size of a subsidiary bank is positively and significantly related to the bank's lending growth rate, and the effect is large: if the size of the subsidiary bank increases by 1 percent, its lending growth rate would be 21.9 percentage points higher on average during the sample period; bank liquidity is negatively related with the loan growth rate and this effect

Table 3
Baseline results.

Dependent variable	Diff-in-Diff		
Loan growth	(1)	(2)	(3)
Exposure	5.325**	3.083	7.108
	(2.100)	(2.257)	(4.794)
Post	−12.918***	−7.701*	−5.017
	(2.767)	(4.323)	(6.730)
Exposure∗Post	**−5.189*** **	**−3.920****	**−5.756****
	(1.476)	**(1.590)**	**(2.354)**
Subsidiary Characteristics			
Size		14.546**	21.892**
		(6.439)	(10.901)
Deposit		−0.109	−0.048
		(0.161)	(0.326)
Capital		−0.420	−0.527
		(0.533)	(0.633)
Profitability		2.779	3.543
		(2.623)	(3.248)
Liquidity		−0.971***	−1.404***
		(0.245)	(0.434)
Parent Characteristics			
Size			−8.077
			(9.466)
Capital			−0.163
			(0.321)
Profitability			0.195
			(0.319)
Liquidity			−0.188
			(0.154)
Interest Margin			−2.301*
			(1.262)
Constant	18.835***	−149.046	−85.719
	(2.252)	(97.619)	(191.716)
Observations	3001	2736	1616
No. of banks	638	590	393
R^2	0.030	0.108	0.158

Notes: This table presents the Baseline results of this study, where the dependent variable is the annual growth rate of gross loans. Year fixed effect and bank level fixed effect are controlled in each regression. We do not include any control variables in the first regression while the second regression includes controls for subsidiary's characteristics and then in the third regression we further include controls for parent's characteristics (GDP growth and Unemployment rate are also included in the regressions). *Size* is log of a bank's total assets. *Deposit* is a bank's customer deposit divided by its total assets. *Liquidity* is a bank's liquid assets over total assets, while *Capital* is a bank's total equity over total assets. *Interest Margin* is a bank's net interest margin indicating the bank's capability in its core business. *Profitability* is indicated by bank's return on total assets. The interaction between *Exposure* and *Post* dummy is the key term in the conventional DID analysis. Overall, the estimates from the conventional DID method suggest that the liquidity crisis in GIIPS countries were transmitted to other European countries though bank's cross-border ownership linkages. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

is also significant: a 1 percentage point increase in a bank's liquid assets reduce its loan growth rate by 1.4 percentage points; however, subsidiary bank's deposit, capital and profitability are not significantly related with a bank's lending activity during our sample period. Apart from bank level controls, host country's characteristics controlling for country-level demand-effects also have significant effects on bank performance. As to be expected, the subsidiary bank's lending growth is positively related with the host country's GDP growth while negatively related with the unemployment rate. This suggests that the subsidiary banks expand their credit supply faster in those countries where the economy is growing.

The parent bank's characteristics are also important for the subsidiary's lending activity, as suggested by the internal market hypothesis. As the third panel of Table 3 shows, the interest margin of parent bank is the only significant factor. Contrary to the findings by De Haas and Van Lelyveld (2010), a parent bank's interest margin is negatively related with tis subsidiary's lending growth. Since interest margin captures a bank's capability in its core business, this result suggests that the subsidiaries of parent banks with better performance tend to have a lower lending growth rate during the sample period. However, this could be explained by the internal capital market hypothesis that if the parent bank observe better investment opportunities in the home country, then they would focus more on its own market rather than support its subsidiary banks abroad, thus the foreign subsidiaries would have relatively lower lending growth rates. Besides, the control variables for home country characteristics have no significant effect on a subsidiary bank's lending growth.

In the appendix we explore the heterogeneity of the effect by both subsidiary and parent bank's characteristics. In terms of subsidiary bank's characteristics, we find that small banks, banks with lower profitability, and banks with higher capital ratio are more likely to be affected by a foreign liquidity shock. In terms of parent bank's characteristics, we find that if the parent bank is more risk-averse, less capable in its core business, or has higher profitability liquidity shocks are more likely to spillover to foreign countries.[5]

6.2. Subsidiary location: west vs. east

In this section, we separate the sample according to the subsidiary bank's location to explore the difference between the subsidiaries banks located in Western European countries and those in Eastern European countries. By doing this, we would like to observe whether the strength of the crisis transmission is contingent on the operating country of the subsidiary bank. In particular, are foreign banks in developing economies less resilient to an external liquidity shock than those foreign banks in developed economies?

