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Contagion and Banking Crisis — International Evidence for 2007-2009

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Contagion and Banking Crisis - International Evidence for 2007-2009*

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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 50 economies. We identify three channels of contagion - systematic, idiosyncratic and volatility - and find evidence for these in 41 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 27 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.

Keywords: Global financial crisis, financial contagion, banking institutions, asset pricing, GARCH

JEL Classification: F30, G21, E58

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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% of GDP associated with a banking crises in the last quarter of the 20th century, and in the most recent period Laeven & Valencia (2012) document losses of about 30% of GDP. 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.*, 2013b), particularly as banking crises are often observed to precede even more costly currency and debt crises (Laeven & Valencia, 2012; Reinhart & Rogoff, 2008).

This paper empirically examines the evidence for the unexpected international transmission of banking crises via stressful conditions in financial markets. These transmissions are beyond those which would occur by the known spillovers between banking sectors in different jurisdictions due to trading or portfolio links, and instead consist of contagion effects; see also van Rijckeghem & Weder (2001),Bae *et al.* (2003); Bekaert *et al.* (2005); Corsetti *et al.* (2005); Dungey *et al.* (2005); Forbes & Rigobon (2002); Iwatsubo & Inagaki (2007). We find significant evidence not only for the existence of contagion, 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 *et al.*, 2010; Brealey *et al.*, 2012; Kalemli-Ozcan *et al.*, 2013b; Popov & 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 *et al.*, 1990; 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 & 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.* (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 49 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 50 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 market 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, only about 40 percent of sample banking markets experienced volatility contagion during the crisis period. 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 Leaven and Valencia (2012) 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 27 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 & Bouwman, 2013; Cole, 2012; Miles *et al.*, 2013), the size of the banking sector and higher market concentration (Allen & 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 and retail banking activities lead to reduced probability of banking crisis even in the presence of contagion effects, but that while the impact of higher market concentration is positive it is insignificant. The evidence suggests a larger economic impact of stronger regulatory capital, which reduces the probability of crisis by 11 percent, than for proportion of non-interest income in total income, which only increases the probability of crisis by less than 1 percent. Likewise, domestic conditions can help ameliorate the probability of crises, increased banking assets as a proportion of GDP lower the the probability of crisis, but the economic impact is very small, at 0.1 percent. An increase in the external debt to GDP ratio also increases the probability of crisis, by 1 percent, consistent with the hypothesis that a feedback loop exists between sovereign debt and banking crises, (Acharya *et al.*, 2011; Adler, 2012).

Our results argue that systematic contagion effects are being adequately tackled with current policy responses – they are not significantly affecting the probability of a domestic banking crisis emerging as a result of a crisis elsewhere. However, there is scope for further reduction in 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 or trading links which are present during non-crisis periods also, but perhaps consistent with arguments around herding behavior. Potentially there is gain for regulators and policy makers to consider how to creatively respond to calm these transmissions and 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 describes the sample and data. Section 3 provides the results for contagion. In Section 4 we examine the cross-section of systemic banking crisis and Section 5 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. 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.[1]

Let $r_{i,t}$ represents 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 .

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 the crisis period; the existing network of relationship across the market participants may break down, or the failure of a few financial institutions may have 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, 2011) as revealed in Equation (2) below:

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

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

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.[2] This is akin to the debate around whether increased international financial integration may or may not contribute to increased output correlation (Kalemli-Ozcan *et al.*, 2013a,b).

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 a global reserve currency. Following Masson (1999), we denote these as *spillover effects*. 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 & 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. Finally, Forbes & Rigobon (2002) argue that a crisis may bring a structural shift in the existing relationships above and beyond that accounted for by structural breaks in factor relationships; potentially attributable to herding behavior amongst investors which does not depend on economic fundamentals (Bekaert *et al.*, 2011).[3] Our final levels specification captures each of these channels as follows:

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

where the US factor, f^{US}, is extracted as the residual from applying equation (2) to $i = US$, thus orthogonalizing the global and US factors. In Eq. (3), the coefficient

[2] 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.

[3] Bekaert *et al.* (2011) refer this as "herding contagion".

$b_{1,j}$ 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.

