Journal of Banking & Finance 60 (2015) 271–283

Contents lists available at ScienceDirect

Journal of Banking & Finance

journal homepage: www.elsevier.com/locate/jbf

Contagion and banking crisis – International evidence for 2007–2009 ☆

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ARTICLE INFO

Article history:
Received 21 September 2014
Accepted 3 August 2015
Available online 19 August 2015

JEL classification:
F30
G21

Keywords:
Global financial crisis
Financial contagion
Banking institutions
Asset pricing

ABSTRACT

Policy makers aim to avoid banking crises, and although they can to some extent control domestic conditions, internationally transmitted crises are difficult to tackle. This paper identifies international contagion in banking during the 2007–2009 crisis for 54 economies. We identify three channels of contagion – systematic, idiosyncratic and volatility – and find evidence for these in 45 countries. Banking crises are overwhelmingly associated with the presence of both systematic and idiosyncratic contagion. The results reveal that crisis shocks transmitted from a foreign jurisdiction via idiosyncratic contagion increase the likelihood of a systemic crisis in the domestic banking system by almost 37 percent, whereas increased exposure via systematic contagion does not necessarily destabilize the domestic banking system. Thus while policy makers and regulatory authorities are rightly concerned with the systematic transmission of banking crises, reducing the potential for idiosyncratic contagion can importantly reduce the consequences for the domestic economy.

1. Introduction

Banking crises are costly, and a great deal of prudential effort is undertaken to avoid them. Bordo et al. (2001) estimate losses of around 6 percent of GDP associated with a banking crisis in the last quarter of the 20th century, whilst Laeven and Valencia (2013) document losses of about 30 percent of GDP during the global financial crisis (GFC) of 2007–2009. Maintaining sound macroeconomic fundamentals, a clear legal framework and strong prudential oversight are preventative measures within the remit of domestic authorities. However, banking crises transmitted from other jurisdictions present a considerable risk to the domestic economy (Kalemli-Ozcan et al., 2013), particularly as banking crises are often observed to precede even more costly currency and debt crises (Laeven and Valencia, 2013; Reinhart and Rogoff, 2009).

This paper empirically examines the evidence for the unexpected international transmission of banking crises via stressful conditions in financial markets during 2007–2009. These transmissions are beyond those which would occur by the known spillovers between banking sectors in different jurisdictions due to trading or portfolio links or institutional structures such as international subsidiaries, and instead consist of contagion effects; see also van Rijckeghem and Weder (2001), Bae et al. (2003), Bekaert et al. (2005), Corsetti et al. (2005), Dungey et al. (2005) and Forbes and Rigobon (2002). Although the crisis is often seen as having origins in overheated housing markets and the associated mortgage backed securities market, we concentrate on the international transmission of this stress which Aalbers (2009) forcefully argues is due to the financial intermediaries rather than the localized housing markets themselves.[1] We find significant evidence not only for the existence of contagion between banking sectors, but also for its role in promoting banking crises in regions geographically removed from the crisis source. Thus, we contribute to the growing body of literature examining the role of banks in the transmission of financial crisis of 2007–2009, most of whom find evidence of international transmission via the banking sector (Allen

☆ We would like to thank Vitali Alexeev, Nagaratnam Jeyasreedharan, Graciela Kaminsky, Graeme Wells, Wenying Yao, and seminar participants at 2013 Australian Conference of Economists, University of Tasmania and Economic Society of Australia-Tasmania for helpful comments and suggestions. We are particularly grateful to two anonymous referees for comments that have significantly improved the paper. This paper is supported by funding from Australian Research Council (ARC DP130100168).

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[1] Allen and Carletti (2010) conclude that the housing price booms in a number of countries are due to common features of international credit conditions and loose monetary policy, and Claessens et al. (2010) find that pre-crisis house price appreciation is associated with the severity of the subsequent crisis recession.

http://dx.doi.org/10.1016/j.jbankfin.2015.08.007
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et al., 2014; Brealey et al., 2012; Kalemli-Ozcan et al., 2013; Popov and Udell, 2012).

The model encapsulates several potential channels of contagion and testable hypotheses in a single framework. Specifically, it captures potential structural changes in global systematic risk exposure (systematic contagion), additional US idiosyncratic shocks (idiosyncratic contagion), a structural shift (shift contagion), and additional US volatility spillovers to other markets (volatility contagion). The latter captures the argument that financial markets exhibit explosive volatility during crises that may spillover to other markets (Edwards, 1998; Engle, 2004; Hamao et al., 1990). Using a standard factor model representation of an international CAPM framework, the model allows for spillover effects outside crisis periods (Kim, 2001; Laxton and Prasad, 2000), volatility spillovers, heteroskedasticity and skewness in the financial data with a nested EGARCH specification. The framework is most closely related to the models of Baur (2012), Bekaert et al. (2014), Bekaert et al. (2005) and Dungey et al. (2005). As the crisis is widely accepted to have originated in the US we consider contagion effects from the US to 53 country banking sector indices - covering both non-crisis and crisis conditions from 2001 to 2009.

There are two major results. First, we categorize the evidence for contagion between the 54 banking sectors. The banking sectors in most economies experienced contagion from the US in some form – that is systematic, idiosyncratic, shift or volatility – but not necessarily all forms. About 60 percent of our sample banking markets experienced a break in global systematic risk exposure and about 60 percent of banking markets in our sample experienced idiosyncratic contagion originating from the US banking market. While most of the banking markets have volatility spillovers from the US banking market in non-crisis periods, the evidence for volatility contagion during the crisis is more mixed – when we divide the crisis into two phases volatility contagion is limited in the first phase and more prevalent in the second phase. Finally, shift contagion is always accompanied by other forms of contagion.

The second contribution links evidence on contagion to the occurrence of banking crises. Linking our results for contagion with the systemic banking crisis data in Laeven and Valencia (2013) reveals that crisis shocks transmitted from a foreign jurisdiction via idiosyncratic contagion increase the likelihood of a systemic crisis in the domestic banking system by almost 37 percent, whereas increased global systematic risk exposure via systematic contagion does not necessarily destabilize the domestic banking system. The existing literature argues that the probability of systemic banking crises is reduced by stronger regulatory capital (Acharya et al., 2010; Berger and Bouwman, 2013; Cole, 2012; Miles et al., 2013), the size of the banking sector and higher market concentration (Allen and Gale, 2000; Beck et al., 2006; Bretschger et al., 2012; Mirzaei et al., 2013), and reduced activity in the shadow banking sector (De Jonghe, 2010; Lepetit et al., 2008). We find that stronger regulatory capital, retail banking activities and higher market concentration lead to a reduced probability of banking crisis even in the presence of contagion effects. The evidence suggests a larger economic impact of stronger regulatory capital, where a 1 percent increase over current level reduces the probability of a crisis by around 15 percent, than for the proportion of non-interest income in total income, where a 1 percent decrease in income from this source decreases the probability of a crisis by less than 2 percent. Likewise, domestic conditions can help ameliorate the probability of crises; increased banking assets as a proportion of GDP lower the probability of crisis, but the economic impact is very small. An increase in the external debt to GDP ratio also increases the probability of crisis, consistent with the hypothesis that a feedback loop exists between sovereign debt and banking crises (Acharya et al., 2014; Adler, 2012). We extend the model to include interaction effects between contagion sources and the bank capital, and find that this interaction effect significantly decreases the probability of a banking crisis over the effects of the contagion channels alone.

The results indicate that the systematic contagion effects present in these markets during this crisis could not have been reduced by further banking regulatory measures such as increased capital requirements. However, there is scope for further reduction in the probability of banking crises promoted by international linkages via idiosyncratic contagion. Idiosyncratic contagion occurs in response to unanticipated country-specific banking sector shocks, and represents the transmission of these shocks other than via usual linkages such as portfolios, subsidiary or trading links which are also present during non-crisis periods, but perhaps consistent with arguments around herd behavior. Potentially there is gain for regulators and policy makers to consider how to creatively respond to calm these transmissions from extra vulnerability generated in one economy, but unexpectedly transmitting to another.

The rest of the paper proceeds as follows. In Section 2, we propose a model to test for several forms of contagion and describe the sample and data. Section 3 provides the results for contagion. In Section 4 we examine the cross-section of systemic banking crisis. Section 5 provides robustness checks for the results and Section 6 concludes the paper.

