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Determinants of Bank-Sovereign Distress

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Abstract

This paper computes, for 15 advanced countries, the probability of bank-to-sovereign contagion, i.e. the probability of default of a sovereign, conditional on default in one of the domestic banks, and assesses the relevance of underlying structural characteristics in explaining the possibility of contagion. The probability of contagion is computed using the CIMDO methodology developed by Segoviano (2006). A panel model on quarterly data between 2005-q1 and 2012-q4 shows that the macroeconomic and financial outlooks, banking sector characteristics, initial fiscal positions, and the share of public debt held by domestic banks are all significant determinants of the probability of bank-to-sovereign contagion. GDP growth projections and capital buffers in banks were more important determinants before the start of the euro-area debt crisis. Since then, the fiscal situation has become more relevant. The share of government bonds held by domestic banks was especially important for the GIIPS countries. On the contrary, the fiscal situation was less pertinent for countries outside the euro-zone, in line with the theoretical prior that countries with their own currencies can better handle banking and fiscal crises.

JEL Classification Numbers: E43, E44, G01, G10

Keywords: Sovereign spreads; contagion; market price of risk; fiscal policy.

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1. Introduction

As the global crisis unfolded, several factors might have affected the valuations of sovereign risk. First, the global market price for risk went up, as investors sought higher compensation for risk. Deleveraging and balance sheet-constrained investors developed a systemically stronger preference for a few selected assets vis-à-vis riskier instruments. This behavior not only benefited sovereign securities as an asset class at the expense of corporate bonds and other riskier assets, but also introduced a higher degree of differentiation within the sovereign spectrum itself. Second, as the crisis spread to the public sector and policy authorities stepped in to support troubled financial institutions, probabilities of distress went up across sovereigns.

In this context, two distinct channels may be identified: (i) an external channel, as higher probabilities of distress spread among sovereigns with direct and indirect linkages and (ii) a domestic channel, as fundamentals started deteriorating (including debt sustainability and the health of the financial system). External factors have been recently analyzed in Caceres, Guzzo, Segoviano (2010), and in De Santis (2012).

In this paper, we focus our attention on the domestic channel, specifically, on improving our understanding of the linkages observed between sovereigns and financial institutions and devising policy recommendations to minimize the contagion risk between sovereigns and financials.

First, we propose a measure to quantify and characterize contagion-risk between sovereigns and financials. Compared to the existing literature (e.g. De Bruyckere et al. 2013), one innovation in this paper is to use a measure of contagion that takes into account non-linear dependence at the tail (something not well captured by correlation measures, using Segoviano (2006)'s CIMDO method. Second, we characterize the determinants of Sovereign-Financial Contagion Risk (SFCR). We analyze an extensive sample of economic and financial risk factors that might have an impact on explaining SFCR and identify the most significant factors. Third, we assess how contagion risk and the factors that explain it changed across time and different countries during the recent crisis. Lastly, based on our findings, we propose policy recommendations to mitigate the impact of risk factors on sovereign-financial contagion risk.

This paper is organized as follows. Section 2 introduces the different variables and explains how the probability of contagion and the market price of risk under distress were computed. Section 3 presents some stylized facts and Section 4 discusses the main findings. Section 5 uses the model in order to explain the developments in the probability of contagion for each country during the crisis and Section 6 concludes.

2. Literature

Since the crisis, several studies have investigated the contagion channel between banks and sovereigns, especially as it fed into the debate over the importance of the Eurozone Banking Union. The BIS (2011) noted that several channels of contagion between banks and sovereigns could exist, on top of the direct exposures in the banks' balance sheets. The most important additional channels of contagion include: (i) the value of government bonds held as collateral (see e.g. Angeloni and Wolff, 2012); (ii) the comovement in rating downgrades between banks and sovereigns, which affect bank funding costs (Arezki et al., 2011); (iii) the role of government guarantees, which would be weakened when governments finances are in trouble (Brown and Dinc, 2011).

The economic and political economy origins of the 'diabolic loop' between banks and sovereigns have been investigated in e.g. Altavilla et al. (2015), who found that yield seeking and moral suasion could explain the high share of domestic debt in banks portfolios in Europe.

De Marco and Macchiavelli (2015) also showed that state-owned banks or banks with former politicians on their board held a larger share of government bonds, and that this political pressure was twice as strong in countries with tighter financial constraints. In addition to political factors, Cornand et al. (2015) found that fiscal shocks, bond spreads, and volatility shocks explain the home bias in government debt.

Looking at the consequences of such tight relationships, several papers estimated the links between sovereign risk and bank credit risk. Altavialla et al. (2015) found that sovereign exposure doubled the response of banks' CDS spreads to the sovereign spreads.

Our paper is most closely related to De Bruyckere et al. (2013), who defined contagion as the extent of excess correlation between bank and sovereign spreads. De Bruyckere et al. (2013) found that contagion was stronger the larger the share of domestic bonds in the banks portfolios, the weaker the capital and liquidity positions of the banks, and the larger the debt ratios. However, our modelling of contagion is based on a measure of distress dependence, i.e. the probability of distress of a country conditional on a bank defaulting. This modeling is closer to what is meant in the literature on contagion, and since the emphasis is on dependence at tail events, the measure captures the idea of the 'diabolic loop' more accurately. The next section explains in detail how this measure is constructed.

3. Data and Construction of the Main Variables

Measure of distress dependence

We define our measure of distress dependence as the probability of distress of a country conditional on a bank defaulting. The conditional probability is constructed with the following method:

(i) For each country in our sample, the (marginal) probability of default of the sovereign *A*, and the (marginal) probabilities of default of all the banks (B, C, etc.) listed for that country (and for which data was available) were extracted from the individual CDS spreads of the country and its banks.[3]

(ii) Then, the joint probability of default of *A, B,* (for instance), *P (A, B),* is obtained using the CIMDO methodology developed by Segoviano (2006). This methodology is used to estimate the multivariate empirical distribution (CIMDO-distribution) that characterizes the probabilities of distress of banks and the sovereign under analysis and their distress dependence. The CIMDO methodology is a non-parametric methodology, based on the Kullback (1959) cross-entropy approach, which does not impose parametric pre-determined distributional forms; whilst being constrained to characterize the empirical probabilities of distress observed for each institution under analysis (extracted from the CDS spreads). The joint probability of distress of the entire group of sovereign and banks and all the pair wise combinations of sovereign-banks within this group, i.e., *P (A, B); P (A,C); P (B, C),* etc. , are estimated from the CIMDO-distribution.

We describe the method in more detail here. For illustration purposes, we focus on a 'portfolio' containing two assets only, whose logarithmic returns are characterized by the random variables *x* and *y*.The objective is to minimize the 'distance' $C[p,q]$ between a prior multivariate distribution and a posterior distribution

$C[p,q]=\int\int p(x,y)\ln\left[\frac{p(x,y)}{q(x,y)}\right]dxdy$, where q(x,y) the is prior distribution and *p(x,y)* the posterior distribution.