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. GARCH(1,1) is usually sufficient to capture the financial data properties (Engle, 1982; Hansen & Lunde, 2005). The variance equation of the EGARCH model (to accompany mean equations given in equations (1-3)) can be expressed as:

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

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

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

In Eq. (5), the parameter estimate $\pi_{1,j}$ captures the general US volatility spillover and $\pi_{2,j}$ captures *additional* US volatility spillover for market j during the crisis period which we denote as volatility contagion. The GARCH framework provided in Eq. (5) is motivated by Hamao *et al.* (1990); Engle *et al.* (1990); Edwards (1998); Iwatsubo & Inagaki (2007), amongst others.

2.3 Sample, Data and Crisis period

The data set comprise daily banking sector indices for 50 countries including the US for January 2, 2001 to May 8, 2009 available in Thompson Datastream. The aggregate world banking sector index return provides the global factor.[4] 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 & Rigobon (2002), and adjust time/date as Day 01 in US/Americas = Day 2 in Asia and Europe. We follow the approach of Wang & 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 & 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 08, 2009. These dates are consistent with the existing literature, see Bekaert *et al.* (2011) and the extensive overview of dates provided in Dungey *et al.* (2013). Table 1 provides the list of banking markets considered in this study.

3 Contagion Results and Discussion

The resulting evidence for contagion is reported in Table 2. Almost all of the 49 individual banking markets have 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 & Valencia (2012). These cross-border linkages may reflect both on and off balance sheet channels (Cetorelli & Goldberg, 2011; Sbracia & 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 29 of the 49 coun-

[4]The series used is Datastream mnemonic *bankswd*. The literature suggests that banking and insurance sectors have high level of global integration at sectoral level (Bekaert *et al.*, 2009) and industry factors dominate country factors while explaining the equity returns (Cavaglia *et al.*, 2000). The results are robust to the alternative of using the aggregate world equity index (*totmkwd*) as the global factor.

Table 1: List of banking markets considered

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

tries, that is $b_2 \neq 0$ as reported in Table 3, consistent with these markets experiencing systematic contagion during the crisis, and 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 either 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 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).

Four countries did not have a significant link with the global factor during the pre-crisis period, that is $b_1 = 0$. This potentially reflects that each of these countries, Bulgaria, Peru, Sri Lanka, and Venezuela, is a relatively small and closed market. However, during the crisis, this was no longer the case for Peru and Bulgaria, ($b_2 \neq 0$) 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 49 markets, 29 experienced idiosyncratic shock effects from the US banking market, evidenced by $b_3 \neq 0$. The notable exceptions are a mixture of 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 this parameter 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,(Allen & Gale, 2000; Beck *et al.*, 2006; Bretschger *et al.*, 2012; Mirzaei *et al.*, 2013), 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 $b3 + b4 = 0$ is not rejected in most of these markets. The Brazilian and Peruvian markets appear to have consistently negative response to US originated shocks even during the crisis period, consistent with recent evidence that the Latin American banking market was little effected by the GFC (Kamil & Rai, 2010; Ocampo, 2009).

Almost all of the banking sectors show evidence of volatility spillover effects during the non-crisis period, supporting the contention that the inclusion of volatility transmission is important in the model specification.[5] During the non-crisis period the countries which do not experience volatility spillovers are two Asian markets - China and Pakistan and two Latin American markets - Argentina and Peru. Clearly, the overall evidence presented here supports the banking sector in Peru as relatively isolated from international capital markets.

The crisis also caused a structural shift as specified in Eq. (3), that is $b_5 = 0$ is rejected for 23 of the 49 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 are consistent with the occurrence of herding behavior in addition to global shocks and the US idiosyncratic shocks during the GFC.

3.1 Evidence of Contagion

Table 3 shows that almost all of the 49 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 most cases.[6] The exceptions are Hong Kong, Hungary, Israel, Malaysia, Singapore,

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

[6]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 always accompanied some other contagion estimates (b_2,b_4, or π_2).

Taiwan, and Venezuela. These markets are generally small economies although with a great variety of exposure to international markets. Israel, for example, is an isolated small developed market. The exception is Malaysia, a relatively large economy, which had built significant buffers in the aftermath of the Asian crisis of 1997-98, and a banking system with negligible exposure to US sub-prime loan products (Khoon & 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 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 are 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 Report 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.