As Table 4 shows, the estimates on the interaction term are statistically significant without parent bank controls, and the size of the negative effect is similar for subsidiary banks located in both Western and Eastern Europe. However, once we control for parent characteristics in Columns (3) and (6), a relatively greater negative effect is estimated for Eastern European banks while the interaction term is not statistically significant for banks located in Western European countries.

This result suggests that banks located in developing countries (Eastern Europe) are more fragile when facing an external shock, compared with banks located in developed countries (Western Europe). One possible explanation is that subsidiary banks operating in developing countries are more dependent on their parent banks' liquidity support, as the financial sector is usually less developed in developing countries. For banks operating in a developed financial system, they would have easier access to alternative funding even if their parent banks or the banking group as a whole are suffering from a liquidity shock. One policy implication can be drawn here. Regulatory authorities in developing countries might wish to target liquidity regulation specifically at foreign subsidiary banks operating in their domestic banking sector. This could be justified if, as suspected, a higher dependency on parent bank funding harms the stability of the domestic banking system should an external liquidity shock occur.

6.3. Parent location: scenario 2 vs. scenario 3

This section explores the heterogeneity in terms of parent banks' location. We divide our sample according to the three possible scenarios for the subsidiary banks.[6] Notice that subsidiary banks in scenario 1 are always included in the sub-sample as they are the control group in our DID regression. Results are presented in Table 5. It shows that the negative and significant result is mainly driven by subsidiary bank in scenario 3, as the estimates for scenario 2 banks are consistently insignificant. This implies that subsidiary banks located in non-GIIPS countries that are indirectly exposed to the crisis were not significantly affected by the external liquidity shock, suggesting that the parent bank could act as a buffer which could isolate external shocks and stop the crisis transmission.

This analysis also presents an implication for policy makers. The performance of the foreign banks in domestic banking system are increasingly important, particularly in developing economies. Therefore, as argued above, it could be necessary for the regulatory authorities to monitor a foreign bank's parent bank and the economic and financial situation in its home country. In addition, our analysis in this section suggests that it is not so necessary to supervise the parent bank's operations in other countries, apart from its home country, as a liquidity shock received by a subsidiary bank in other countries would be isolated by the parent bank. Hence the shock would be less likely to affect the domestic banking system.

6.4. Network distance to the crisis: Level 1 vs. Level 2+ subsidiaries

As the bank ownership network is constructed based on the banks' direct ownership linkages, it allows us to observe the position of a single subsidiary bank in the network hierarchy. Given this feature of our data, we are able to explore the heterogeneity in the banks' 'network distance' to the crisis. In other words, we test how far the liquidity crisis can be transmitted through the bank ownership network.

We define a Level 1 connection as the connection between the parent bank and its immediate subsidiary bank, while a Level 2 connection is the connection through which the parent bank owns the subsidiary bank's subsidiaries. In this case, the network distance between Level 2+ banks and the parent bank is longer than Level 1 banks. As the crisis would be transmitted from the parent bank to the subsidiary banks in the sample, Level 1 bank are at the front line of the ownership network

[5] Additionally, we explored whether differences emerge between nearly wholly subsidiaries (90–100% ownership) and majority owned subsidiaries (50–90% ownership). Splitting the sample at this cut-off did not reveal differences between these entities and the results of this exercise are available on request.

[6] As mentioned in Section 3, there are three possible scenarios of the bank ownership network in our empirical setting. Scenario 1 is the case where both the parent and subsidiary banks are located in non-GIIPS countries, thus they have no exposure to the crisis. In scenario 2, certain subsidiary banks from a banking group are located in GIIPS countries, thus their peer subsidiary banks located in non-GIIPS countries are indirectly exposed to the crisis due to the ownership linkages. Scenario 3 is where the parent bank of a banking group is located in the GIIPS countries, thus subsidiary banks in this banking group are highly exposed to the crisis, though they are located in Non-GIIPS countries.

Table 4
Subsidiary location: west vs east.