The information provided by the CDS spreads (the recovered marginal probability of default) for each asset in incorporated to the minimization problem as moment-consistency constraints of the form:

$$\int\int p(x,y)\,\chi_{\left(x_d^x,\infty\right)}dxdy=PoD_t^x,\int\int p(x,y)\,\chi_{\left(x_d^y,\infty\right)}dydx=PoD_t^y$$

where $p(x,y)$ is the posterior multivariate distribution that represents the unknown to be solved. PoD_t^x and PoD_t^y are the empirically observed probabilities of default (PoDs) for

[3] We assume a recovery rate of 40%, as commonly used in the literature.

each borrower in the portfolio and $\chi_{\left(x_d^x,\infty\right)}, \chi_{\left(x_d^y,\infty\right)}$ are the indicating functions defined with the default thresholds for each borrower in the portfolio. In order to ensure that $p(x,y)$ represents a valid density, the conditions that $p(x,y)\geq 0$ and the probability additivity constraint, $\iint p(x,y)\,\mathrm{dxdy}=1$, also need to be satisfied. Imposing these constraints on the optimization problem guarantees that the posterior multivariate distribution contains marginal densities that in the region of default are equalized to each of the borrowers' empirically observed probabilities of default. The CIMDO density is recovered by minimizing the functional

$$
\begin{aligned}
\min_p L \quad = \quad & \int\int p(x,y)\left(\ln p(x,y) - \ln q(x,y)\right)dxdy \\
& +\lambda_x\left[\int\int p(x,y)\chi_{\left[X_d^x,\infty\right]}dxdy - PoD_t^x\right] \\
& +\lambda_y\left[\int\int p(x,y)\chi_{\left[X_d^y,\infty\right]}dydx - PoD_t^y\right] \\
& +\mu\left[\int\int p(x,y)dxdy - 1\right]
\end{aligned}
$$

where $\lambda_1 \lambda_2$ represent the Lagrange multipliers of the moment-consistency constraints and represents the Lagrange multiplier of the probability additivity constraint.

By using the calculus of variations, the optimization procedure is performed. The optimal solution is represented by the following posterior multivariate density as

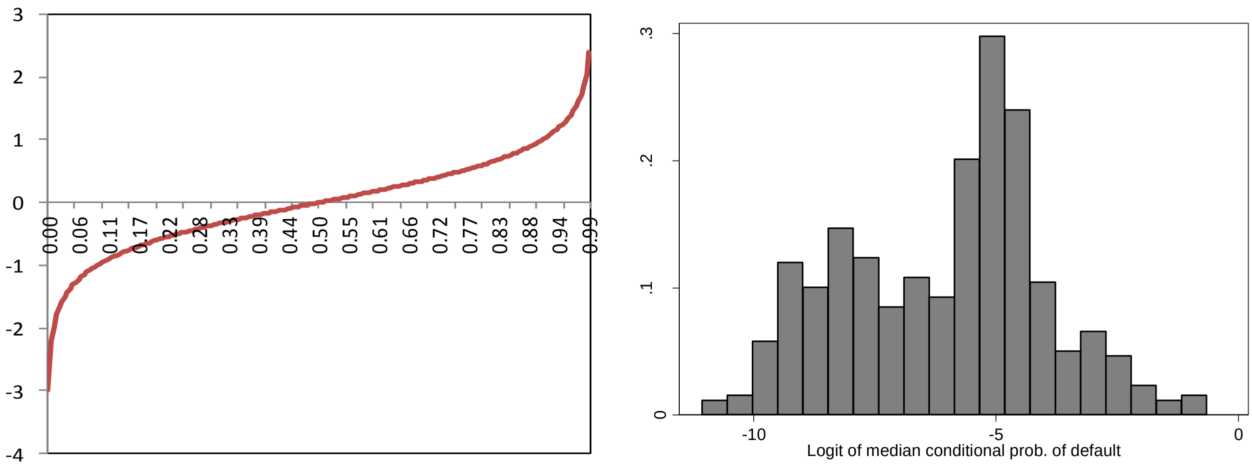
$$
\hat{p}(x,y) = q(x,y)\exp\left\{-\left[1+\mu+\left(\lambda_x\chi_{\left[X_d^x,\infty\right]}\right)+\left(\lambda_y\chi_{\left[X_d^y,\infty\right]}\right)\right]\right\}
$$

(iii) Finally, the conditional probability of default P(A/B) is obtained by using the Bayes' law: *P(A/B) = P(A,A$_B$) / P(B).*

Contrary to simple correlations, or relationships based on the first few moments of different default probability series, the CIMDO methodology enables us to characterize the entire distributional links between these series, i.e. linear (correlations) *and* non-linear distress dependence, and their evolution throughout the economic cycle. This reflects the fact that dependence increases in periods of distress. This is a key technical improvement over traditional risk models, which usually account only for linear dependence (correlations) that are assumed to remain constant over the cycle, over a fixed period of time, or over a rolling window of time. Such dependence structure is characterized by a copula function (CIMDO-copula), which changes at each period in time, consistently with changes in the empirically observed distress probabilities.

Finally, for each set of bank-to-sovereign contagion probabilities {*P(A/B)*, *P(A/C)*,*P(A/D)*…}, we keep only the median value, which we call the median probability of contagion. As is common when modeling probabilities, the logit transformation (see left hand side of figure 1) was computed so as to ensure that the dependent variable is distributed on]-∞, +∞[, and so that probabilities estimated from the model remain between 0 and 1. The logit transformation also ensures the dependent variable of the model is well behaved (see right hand side of figure 1).

Figure 1. Logit transform and Distribution of the dependent variable



The Market Price of Risk under Distress

The credit crisis raised the importance of assessing the underlying dynamics of default probabilities. These probabilities can be estimated by using models of the value of the firm (e.g. the Black-Scholes-Merton model) or by relying on measures of market assessment, such as CDS spreads.

CDS spreads are widely used to generate risk-neutral probabilities of default[4]. Yet, these spreads, just as any other market risk indicator, are in fact asset prices that depend on the price of risk (i.e. the cost of insurance against a distress event) as well as idiosyncratic news on the actual probability of default of a specific firm or sovereign. Therefore, it is necessary to control for the price effect of risk aversion in order to be able to use CDS spreads to compute probabilities of default.

We use the method developed by Espinoza and Segoviano (2011), which we summarize here, to estimate the market price of risk under distress. This price is needed what is obtained from CDS spread is a risk-neutral probability $\hat{\pi}_d$

[4] These probabilities of default are estimated by dividing the level of the Credit Default Swap (CDS) by its Recovery Rate (R). See Luo (2005).

On the contrary, what we are interested in is the actual probability of default, which is linked to the risk-neutral probability by the equation:

$$\pi_d = \frac{\hat{\pi}_d}{R^f_{t+1} E_t[m_{t+1} | \; distress]}$$

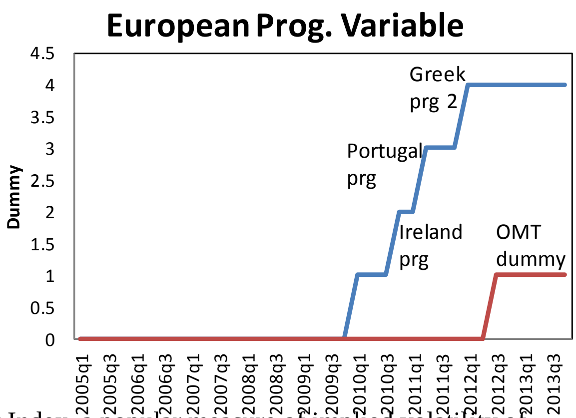
where R^f_{t+1} , the gross, risk-free, interest rate can be proxied by the OIS rate, but where the market price of risk under stress $E_t[m_{t+1} | \; distress]$ is not observable. Calibrations based on the shape of the utility functions, derived from a consumption-CAPM version of equation (1) could also be used, but the link between asset prices and utility functions is subject to many difficulties, as evidenced by the numerous puzzles spurred by the equity risk-premium literature. Thus, the method developed in Espinoza and Segoviano (2011) estimate it from market prices, making use of the conditional expectation of the market price of risk

$$E_t[m_{t+1} | \; distress] = E_t[m_{t+1} | \; m_{t+1} > threshold] = \mu_t + \sigma_t \lambda(\alpha_t)$$

