School of Economics and Management
TECHNICAL UNIVERSITY OF LISBON

Department of Economics

Andrea Amaral, Margarida Abreu and Victor Mendes

Contagion in Banking Crises: A Spatial Probit Model

WP 03/2010/DE

WORKING PAPERS

ISSN Nº 0874-4548

CONTAGION IN BANKING CRISES: A SPATIAL *PROBIT* MODEL

Andrea Amaral

FEP - Faculdade de Economia do Porto
R. Dr Roberto Frias
4200 Porto - Portugal

Margarida Abreu

ISEG – Instituto Superior de Economia e Gestão
Rua Miguel Lupi, 20
1200 Lisboa - Portugal
Email: mabreu@iseg.utl.pt

Victor Mendes*

CMVM - Portuguese Securities Commission
Avenida da Liberdade, 252
1250 Lisboa – Portugal
and CEFAGE-UE (Center for Advanced Studies in Management and Economics)
Largo dos Colegiais, 2
7000-803 Évora - Portugal
Email: victormendes@cmvm.pt
Telephone: + 351 213177000
Fax: + 351 213537077

September 23, 2009

JEL classification: C21, C25, G01, G21.
Keywords: Spatial Probit, banking crises, contagion.

ABSTRACT

We use a spatial *Probit* model to study banking crises and show that the probability of a systemic banking crisis depends on contagion and that this effect may result from business connections between institutions or from similarities between banking systems.

* Corresponding author. The author gratefully acknowledges partial financial support from FCT, program POCTI. The views stated herein are those of the author and are not necessarily those of the CMVM.

1. INTRODUCTION

Most of the existing empirical research on systemic banking crises evaluates the probability of a banking system going into crisis using *Probit* models. We use a spatial *Probit* model instead, which allows us to consider the contagion effect between banking systems without assuming that contagion exists. The spatial model lies on a web of connections between observations, through which instability waves propagate, summarized in the proximity matrix. Two ways of interpreting proximity are considered. One is to accept that two banking systems are close because flows of funds take place between them, either by way of transactions or capital participation. Contagion is the spreading of a crisis to neighbouring economies which are strongly dependent and connected. This contagion is based on the fundamentals and interdependence of economies (Dornbusch et al. 2000). The other is to identify structurally similar banking systems. Here we have what we call a *mimetic contagion*, ie, the banking systems may not be operationally connected, but as they have similar characteristics the agents expect that whatever has affected banks in one system will also affect banks in other countries and react accordingly. Contagion spreads through agents' behaviour and fundamental connections do not have to necessarily exist. The information that a country is going through a crisis causes "*wake up calls*" in other economies.

2. THE SPATIAL *PROBIT* MODEL

The spatial *Probit* model (version "Lag") is

$$Y_i = \rho w_{i1} Y_1 + \rho w_{i2} Y_2 + \ldots + \rho w_{iN} Y_N + \boldsymbol{X}_i \boldsymbol{\beta} + \varepsilon_i \qquad (1)$$

where Y_i is the crisis indicator, $\boldsymbol{X}_i$ is the vector of explanatory variables, ρ measures contagion, w_{ij} represents the proximity between countries (i,j), and ε_i is the random disturbance. It represents a substantive spatial dependence (Anselin 1999); what happens with the *i*-th observation depends on its links with the other observations.

The other possibility is to consider the links as secondary: the agent's actions are correlated because they suffer influence from a common shock. It is the "Error" version, in which λ is the contagion parameter:

$$Y_i = \boldsymbol{X}_i \boldsymbol{\alpha} + \varepsilon_i \text{ with } \varepsilon_i = \lambda \sum_{j=1}^{n} w_{ij} \varepsilon_j + u_i \qquad (2).$$

Apparently, the differences of model (1) against the traditional *Probit* model aren't significant; it is just about including a "crisis indicator average" of the remaining banking systems in the model. However, this procedure has profound implications in the information necessary to estimate the model and in the parameter interpretation.

The elements w_{ij} form the proximity matrix. The matrices we build try to recreate the real mesh of connections between banking systems and not through entropy maximization, as in Wells (2002) and Degryse and Nguyen (2004). Entropy maximization assumes that each element establishes equal relations with all the others. This assumption is criticized in the context of a given banking system, and influences the reliability of the findings. It would be less realistic in our work for we analyze different banking systems, not just one.

The proximity matrix is a *proxy* for the operational connections between banking systems. We use the exports ($\mathbf{W_x}$), disaggregated by destination: countries with intense commercial flows are countries with strongly connected banking systems. We use exports here as a *proxy* for the interdependency level of the banking systems, and not because international trade is a contagion channel.

A second matrix ($\mathbf{W_{ba}}$) is also built with the objective of measuring the existence of contagion by imitation. It captures the similarities between the banking structures of each pair of countries via the degree of the restrictions imposed on bank activities. Countries with similar banking systems exhibit equivalent values and therefore the distance between them is smaller.