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

3.1.1 Volatility contagion driven

A small group of countries (Indonesia, Korea, Mexico, Russia and Sri Lanka) have contagion effects driven largely by volatility contagion. These countries do not have level

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	Israel	0.297***	0.020	0.077	0.000	-0.003	2.26	0.27	2.02	2.35
2	Malaysia	0.256***	0.044	0.031	0.000	-0.005	3.31	2.45	1.47	3.79
3	Singapore	0.472***	-0.036	0.015	0.000	0.003	0.64	1.12	0.62	1.17
4	Taiwan	0.445***	-0.013	0.064	0.000	0.018	1.23	2.17	3.45	3.47
5	Venezuela	0.036	-0.008	0.019	0.000	-0.014	0.31	1.81	1.99	2.02
6	Hong Kong	0.511***	0.066**	0.027	0.001**	-0.002	4.79*	4.27	1.13	5.25
7	Hungary	0.578***	-0.045	0.150*	-0.003***	-0.001	3.79	0.35	3.50	3.82
					Panel B: Volatility contagion driven					
8	Indonesia	0.575***	0.000	0.100	0.000	0.039***	2.03	11.70***	13.61***	13.64***
9	Korea	0.880***	-0.111	0.078	-0.003***	0.077***	3.18	26.88***	25.60***	27.78***
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	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					
13	Canada	0.633***	0.212***	0.045	0.000	0.006	49.02***	46.00***	2.38	49.33***
14	Germany	0.703***	-0.195***	0.086	-0.001	0.001	12.67***	10.73***	2.62	12.84***
15	Peru	0.018	0.188***	-0.032	0.000	-0.013	67.10***	67.17***	2.41	67.72***
16	Spain	0.678***	-0.225***	0.027	-0.001	0.005*	18.55***	21.41***	3.07	21.72***
					Panel D: Idiosyncratic contagion driven					
17	Chile	0.519***	-0.051	0.101***	-0.001*	0.006	9.58***	2.65	8.20**	9.89**
18	France	0.673***	0.040	0.161***	-0.002**	0.001	8.02**	0.64	7.83**	8.07**
19	Greece	0.496***	0.082	0.200***	-0.001	0.007	16.68***	2.89	15.09***	18.12***
20	Italy	0.539***	-0.066	0.139***	-0.001*	0.001	10.72***	1.80	9.61***	10.98**
21	Malta	0.064***	0.005	0.102***	0.000	0.011	13.28***	1.08	13.94***	14.47***
22	Norway	0.491***	0.081	0.407***	-0.001	-0.002	34.87***	1.29	34.24***	35.35***
23	Poland	0.410***	0.089	0.140**	-0.002**	0.010	7.23**	2.55	5.39*	7.59*
24	UK	0.573***	0.063	0.246***	-0.002***	0.000	19.85***	1.13	18.92***	19.87***
25	Czech Rep	0.375***	0.124**	0.174***	0.000	-0.003	12.36***	4.21	7.03**	12.72***
26	Japan	0.716***	-0.095*	0.216***	0.000	0.002	14.90***	3.17	13.46***	15.03***
27	Portugal	0.316***	-0.016	0.255***	-0.003***	-0.016*	36.19***	3.45	41.10***	41.17***