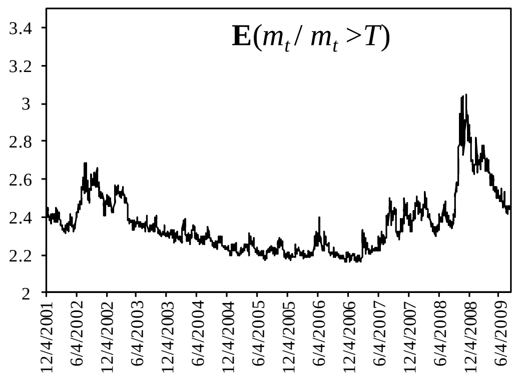
where $\alpha_t = (threshold - \mu_t)/\sigma_t = (T - \mu_t)/\sigma_t$; $\mu_t = E_t[m_{t+1}]$; $\sigma_t = \text{var}_t[m_{t+1}]$; $\lambda(\alpha) = \varphi(\alpha)/[1 - \Phi(\alpha)]$; and $\Phi(.)$ is the standard normal cumulative distribution function. λ (α) is the inverse Mills ratio. The calculation requires using an estimate of the mean $\mu_t = E_t[m_{t+1}]$. The VIX[5] is used as it has been suggested in the literature as a good proxy and as it was shown to correlate strongly with the principal component of returns. Figure 2 shows the evolution of the market price of risk. It implies that the cost of an insurance that would yield 1 dollar in the worst 16th percentile states would have evolved between 0.36 and 0.50 cents (0.16 times 2.2 and 0.16 times 3.1).

Figure 2. Market price of risk under distress

Figure 3. Dummy variables



[5] VIX is the Chicago Board Options Exchange Volatility Index, a popular measure of implied volatility of S&P 500 index options.



Other Variables

We will estimate a model to explain the probability of contagion (from banks to sovereign) as a function of macroeconomic, financial and fiscal fundamentals. The list of possible fundaments include:

Macroeconomic and financial outlook: Growth prospects and valuation prospects in the banking sector are expected to reduce the probability of contagion. We thus include as explanatory variables the GDP growth forecast and the price to book value of banks.

Underlying financial characteristics: Large banks balance sheets and high leverage are likely to increase losses to the sovereign in the event of a bank default. We thus include banks loans/GDP and the banking sector capital/asset ratio to investigate the effect of leverage and buffers.

Underlying fiscal characteristics: A high stock of short-term public debt is likely to increase the probability of default of the sovereign. In addition, dependence of the sovereign on domestic banks' financing is also likely to increase funding risk for the sovereign if a bank defaults. We thus include short-term public debt/GDP and government bonds held by domestic banks (as a share of /banks' capital) as measures of the extent fiscal stress and dependency on the banking sector.

Control variables: Earlier papers in the literature on contagion to sovereigns (De Santis, 2012; Caceres et al. 2010) have identified international spillovers and developments in other crisis countries as key factors explaining sovereign spreads. Since our focus in on domestic characteristics, we do not investigate this channel here. Rather, we control for the intensification of the euro debt crisis by including a dummy, step, variable that takes the value 1 after the first Greek Program was approved (2010-Q1). This variable is assumed to increase with the series of 'Troika programs' as showed in Figure 3. We also add an 'OMT' dummy variable that takes the value 1 on and after 2010-Q3 to capture the European announcements that the ECB would do 'what it takes' to protect the euro.

4. Stylized facts

Developments during the crisis

Our final dataset is a quarterly dataset for 13 European countries, the US and Japan, over the period 2005q1-2012q4. We describe here our data by grouping countries under three groups:

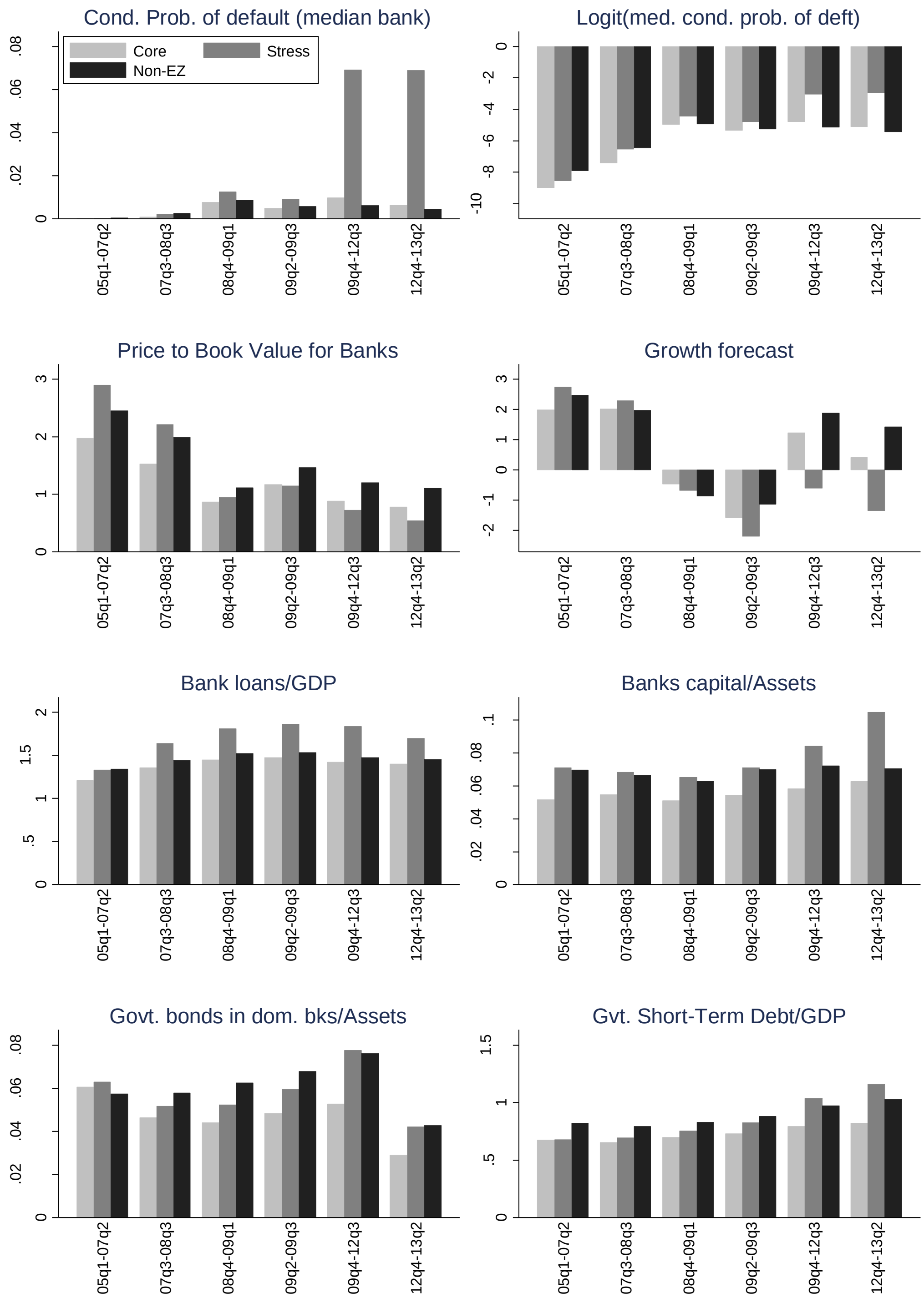
(i) the core eurozone countries (Austria, Belgium, France, Germany, Netherlands)
(ii) the eurozone countries under stress or in a Troika program (Greece, Ireland, Italy, Spain, Portugal)
(iii) countries outside the eurozone (Sweden, Switzerland, Japan, the UK, and the US)

We also distinguish between 6 different periods:
(i) pre-crisis (2005q1-2007q2)
(ii) crisis build-up (2007q3-2008q3)
(iii) the Lehman-related banking crisis (2008q4-2009q1)
(iv) the 'global stimulus' period (2009q2-2009q3)
(v) the Euro Area debt crisis (2009q4-2012q3)
(vi) the post-OMT period (2012q4-)

Figure 4 below shows that the probability of contagion has increased dramatically in the stress countries. For the other countries, the increase was more moderate, and the risk of contagion was mitigated by the different policy measures (fiscal stimulus, OMT) taken since 2009. Nevertheless, the outlook for the economy and for banks, which deteriorated in all countries since 2007, remain poor. The growth forecast has recovered for countries outside the eurozone, but even in these countries, valuations in the banking sector indicate a pessimistic outlook.