2. Modeling financial contagion

2.1. The empirical framework

In modern banking systems, banking institutions are often globally integrated through both on-balance sheet and off-balance sheet linkages.[2] These global linkages make the banking sector potentially more exposed to global systematic risk than other sectors. The financial sector is known to be highly globally integrated at sectoral level (Bekaert et al., 2009). We postulate that in a globally integrated banking system the exposure of banks in a given country to global systematic risk depends on the extent of global integration of the banking system.[3] We utilize a CAPM style framework based on a factor approach rather than based on observed linkages such as trade, subsidiary relationships or bank capital flows. The advantage of our approach is that it does not require an exhaustive and mutually exclusive list of data, but with the disadvantage that the exact source of the transmission in terms of observed variables is not available. The approach is related to the latent factor specifications used in the literature reviews of Corsetti et al. (2005) and Dungey et al. (2005) who both show how other frameworks to test contagion are nested within this general specification.

Let $r_{i,t}$ represent the return for banking sector of country i at time t. A standard international market model representation of asset returns takes the following form:

$$r_{i,t} = a_{0,i} + a_{1,i} f_t^{global} + e_{i,t}, \tag{1}$$

where f^{global} refers to global factor or common shock and can be proxied by the return on the aggregate global banking sector index and $a_{1,i}$ measures the global systematic risk exposure of banking sector of country i. This approach removes the common global effects from individual index returns.

[2] Our approach does not distinguish between parent and subsidiary institutions. There is some evidence that supports the transmission of liquidity shocks from parent to international subsidiary institutions in Allen et al. (2014). As this distinction requires balance sheet data and firm level characteristics we leave this extension for future research.

[3] See Kalemli-Ozcan et al. (2013) for a recent theoretical contribution.

Crises may be associated with structural changes in the global systematic risk exposure of banking markets through a number of possible channels. For example, the interbank market may not function properly during a crisis period; the existing network of relationships across the market participants may break down, or the failure of a few financial institutions may have a systemic impact on other banks. The potential increased exposure of banks to global systematic risk during a crisis period is denoted as systematic contagion, and is analogous to a common shocks effect or fundamentals based contagion (Baur, 2012; Bekaert et al., 2005, 2014) as revealed in (2) below:

$$r_{i,t} = a_{0,i} + a_{1,i}f_t^{global} + a_{2,i}f_t^{global}I_t + \varepsilon_{i,t}, \tag{2}$$

where I_t is an indicator function that takes value 0 during the normal period and 1 during a crisis period. The coefficient $a_{2,i}$ captures the changes in global systematic risk exposure during the crisis period.

Policy intervention in the financial system during crisis periods is often specifically designed to reduce an individual country's global systematic risk exposure. If the policy measures were effective, then the global systematic risk exposure of a given banking market may have been reduced during the crisis instead of increased.[4] This is akin to the debate around whether increased international financial integration contributes to increased output correlation (Kalemli-Ozcan et al., 2013).

The existing literature suggests that US shocks have a significant influence on other economies during calm periods, reflecting its market leadership in many segments of the economy, its influence in portfolios, and the position of the US dollar as the major global reserve currency. Following Masson (1999), we denote these as *spillover effects*. We control for these relationships by specifically including a US factor in the mean specification to capture the known relationships between market *i* and the US, shown below in (3). However, during a period of stress, shocks from the crisis-originating economy may impact over and above these spillovers, denoted as *idiosyncratic contagion*, (Dungey et al., 2005; Dungey and Martin, 2007). In the current paper we denote the US banking sector as the crucible of the crisis and consider the evidence for idiosyncratic contagion from the US to other markets. Further, Forbes and Rigobon (2002) argue that a crisis may bring a structural shift in the existing relationships exceeding that accounted for by structural breaks in factor relationships; potentially attributable to herd behavior amongst investors which does not depend on economic fundamentals (Bekaert et al., 2014). Our final levels specification captures each of these channels as follows:

$$r_{j,t} = b_{j,0} + b_{1,j}f_t^{global} + b_{2,j}f_t^{global}I_t + b_{3,j}f_t^{US} + b_{4,j}f_t^{US}I_t + b_{5,j}I_t + \xi_{j,t}; \quad j = 1,\ldots,n-1 \neq US \tag{3}$$

where the US factor, f^{US}, is extracted as the residual from applying (2) to $i = US$, thus orthogonalizing the global and US factors. In (3), the coefficient $b_{1,j}$ represents a standard CAPM beta coefficient against global markets, $b_{2,j}$ represents systemic contagion, $b_{3,j}$ measures the general spillover effects of US shocks, $b_{4,j}$ measures the *additional* effects of US shocks during the crisis period, that is idiosyncratic contagion, and $b_{5,j}$ captures any intercept shift in the factor model representation or shift contagion during the crisis period.

[4] However, the alternative to reduced global exposure is not necessarily proof of lack of policy efficacy as we do not have a true proxy of what the outcome would have been in the absence of policy actions.

2.2. The GARCH framework and measuring volatility contagion

Financial returns series generally exhibit heteroskedasticity. To capture this we incorporate the exponential generalized autoregressive conditional heteroskedasticity (EGARCH) model of Nelson (1991), which has the advantage that it does not require non-negativity constraints on parameters. We implement EGARCH to accommodate potential asymmetry in leverage effects in preference to a threshold GARCH specification because we wish to capture the entire distribution in preference to volatility tails in this framework.[5] A GARCH(1,1) is chosen, corresponding to the existing evidence that this is usually sufficient to capture the volatility clustering properties of financial data (Engle, 2004; Hansen and Lunde, 2005). The variance equation of the EGARCH model to accompany mean equations given in (1–3) is expressed as:

$$\begin{aligned} & ln(\sigma_{i,t}^2) = c_{0,i} + c_{1,i}(|z_{i,t-1}| - E|z_{i,t-1}|) + c_{2,i}z_{i,t-1} + c_{3,i}ln(\sigma_{i,t-1}^2); \\ & z_{i,t-1} = \eta_{i,t-1}/\sigma_{i,t-1}; \eta_{i,t} = \{e_{i,t}, \varepsilon_{i,t}, \xi_{j,t}\} \\ & \eta_{i,t} \sim Student - t(0, \sigma_{i,t}^2). \end{aligned} \tag{4}$$

To capture the US volatility spillover effects in the variance equation of the non-US markets, the variance equation for those markets takes the following form:

$$\begin{aligned} ln(\sigma_{j,t}^2) &= c_{0,j} + c_{1,j}(|z_{j,t-1}| - E|z_{j,t-1}|) + c_{2,j}z_{j,t-1} + c_{3,j}ln(\sigma_{j,t-1}^2) \\ &\quad + \pi_{1,j}ln(\hat{\sigma}_{us,t}^2) + \pi_{2,j}ln(\hat{\sigma}_{us,t}^2)I_t; \quad j = 1,\ldots,n-1 \neq US. \end{aligned} \tag{5}$$

In (5), the parameter estimate $\pi_{1,j}$ captures the general US volatility spillover and $\pi_{2,j}$ captures the *additional* US volatility spillover for market *j* during the crisis period which we denote as volatility contagion. The GARCH framework provided in (5) is motivated by Hamao et al. (1990), Engle et al. (1990), Edwards (1998) and Iwatsubo and Inagaki (2007), amongst others.[6] The volatility specification could be extended to include global and US influences in a similar manner to that applied to the mean equation. However, given that existing evidence strongly supports that a single source is sufficient to capture GARCH effects in global models (Bekaert et al., 2005; Dungey et al., 2005; Dungey et al., 2015), and that introducing multiple GARCH interactions into the framework adds significant computational complexity we opt for the more tractable specification of (5). Robustness tests support this modeling choice.

2.3. Sample, data and crisis period

The data set comprise daily banking sector indices available from Thomson Reuters Datastream for the sample period of January 2, 2001 to May 8, 2009. These banking indices are constructed by Thomson Reuters Datastream as Industry Classification Benchmark Datastream Level 2 indices, containing the stocks in the banking sector for each country where data are available. The mnemonics for these indices are given as *banksxx* where *xx* indicates the country mnemonic commonly applied in this database service. To represent the global factor we use the Datastream mnemonic *bankswd* which aggregates the market indices into a world index, intended to cover a minimum of 75–80 percent of total market capitalization from each market (the results are robust to the alternative of using either the global banking index less the US market, *bankswu*, or the total global equity index, *totmkwd*, as the global factor). For more details on either the global or country banking indices see the Datastream Global Equity Indices User Guide.

[5] Robustness to a TARCH specification shows very similar results to those reported here.

[6] There is a long line of literature that examines volatility spillovers in international financial markets. See for example, Chiang and Wang (2011), Diebold and Yilmaz (2009), Edwards and Susmel (2001), Hamao et al. (1990), Jung and Maderitsch (2014), King and Wadhwani (1990) and Susmel and Engle (1994).