3. Dataset and Variables

The sample includes information for 87 countries in the year 1998, and the following variables: CRIS = 1 if the country's banking system is in crisis (Caprio and Klingebiel's 2003 chronology is used); Inf = Inflation Rate; GDPg = GDP real growth rate; PubExpenses = Public expenses in % of GDP; PCI = *per capita* income; Dep = 1 if there is deposit insurance; ETA = Equity-to-Total Assets ratio; ROA = Return on

Assets; LIQ = Loan-to-deposit ratio; SDAssets = standard deviation of the log (total assets); Quality = Loan loss reserves-to-total assets ratio; CV_ROA = Coefficient of variation of ROA; CV_LIQ = Coefficient of variation of LIQ; HighROA = Percentage of banks with above average ROA; HighLIQ = Percentage of banks with above average LIQ. The sources of information are the World Bank, IMF and Bankscope.

4. RESULTS

The spatial model is estimated by the Recursive Importance Sampling (RIS) method, taking the estimates of the traditional *Probit* as initialization parameters. Results are in Table 1, and are structurally more robust than those of the traditional model. The inflation rate has a negative impact, as opposed to the one obtained by Demirgüç-Kunt and Detragiache (1997, 1999). One possible justification may be the fact that the sample's average inflation rate is low[1], and therefore any rise allows bank profitability to increase (Boyd and Champ 2006). The negative sign of PubExpenses may be linked to the frequent use of public expenses as a policy mechanism, and is consistent with Demirgüç-Kunt and Detragiache (1999). Countries with higher PCI levels and with deposit insurance are more stable (Barth el al. 1999, 2001). Results suggest that the minor incentive to deposit runs resulting from the implementation of deposit insurance schemes overcompensates the negative effects of moral hazard.[2]

Countries in which banks have higher ETA achieve greater stability. The negative sign of LIQ indicates that a reduction in the average banking system liquidity harnesses its stability. Although increased liquidity heterogeneity contributes to stability, one cannot say the same in regard to the profitability heterogeneity. Estimates for the ROA, asset quality and heterogeneity coefficients are equally robust.

Table 1– Estimation results, spatial *Probit* (dependent variable: CRIS)

	W_{ba} Lag	W_{ba} Error	W_x Lag	W_x Error	Traditional Probit
Const	5.794	6.891	8.211	6.607	4.473
	(+9.05)**	(+14.69)**	(+14.27)**	(+14.21)**	(+1.50)
Inf	-0.054	-0.062	-0.059	-0.058	-0.039

[1] Excluding Indonesia and Romania, the average inflation rate in the crisis (stable) countries is 6% (6,6%).
[2] This contradicts the findings of Demirgüç-Kunt and Detragiache (1997, 2000)

	(-14.99)**	(-16.25)**	(-16.51)**	(-17.19)**	(-1.81)*
GDPg	-0.299	-0.314	-0.329	-0.298	-0.204
	(-25.77)**	(-24.16)**	(-20.92)**	(-25.04)**	(-2.71)**
PubExpenses	-0.155	-0.155	-0.171	-0.155	-0.105
	(-19.51)**	(-19.14)**	(-19.30)**	(-19.05)**	(-2.01)**
PCI	-0.022	-0.023	-0.024	-0.022	-0.015
	(-15.10)**	(-14.69)**	(-14.18)**	(-14.75)**	(-1.55)
Dep	-0.354	-0.251	-0.213	-0.303	-0.208
	(-3.96)**	(-2.83)**	(-2.34)**	(-3.46)**	(-0.37)
ETA	-0.047	-0.043	-0.074	-0.046	-0.032
	(-6.43)**	(-5.90)**	(-7.96)**	(-6.31)**	(-0.68)
ROA	-0.444	-0.452	-0.491	-0.438	-0.301
	(-19.10)**	(-19.06)**	(-18.16)**	(-18.49)**	(-1.98)**
LIQ	-0.028	-0.029	-0.027	-0.027	-0.018
	(-10.94)**	(-10.98)**	(-10.39)**	(-10.53)**	(-1.13)
SDAssets	0.236	0.217	0.204	0.260	0.180
	(+2.53)**	(+2.32)**	(+2.12)**	(+2.78)**	(+0.29)
Quality	-0.010	-0.013	-0.035	-0.012	-0.009
	(-3.01)**	(-3.05)**	(-2.16)**	(-2.91)**	(-0.33)
CV_ROA	-0.032	-0.031	-0.035	-0.032	-0.022
	(-6.71)**	(-6.53)**	(-5.89)**	(-6.61)**	(-0.71)
CV_LIQ	1.336	1.344	1.814	1.374	0.945
	(+7.83)**	(+7.93)**	(8.38)**	(+8.02)**	(+0.87)
HighROA	-0.004	-0.002	-0.009	-0.003	-0.002
	(-1.54)	(-0.72)	(-2.84)**	(-0.92)	(-0.12)
HighLIQ	-0.049	-0.051	-0.048	-0.048	-0.032
	(-13.59)**	(-13.69)**	(-13.11)**	(-13.24)**	(-1.39)
ρ	-0.479		0.31		
	(-1.89)*		(+7.81)**		
λ		-1.056		0.004	
		(-7.27)**		(+0.05)	
n	87	87	84	84	87

** and * indicates statistical significance at 5% (or less) and 10%, respectively.

Finally, the ρ estimate associated with the $\mathbf{W_x}$ matrix is positive, and negative in the sample "*Banking Activity*".[3] Thus, if a country is in crisis this increases the probability of neighbouring countries being equally affected. Contagion motivated by a common shock is only confirmed with the sample "*Banking Activity*".