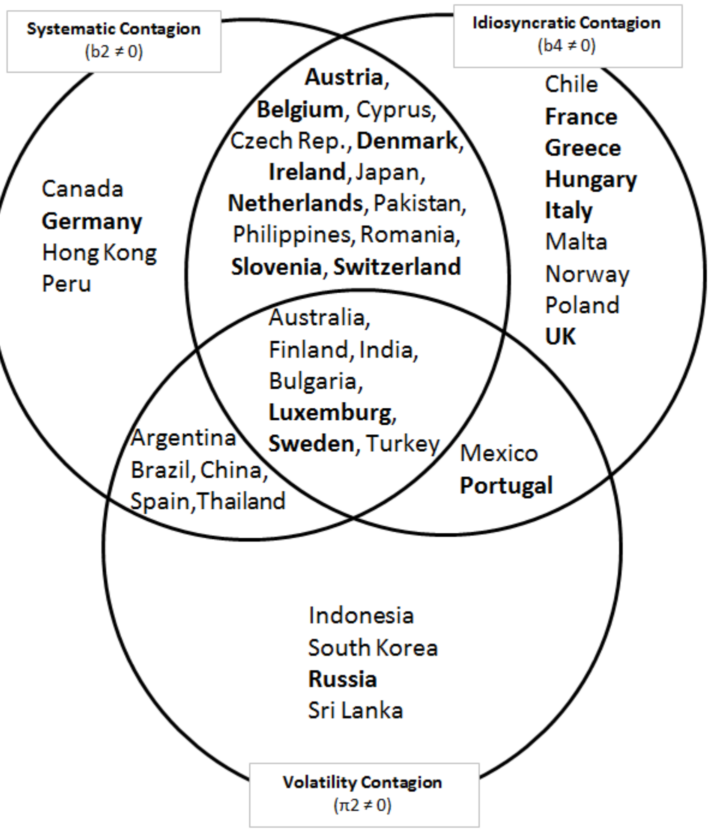
Note: The values in column for b_1, b_2, b_4, b_5 and π_2 are the parameter estimates and values for joint test are the Chi-square values. ***, **, and * indicate statistical significance at 1%, 5% and 10% respectively.

Table 2 *continue*: 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 E: Multiple drivers					
28	Austria	0.324***	0.328***	0.261***	-0.002**	-0.016	50.99***	30.44***	21.14***	51.97***
29	Belgium	0.558***	0.183***	0.259***	-0.002***	0.001	28.10***	7.94**	19.39***	28.19***
30	Cyprus	0.440***	0.233***	0.177***	0.000	0.005	24.63***	14.63***	9.48***	24.95***
31	Denmark	0.465***	0.088*	0.204***	-0.002***	0.012	20.14***	5.24*	18.35***	22.71***
32	Ireland	0.521***	0.356***	0.367***	-0.003***	-0.002	32.02***	15.75***	21.19***	32.54***
33	Netherlands	0.668***	-0.253***	-0.165***	-0.002**	-0.001	26.94***	16.43***	8.11**	26.96***
34	Pakistan	0.196***	-0.170***	0.136***	-0.002***	0.009	25.69***	20.60***	10.07***	27.81***
35	Philippines	0.315***	0.124***	0.126***	0.000	-0.016	22.73***	11.29***	10.23***	24.15***
36	Romania	0.165***	0.359***	0.227***	-0.002***	-0.019	64.26***	48.07***	18.37***	69.00***
37	Slovenia	0.050**	0.108***	0.147***	0.000	0.027	39.53***	15.21***	25.18***	41.64***
38	Switzerland	0.803***	-0.122**	0.128**	-0.002***	0.003	9.35***	5.45*	6.42**	10.57**
39	Argentina	0.544***	-0.193***	0.038	-0.002***	0.021**	19.78***	25.80***	6.40**	25.89***
40	Brazil	1.179***	-0.193***	-0.009	-0.001	0.035***	11.96***	22.55***	12.37***	22.69***
41	China	0.129***	0.121***	-0.018	0.000	-0.084***	7.10**	33.37***	25.60***	33.38***
42	Thailand	0.490***	-0.133**	0.037	0.000	0.047***	6.59**	14.77***	9.20**	14.99***
43	Australia	0.515***	0.217***	0.127***	-0.001	-0.022**	27.16***	23.46***	13.08***	33.70***
44	Finland	0.340***	0.114**	0.302***	-0.001	-0.035**	38.71***	0.64	7.83**	8.07**
45	India	0.443***	0.154**	0.255***	0.000	-0.036***	22.13***	13.78***	24.35***	32.20***
46	Bulgaria	0.049	0.388***	0.094*	-0.003***	-0.062***	49.55***	55.23***	12.94***	60.89***
47	Luxemburg	0.162***	0.118***	0.150***	-0.001***	-0.044***	34.91***	25.57***	29.56***	46.50***
48	Sweden	0.691***	-0.166**	0.263***	-0.002**	0.011**	22.04***	11.86***	21.75***	27.80***
49	Turkey	0.770***	-0.245**	0.205*	-0.001	0.047***	8.68**	23.57***	20.60***	25.64***
50	US	0.908***	0.268***		-0.002**					

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.