The banking sector indices are available for 57 countries, of which we are able to use 54 of these countries in our study – the omitted countries (Kuwait, Qatar, and United Arab Emirates) have a limited data sample. Table 1 provides the list of banking markets covered. In line with existing literature, we use two-day rolling moving averages to deal with differing time zones and asynchronous trading times as in Forbes and Rigobon (2002), and adjust time/date as Day 1 in US/Americas = Day 2 in Africa, Asia and Europe. We follow the approach of Wang and Nguyen Thi (2012) and define the crisis period endogenously using the iterative cumulative sum of square (ICSS) algorithm based on the CUSUM test to detect the structural change in variance of an individual return series (Inclan and Tiao, 1994; Sanso et al., 2004) and use the identified break in the US banking sector index return to determine the crisis period. Using this procedure the endogenously chosen crisis period is from July 19, 2007 to May 8, 2009. These dates are consistent with the existing literature, see Bekaert et al. (2014) and the extensive overview of dates provided in Dungey et al. (2015). For robustness we have also checked the results with a start date of August 9, 2007, a date often used in the crisis literature as it is consistent with the beginning of European Central Bank (ECB) interventions in the market. The results are qualitatively similar.

Table 1
List of banking markets considered.

America		*Europe*	
1	USA	28	Austria
2	Argentina	29	Belgium
3	Brazil	30	Bulgaria
4	Canada	31	Cyprus
5	Chile	32	Czech Rep
6	Colombia	33	Denmark
7	Mexico	34	Finland
8	Peru	35	France
9	Venezuela	36	Germany
Africa and Asia		37	Greece
10	Australia	38	Hungary
11	China	39	Ireland
12	Egypt	40	Italy
13	Hong Kong	41	Luxemburg
14	India	42	Malta
15	Indonesia	43	Netherlands
16	Israel	44	Norway
17	Japan	45	Poland
18	Malaysia	47	Romania
19	Morocco	48	Russia
20	Pakistan	49	Slovenia
21	Philippine	50	Spain
22	Singapore	51	Sweden
23	South Africa	52	Switzerland
24	South Korea	46	Portugal
25	Sri Lanka	53	Turkey
26	Taiwan	54	UK
27	Thailand		

3. Contagion results and discussion

The resulting evidence for contagion for 53 individual banking markets taking the US banking market as a crisis-originating market is reported in Table 2. Almost every banking market in our sample has a statistically significant and positive systematic comovement with the global banking market throughout the sample, evidenced by $b_1 \neq 0$, indicating exposure to global systematic risk. The parameter estimates support that the level of global integration is higher for advanced countries; consistent with evidence in Laeven and Valencia (2013). These cross-border linkages may reflect both on and off balance sheet channels (Cetorelli and Goldberg, 2011; Sbracia and Zaghini, 2003).

The results provide evidence for the severity of disruptions in the 2007–2009 crisis. Exposure to the global systematic risk factor changed significantly for 31 of the 53 countries, that is $b_2 \neq 0$ as reported in Table 2, consistent with these markets experiencing systematic contagion during the crisis, and also with prior evidence on structural breaks in the relationship with global conditions during crisis periods (Dornbusch et al., 2000; Dungey et al., 2005). However, this evidence is strongly skewed towards the developing markets. Many of the advanced markets did not experience a structural break, that is the hypothesis of $b_2 = 0$ is not rejected in France, Greece, Italy, Malta, Norway, Portugal and the UK. We cannot distinguish here whether the policy actions undertaken were sufficient to offset any potential change, or whether no change was experienced. In Japan, Germany, the Netherlands, Spain, Sweden and Switzerland, the results go further in that the hypothesis that $b_2 < 0$ is not rejected. In these countries the potential for an increased factor loading (b_2) during the crisis, which was observed in other jurisdictions, was not present, and this may reflect that their policy initiatives were effective in suppressing the transmission of the crisis to the domestic banking system, in line with the findings of Ait-Sahalia et al. (2012).

Bulgaria, Colombia, Peru, Sri Lanka and Venezuela did not have a significant link with the global factor during the pre-crisis period $b_1 = 0$; which possibly reflects the relatively small closed nature of these economies. However, during the crisis, this was no longer the case for Bulgaria, Colombia and Peru, ($b_2 \neq 0$) and they were exposed to global conditions, although Sri Lanka and Venezuela continued to remain isolated in this respect.

In addition to responding to global conditions, the majority of markets also experienced spillovers from the US during the non-crisis periods. Of the 53 markets, 30 experienced idiosyncratic shocks from the US banking market, evidenced by $b_3 \neq 0$. The notable exceptions are from both advanced banking markets (Australia, Austria, Czech Republic, Denmark, Finland, Greece, Korea, Norway, Portugal and Taiwan) and emerging banking markets (China, Indonesia, Hungary, Malaysia, Poland, Sri Lanka, Thailand, Turkey and Venezuela). When b_3 is negative, it indicates the potential for portfolio diversification benefits relative to the US, which is the case for a mixture of advanced markets such as Japan, Luxembourg, Malta, and Slovenia and emerging markets such as Brazil, Chile, India, Pakistan, and Philippines. However, this effect appears to be dampened during the crisis, as the US idiosyncratic effects have an overwhelmingly positive transmission to these markets. The hypothesis test of $b_3 + b_4 = 0$ is not rejected in most of these markets. The Brazilian and Peruvian markets appear to have consistently negative responses to US originated shocks even during the crisis period, consistent with recent evidence that the Latin American banking market was minimally effected by the GFC (Kamil and Rai, 2010; Ocampo, 2009).

Almost all of the banking sectors show evidence of volatility spillover effects during the non-crisis period, supporting the claim that the inclusion of volatility transmission is important in the model specification.[7] During the non-crisis period the countries which do not experience volatility spillovers are two Asian markets and two Latin American markets – China and Pakistan and Argentina and Peru. Clearly, the overall evidence presented here supports that the banking sector in Peru is relatively isolated from international capital markets.

The crisis also caused a structural shift as specified in (3); that is $b_5 = 0$ is rejected for 25 of the 54 countries. Each of these countries also have evidence of a break in the structural parameters (b_2, b_4 or π_2). The evidence for structural shifts during the crisis period is consistent with the occurrence of herding behavior in addition to global shocks and the US idiosyncratic shocks during the GFC.

[7] The statistically significant parameter estimates for c_1 and c_2 for most of the markets support the EGARCH specification in (5).

Table 2
Parameter estimates and hypothesis testing results.