Dependent variable	West European banks			East European banks		
Loan growth	(1)	(2)	(3)	(4)	(5)	(6)
Exposure	5.732**	4.24	5.284	5.258*	1.889	9.576
	−2.883	−2.853	−4.228	−2.883	−3.481	−9.101
Post	−7.264**	−8.596**	−10.393	−22.535***	−7.742	−0.751
	−2.898	−4.323	−6.324	−5.878	−11.339	−14.118
Exposure∗Post	**−4.569****	**−4.184***	**−3.023**	**−5.966*****	**−4.465****	**−10.210*****
	−2.298	**−2.301**	**−2.29**	**−1.885**	**−2.087**	**−3.740**
Subsidiary Controls		Yes	Yes		Yes	Yes
Parent Controls			Yes			Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1913	1764	932	1088	972	684
No. of banks	393	367	224	245	223	169
R^2	0.03	0.067	0.124	0.057	0.213	0.252

Notes: This table shows the results for bank heterogeneity in terms of the bank's location. Refer to Table 3 for full specifications. The estimates on the interaction term are consistently significant without parent bank controls, and the size of the negative effect are similar for subsidiary banks located in both Western and Eastern Europe. However, once we control for parent characteristics in Column (3) and (6), a relatively greater negative effect is estimated for Eastern European banks while the interaction term is not statistically significant for banks located in Western European countries. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 5
Parent location: scenario 2 vs scenario 3.

Dependent variable	Scenario 2			Scenario 3		
Loan growth	(1)	(2)	(3)	(4)	(5)	(6)
Exposure	0.593	0.161	−3.37	5.963***	3.341	17.260**
	−2.379	−3.013	−8.333	−2.195	−2.656	−7.04
Post	−12.530***	−6.692	−5.18	−14.105***	−10.282**	−8.674
	−2.87	−4.519	−7.597	−2.959	−4.755	−7.665
Exposure∗Post	**−0.891**	**−1.12**	**1.063**	**−5.541*****	**−4.011****	**−8.886*****
	−1.956	**−2.321**	**−4.582**	**−1.606**	**−1.853**	**−2.935**
Subsidiary Controls		Yes	Yes		Yes	Yes
Parent Controls			Yes			Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2655	2403	1336	2579	2342	1256
No. of banks	566	523	334	550	506	314
R^2	0.02	0.11	0.154	0.031	0.116	0.193

Notes: This table presents results for the Scenario test. Refer to Table 3 for full specifications. In scenario 2 the parent bank of a banking group is located in non-GIIPS countries, and subsidiary banks in non-GIIPS countries are indirectly exposed to the crisis; while in scenario 3 the parent bank is located in GIIPS countries thus the subsidiary banks are directly exposed to the crisis. It shows that the negative and significant result is mainly driven by subsidiary bank in scenario 3, as the estimates for scenario 2 banks are consistently insignificant. This implies that subsidiary banks located in non-GIIPS countries that are indirectly exposed to the crisis were not significantly affected by the external liquidity shock, as the parent bank could act as a buffer which could isolate external shocks and stop the crisis transmission. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

facing the crisis, while Level 2+ banks are farer from the crisis in the network. The regression results in Table 6 show that the estimated coefficients on the DID term are consistently statistically significant for Level 1 banks across different models while for Level 2 banks the coefficients are not consistently significant at conventional levels. This implies that the bank ownership network could act as a liquidity crisis transmission while its power would be limited to the Level 1 connections, as the negative effect on Level 2+ banks is weaker. [7]

7. Robustness checks

7.1. Dynamic difference-in-difference

In this section we estimate the dynamic DID method to examine our hypothesis; results are presented in Table 7. The estimated coefficient on *Exposure* is still positive and statistically significant; this is consistent with the estimates from

[7] This result implies that subsidiary banks can also act as a buffer thus alleviating the liquidity shock within the network, and stop the crisis being transmitted further. This is consistent with the implication from our previous analysis on banks in different scenarios. Both analyses could help policy makers to consider the extent to which the foreign banks and their parent banks need to be supervised and regulated.

Table 6
Network distance to the crisis: Level 1 vs Level 2+ connections.

Dependent variable	Level 1 Connection			Level 2+ Connection		
Loan growth	(1)	(2)	(3)	(4)	(5)	(6)
Exposure	8.876***	4.652	11.290**	5.214	0.275	7.556
	−3.287	−5.087	−4.841	−3.594	−2.828	−10.996
Post	−13.872***	−8.222*	−5.526	−7.883	−10.38	−10.042
	−3.018	−4.372	−6.825	−7.018	−11.615	−24.2
Exposure∗Post	**−5.850*** **	**−3.872***	**−5.583****	**−6.707***	**−3.684**	**−16.874***
	−1.649	**−2.237**	**−2.421**	**−3.524**	**−2.826**	**−8.892**
Subsidiary Controls		Yes	Yes		Yes	Yes
Parent Controls			Yes			Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2285	2091	1286	716	645	330
No. of banks	566	523	334	550	506	314
R^2	0.032	0.162	0.215	0.039	0.109	0.267