As the banking sector was re-structured in most of the crisis countries, the bank loans/GDP ratio declined in the group of countries under stress, and the capital/asset ratio increased. However, banks recapitalizations implied an increasing stock of public debt, and for countries under stress, a difficult situation in international capital markets led to a stronger dependence on financing from domestic banks.

Figure 4. Stylized facts



Bivariate relationships

A first look at scatter plots (figure 5) indicates that the bivariate relationships between the different potential explanatory variables and the probability of default of the sovereign (conditional on a bank default) behave as expected. There is a strong negative relationship between the price to book value for banks and the conditional probability of default of the sovereign, and between the growth forecast and the same conditional probability of default. Both relationships indicate that the macro-economic and financial outlook is relevant for the probability of contagion to the sovereign, even though the contagion indicator used is a *conditional* probability (note also that the two explanatory variables price-to-book value and growth forecast are strongly correlated, see table 1). There are some differences in the slope coefficients when looking at the different groups of countries (the regression analysis with allow us to test for how significant these differences are).

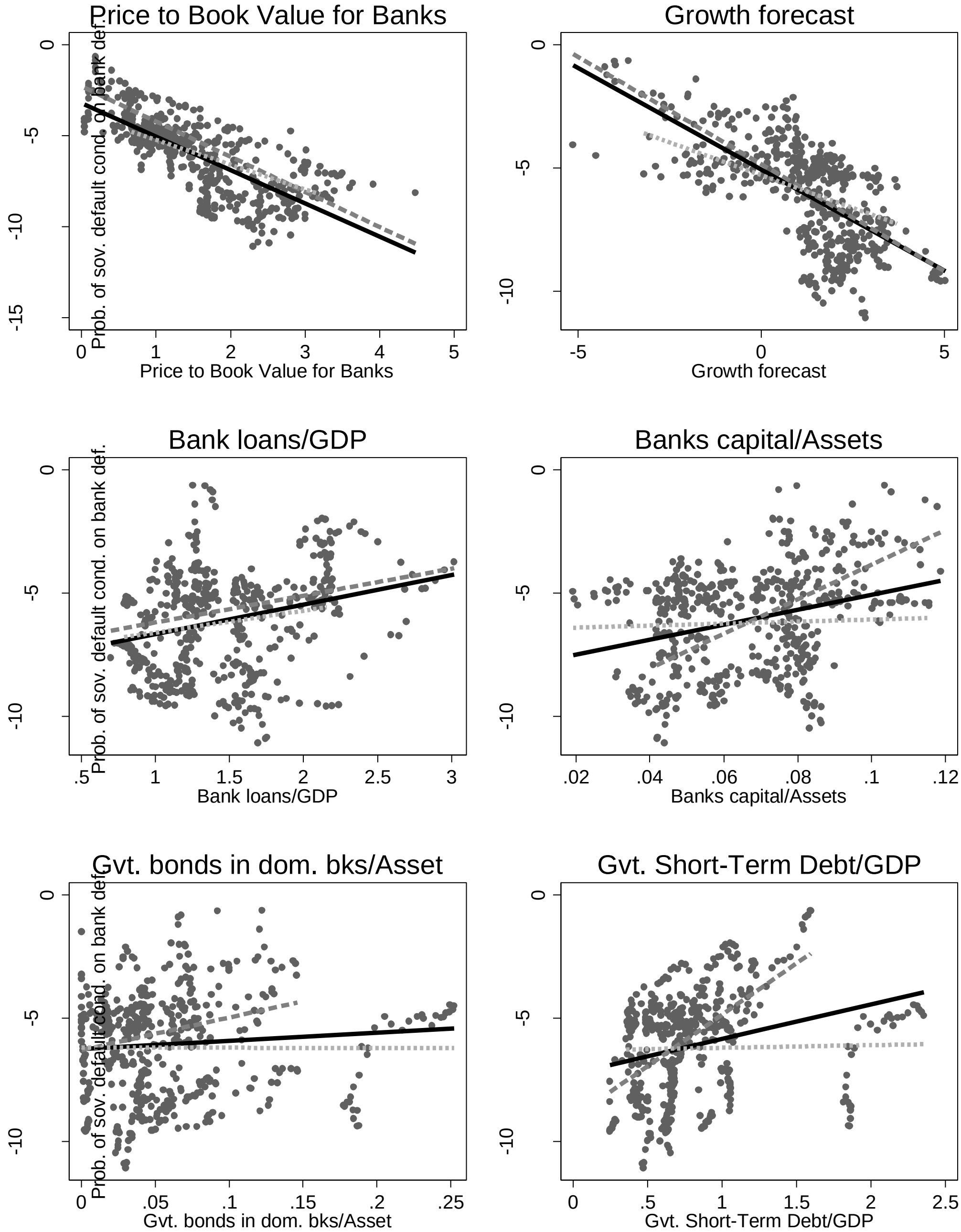
Looking at banking-specific characteristics next, the scatter plots indicate that the volume of banks loans is positively related to the index of contagion. On the other hand, our measure of the extent of buffer in the banking system (banks capital/assets) is positively related to the index of contagion. This result is unexpected, and it will thus be important to assess whether this linkage remains unintuitive in the multivariate regressions.

Signs of fiscal stress are also correlated to the contagion index, especially for the countries under stress. Both short-term public debt and government bonds held by domestic banks are positively correlated with the indicator of contagion. Note that although the two variables are thought to capture different sources of vulnerabilities, they are strongly correlated (table 1). The regression exercise discussed below will allow to us to assess whether both sources of vulnerabilities can simultaneously be included in the model.