SN	Country	b_1	b_2	b_4	b_5	π_2	$b_2 = b_4 = 0$	$b_2 = \pi_2 = 0$	$b_4 = \pi_2 = 0$	$b_2 = b_4 = \pi_2 = 0$
Panel A: No contagion										
1	Egypt	0.099***	0.024	0.041	0.001	0.014	1.90	1.97	2.55	3.30
2	Hong Kong	0.511***	0.066**	0.027	0.001**	−0.002	4.79*	4.27	1.13	5.25
3	Hungary	0.578***	−0.045	0.150*	−0.003***	−0.001	3.79	0.35	3.50	3.82
4	Israel	0.297***	0.020	0.077	0.000	−0.003	2.26	0.27	2.02	2.35
5	Malaysia	0.256***	0.044	0.031	0.000	−0.005	3.31	2.45	1.47	3.79
6	Singapore	0.472***	−0.036	0.015	0.000	0.003	0.64	1.12	0.62	1.17
7	Taiwan	0.445***	−0.013	0.064	0.000	0.018	1.23	2.17	3.45	3.47
8	Venezuela	0.036	−0.008	0.019	0.000	−0.014	0.31	1.81	1.99	2.02
Panel B: Volatility contagion driven										
9	Indonesia	0.575***	0.000	0.100	0.000	0.039***	2.03	11.70***	13.61***	13.64***
10	Mexico	0.527***	0.009	−0.082**	0.000	0.062***	3.99	18.87***	22.68***	22.71***
11	Russia	0.380***	0.029	−0.016	−0.003***	0.026**	0.22	6.81**	6.66**	6.91*
12	South Korea	0.880***	−0.111	0.078	−0.003***	0.077***	3.18	26.88***	25.60***	27.78***
13	Sri Lanka	0.010	0.027	0.004	−0.001***	0.056***	1.02	19.02***	18.09***	19.13***
Panel C: Systematic contagion driven										
14	Canada	0.633***	0.212***	0.045	0.000	0.006	49.02***	46.00***	2.38	49.33***
15	Germany	0.703***	−0.195***	0.086	−0.001	0.001	12.67***	10.73***	2.62	12.84***
16	Peru	0.018	0.188***	−0.032	0.000	−0.013	67.10***	67.17***	2.41	67.72***
17	Spain	0.678***	−0.225***	0.027	−0.001	0.005*	18.55***	21.41***	3.07	21.72***
Panel D: Idiosyncratic contagion driven										
18	Chile	0.519***	−0.051	0.101***	−0.001*	0.006	9.58***	2.65	8.20**	9.89**
19	France	0.673***	0.040	0.161***	−0.002**	0.001	8.02**	0.64	7.83**	8.07**
20	Greece	0.496***	0.082	0.200***	−0.001	0.007	16.68***	2.89	15.09***	18.12***
21	Italy	0.539***	−0.066	0.139***	−0.001*	0.001	10.72***	1.80	9.61***	10.98**
22	Malta	0.064***	0.005	0.102***	0.000	0.011	13.28***	1.08	13.94***	14.47***
23	Morocco	0.084***	0.009	0.085***	0.000	0.005	7.34**	0.29	6.98**	7.45*
24	Norway	0.491***	0.081	0.407***	−0.001	−0.002	34.87***	1.29	34.24***	35.35***
25	Poland	0.410***	0.089	0.140**	−0.002**	0.010	7.23**	2.55	5.39*	7.59*
26	South Africa	0.564***	−0.069	0.257***	−0.001	−0.009	12.18***	1.58	12.67***	13.08***
27	UK	0.573***	0.063	0.246***	−0.002***	0.000	19.85***	1.13	18.92***	19.87***
28	Czech Rep	0.375***	0.124**	0.174***	0.000	−0.003	12.36***	4.21	7.03**	12.72***
29	Japan	0.716***	−0.095*	0.216***	0.000	0.002	14.90***	3.17	13.46***	15.03***
30	Portugal	0.316***	−0.016	0.255***	−0.003***	−0.016*	36.19***	3.45	41.10***	41.17***
Panel E: Multiple drivers										
31	Austria	0.324***	0.328***	0.261***	−0.002**	−0.016	50.99***	30.44***	21.14***	51.97***
32	Belgium	0.558***	0.183***	0.259***	−0.002***	0.001	28.10***	7.94**	19.39***	28.19***
33	Cyprus	0.440***	0.233***	0.177***	0.000	0.005	24.63***	14.63***	9.48***	24.95***
34	Denmark	0.465***	0.088*	0.204***	−0.002***	0.012	20.14***	5.24*	18.35***	22.71***
35	Ireland	0.521***	0.356***	0.367***	−0.003***	−0.002	32.02***	15.75***	21.19***	32.54***
36	Netherlands	0.668***	−0.253***	−0.165***	−0.002**	−0.001	26.94***	16.43***	8.11**	26.96***
37	Pakistan	0.196***	−0.170***	0.136***	−0.002***	0.009	25.69***	20.60***	10.07***	27.81***
38	Philippines	0.315***	0.124***	0.126***	0.000	−0.016	22.73***	11.29***	10.23***	24.15***
39	Romania	0.165***	0.359***	0.227***	−0.002***	−0.019	64.26***	48.07***	18.37***	69.00***
40	Slovenia	0.050**	0.108***	0.147***	0.000	0.027	39.53***	15.21***	25.18***	41.64***
41	Switzerland	0.803***	−0.122**	0.128**	−0.002***	0.003	9.35***	5.45*	6.42**	10.57**
42	Argentina	0.544***	−0.193***	0.038	−0.002***	0.021**	19.78***	25.80***	6.40**	25.89***
43	Brazil	1.179***	−0.193***	−0.009	−0.001	0.035***	11.96***	22.55***	12.37***	22.69***
44	China	0.129***	0.121***	−0.018	0.000	−0.084***	7.10**	33.37***	25.60***	33.38***
45	Thailand	0.490***	−0.133**	0.037	0.000	0.047***	6.59**	14.77***	9.20**	14.99***
46	Australia	0.515***	0.217***	0.127***	−0.001	−0.022**	27.16***	23.46***	13.08***	33.70***

(*continued on next page*)

Table 2 (*continued*)

SN	Country	b_1	b_2	b_4	b_5	π_2	$b_2 = b_4 = 0$	$b_2 = \pi_2 = 0$	$b_4 = \pi_2 = 0$	$b_2 = b_4 = \pi_2 = 0$
47	Colombia	0.000	0.431***	−0.111***	0.000	−0.834***	1223.29***	4397.55***	3007.69***	4399.51***
48	Finland	0.340***	0.114**	0.302***	−0.001	−0.035**	38.71***	9.38***	7.83**	8.07**
49	India	0.443***	0.154**	0.255***	0.000	−0.036***	22.13***	13.78***	24.35***	32.20***
50	Bulgaria	0.049	0.388***	0.094*	−0.003***	−0.062***	49.55***	55.23***	12.94***	60.89***
51	Luxemburg	0.162***	0.118***	0.150***	−0.001***	−0.044***	34.91***	25.57***	29.56***	46.50***
52	Sweden	0.691***	−0.166**	0.263***	−0.002**	0.011**	22.04***	11.86***	21.75***	27.80***
53	Turkey	0.770***	−0.245**	0.205*	−0.001	0.047***	8.68**	23.57***	20.60***	25.64***

Note: The values in column for b_1, b_2, b_4, b_5 and π_2 are the parameter estimates and values for joint test are the Chi-square values. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively.

3.1. Evidence of contagion

Table 2 shows that almost all of the 53 banking markets in the sample experienced some form of contagion from the US. The null of no contagion in any form – systematic, idiosyncratic or volatility – given by the joint test for $b_2 = b_4 = \pi_2 = 0$, is rejected in 45 markets.[8] The exceptions are Egypt, Hong Kong, Hungary, Israel, Malaysia, Singapore, Taiwan, and Venezuela. These markets are generally small economies yet display various levels of exposure to international markets. Hong Kong, for example, is developed and strongly influenced by international conditions, whereas Venezuela is a developing closed economy. One outlier, however, is Malaysia; a relatively large economy which had built significant buffers in the aftermath of the Asian crisis of 1997–98, and had little exposure to US sub-prime loan products (Khoon and Mah-Hui, 2010). Also in Asia, the financial hub of Singapore, had liquid and well capitalized domestic banks and foreign banks with liquidity assurance from their head office (a formal commitment required for licensing procedure) which may have reduced the exposure of the Singaporean banking sector to contagion. Hong Kong and Hungary represent somewhat different cases in that the null hypothesis for the joint test ($b_2 = b_4 = \pi_2 = 0$) is not rejected but the null hypothesis for individual univariate tests of contagion effects is rejected. In the case of Hong Kong, the null of no systemic contagion $b_2 = 0$ is rejected; and in the case of Hungary, the null of no idiosyncratic contagion, $b_4 = 0$, is rejected. Despite the overall evidence for no contagion, the Hong Kong banking sector displays sensitivity to global shocks (fundamentals), and the Hungarian banking sector to US idiosyncratic shocks. Our results for the banking sectors in these countries are consistent with the IMF Country Reports for 2008 and 2009 for these countries which suggest that their banking sectors performed well during the crisis, an outcome often attributed in the discourse to effective policy initiatives.

Fig. 1 provides a schematic representation of the clustering of the different individual coefficient hypothesis testing results for systematic contagion, idiosyncratic contagion and volatility contagion, to provide a convenient means of discussion. The distinction between bold and plain text relates to the links to identified systemic banking crises are discussed below.

3.1.1. Volatility contagion driven

A small group of countries (Indonesia, Mexico, Russia, South Korea and Sri Lanka) have contagion effects driven largely by volatility contagion. These countries do not have level effects – that is no evidence of either systematic contagion or idiosyncratic contagion.[9] With the exception of Sri Lanka, the countries in this group are markets which were involved in financial crises during the 1990s and may have learned from that experience. However, the high level of market uncertainty caused by the GFC resulted in increased market volatility in these countries. The literature suggests that the banking systems in Indonesia and South Korea in particular were relatively healthy and had less exposure to US sub-prime products (IMF, 2009a,b). In the case of Mexico, although the aggregate economy was hit hard, the banking sector was relatively resilient during the crisis (IMF, 2009c).

3.1.2. Systematic contagion driven

A further small group of countries (Canada, Germany, Peru, and Spain) have evidence of contagion effects driven largely by systematic contagion. These are large advanced economies (except Peru

[8] We also consider potential joint tests incorporating b_5, such as $b_2 = b_4 = b_5 = \pi_2 = 0$; $b_2 = b_4 = b_5 = 0$. The results are similar as b_5 is mostly accompanied by some other contagion estimates (b_2, b_4, or π_2).

[9] When we look at univariate hypothesis testing, however, the null for no idiosyncratic contagion ($b_4 = 0$) is rejected for Mexico.

which is a small closed economy) with strong international banking linkages. It may be that these linkages are sufficient to enable systematic contagion to effect the domestic markets. None of these markets experienced idiosyncratic contagion. Despite the fact that the German banking sector experienced huge losses – about 57 percent of stock market capitalization for banking sector stocks – and German banks were highly involved in asset backed securities, we do not find a statistically significant result for idiosyncratic contagion from the US to Germany. The German banking system forms the basis of its capital markets, and during the crisis German banks faced problems with leverage, liquidity and funding (Acharya and Schnabl, 2010).