Notes: This table shows regression results for the heterogeneity test in banks' network distance to the crisis. Refer to Table 3 for full specifications. Level 1 connection is the connection between the parent bank and its immediate subsidiary bank, while Level 2 connection is the connection through which the parent bank owns the subsidiary bank's subsidiaries. In this case, the network distance between Level 2+ banks and the parent bank is longer than Level 1 banks. As the crisis would be transmitted from the parent bank to the subsidiary banks in the sample, Level 1 bank are at the front line of the ownership network facing the crisis, while Level 2+ banks are farer from the crisis in the network. The estimated coefficients on the interaction term are consistently significant for Level 1 banks across different models while for Level 2 banks the coefficients are estimated less significant. It implies that the bank ownership network could act as a liquidity crisis transmission while its power would be limited to the Level 1 connections. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the conventional DID regressions. The key terms in these regressions are the interactions between *Exposure* and year dummy variables, rather than the *Post* dummy variables in the conventional DID method. The interaction with the dummy variable for the year of 2008 is the omitted base year. As Table 7 shows, the estimated coefficients on the interactions between *Exposure* and dummy for the year 2009 are negative but not statistically significant, which suggests that the difference in lending growth between highly exposed banks and less exposed banks in the year of 2009 are not statistically different from the year of 2008. This implies that there is a common trend between bank's lending activity over the pre-crisis period, which satisfies one of the key assumptions of the DID approach. Then, the interaction terms become significant starting from the year of 2010 which is the first year of the crisis. As column (1) shows, the estimates on interaction terms for each year in the crisis period are negative and significant and the size of the effect is considerable, suggesting that bank's exposure has a long-term negative effect on bank's lending activity. However, once we include subsidiary bank's characteristics as control variables in column (2), both the significance and size of the interaction estimates decrease, especially for the years of 2012 and 2013. Moreover, as column (3) results show, once we add parent bank's characteristics into the regression, the significance drops further, and the negative number for the year of 2013 is no longer significant. Overall this implies that bank's exposure has a pronounced effect during the crisis period (2010–2012), but it reverts back to the mean in 2013.

Another implication from the dynamic DID analysis is that the magnitude of the negative effect of bank's exposure reaches its highest level in 2011, when the GIIPS sovereign debt crisis also peaked, as suggested by Fig. 1. This trend is consistently predicted by all three models. Looking at column (3), for instance, banks with 1 percent higher exposure would reduce their lending growth rate by 6.51 percentage points in the year of 2010, while in 2011 these banks would reduce lending growth rate by 7.9 percentage points, compared with the lending growth rate in the base year, 2008. In 2012, the negative effect of exposure on loan growth rate reduces to 6.59 percentage points, and it is only significant at 10 percent level. This effect drops further in the year of 2013, and becomes no longer significant.

7.2. Dynamic ownership network

The baseline results of our analysis are estimated based on a static bank ownership network, which is constructed with bank ownership data in December 2010. Throughout the analysis we assume that the ownership network did not change over the sample period. However, the networks may have changed over the crisis period.[8]

In this section, we conduct the DID analysis based on a dynamic ownership network as a robustness check for our baseline result. The dynamic ownership network is constructed year by year using the time varying ownership data. The regression results are presented in Table 8. It reveals that the estimated coefficient on the key terms are qualitatively the same as the baseline results. Overall, the robustness checks confirm our baseline results that the liquidity crisis in GIIPS countries were transmitted to other European countries through bank's cross-border ownership linkages.[9]

[8] The reason why we initially focused on a static network is that the direct ownership data in Bankscope is not consistently recorded for bank in each year. Some ownership linkages are not recorded in a specific year while they appear in later periods. In this case, a dynamic network may suffer from the problem of inconsistency.

[9] Further robustness checks were performed in relation to the timing of the liquidity crisis. For example, since the crisis arrived later in Italy and Portugal than Greece, Ireland and Spain, we recoded the post-period to reflect this. Our results were unaffected and the results of these checks are available on request.

Table 7
Robustness checks: dynamic difference-in-difference.