Table 1. Correlation matrix of variables

	Contagion index	GDP forecast	Banks Price/ Book	Loans/ GDP	Banks capital	ST public debt/ GDP	Bonds in dom banks	Price of risk
Contagion index	1.00							
GDP forecast	-0.66	1.00						
Banks Price/Book	-0.74	0.61	1.00					
Loans/GDP	0.26	-0.27	-0.28	1.00				
Banks capital	0.29	-0.11	0.04	-0.09	1.00			
ST public debt/GDP	0.28	-0.26	-0.32	-0.17	-0.13	1.00		
Bonds in dom banks	0.11	-0.11	-0.13	-0.31	-0.21	0.90	1.00	
Price of risk	0.33	-0.36	-0.30	0.15	-0.09	-0.02	-0.06	1.00

Figure 5. Bilateral relationships



Note: black regression line for the overall sample; dark grey line for the stress country group; light grey regression line for the non-eurozone country group

4. Regression Results

Main results

Using our quarterly data for 13 European countries, the US and Japan over the period 2005q1-2012q4, we estimate a panel model linking the logit of the index of contagion to the different explanatory variables (noted as $X_1 \ldots X_n$ in equation 9):

$$\log(P_{it}/(1-P_{it})) = \beta_1 X_{1,it} + \ldots \beta_n X_{n,it} + \gamma_1 MkrPr_t + \gamma_2 EZProg_t + \gamma_3 OMT_t + \alpha_i + \varepsilon_{it} \quad (9)$$

In addition, we add the three time variables capturing global risk (the market price of risk) and the developments in the eurozone (the European program variable, EZProg, and the OMT dummy), as discussed above. The baseline regression is presented in column 1 of Table 2. The model is estimated with fixed effects α_i (i.e. country-specific dummies) because the Breusch-Pagan test rejected the homogeneity assumption of no-country specific effects (regression in column 2), and because the Hausman test rejected the random effect model (Column 3). In addition, the baseline model estimates a country group-specific slope coefficient for the price-to-book value because we found that the relationship between this variable and the contagion index is very different for the core Euro countries (group 1) from that of the countries under stress (group 2) or the non-eurozone countries (group 3). In addition, differentiating the effect of the price to book value by group was found to be critical to ensure that the residuals of the model are well behaved. [6]

The baseline model presented in column 1 confirms the main findings obtained looking at the bilateral relationships. Growth projections and price-to-book values for banks are negatively related to the index of contagion (despite the strong correlation between the two variables, they are both significant at the 1 percent confident level in the multivariable model). Price-to-book values in the banking sector matter less however when the comparison is done within countries under stress or within countries outside the eurozone.

Unfortunately, the magnitude of the coefficients cannot be interpreted simply because the dependent variable is the logit transformation of the conditional probability of default, and thus the model is non-linear in P_t. However, the model is linear in $\log(P_t/(1-P_t))$. We will thus present in the next section the contributions of the different variables to logit of P_t along the evolution of P_t itself.[7]

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[6] The results of two panel integration tests are presented at the bottom of the table; the tests reject the null hypothesis that residuals are integrated in all specifications presented in the table.

[7] An alternative would be to present the marginal effect of each variable at some specific values of the other variables; however, this would be complicated by the need to differentiate by country groups.

Table 2. Regression results

VARIABLES	(1) Panel Fixed effects (FE)	(2) Pooled OLS	(3) Panel random effects	(4) Panel FE time dummies	(5) Panel FE by group	(6) Panel FE by group	(7) Panel FE by group	(8) Panel FE by period	(9) Panel FE by period	(10) Panel FE by period	(11) Panel FE by period
Growth forecast	-0.112***	-0.362***	-0.112***	-0.164***		-0.105***	-0.0706**		-0.141***	-0.159***	-0.163***
	[-3.474]	[-12.16]	[-3.658]	[-4.382]		[-3.368]	[-2.332]		[-4.147]	[-4.969]	[-4.805]
Price to Book Value for Banks * I(group=1)	-1.886***	-1.257***	-1.886***	-0.438***	-1.734***	-1.874***	-1.616***	-1.728***	-1.792***	-1.758***	-1.714***
	[-11.32]	[-9.517]	[-12.56]	[-3.624]	[-10.29]	[-11.18]	[-10.16]	[-9.902]	[-10.82]	[-10.83]	[-10.31]
Price to Book Value for Banks * I(group=2)	-0.815***	-0.671***	-0.815***	-0.139	-1.036***	-0.822***	-0.648***	-0.805***	-0.722***	-0.669***	-0.679***
	[-6.107]	[-6.610]	[-7.070]	[-1.645]	[-5.592]	[-5.942]	[-5.131]	[-5.987]	[-5.478]	[-5.228]	[-5.207]
Price to Book Value for Banks * I(group=3)	-0.546***	-0.687***	-0.546***	0.731***	-0.476***	-0.682***	-0.770***	-0.358**	-0.489***	-0.348**	-0.394***
	[-4.144]	[-6.328]	[-4.451]	[5.716]	[-3.573]	[-4.940]	[-6.212]	[-2.410]	[-3.757]	[-2.437]	[-2.892]
Bank loans/GDP	1.849***	0.0529	1.849***	1.357***	1.926***	1.664***	1.897***	1.730***	1.878***	1.664***	1.869***
	[6.457]	[0.491]	[6.768]	[6.360]	[6.628]	[5.902]	[6.795]	[5.909]	[6.831]	[6.108]	[6.880]
Banks capital/Assets	-6.364*	13.22***	-6.364*	-5.319**	-7.145*	-12.04***	-13.05***	-7.892**	-3.236		-2.190
	[-1.760]	[6.231]	[-1.784]	[-2.108]	[-1.960]	[-2.993]	[-3.346]	[-2.151]	[-0.878]		[-0.600]
Govt. bonds held by dom. banks/Assets	8.847***	2.605	8.847***	6.170***	7.608***		11.86***	8.222***		8.687***	6.295***
	[3.853]	[1.121]	[3.375]	[3.253]	[3.183]		[4.904]	[3.525]		[3.986]	[2.700]
Gvt. Short-Term Debt/GDP	2.833***	-0.248	2.833***	2.060***	2.885***	3.209***		2.684***	2.638***	2.660***	
	[7.853]	[-0.873]	[7.678]	[8.254]	[7.666]	[7.752]		[7.345]	[7.432]	[7.628]	
Mkt. Price of risk	17.80***	21.07***	17.80***		16.24***	16.63***	19.70***	17.70***	17.82***	19.52***	18.87***
	[8.023]	[7.412]	[8.086]		[7.271]	[7.265]	[9.180]	[7.852]	[7.943]	[8.566]	[8.350]
European programs variable	0.334***	0.606***	0.334***		0.350***	0.325***	0.279***	0.342***	0.277***	0.227***	0.232***
	[8.429]	[12.98]	[7.819]		[8.905]	[8.163]	[6.978]	[8.631]	[6.983]	[5.915]	[5.903]
OMT dummy	-0.501***	-0.904***	-0.501***		-0.539***	-0.485***	-0.397***	-0.424***	-0.456***	-0.379***	-0.399***
	[-4.052]	[-5.950]	[-3.414]		[-4.339]	[-3.991]	[-3.268]	[-3.391]	[-3.791]	[-3.029]	[-3.363]
Growth forecast * I(group=1)					-0.230***						
					[-5.403]						
Growth forecast * I(group=2)					0.0229						
					[0.478]						
Growth forecast * I(group=3)					-0.190***						
					[-3.870]						
Govt. bonds held by dom. banks/Assets * I(group=1)						-9.521					
						[-1.366]					
Govt. bonds held by dom. banks/Assets * I(group=2)						15.24***					
						[5.481]					
Govt. bonds held by dom. banks/Assets * I(group=3)						-2.055					
						[-0.434]					
Gvt. Short-Term Debt/GDP * I(group=1)							7.425***				
							[6.782]				
Gvt. Short-Term Debt/GDP * I(group=2)							4.706***				
							[10.04]				
Gvt. Short-Term Debt/GDP * I(group=3)							1.156***				
							[2.931]				
Growth forecast * I(time<2010q1)								-0.178***			
								[-4.102]			
Growth forecast * I(time>2010q1)								-0.0222			
								[-0.587]			
Govt. bonds held by dom. banks/Assets * I(time<2010q1)									4.338		
									[1.577]		
Govt. bonds held by dom. banks/Assets * I(time>2010q1)									8.956***		
									[3.902]		
Banks capital/Assets * I(time<2010q1)										-13.10***	
										[-3.295]	
Banks capital/Assets * I(time>2010q1)										-4.593	
										[-1.316]	
Gvt. Short-Term Debt/GDP * I(time<2010q1)											1.938***
											[4.983]
Gvt. Short-Term Debt/GDP * I(time>2010q1)											2.617***
											[7.465]
R-squared	0.911	0.816	0.904	0.957	0.914	0.914	0.919	0.913	0.914	0.915	0.917
Im-Pesara-Shin p-value	0.00820	0.0279		0.00850	0.00789	0.00995	0.000781	0.00543	0.00385	0.00277	0.00168
Phillips-Perron L* p-value	0.00405	0.0169		0.0304	0.00174	0.00376	0.000901	0.00315	0.00220	0.00208	0.00120
Number of countryid			15								
Breusch-Pagan p-value			0								
Hausman test p-value			0								