In Spain, the direct impact of the crisis on the banking sector was limited as the banks had a retail-oriented business model and negligible exposure to US sub-prime mortgages (Acharya and Schnabl, 2010; IMF, 2009d). However, when the crisis spread to the global financial conditions and the real sector, it was transmitted to the Spanish banking sector through common conditions such as tighter liquidity. The Spanish banking sector additionally experienced volatility contagion in response to the higher turmoil in the US markets. A possible alternative explanation for the financial crisis in Spain was via an independent but coincidental collapse in the Spanish housing market, causing turmoil in Spanish markets. However, many of the Spanish problems were exacerbated by the dependence of the banking sector on international markets as a source of funding for housing development, a strategy that caused significant stress in the period after the collapse of Northern Rock in late 2007. Further, Allen and Carletti (2010) argue that the conditions behind the apparently coincidental housing price booms in a number of countries is the consequence of international credit conditions and inappropriately loose monetary policy affecting those jurisdictions.[10] The intertwining of domestic and international shocks is important in understanding the details of the individual crises for each specific country, but the presence of so many contemporaneous crisis conditions strongly supports the hypothesis that these crises are not coincidentally independent, as statistically demonstrated in Dungey et al. (2015). However, a potential limitation of our analysis is that if there are coincidental crises caused by alternative pathways, these cannot be separately identified with this approach; see for example the analysis of German Landesbanken in Puri et al. (2011).

In the case of the Canadian banking system, despite its close proximity to the US (with strong real and financial linkages), it avoided crisis effects. Canadian banks follow relatively conservative banking practices with strong prudential regulation, and consequently had lower exposure to sub-prime effects than the US (IMF, 2009e).

3.1.3. Idiosyncratic contagion driven

In about one-fifth of the countries US idiosyncratic shocks played a dominant role during the crisis. Countries in this group have a high level of global integration, are advanced and relatively large: including a host of European countries (Czech Republic, France, Greece, Italy, Malta, Norway, Poland, Portugal, and UK) as well as Japan and Chile. Countries in this group did not generally experience systematic contagion (except the Czech Republic and Japan) or volatility contagion (except Portugal). Since the banking fundamentals of these countries were generally strong (Chile, Japan, France, and Italy), and banks follow a traditional retail business model, these banking systems were relatively resilient to the crisis. Consequently, the large drop in banking sector returns during the crisis was directly attributable to the idiosyncratic shocks originating in the US banking sector.

The impact of these shocks are highly varied, reflecting that this effect picks up the different nature and response of a great variety of markets which is precisely why their responses are idiosyncratic. For example, markets are observed to have different banking ownership structures (dominated by foreign banks versus dominated by domestic banks), different concentration, different underlying product offerings (the dominance of fixed or variable rate mortgage rate products varies greatly (Warnock and Warnock, 2008)), face different regulatory structures and different legal environments.

3.1.4. Multiple drivers

The final group consists of all those countries where the null hypothesis of joint tests (bivariate and multivariate test) is rejected in all cases. All the countries in this group experienced systematic contagion and the majority of the countries are part of the European Union. Eight countries (Australia, Bulgaria, Colombia, Finland, India, Luxemburg, Sweden and Turkey) have all effects - that is the null hypothesis is rejected in univariate, bivariate and multivariate hypothesis tests. Four countries (Argentina, Brazil, China and Thailand) have no idiosyncratic contagion from the US (univariate test) and 11 countries (Austria, Belgium, Cyprus, Denmark, Ireland, the Netherlands, Pakistan, Philippines, Romania, Slovenia, and Switzerland) have no volatility contagion.

4. Contagion and the systemic banking crises

4.1. Contagion and the cost of crisis

We couple the evidence for contagion in the banking system with the banking system crisis data in Laeven and Valencia (2013) to address the relationship between channels of contagion and the presence and cost of banking crises. The loss in economic activity through this crisis period ranges from 0 to over 100 percent of GDP for the sample countries (see Table 3). In terms of earlier periods of systemic risk and major banking crises, the evidence for impact on economic activity is mixed. Cecchetti et al. (2009) document losses of up to 27 percent of GDP during an associated recession, but again some countries experience no loss. Of the 45 banking markets in our sample which experienced contagion in any form, 18 of these banking markets experienced a banking system crisis during the GFC as documented in Laeven and Valencia (2013). The average output loss for these countries is about 30 percent of GDP and the average fiscal cost is about 7 percent of GDP.[11]

Fig. 1 highlights in bold the countries which experienced systemic banking crises within each of the channels of contagion. The majority of the countries which experienced a banking crisis are clustered in two groups; either experiencing both idiosyncratic and systematic contagion (Austria, Belgium, Denmark, Ireland, Netherlands, Slovenia, Switzerland) or idiosyncratic contagion only (France, Greece, Hungary, Italy and the UK). Seven of 12 countries in the systematic and idiosyncratic contagion group experienced a banking crisis. Table 3 shows that the average output loss (as a proportion of GDP) for these countries was almost 34 percent, and

[10] They give the example of European monetary policy being too loose for Spain and Ireland but appropriate for Germany and France, leading to housing price booms in the former but not the latter.

[11] Laeven and Valencia (2013) consider a banking crisis as systemic if (i) there is financial distress (as indicated by bank runs, losses in the banking system, and/or bank liquidations), and (ii) there is a policy intervention in response to significant losses in the banking system. Output losses are computed as the cumulative sum of the differences between actual and trend real GDP over the crisis period and the fiscal costs are defined as the component of gross fiscal outlays related to the restructuring of the financial sector. They include fiscal costs associated with bank recapitalization but exclude asset purchases and direct liquidity assistance from the treasury. See Laeven and Valencia (2013) for details.

when we exclude Switzerland, which experienced no output loss, this rises to around 39 percent. The standard deviation of the output loss in this group is high, at 34 percent. The five countries which experience a banking crisis with only idiosyncratic contagion have a similar output loss of 33 percent, but a much lower standard deviation of this loss at almost 9 percent. The other forms of contagion associate less strongly with banking crises than these two categories, with volatility contagion relatively unimportant.

The evidence from Fig. 1 and Table 3 indicates that banking crises in this sample are frequently associated with idiosyncratic contagion - which tends to result in output loss. However, when this is coupled with the presence of systematic contagion, there is great uncertainty about the output loss, in our sample the output loss for this group ranges from nothing in Switzerland to 106 percent of GDP in Ireland. By contrast, when only idiosyncratic contagion is associated with a banking crisis, the range for output loss is smaller, between 20 and 40 percent of GDP.

The fiscal costs associated with the countries experiencing a banking crisis do not show this distinction between the dominant types of contagion; the average fiscal costs are 8 percent or 10 percent of GDP for countries with both systemic and idiosyncratic contagion or idiosyncratic contagion only. These results point to the importance of understanding the source of contagion and its links to banking crises. For policy makers, it appears that the maximum uncertainty about the outcome of a banking crisis occurs when both idiosyncratic and systematic contagion affect the market.

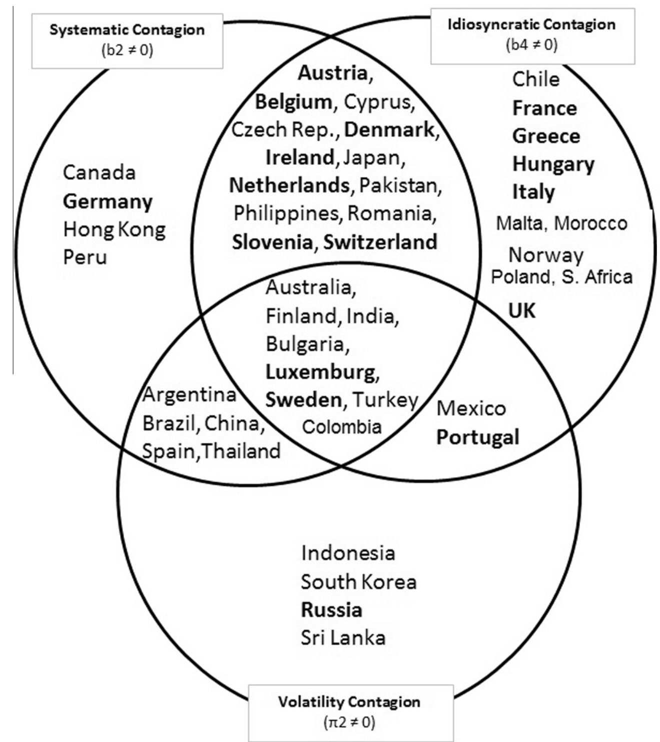

Fig. 1. Univariate hypothesis test.