Dependent variable	Dynamic DID		
Loan growth	(1)	(2)	(3)
Exposure	6.873***	4.611*	8.428
	(−2.558)	(−2.682)	(−5.401)
Exposure*2009	−2.977	−3.391	−3.117
	(−2.319)	(−2.455)	(−2.387)
Exposure*2010	−5.787**	−4.989**	−6.512**
	(−2.294)	(−2.304)	(−3.027)
Exposure*2011	−7.635***	−6.350***	−7.922**
	(−2.167)	(−2.180)	(−3.129)
Exposure*2012	−6.117***	−4.820**	−6.592*
	(−2.145)	(−2.200)	(−3.581)
Exposure*2013	−6.663***	−5.563**	−5.714
	(−2.027)	(−2.158)	(−3.791)
Subsidiary Controls		Yes	Yes
Parent Controls			Yes
Year FE	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes
Observations	3001	2736	1616
No. of banks	638	590	393
R^2	0.032	0.11	0.16

Notes: This table shows the robustness check for our baseline result with a dynamic DID setting. Refer to Table 3 for full specifications. Year effect and bank level fixed effect are controlled in each regression. We do not include any control variables in the first regression while the second regression includes controls for subsidiary's characteristics and then in the third regression we further include controls for parent's characteristics. The number of observations decreases as we include more control variables into the model due to data availability. The interactions between *Exposure* and year dummy variables are the key term in the dynamic DID regressions. Overall, the estimates from the dynamic DID approach are consistent with the findings from the conventional DID method that the liquidity crisis in GIIPS countries were transmitted to other European countries though bank's cross-border ownership linkages. What is more, the dynamic DID regressions show that the transmission effect is most effective in 2011 when the GIIPS crisis reach the peak, and it dies out in the year of 2013 as the crisis is mitigated in most GIIPS countries. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8
Robustness check: dynamic ownership network.

Dependent variable	Conventional DID		
Loan growth	(1)	(2)	(3)
Exposure	2.461	0.84	1.94
	(−1.736)	(−1.878)	(−2.716)
Post	−11.940***	−9.876**	−12.476**
	(−3.066)	(−4.073)	(−4.905)
Exposure*Post	**−4.617*****	**−3.385****	**−3.829****
	(−1.491)	**(−1.564)**	**(−1.725)**
Subsidiary Controls		Yes	Yes
Parent Controls			Yes
Year FE	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes
Observations	2753	2519	1899
No. of banks	575	531	462
R^2	0.029	0.08	0.11

Notes: This table shows the robustness check for our baseline result with a dynamic ownership network, which is constructed year by year using the time varying ownership data. Refer to Table 3 for full specifications. The estimated coefficient on the key terms are qualitatively the same with the baseline results. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

8. Conclusion

Over the past two decades, the world's economies are increasingly interconnected through bank ownership ties. There has been a substantial increase in foreign bank ownership in the domestic banking system. As such, it is important to understand the possible consequences of the interconnectedness of the global banking system. It has been argued that the presence of foreign banks can stimulate competition and innovation in domestic banking system thus improving the overall efficiency of the financial sector. This should have a long-term positive effect on the development of the domestic economy. However, a large proportion of foreign owned banks could expose the domestic baking system to international liquidity crises. This paper examined whether a liquidity crisis can be transmitted internationally through a bank's cross-border ownership linkages.

The 2010 European debt crisis provided a unique opportunity to identify this transmission. The ownership network for international banks operating in the European countries was constructed, based on the ownership data provided by Bankscope. Then the exposure to the liquidity crisis in GIIPS countries was calculated for each subsidiary bank located in non-GIIPS countries, measured by the proportion of their banking groups' assets in GIIPS countries. The Difference-in-Difference method was implemented to examine the transmission effect. The results from the DID regressions show that the treatment has a negative and significant effect on a bank's lending growth rate during the crisis period, and the magnitude of the effect is large. Overall the results of this study suggest that subsidiary banks operating in non-GIIPS countries who were exposed to the liquidity crisis in GIIPS countries due to the ownership linkages tend to have a lower lending growth rate during the crisis period, compared with those who were not exposed. This, in turn, suggests that the liquidity crisis in GIIPS countries banking system was transmitted to other European countries through cross-border bank ownership linkages.

Our study also presents opportunities for future work. While our data has allowed us to identify ownership ties, given the relatively small number of observations within GIIPS countries and incomplete information on changes in ownership over time we have been unable to test the 'support effect' of the internal capital market. The 'support effect' is the notion that subsidiary banks suffering liquidity shock in GIIPS countries could be supported by their owners located outside of GIIPS countries.

An important caveat to our findings is that we are unable to fully capture the banks' exposure to government bonds. While we can control for the bank-specific time-invariant levels of exposure through a bank-fixed effect, it is not possible with our current data to control for the time-varying exposure to GIIPS debts.