Robust t-statistics in brackets
*** p<0.01, ** p<0.05, * p<0.1

Financial sector structural characteristics also affect the contagion index. High levels of credit in the economy (bank loans/GDP) and low buffers in the banking sector (low levels of banks' capital) are strongly related to the contagion index. This result runs counter to the bivariate, unintuitive, scatter plot found earlier. It is thus important to condition the model (as done in a multivariate regression) to estimate effect of bank capital on the probability of contagion. Finally underlying weaknesses in the public sector (short-term debt/GDP) and high sovereign-banking financial relationships (government bonds held by domestic debt) contribute to the risk of contagion. Note that both variables remain significant in this multivariate model. Overall, the model explains well the variance in the data (the R2 is 0.92). Even when country fixed effects are removed, 50 percent of the variance is explained by the model.

Robustness

The variables controlling for global development (market price of risk, the European Program variable, and a time dummy corresponding to the OMT-related announcements) were found to be both significant and with the expected sign in the baseline regression. An alternative specification is to include time dummies to control for common factors, i.e. for any potential factor affecting all countries similarly. This estimation is shown in column 4. All the coefficients keep the correct sign (expect for the price to bank value for non-eurozone countries) and remain significant, although there are significant differences in the coefficient estimates compared with the baseline model of column 1.

We also explore the possibility that some of the explanatory variables have different effects for different country groups. Columns 5-7 present some alternative models where some variables have been split by country group. Column 5 shows the model where the slope coefficient for the growth forecast is estimated separately for the different country groups. Growth forecasts do not seem to affect the contagion index for those countries under stress (group 2), probably because all these countries already suffer from a high level of contagion and poor growth forecasts (data heterogeneity is reduced significantly when looking at subsamples). The coefficient of growth forecast for the non-eurozone countries is similar to that for the whole sample. The coefficients for the other variables are robust to this modification of the model.

Column 6 shows that the volume of government bonds held domestically is most important for the stress countries. The variable is not significant for the core eurozone countries and for countries outside the eurozone. Similarly, short-term debt is less important for countries outside the euro area. As has been extensively discussed during the recent euro area debt crisis, fiscal positions matter much less for countries that can issue their own currency.

Finally Columns 8-11 estimate different coefficients for different sub-periods (pre- and post- the first Greek program). The growth outlook and buffers in the banking sector would have mattered much more pre-crisis. On the contrary, since the crisis broke, the dependence of government financing on domestic banks and the stock of short-term debt have become more important.

5. Interpreting developments during the crisis

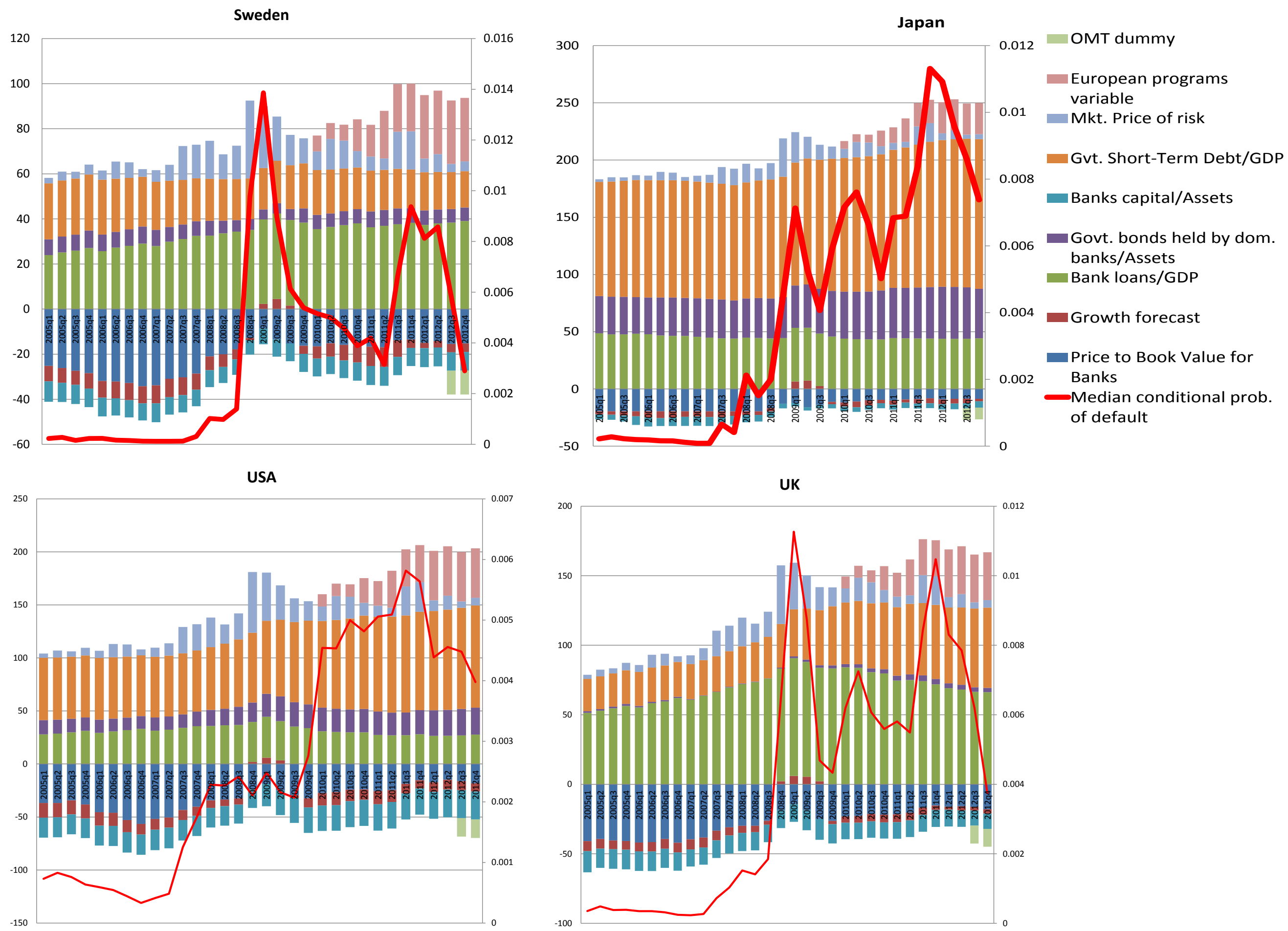
We now apply the model estimates (we choose the baseline regression presented in column 1 of table 2) to the 15 countries in our sample to interpret the evolution of the contagion index in each country (figures 6 to 8). The model estimates of the contributions of each factor[8] are shown for each country, along with the conditional probability of default itself (right-hand side scale).