4.2. Contagion, industry characteristics and the systemic crises

In this section we formalize the discussion from the previous section and examine the empirical evidence for the transmission of banking crises via different contagion channels incorporating industry characteristics as control variables using a Probit model as follows:

$$Pr(BankCrisis_i = 1) = \Phi(\gamma_o + X_i'\lambda + W_i'\theta + Z_i'\delta) \tag{6}$$

where X_i is a vector of indicator variables representing the contagion measures identified in the previous section, taking the value of 1 when that contagion channel is statistically significant in the first stage regressions (we exclude the volatility channel as it is completely coincident with all occurrences and non-occurrences of crisis), W_i is a vector of banking industry characteristics, Z_i, is a vector of macroeconomic control variables; λ, θ, and δ are the vectors of weights on each of these effects, and Φ is the cumulative distribution function of a standard normal random variable. The data for banking industry characteristics and control variables are from Cihak et al. (2012) and are available from the World Bank website. [12] Motivated by Beck et al. (2006), Berger and Bouwman (2013), Caprio et al. (2014) and Lepetit et al. (2008), we consider market concentration, bank capital, credit growth, bank income structure, and non-performing loans to characterize the banking industry, whilst the relative size of the banking sector, credit growth rate and external debt exposure are taken as macroeconomic control variables.[13] Table 4 provides a brief data description for the selected control variables. A detailed data description is available in Cihak et al. (2012) or on the Global Financial Development Database (GFDD) of the World Bank website. The control variables are kept at their pre-crisis period average.

Five specifications of the model are presented in Table 5. Specification (1) presents the marginal effects where only contagion channels are present, specifications (2) and (3) extend this model to include selected market control variables. Potential multicollinearity between bank capital and non-performing loan and credit growth motivate the different control variables used in these two specifications (Aebi et al., 2012; Bruyckere et al., 2013; Shrieves and Dahl, 1992). Specification (4) provides the full set of X, W, Z variables, and finally, column (5) reports on results with the addition of an interaction term between idiosyncratic contagion and regulatory capital.[14]

The probit model results reported in Table 5 support the hypothesis that idiosyncratic contagion is an important avenue for systemic banking crises. The presence of idiosyncratic contagion (a shock transmitted from the crisis-originating country), increases the probability of systemic banking crisis in a country by almost 37 percent. The contribution of systematic contagion, however is not statistically significant at conventional levels which suggests that increased interdependence among banking sectors does not necessarily destabilize the domestic banking system. This does not necessarily mean that the potential for systematic contagion should be paid less attention by policy makers; other evidence suggests that policy initiatives taken during the global financial crisis contributed to reduced tail risk in the financial system (Ait-Sahalia et al., 2012; Gagnon et al., 2011; Klyuev et al., 2009).

[12] http://data.worldbank.org/data-catalog/global-financial-development.

[13] There is a growing body of literature that examines macro-financial linkages. For example, Beck et al. (2006) examine the relationship between the banking industry structure and the banking crisis for 69 countries from 1980 to 1997 covering 47 banking crisis episodes over the period. Caprio et al. (2014) examines the macro-financial determinants of financial crises using the data for 83 countries over the period 1998 to 2006. In our paper, we have used the data for systemic banking crisis within the GFC period (2007–2009). Hence, our sample size limited us from including more control variables in the probit model.

[14] In addition to the list of control variables in Table 4, we also considered other variables such as bank liquidity (ratio of liquid assets total asset) and foreign bank subsidiaries (ratio of foreign banks assets to total banks assets). We also considered potential interaction between control variables and different forms of contagion. However, none of these effects were statistically significant and did not change the other results. In the interests of preserving degrees of freedom and space they are not reported here.

However, our results do suggest that there remains significant evidence that crises transmitted via idiosyncratic shocks may destabilize the domestic financial system, and policies designed to reduce the potential for idiosyncratic contagion may result in a reduced impact on domestic economies.

We specifically test the hypotheses in the existing literature that larger, more concentrated banking sectors with lower engagement in shadow banking activities and higher regulatory capital will have lower probability of crisis occurrence (Acharya et al., 2010; Allen and Gale, 2000; Beck et al., 2006; Berger and Bouwman, 2013; Bretschger et al., 2012; Cole, 2012; Bruyckere et al., 2013; De Jonghe, 2010; Lepetit et al., 2008; Miles et al., 2013; Mirzaei et al., 2013). The results show support for the hypothesis that higher regulatory bank capital reduces the likelihood of a systemic banking crisis by about 15 percent.[15] In addition, bank capital also helps to reduce the contribution of idiosyncratic contagion to the risk of banking crises; the interaction term between idiosyncratic contagion and regulatory capital has a significantly negative marginal effect. However, higher market concentration results in only a small reduction in the probability of a crisis, statistically significant at the 10 percent level; providing limited support for the hypothesis that market concentration decreases the probability of a banking crisis.[16] The size of the banking sector (given by the banking sector to GDP ratio) has no significant effect. While the results for the non-interest income to total income ratio variable are uniformly significant across all the specifications, the marginal effects indicate that where the banking sector engages less in retail banking activities and more in shadow banking activities the probability of a systemic crisis is increased by almost 2 percent. The non-performing loan ratio and private credit growth variables have no statistically significant marginal effects. Finally, the statistically significant (at 10 percent) marginal impact of the external debt to GDP ratio on the probability of banking crisis supports the hypothesised feedback loop between sovereign debt and banking crises (Acharya et al., 2014; Adler, 2012).

In summary, the results show that the existence of idiosyncratic contagion during a crisis provides a statistically significant contribution to increasing the probability of a banking crisis in the recipient country, of 37 percent. Thus, idiosyncratic contagion is an important channel, worthy of policy makers' attention to mitigate the effects of foreign sourced crises on domestic economies. The usual finding that good macroeconomic policy settings, such as influence the external debt to GDP ratio, is confirmed. As the literature suggests, higher regulatory capital can play a significant offsetting role in reducing banking crises, although there may be a potential cost through the changing nature of banks' behavior in international markets and/or reducing international banking relationships; see for example Aiyar et al. (2014) and Ongena et al. (2013). Proposals around the size of the banking sector, market structure and relative engagement in shadow banking are economically less significant in this analysis.

5. Robustness check

The analysis presented thus far is robust to a number of checks already presented in the discussion; in particular the specification of the GARCH as either EGARCH(1,1) or TARCH reported in Section 2.2; the choice of global factor data reported in Section 2.3; the definition of bank concentration and bank capital, and choice of dating for the control variables in Section 4.2. We have also considered changing the start point of the crisis period to August 9, 2007; which is the point at which the ECB first intervened in the markets in response to the worsening credit conditions. The results are very similar to those reported in Table 2.

Table 3
Cost of systemic banking system crisis.

	Output loss	Fiscal cost		Output loss	Fiscal cost
Systematic and idiosyncratic			*Idiosyncratic only*		
Austria	14	4.9	France	23	1
Belgium	19	6	Greece	43	27.3
Denmark	36	3.1	Hungary	40	2.7
Ireland	106	40.7	Italy	32	0.3
Netherlands	23	12.7	UK	25	8.8
Slovenia	38	3.6	Average	32.6	8.0
Switzerland	0	1.1	St. dev.	8.8	11.3
Average	33.7	10.3			
St. dev.	34.4	13.9	*Systematic and volatility*		
Average (excl. Swiss)	39.3	11.8	Spain	39	3.8
St. dev.	34.0	14.6			
			All forms of contagion		
Systematic only			Luxembourg	36	7.7
Germany	11	1.8	Sweden	25	0.7
			Average	30.5	4.2
Idiosyncratic and volatility			stdev	7.8	4.9
Portugal	37	0			
			Overall		
Volatility only			Average	30.4	7.1
Russia	0	2.3	St. dev.	23.0	10.6

Note: Output loss and fiscal cost are expressed in percent of GDP. Data source: (Laeven and Valencia, 2013).

In this section we perform a more significant analysis on the impact of splitting the crisis sample into two sub-samples. Authors such as Claessens et al. (2010) and Mishkin (2011) suggest splitting the crisis into phases: the turmoil phase (from August 2007 to mid September 2008, until the demise of Lehman Brothers) and the acute phase (after the collapse of Lehman Brothers until May 2009), where the end point is consistent with the end of the recession in the US. The turmoil period (Phase I) captures the sub-prime crisis, and its effects on financial markets worldwide. For example, August 2007 is characterized by a credit freeze in interbank markets; central banks provided substantial liquidity support to the banks and governments took action to rescue financial institutions such as ABN Amro in the Netherlands, Northern Rock in the UK, and Bear Stearns in the US. The acute period (Phase II) consists of the period following the failure of Lehman Brothers, when turmoil in financial markets led to the failure of a large number of financial institutions globally, government intervention in the form of bailouts, deposit guarantees, liquidity support and capital injections, and a severe contraction in the real economy. The empirical literature documents that the policy initiatives were largely effective in reducing the systemic nature of the crisis (Ait-Sahalia et al., 2012; Klyuev et al., 2009). If that is the case, we are less likely to find evidence for contagion during the second phase of the crisis, but rather to find evidence for turmoil in the markets themselves.