Our analysis has implications for policy in terms of the regulation of international banks. First, as a liquidity shock can be transmitted through cross-border bank ownership linkages, regulatory authorities across countries might to think carefully about the activities of international banks and whether any of these should be ring fenced. Specific policies targeted at international banks so as to isolate foreign liquidity shocks could help support the stability of a domestic banking system. While such regulation may come at an operational cost for the banks involved, this has to be balanced against the need for a stable financial system. Second, the paper provides empirical evidence for operation of the internal capital market within banking groups in which international banks allocate their banking assets in order to maximise the profits. Regulators across countries would do better to coordinate their activities and agree policy on an international rather than domestic level. This may help alleviate the potential for contagion across an international bank's internal capital market.

Appendix A. Bank heterogeneity

The main results suggest that the liquidity crisis in GIIPS countries' was transmitted to other European countries through the banks' cross-border ownership linkages. In this section, we try to disentangle the transmission effect by looking at bank heterogeneity. In other words, we examine which characteristics of the banks could help subsidiary banks to be more resilient to external liquidity shocks, and which characteristics could instead intensify the propagation of the shock.

To do this, the sample is evenly divided into 3 sub-samples according to different levels of a bank's pre-crisis balance sheet structure as of 2009. For example, in terms of the size of the subsidiary banks measured by log of total assets, the level I sub-sample only includes small banks in the initial sample, while big banks are categorised into the level III sub-sample, leaving banks in level II of the sub-sample as medium sized. Then the DID method is implemented with the same estimating specifications for the sub-samples separately to show whether the transmission effect varies with the size of the subsidiary banks.

A.1. Subsidiary characteristics

We first explore the heterogeneity in the subsidiary banks' characteristics. Table A1 presents results from the DID regressions. Six types of subsidiary bank features are tested: size, deposit, profitability, capital, liquidity and interest margin. The interaction between bank's exposure and *Post* dummy variable is the key variable of interest in these regressions.

The bank size test shows that smaller banks are more vulnerable to the external liquidity shock if the subsidiary bank is highly exposed, since the estimated coefficient on the interaction term is only significant for banks in level I sub-sample. This could be due to the fact that smaller banks do not have access to various alternative funding sources, and hence would be

Table A1
Heterogeneity in Subsidiary's Characteristics.

Dependent variable	Level I		Level II		Level III	
Loan growth	(1)	(2)	(3)	(4)	(5)	(6)
Size						
Exposure∗Post	−9.618*	−12.343*	−2.558	−2.142	−0.485	−0.331
	(5.029)	(6.421)	(2.169)	(2.650)	(1.191)	(1.848)
Observations	768	484	943	574	921	505
No. of banks	176	125	179	127	171	104
R^2	0.132	0.235	0.162	0.217	0.241	0.246
Deposit						
Exposure∗Post	−2.090	−0.681	−8.755***	−7.386*	−3.043	−1.837
	(2.100)	(5.386)	(2.918)	(3.869)	(2.475)	(2.718)
Observations	768	484	943	574	921	505
No. of banks	174	109	173	115	173	130
R^2	0.256	0.361	0.158	0.226	0.058	0.150
Profitability						
Exposure∗Post	−10.158**	−7.825	−3.774*	−4.735	−0.086	−1.570
	(4.607)	(4.917)	(2.059)	(3.244)	(1.620)	(3.011)
Observations	909	532	912	516	808	532
No. of banks	183	126	175	116	167	112
R^2	0.112	0.155	0.146	0.205	0.240	0.215
Capital						
Exposure∗Post	−0.257	0.817	−6.259*	−2.157	−4.839**	−11.265**
	(1.730)	(2.892)	(3.317)	(2.205)	(2.271)	(5.233)
Observations	876	502	924	547	832	514
No. of banks	168	109	179	122	179	125
R^2	0.126	0.186	0.090	0.259	0.168	0.244
Liquidity						
Exposure∗Post	0.900	−0.473	−4.628**	−8.435**	−6.634	−4.824
	(1.279)	(2.156)	(2.277)	(4.146)	(4.499)	(4.426)
Observations	873	520	930	591	829	452
No. of banks	169	111	181	130	176	115
R^2	0.266	0.305	0.151	0.198	0.115	0.208
Interest Margin						
Exposure∗Post	−7.797	−13.763***	−1.419	−0.018	−3.399	−7.945**
	(4.724)	(5.210)	(1.744)	(2.645)	(2.160)	(3.701)
Observations	789	377	917	594	836	557
No. of banks	159	91	176	131	174	126
R^2	0.097	0.237	0.130	0.221	0.240	0.322
Subsidiary Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parent Controls		Yes		Yes		Yes