A. Countries outside the Eurozone

We start describing our results for the countries in our sample that are outside the Eurozone. In Switzerland, the contagion probability has been overall small, despite the oversized banking sector (the ratio bank loans/GDP is the largest risk factor identified by the model in Switzerland). Favorable price to book values in the banking sector as well as a healthy fiscal position, contributed to the low probability of contagion. A moderate buildup in risk culminated immediately after the Lehman Brothers' collapse in 2009q1. The model associates the increased probability of contagion to the sharp reduction in the price-to-book value for Swiss banks, and to a higher market price of risk (or global risk aversion; both these effects could also be associated to the freezing in interbank markets, which is not modeled here). Banks valuation in Switzerland quickly recovered; global risk aversion decreased in 4 quarters, and by 2009q4, the contagion index in Switzerland had converged back to its low, pre-crisis, level.

Figure 6 – Countries outside the Euro Area

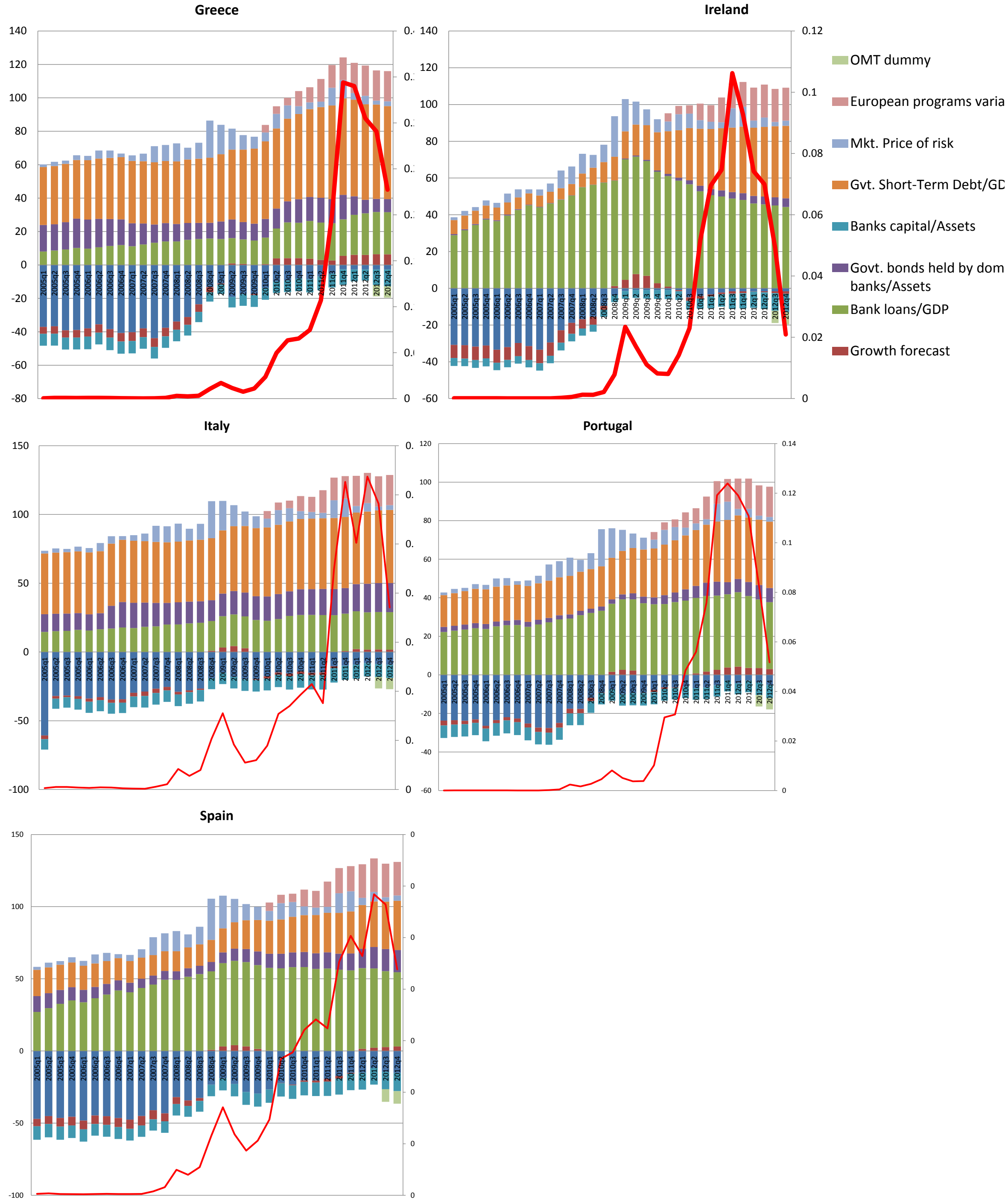
[8] For each country indexed by i, we show as stacked bars the values $100\ \beta_1 X_{1,it} /(Y_i^{max}-Y_i^{min})$, … , $100\ \beta_n X_{n,it} /(Y_i^{max}-Y_i^{min})$, $100\ [\gamma_1 \text{ Mkt Pr}_t + \gamma_2 \text{ EZProg}_{t+} \gamma_3 \text{ OMT}] /(Y_i^{max}-Y_i^{min})$, where Y_i^{max} and Y_i^{min} are, respectively, the highest and smallest values of $\log(P_{i,t} /(1-P_{i,t}))$ for each country i. Note that: (i) the contributions are contributions to the ***logit*** of the conditional probability of default (ii) we do not show the fixed effects α_i nor the residuals $\varepsilon_{it.}$ This explains why the stacked bars do not sum to the probability of default.



In Japan and the US, the two non-European countries in our sample, the estimated contagion probabilities are very small. In the US, public debt financial leverage are identified as the largest risk factor, whereas in Japan, the fiscal situation and the share of public debt held by domestic banks would be the major sources of risk. In both countries, risk increased as valuation of the banking sectors declined in 2008 and as the fiscal situation deteriorated since 2010. In Japan, the increasing share of public debt held domestically also contributed to the rise in the probability of contagion.

Sweden and the UK were affected by both the Lehman event and by contagion from the Euro debt crisis. Although Sweden and the UK are not part of the Euro Area, markets' perception of banking-sovereign contagion risks increased for these countries during the Euro Area debt crisis – the difference with Switzerland is telling in that respect. For the UK, the deteriorating fiscal position may have explained this vulnerability, but the evolution of the conditional probability of default of Sweden cannot be explained by this factor. A speculative interpretation of this difference could be that membership in the European Union is an additional risk factor.

Figure 7 - Stress Euro Area Countries



B. Stress countries in the Eurozone

We now pay particular attention to the evolution of risk factors across the stress countries in Europe (Figure 7). We start with Greece. Between 2007 and 2009, the model identifies a build-up in risk, stemming principally from a weakening of buffers (banks' capital/asset ratio decreased) and a deterioration of the outlook for banks (the price to value ratio declined sharply). However, this did not affect significantly the conditional probability of default, even in the aftermath of the Lehman bankruptcy. But risks cumulated in 2010, tipping the balance to a situation of crisis, as the probability of contagion increased to levels higher than 25 percent. Because the logit model is non-linear, the marginal effect of risk factors is small when there are only a few factors of risk. However, as risk factors cumulate, the marginal effect of additional risk factors is large. This explains why the probability of contagion rose dramatically in 2010 when growth forecasts turned to negative and public debt rose sharply. In 2012, contagion risk decreased significantly (though it remained elevated). The model attributes this reduction to the fall in public debt held by domestic banks (which was engineered by the debt workout under the last Greek program) and to the OMT announcements.