To incorporate two phases of crisis in our model, we extend (3) and (5) as follows:

$$r_{j,t} = b_{0,j} + b_{1,j}f_t^{global} + b_{2,j}f_t^{global}I1_t + b_{3,j}f_t^{global}I2_t + b_{4,j}f_t^{US} + b_{5,j}f_t^{US}I1_t + b_{6,j}f_t^{US}I2_t + b_{7,j}I1_t + b_{8,j}I2_t + \xi_{j,t} \quad (7)$$

$$ln(\sigma^2_{j,t}) = c_{0,j} + c_{1,j}(|z_{j,t-1}| - E|z_{j,t-1}|) + c_{2,j}z_{j,t-1} + c_{3,j}ln(\sigma^2_{j,t-1}) + \pi_{1,j}ln(\hat{\sigma}^2_{US,t}) + \pi_{2,j}ln(\hat{\sigma}^2_{US,t})I1_t + \pi_{3,j}ln(\hat{\sigma}^2_{US,t})I2_t \quad (8)$$

where $I1$ and $I2$ are binary indicator functions for Phase I and Phase II respectively. We consider July 19, 2007 to September 12, 2008 as Phase I and September 15, 2008 to May 8, 2009 as Phase II.

[15] The result is robust to the use of equity capital to total asset ratio as an alternative measure of bank capital.

[16] For robustness, we considered the alternatives of the 5 largest banks based concentration ratio. The results are very similar.

Table 4
Control variables: Code, definition and description.

Variables	Definition and description	GFDD Series code
Market concentration	Market share of 3 largest banks in terms of total assets; ratio of assets of three largest commercial banks to total commercial banking assets. Total assets include total earning assets, cash and receivables from banks, foreclosed real estate, fixed assets, goodwill, other intangibles, current tax assets, deferred tax assets, discontinued operations and other assets	GFDD.OI.01
Regulatory capital	The ratio of regulatory capital to risk-weighted assets; the capital adequacy of deposit takers; ratio of total regulatory capital to assets held, weighted according to the risk of those assets	GFDD.SI.05
Non-interest income	Ratio of non-interest income to total income; the non-interest income of banks includes net gains on trading, derivatives and other securities, net fees and commissions and other operating income	GFDD.EI.03
Non-performing loan	Non-performing loan to total gross loan; non-performing loan refers to the loans on which payments of interest and principal past due by 90 days or more; the loan amount recorded as non-performing includes the gross value of the loan as recorded on the balance sheet, not just the amount that is overdue	GFDD.SI.02
Private Credit Growth	Percentage change in private credit to GDP ratio; private credit by deposit money banks and other financial institutions to GDP	GFDD.DI.12
Banking Assets/GDP	Ratio of total banking assets to GDP; the banks include commercial banks and other financial institutions that accept transferable deposits, such as demand deposits	GFDD.DI.02
External Debt	Ratio of outstanding external private debt to GDP; the external private debt includes long-term bonds and notes and money market instruments issued in international markets	GFDD.DM.05

Note: The GFDD compiles data from different sources such as Bankscope, BIS, Global Financial Stability Report, and International Financial Statistics (IMF). For more detail, see Cihak et al. (2012).

Table 5
Probit model results: Marginal effects.

	(1)	(2)	(3)	(4)	(5)
	Dependent variable: Systemic banking crisis dummy				
Systematic Contagion	−0.0438			−0.1503	−0.1605
	(0.128)			(0.157)	(0.183)
Idiosyncratic Contagion	0.3188***			0.4735***	0.3655***
	(0.115)			(0.147)	(0.158)
Shift Contagion	0.451***			0.2592	0.2618
	(0.117)			(0.165)	(0.171)
Market Concentration		−0.0067*	−0.0052	−0.012**	−0.0126**
		(0.004)	(0.004)	(0.005)	(0.006)
Regulatory Capital/Risk-weighted Asset		−0.1195***		−0.1412***	−0.1493**
		(0.035)		(0.052)	(0.059)
Non-interest Income/Total Income		0.0166**	0.0127*	0.0188**	0.0189**
		(0.007)	(0.008)	(0.008)	(0.008)
Non-performing Loan			0.0043		
			(0.025)		
Private Credit Growth			−0.0051		
			(0.014)		
Idio. Contaigon x Regulatory Capital					−0.0128**
					(0.007)
Banking Asset/GDP		−0.0044	−0.0048**	−0.002	−0.0021
		(0.003)	(0.002)	(0.003)	(0.003)
External Debt/GDP		0.0173**	0.0212***	0.0147**	0.015*
		(0.008)	(0.008)	(0.007)	(0.008)
N	53	43	40	42	42
Wald Chi-Sq	11.54	17.81	14.99	17.14	18.16
p-value	0.009	0.003	0.020	0.029	0.033
Pseudo R-sq	0.309	0.574	0.5182	0.697	0.697

Table 6 provides the evidence of contagion for Phase I and Phase II. During Phase I of the GFC, 28 markets experienced systematic contagion, 35 markets experienced idiosyncratic contagion, 31 markets experienced shift contagion and 20 markets experienced volatility contagion. During Phase II of the GFC, 25 markets experienced systematic contagion, 22 markets experienced idiosyncratic contagion, 11 markets experienced shift contagion and 36 markets experienced volatility contagion.

The overall results show that during the first phase of the crisis idiosyncratic and systematic contagion dominate, along with structural shifts, in a manner very close to the results reported in the main body of the paper. The second phase predominantly shows evidence of volatility contagion. This is consistent with underlying uncertainty in the market during this time. The unconventional policy measures which aimed to reduce market uncertainty resulted in a degree of policy uncertainty due to lack of experience with the approaches implemented around the globe; see the critique in Allen and Carletti (2010). Not only were these policies aimed at reducing systematic effects through global exposure (such as limiting capital flows), these policies also acted to reduce the transmission of idiosyncratic shocks.

Unfortunately it is not straightforward to align the two phase crisis results with the evidence for systemic banking crises in Laeven and Valencia (2013) as the data do not allow a clear distinction between the phases. Highly detailed data such as that collected by Ureche-Rangau and Burietz (2013) for 11 major European countries would be required to conduct such an analysis. However, the evidence for the probit model on the probability of

Table 6
Contagion results based on 2 phases of the GFC.