Notes: This table presents test results for heterogeneity in subsidiary bank's characteristics. Year fixed effect and bank level fixed effect are controlled in each regression. Refer to Table 3 for full specifications. It shows that smaller bank is more vulnerable to the external liquidity shock if the subsidiary bank is highly exposed; that higher profitability would alleviate the external liquidity shock that transmitted from foreign parent banks to domestic subsidiaries; that bank with more capital would be more cautious on expanding their credit during the crisis period; that there is trend that banks with more liquid assets would reduce their lending growth more during the crisis; and that there is no clear evidence suggesting that bank's interest margin would affect subsidiary banks lending activities during the crisis period. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

more reliant on the funding from their parent bank. As a result, a liquidity shock received by the parent bank in the home country could be directly transmitted to smaller subsidiary banks. Larger subsidiary banks (banks with more assets) have easier access to alternative liquidity support (Holmstrom and Tirole, 1997).

We then test the influence of a bank's deposit funding on the transmission effect. Previous empirical work by Ivashina and Scharfstein (2010) suggests that a bank's lending activity would be more resilient during the global financial crisis if the banks had better access to deposit financing and less reliant on other forms of short-term debt. Thus it is expected that the transmission effect would be alleviated if the subsidiary banks relies more on deposit funding. However, we found weak evidence for this argument. As the table shows, the interaction term is only significant for banks in level II sub-sample, but not significant for level I or level III banks, though the coefficients are all estimated to be negative. This suggests that there is no clear trend that banks with more deposit funding would be more resilient to external liquidity shocks.

In terms of bank's profitability, panel three shows that the interaction term is negative and significant if the bank has a lower ROA (level I), while it is not significant for level III banks where banks' ROA are relatively higher. Though the interaction term is also marginally significant for level II banks, there is still evidence that higher profitability would alleviate the external liquidity shock that transmitted from foreign parent banks to domestic subsidiaries.

Bank capital and liquidity are tested as a measurement for a bank's risk aversion that could have a negative effect on a bank's loan growth performance; or as a indicator for a bank's capital or liquidity constraints to expand their loan business

thus could also be positively related with a bank's lending activity. De Haas and Van Lelyveld (2010) show that subsidiary banks' capital and liquidity conditions are negatively related with their lending growth, suggesting that subsidiary banks with higher capital ratios and more liquid assets would be more risk-averse thus tend to have a lower lending growth rate. Moreover, Black and Strahan (2002) suggest that less capitalised subsidiary banks are more likely to expand credit quickly due to moral hazard. Our tests would show the effect of bank capital and liquid assets on a bank's lending growth when their parent bank is suffering from a liquidity crisis.

As the table shows, the interaction term is only significant for the level III sample where banks are better capitalised, while for less capitalised banks in level I the effect is estimated as small and insignificant. This implies that a bank with more capital would be more cautious on expanding their credit during the crisis period. In terms of a bank's liquidity condition, the effect is similar with bank capital. It shows that the interaction term is only significant for level II banks with a medium level of liquid assets, while it is not significant for banks in levels I and III. However, if we compare the estimated coefficient for level I and level III banks, there is a very clear trend that banks with more liquid assets would reduce their lending growth more during the crisis. These findings show that a liquidity crisis in a home country could intensify a subsidiary bank's moral hazard problem.

We also test the influence of a bank's interest margin, which reflects a bank's capability in their core business. However, there is no clear evidence suggesting that these factors would affect subsidiary banks lending activities during the crisis period. Thus the transmission effect of ownership linkages is not likely to be affected by this characteristic of the subsidiary bank.

A.2. Parent characteristics

We repeat the analysis above by considering the parent banks' characteristics. The liquidity shock in home country is transmitted from parent banks to subsidiary banks located in the host countries thus it is reasonable to test whether parent banks' characteristics would affect the transmission effect, as the internal capital market hypothesis suggests. We test four types of parent banks' characteristics: profitability, capital, liquidity and interest margin. Table A2 presents the results for the heterogeneity tests.

Table A2
Heterogeneity in parent's characteristics.