Figure 1: Univariate hypothesis test



effects - that is no evidence of either systematic contagion or idiosyncratic contagion.[7] With the exception of Sri Lanka, the countries in this group are markets which were involved in financial crises during the 1990s and might 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 Korea particularly were relatively healthy and had less exposure to US subprime 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 which is a small closed economy) with strong international bank-

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

ing linkages. It may be that these linkages are sufficient to enable systematic contagion to effect the domestic markets. None of these market experienced idiosyncratic contagion. Despite the fact that 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 & 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 & Schnabl, 2010; IMF, 2009d). However, when the crisis spread to the global financial conditions and the real sector, the crisis 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.

In the case of the Canadian banking system, despite its close proximity to 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 European countries (Czech Republic, France, Greece, Italy, Malta, Norway, Poland, Portugal, and UK) and Japan and Chile. Countries in this group did not generally experience systematic contagion (except 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 the banking sector returns during the crisis was directly attributable to the idiosyncratic shocks originating in the US banking sector.

3.1.4 Multiple drivers

The final group consists of all those countries where the null of joint hypotheses (bivariate and multivariate test) is rejected in all cases. All the countries in this group experience systematic contagion and the majority of the countries are part of the European Union. Seven countries (Australia, Finland, India, Luxemburg, Romania, Sweden and Turkey) have all effects, that is the null hypothesis is rejected in univariate, bivariate and multivariate hypothesis tests. Five countries (Argentina, Brazil, Bulgaria, China, and Thailand) have no idiosyncratic contagion from the US (univariate test) and 10 countries (Austria, Belgium, Cyprus, Denmark, Luxemburg, Netherlands, Pakistan, Philippines, 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 recording banking system crisis data in Laeven & Valencia (2012) to address relationship between channels of contagion and the presence and cost of banking crises. Of the 41 banking markets in our sample which experienced contagion in any form, 18 banking markets experienced a banking system crisis during the GFC as documented in Laeven & Valencia (2012). The average output loss for these countries is about 30 percent of GDP and the average fiscal cost is about 7 percent of GDP.[8]

Figure 1 highlights the countries classified by channels of contagion which experienced

[8]Laeven & Valencia (2012) consider a banking crisis as a systemic if (i) there is a financial distress (as indicated by bank runs, losses in banking system, and/or bank liquidations), and (ii) there is a policy intervention in response to significant losses in 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 & Valencia (2012) for details.

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 & Valencia, 2012)

systemic banking crises in emphasized bold. 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 shows that the average output loss (as a proportion of GDP) for these countries was almost 34 percent, and 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 Figure 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, then 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. In 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 in 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.

4.2 Contagion, industry characteristics and the systemic crises

In this section we formalize the discussion from 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 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, and 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 character-

Table 4: Probit model results

	Dependent variable (systemic banking crisis dummy)					
	(1)		(2)		(3)	
	estimate (se) [p]	marginal effect	estimate (se) [p]	marginal effect	estimate (se) [p]	marginal effect
Systematic contagion#	-0.193	-0.065			-0.7235	-0.113
	(0.417)	(0.139)			-0.7566	(0.083)
	[0.643]	[0.643]			[0.339]	[0.175]
Idiosyncratic contagion	1.113	0.340			1.853	0.266
	(0.516)	(0.126)			(0.768)	(0.137)
	[0.031]	[0.007]			[0.016]	[0.050]
Shift contagion	1.342	0.442			0.914	0.168
	(0.450)	(0.125)			(0.669)	(0.169)
	[0.003]	[0.000]			[0.172]	[0.322]
Market concentration			-0.0242	-0.006	-0.0486	-0.008
			(0.015)	(0.004)	(0.025)	(0.004)
			[0.096]	[0.139]	[0.051]	[0.057]
Regulatory capital/Risk-weighted asset			-0.4725	-0.123	-0.6304	-0.109
			(0.140)	(0.036)	(0.210)	(0.052)
			[0.001]	[0.001]	[0.027]	[0.036]
Non-interest income/Total income			0.0513	0.013	0.0546	0.009
			(0.023)	(0.006)	(0.026)	(0.008)
			[0.024]	[0.017]	[0.035]	[0.231]
Banking assets/GDP			-0.0105	-0.003	-0.0082	-0.001
			(0.009)	(0.002)	(0.010)	(0.002)
			[0.253]	[0.251]	[0.389]	[0.420]
External Debt/GDP			0.0648	0.017	0.0681	0.012
			(0.019)	(0.006)	(0.027)	(0.006)
			[0.001]	[0.008]	[0.010]	[0.064]
Constant	-1.874		4.2703		5.9836	
	(0.594)		(1.960)		(3.486)	
	[0.002]		[0.029]		[0.086]	
N	49		44		43	
Wald Chi-sq	11.84		34.18		25.82	
p-value	0.008		0.000		0.001	
Pseudo R-sq.	0.308		0.594		0.706	