Country	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	π_1	π_2	π_3
Argentina	0.543***	−0.164***	−0.245***	−0.084*	0.082	0.008	−0.002***	−0.002***	0.016	0.021**	0.013
Australia	0.513***	0.409***	0.101	0.040	0.171***	0.140**	−0.001*	0.000	0.157***	−0.026***	−0.056***
Austria	0.315***	0.271***	0.441***	0.030	0.309***	0.108	−0.003***	−0.002	0.196***	−0.025*	−0.177***
Belgium	0.560***	0.046	0.486***	0.144***	0.287***	0.154*	−0.003***	−0.001	0.058***	−0.001	−0.019**
Brazil	1.181***	−0.026	−0.290***	−0.105**	−0.006	0.008	0.000	−0.002	0.154***	0.029***	0.040**
Bulgaria	0.043	0.425***	0.390***	−0.155***	0.177***	0.018	−0.003***	−0.003*	−0.053	−0.064***	−0.217***
Canada	0.634***	0.157***	0.247***	0.115***	0.126***	−0.047	0.000	0.000	0.129***	0.003	−0.039**
Chile	0.516***	0.023	−0.106**	−0.157***	0.140***	0.088**	−0.001	0.000	0.190***	0.007	−0.031
China	0.129***	0.534***	−0.046	−0.025	−0.066	0.028	0.000	0.000	−0.084*	−0.076***	−0.104***
Colombia	0.000	0.113***	0.491***	0.000	−0.022	−0.180***	0.000	0.000	0.042**	−0.609***	−0.985***
Cyprus	0.442***	0.301***	0.062	0.007	0.184***	0.145*	0.000	−0.004**	0.084***	0.003	−0.037**
Czech Rep.	0.368***	0.150**	0.105	−0.017	0.214***	0.155	0.000	−0.002	0.077**	−0.006	−0.135***
Denmark	0.465***	0.015***	0.164*	0.052	0.275***	0.095	−0.002***	−0.002	0.186***	0.009	−0.058***
Egypt	0.096***	−0.005	0.077**	−0.042	0.036	0.053	0.001	0.001	0.008	0.014	−0.019
Finland	0.342***	0.119*	0.110	−0.006	0.438***	0.158**	−0.002**	0.000	0.172***	−0.038***	−0.136***
France	0.672***	−0.049	0.136	0.267***	0.228***	−0.048	−0.003***	−0.002	0.057***	0.000	−0.012**
Germany	0.703***	−0.284***	−0.038	0.218***	0.080	0.097	−0.002**	0.000	0.023**	0.000	−0.010**
Greece	0.483***	0.089	0.002	−0.009	0.193***	0.161**	−0.001	−0.006***	0.099***	0.012	−0.080***
Hong Kong	0.510***	0.053	0.051	0.088***	0.019	0.043	0.001*	0.000	0.050***	−0.004	−0.031***
Hungary	0.573***	−0.055	−0.038	0.110*	0.164*	0.189	−0.003***	−0.003	0.111***	−0.005	−0.159***
Indonesia	0.574***	0.081	−0.096	−0.027	0.168**	0.047	0.000	−0.002	0.176***	0.035***	0.025
India	0.429***	0.546***	0.067	−0.100*	0.526***	0.173**	−0.002	−0.001	0.018	−0.036***	−0.086***
Ireland	0.507***	0.225**	0.453**	0.176***	0.437***	−0.068	−0.004***	−0.011*	0.145***	−0.007	−0.082***
Israel	0.295***	−0.118*	0.141**	0.102**	0.102	0.017	0.000	0.000	0.064**	−0.006	−0.055***
Italy	0.539***	−0.143**	0.109	0.094***	0.146***	0.101	−0.001***	0.000	0.040***	0.001	−0.011*
Japan	0.710***	0.226***	−0.214***	−0.204***	0.437***	0.162**	0.001	−0.001	0.056***	0.005	0.010
Luxemburg	0.163***	0.220***	0.082**	−0.102***	0.134***	0.164***	−0.002***	0.000	0.099**	−0.048***	−0.090***
Malaysia	0.255***	0.089**	0.040	−0.025	0.124***	−0.021	0.000	0.001	0.087***	−0.006	−0.021
Malta	0.064***	0.011	0.033	−0.106***	0.098***	0.121***	0.000	−0.002**	0.039	0.010	−0.059***
Mexico	0.526***	−0.149***	0.123***	0.094***	−0.062	−0.130***	−0.001	0.000	0.185***	0.057***	0.012
Morocco	0.084***	0.002	0.021	−0.099***	0.040	0.143***	0.000	0.000	−0.004	0.003	−0.066***
Netherlands	0.669***	−0.011	−0.513***	0.269***	0.054	−0.220***	−0.001**	−0.001	0.015	−0.001	−0.004
Norway	0.494***	−0.162**	0.378**	0.000	0.341***	0.411***	−0.002**	−0.001	0.124***	−0.015	−0.178***
Pakistan	0.198***	−0.071	−0.183***	−0.161***	0.156**	0.147***	−0.003***	−0.002***	0.023	0.006	0.025**
Peru	0.018	0.217***	0.173***	−0.066***	−0.035	−0.030	−0.001**	0.001**	0.066	−0.011	0.006
Philippines	0.316***	0.323***	0.063	−0.079**	0.239***	0.067	−0.001	0.001	0.208***	−0.010	−0.006
Poland	0.402***	0.048	0.115	0.102**	0.158**	0.070	−0.002**	−0.003	0.198***	0.008	−0.218***
Portugal	0.315***	−0.095	0.043	−0.014	0.300***	0.208***	−0.004***	0.000	0.175***	−0.019**	−0.041**
Romania	0.165***	0.468***	0.190**	−0.077*	0.275***	0.162**	−0.003***	−0.002	0.035	−0.020*	−0.087***
Russia	0.374***	0.002	0.051	0.156***	0.079	−0.182*	−0.003***	−0.004	0.137***	0.031***	−0.043**
South Africa	0.562***	−0.082	−0.046	0.069	0.281***	0.273***	−0.002***	0.001	0.076**	−0.014	−0.090***
Korea	0.864***	−0.161**	0.039	0.051	0.139*	−0.056	−0.003***	−0.005*	0.303***	0.076***	−0.032
Sweden	0.682***	−0.271***	0.021	0.159***	0.267***	0.213**	−0.003***	−0.003	0.130***	0.010*	−0.024**
Singapore	0.471***	−0.022	−0.047	0.071**	0.044	−0.003	0.000	−0.001	0.043***	0.002	−0.012
Slovenia	0.049**	0.081**	0.167***	−0.136***	0.154***	0.134***	0.000	−0.002*	0.224***	0.031	−0.082**
Spain	0.675***	−0.284***	−0.135	0.213***	0.016	0.054	−0.001*	0.000	0.040***	0.004	−0.005
Sri Lanka	0.008	−0.017	0.118***	0.008	0.003	−0.008	−0.001***	−0.004***	0.022	0.057***	−0.011
Sweden	0.682***	−0.271***	0.021	0.159***	0.267***	0.213**	−0.003***	−0.003	0.130***	0.010*	−0.024**
Switzerland	0.802***	−0.161**	−0.147	0.312***	0.168***	−0.013	−0.003***	0.000	0.051***	0.003	−0.010
Taiwan	0.441***	−0.065	0.019	0.012	0.073	0.053	0.000	0.000	0.142***	0.015	−0.013
Thailand	0.482***	−0.053	−0.201***	0.000	0.178***	−0.023	−0.001	−0.001	0.157***	0.047***	0.014
Turkey	0.769***	−0.050	−0.388***	0.079	0.398***	0.073	−0.002*	−0.001	0.227***	0.047***	0.056***
UK	0.572***	−0.023	0.122	0.239***	0.297***	0.082	−0.003***	0.000	0.042***	−0.002	−0.012**
Venezuela	0.034	0.034	−0.021	−0.021	−0.004	0.025	−0.001***	0.000	−0.194***	−0.007	−0.015

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

systemic banking crises associated with evidence of contagion from the first phase of the crisis is qualitatively similar to that presented in the main body of the paper - idiosyncratic contagion and bank capital appear as significant contributors to the systemic crisis. These results are available from the authors on request.

6. Conclusions

This paper implements a CAPM based modeling framework that encapsulates several alternative channels of contagion and relates them to the observed evidence for banking crises for 54 countries during the 2007–2009 global financial crisis. We determine that banking crises have a strong positive correlation with the idiosyncratic contagion emanating from crisis-originating countries. Idiosyncratic contagion represents the unanticipated impact of shocks affecting the crisis originating market, in this case the US banking sector, and transmitted to other banking sectors. It is differentiated from the transmission of common shocks that hit global markets, which we denote as systematic contagion. It also differs from general shifts in the market conditions, known as shift contagion, and transmission via changes in market volatility, or volatility contagion. The framework we implement, distinguishes each of these four channels of contagion and finds that although there appears to be clustered evidence for effects of both systematic and idiosyncratic contagion on the probability of banking crises, statistically, only the links with idiosyncratic contagion are significant. It is entirely possible that this result partly arises from the efforts of policy makers around the globe to contain the systematic effects of the crisis, thus dampening the systematic channel.

Our results provide evidence for the severity of the 2007–2009 crisis. Banking sectors across the world were disturbed by the crisis and were not immune to contagion effects. About 60 percent of the sample banking markets experienced a break in global systematic risk exposure, and about 60 percent of banking markets experienced idiosyncratic contagion originating from the US banking market. While most banking markets show evidence of volatility spillovers from the US banking markets during periods of market calm, only about 40 percent of sample banking markets experienced volatility contagion during the crisis. We established that evidence of a banking crisis seemed to be related to two clusters of economies - one which experienced both systematic and idiosyncratic contagion, and one which experienced idiosyncratic contagion only. While the average output loss of banking crises on these two groups of countries was quite similar, at about one-third, the standard deviation of this loss was very different. The group of countries which experienced only idiosyncratic contagion were more likely to experience an average loss - that is, the range of output loss experienced was much smaller than that of the countries where systematic contagion was also significant. When we split the sample into two sub-periods these results are preserved for the first phase of the crisis, but in the period following the demise of Lehman Brothers the major effect is volatility transmission. Our conclusions on the impact of regulatory variables are preserved.

The idiosyncratic shocks channel is empirically an important link in transmitting shocks across international banking sectors, and is strongly related to the subsequent occurrence of a banking crisis in the recipient country. Concentrated banking sectors, strong regulatory capital requirements and a concentration in retail banking income help to reduce the likelihood of systemic crisis, consistent with the existing evidence. However, there is evidently more that can be done by policy in identifying and defusing the transmission of country specific idiosyncratic shocks that are potential sources of idiosyncratic contagion so as to reduce the costs of any consequent banking crises.

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