Dependent variable	Level I		Level II		Level III	
Loan growth	(1)	(2)	(3)	(4)	(5)	(6)
Profitability						
Exposure∗Post	−0.440	−9.760	−5.065	−4.583	−11.671**	−10.111**
	(1.548)	(9.740)	(3.187)	(2.786)	(5.267)	(4.887)
Observations	642	468	634	605	542	483
Number of Banks	135	117	134	132	121	112
R^2	0.098	0.170	0.292	0.308	0.149	0.176
Capital						
Exposure∗Post	−1.528	0.974	−3.420	−6.143	−22.717***	−24.039***
	(2.773)	(2.880)	(2.257)	(3.961)	(7.455)	(9.070)
Observations	619	600	682	642	519	314
Number of Banks	137	134	145	142	109	85
R^2	0.163	0.155	0.215	0.258	0.195	0.336
Liquidity						
Exposure∗Post	−0.040	−1.562	−4.161	−5.868	−4.267*	−6.917*
	(1.510)	(1.738)	(3.892)	(6.216)	(2.506)	(3.714)
Observations	573	433	608	569	584	551
Number of Banks	120	109	135	131	124	120
R^2	0.202	0.224	0.167	0.197	0.217	0.284
Interest Margin						
Exposure∗Post	−4.766*	−11.053***	0.092	−4.812	6.325	1.783
	(2.870)	(3.988)	(2.402)	(4.554)	(7.766)	(3.542)
Observations	590	533	559	539	559	483
Number of Banks	126	120	118	117	125	123
R^2	0.179	0.250	0.118	0.168	0.252	0.283
Subsidiary Controls	Yes	Yes	Yes	Yes	Yes	Yes
Parent Controls		Yes		Yes		Yes

Notes: This table presents the test results for the heterogeneity in parent bank's characteristics. Year fixed effect and bank level fixed effect are controlled in each regression. Refer to Table 3 for full specifications. The test for parent bank's profitability suggests that if the ROA of parent bank is higher then its foreign subsidiary banks tend to have a lower lending growth during crisis period. Capital test shows that if the parent bank is better capitalised then the liquidity shock would be more likely to transmit to its foreign subsidiary banks. Parent bank's liquidity condition is also negatively related with subsidiary bank's lending growth during the crisis period. The interest margin test suggests that subsidiary banks' lending activity would be significantly affected during the crisis period if their parent bank have a low interest margin, while the negative effect is not significant for subsidiary banks with a parent bank that has higher interest margin. Overall, the analysis on the heterogeneity in parent bank's characteristics provide evidence for internal capital market hypothesis. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The test for parent banks' profitability shows that the interaction term is only significant in the level III sample where the parent banks have a better profitability. This suggests that if the ROA of the parent bank is higher then its foreign subsidiary, the bank tends to have a lower lending growth during crisis period. A higher profit of a bank may due to higher risks which may be adversely affected during the liquidity crisis. As a result, the bank's foreign subsidiaries may also be affected as they may highly rely on funding from their internal capital market.

We explore the effect of a parent bank's capital and liquidity. The results in Table A2 show that if the parent bank is better capitalised then the liquidity shock would be more likely to transmit to its foreign subsidiary banks, since the interaction term is only significant for the sample of level III. The parent bank's liquidity condition is also negatively related to the subsidiary bank's lending growth during the crisis period. Again, this could be due to the fact that better capitalised banks and banks with more liquid assets are more risk-averse, thus these banks tend to cut funding support towards their foreign subsidiary banks during the crisis period. Another explanation is that the moral hazard problem is amplified due to the liquidity crisis, thus less capitalised banks and banks with less liquid assets tend to take more risk to expand their credit by supporting foreign subsidiary banks.

Finally, we test whether the transmission effect could be affected by the capability of parent banks in the core business, which is indicated by the bank's interest margin. The interest margin test shows that the interaction term is only significant for the level I sample where the parent bank has a lower interest margin. This suggests that subsidiary banks' lending activity would be significantly affected during the crisis period if their parent bank has a low interest margin, while the negative effect is not significant for subsidiary banks with a parent bank that has higher interest margin. The results from the test imply that if the parent bank has a better performance in its core business, it would be able to keep supporting their foreign subsidiary banks during the crisis period thus the subsidiary banks' lending growth rate would not be significantly affected. Conversely, if the core business performance of the parent bank is inferior, then a liquidity shock hitting the parent bank would be transmitted to its foreign subsidiary banks.

Overall, the analysis on the heterogeneity in a parent bank's characteristics provide strong evidence for the internal capital market hypothesis. It shows that a parent bank's balance sheet structures and business capability have significant effect on the subsidiary bank's lending activity during the crisis. It is noticeable that the transmission effect is not affected by the subsidiary bank's own interest margin and weakness indicator, but can be significantly affected by parent bank's interest margin and weakness, which clearly identifies that the liquidity crisis is transmitted through the internal capital market operating within a bank ownership network.

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