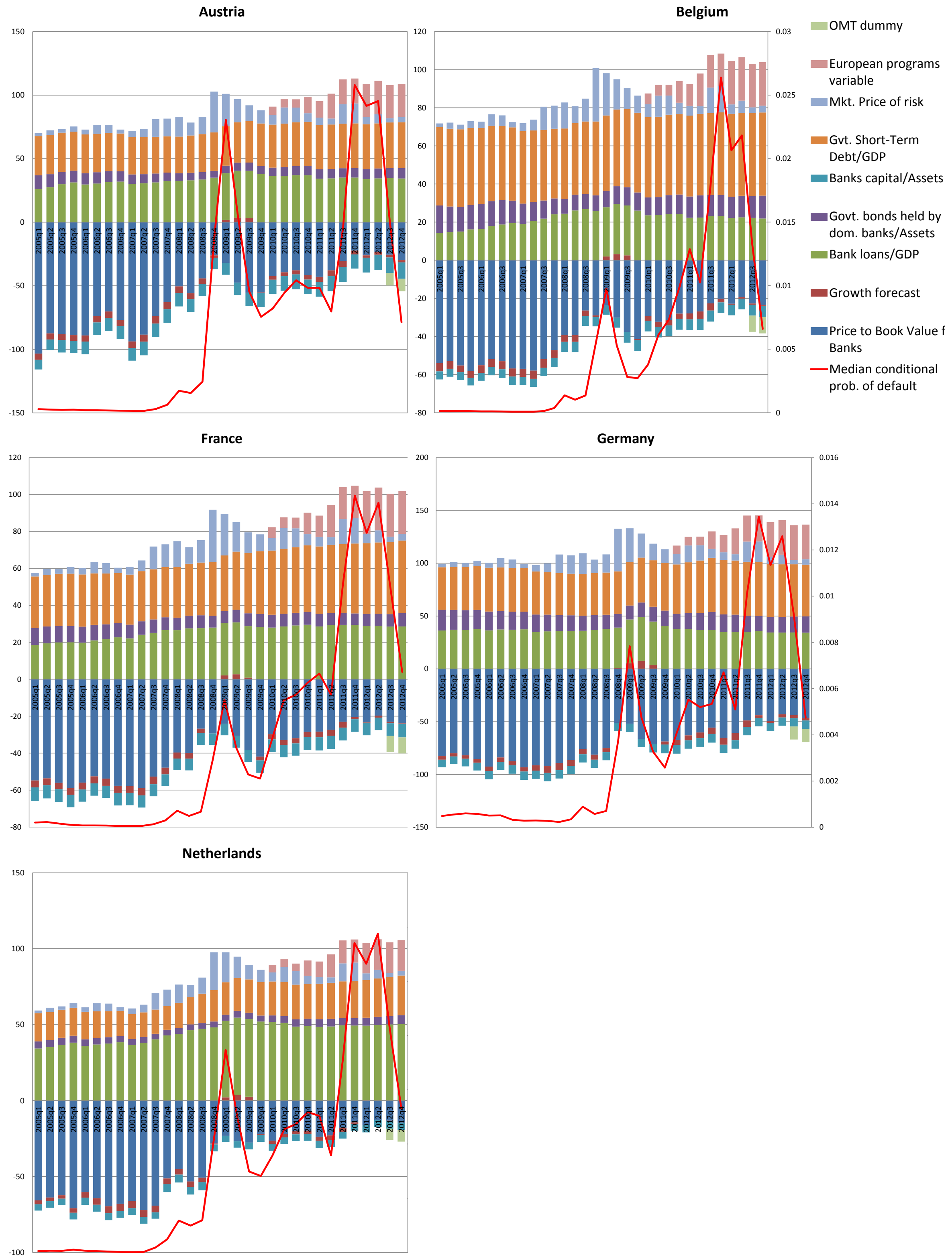
In Portugal, the deterioration of the outlook for banks as well as the fall in market capitalization weakened underlying buffers. The worsening fiscal position and the increasing portion of debt held domestically contribution to the heightened risk of contagion from banks to sovereign. Contagion from other euro area countries (as proxied by the euro area debt crisis variable) also increased the probability of contagion perceived by markets. In Ireland, the model identifies the excessive size of the financial sector as the main risk factor, and it is only partly mitigated by buffers in the banks' capital and bank's price to book value. Following the systemic outbreak in 2008q3, the conditional probability of default increased significantly, driven by global risk aversion, increased banks/GDP ratio, and a negative growth outlook. However, it was again the deteriorating fiscal position, and in particular the increased dependence of government finance to domestic banks that drove the major increase in the probability of contagion at the end of 2011. The model is unable to explain the reduction in the probability of contagion in 2012, but the explanation could lie in the reduction of contagion coming from the Euro Area, in particular after the Greek program was approved in 2012 (De Santis, 2012).

In Italy and Spain, underlying weaknesses explain well the increase in the probability of contagion. Italy's fiscal problems were apparent before the global crisis hit, and during the systemic outbreak, worsening deficits and a large and increasing share of public debt held domestically drove up the probability of contagion. However, in Italy, the spike in the conditional probability of default in 2012 seems to be explained solely by contagion from the Euro Area – no other underlying structural factor worsened significantly during the second half of 2011, when the probability of contagion exceed 6.5 percent. Similarly, the reduction in the probability of default since 2012q3 is probably explained by the OMT announcements un-modeled here). In Spain, the oversized banking system was the main structural risk factor before large deficits since 2008, and an increasing dependence of the government on domestic bank financing, worsened the bank-sovereign nexus. Since 2011, contagion from the Euro Area debt crisis and negative growth forecasts explain the addition jump in the conditional probability of default, which nearly reached 6 percent in 2012q2. As for Italy, the recent moderation in the probability of contagion is most likely explained by the ECB announcements on OMT.

C. Core Euro Area countries

All core euro area countries witnessed increases in the conditional probability of default during the period post-Lehman and during the buildup of the euro area debt crisis. For each country, the increases were of comparable (and small) magnitudes in these two phases. The increase in the contagion probability during the financial crisis build up was typically associated to a reduction in banks' price to book value and the increase in global risk aversion, whereas the increase during the euro area debt crisis was explained by contagion from the southern euro area program countries. The model also indicates some relevant differences across countries: in Belgium and France, public debt is a significant factor of risk (in particular debt held domestically in Belgium), whereas bank loans would be the most important source of risk in the Netherlands.

Figure 8- Core Euro Area Countries



6. Conclusion

The contagion channels between the banking sector and the sovereign are complex. The experience with financial crises has however shown that bank failures are a significant driver of fiscal stress, because banking crises are associated with persistent falls in output (20 to 30 percent of GDP in Laeven and Valencia's (2013) database) and because they often trigger large bailouts (fiscal costs are on typically between 2 and 20 percent of GDP; see again Laeven and Valencia, 2013). Nonetheless, these sovereign interventions have also been found to be needed to reduce the depth of banking crises.

This paper has investigated the determinants of distress dependence between banks and sovereigns, using a panel of advanced countries covering the period 2005q1-2012q4. We found distress dependence between the banking sector and the sovereign was stronger the weaker the macroeconomic and financial outlooks, the worse the fiscal positions, and the higher the share of public debt held by domestic banks. GDP growth projections and capital buffers in banks were more important determinants before the start of the euro-area debt crisis. Since then, the fiscal situation has become more relevant. The share of government bonds held by domestic banks was especially important for the GIIPS countries. On the contrary, the fiscal situation was less pertinent for countries outside the euro-zone, in line with the theoretical prior that countries with their own currencies can better handle banking and fiscal crises.

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