#Here we consider systematic contagion as increased global exposure during the crisis period, that is, $b_2 > 0$ because $b_2 < 0$ may suggest policy efficacy which help to financial stability.

istics and control variables are from Cihak *et al.* (2012) and available from World Bank website.[9] Motivated by Beck *et al.* (2006), Berger & Bouwman (2013), and Lepetit *et al.* (2008), we consider the market concentration ratio (given by the market share of the 3 largest banks), the bank capital ratio (ratio of regulatory capital to risk-weighted assets), and bank income structure (non-interest income to total income ratio) to characterize the banking industry.[10] We use the relative size of the banking sector (ratio of banking sector assets to GDP) and external debt exposure (ratio of total external debt outstanding to GDP) as macroeconomic control variables. The control variables are kept at their pre-crisis period average.[11] A detailed data description is provided in Cihak *et al.* (2012) or on the Global Financial Development Database of the World Bank website.

Three specifications of the model are presented in Table 4. Specification (1) presents the coefficient estimates and marginal effects where only contagion channels are present, specification (2) when only market control variables are applied and specification (3) the full specification with the full set of X, W, Z variables.

The probit model results reported in Table 4 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 27 percent. The contribution of systematic contagion, however is not statistically significant at conventional levels suggesting that increased interdependence among banking sectors through global factor 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; the evidence suggests that policy issues 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). 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

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

[10] For robustness, we consider the alternatives of the 5 largest banks based concentration ratio and the ratio of bank equity capital to total asset to proxy for bank capital. The results are very similar.

[11] The results are robust to keeping control variables at 2006 level.

contagion may result in 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 (see (Allen & Gale, 2000; Beck *et al.*, 2006; Bretschger *et al.*, 2012; Mirzaei *et al.*, 2013), (Acharya *et al.*, 2010; Berger & Bouwman, 2013; Cole, 2012; Miles *et al.*, 2013), and (De Jonghe, 2010; Lepetit *et al.*, 2008), respectively). The results indicate support for the hypothesis that higher regulatory bank capital reduces the likelihood of a systemic banking crisis by about 11 percent. However, higher market concentration results in only an economically small reduction in the probability of a crisis, statistically significant at the 10 percent level; providing only limited support for the hypothesis that market concentration decreases the systemic risk, and 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 not uniformly significant, the marginal effects in specification (3) 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. 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.*, 2011; 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 27 percent. This is a substantial channel, and worthy of policymakers attention in their attempts to mitigage the effects of foreign sourced crises on domestic economies. The usual finding that good macroeconomic policy settings, such as influence the debt to GDP ratio, are confirmed. As the literature suggests, higher regulatory capital can play a significant offsetting role in reducing banking crises, but proposals around the size of the sector and relative engagement in shadow banking are economically significant determinants in this analysis.

5 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 50 countries during the 2007-2009 global financial crisis. We determine that banking crises are strongly positively related to evidence of idiosyncratic contagion channels from the crisis originating countries. Idiosyncratic contagion represents the unanticipated impact of shocks affecting the crisis originating asset, in this case the US banking sector, and transmitted to other banking sectors. It is differentiated from the transmission of common shocks which hit the global markets, which may originate in the US, but can be identified by their very commonality, 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 implemented here 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 evidences for the severity of 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 crises, and one which experienced idiosyncratic contagion only. While the average output loss effect 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 the countries where systematic contagion was also significant.

The idiosyncratic shocks channel is empirically an important link in transmitting shocks across international banking sectors, 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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