4.1. MARGINAL EFFECTS

In the traditional model a one-unit increase in GDPg, for example, will cause a 0.203 latent variable decrease in the same country. The impact on all the other countries is null. In the spatial *Probit* model, that one-unit increase immediately causes a reduction

[3] The sign of ρ adequately varies according to the use of a distance matrix (negative) or a proximity matrix (positive). $\mathbf{W_{ba}}$ is a distance matrix; the bigger w_{ij} the bigger is the distance between observations (i,j), and so it is expected that the occurrence of a crisis becomes less likely when the distance increases.

(between 0.329 and 0.298-units, depending on the model) in the latent variable. However, because the banking systems are interdependent, whatever affects one country has repercussions in all those connected to it, and these changes will feedback to the country where the process began.

The analysis of the impact matrix (Beron et al. 2003) is more interesting than a meticulous, thorough analysis of these results. It condenses the importance of the connections between banking systems and is given by

$$\left(\mathbf{I} - \rho \mathbf{W}_X\right)^{-1} \qquad (3)$$

where **I** is the identity matrix. Each element of the main diagonal gives the total (direct plus feedback) effect of country *i* on itself. The elements outside the main diagonal (γ_{ij}) measure the indirect impact of country *j* on country *i*.

The (incomplete) impact matrix for the Lag/$\mathbf{W}_\mathbf{x}$ case and the GDPg variable is in Table 2. One-unit changes in France, the USA or the United Kingdom have different impacts than those produced by identical changes in Indonesia or Korea. The indirect impact that the USA (Indonesia) has on itself is 0.056 (0.001) and the impact of the USA on Indonesia is 0.085, while that of Indonesia on the USA is only 0.002.

Finally, while in the traditional model the marginal effects are constant to all observations, in the spatial *Probit* model we have as many marginal effects as the sample observations. Again using the simplification of the latent variable, in the traditional model the marginal effect of GDPg is given by

$$\frac{\partial Cris^*_i}{\partial GDPg_i} = \beta_{GDPg}, \qquad \forall i \qquad (4)$$

whereas in the spatial model it is

$$\frac{\partial Cris^*_i}{\partial GDPg_j} = \beta_{GDPg}\gamma_{ij}, \qquad \forall i, j \qquad (5)$$

Table 2 – Impact Matrix (Lag/W_x/GDPg case)

	France	Indonesia	Korea	Malaysia	Thailand	United Kingdom	USA
France	1.016	0.001	0.005	0.003	0.003	0.059	0.057
Indonesia	0.011	1.001	0.023	0.015	0.010	0.017	0.085
Korea	0.011	0.006	1.004	0.014	0.006	0.021	0.100
Malaysia	0.011	0.006	0.012	1.006	0.014	0.022	0.110
Thailand	0.013	0.008	0.008	0.017	1.002	0.024	0.116
United Kingdom	0.051	0,.021	0.004	0.003	0.002	1.015	0.081
USA	0.016	0.002	0.012	0.007	0.004	0.028	1.056
…	…	…	…	…	…	…	…
Average	0.029	0.002	0.008	0.005	0.004	0.038	0.091

Thus, in the traditional *Probit* model the marginal effect of GDPg is -0.203 in each country. In the spatial model a 1-unit increase in the USA has a marginal effect on the latent variable of the USA itself of -0.347 (-0.329*1.056), and -0.028 (-0.329*0.085) in Indonesia's.

5. CONCLUSION

The results from the Spatial *Probit* model are statistically more reliable, and much more pleasing than those from the traditional model. If the observations are inter-related, the maximization of the usual likelihood function in the *Probit* model produces inconsistent and inefficient estimators. This probably explains why previous studies didn't find any significant relationship between the occurrence of crises and the characteristics of the banking sector (Eichengreen and Rose 1998) or bank liquidity (Demirgüç-Kunt and Detragiache 1997, Domaç and Peria 2000).

Contagion is crucial to understanding the occurrence of systemic banking crises but the phenomenon may result from business connections between institutions or from similarities between banking systems. Results show little sensitivity to the proximity concept used, which could be a sign that the contagion channels are diverse. This is also, without a doubt, a sign of the robustness of the phenomenon.

References

Anselin, L. (1999), *Spatial Econometrics*, Bruton Centre, School of Social Sciences, University of Texas.

Barth, J., G. Caprio, and R. Levine (2001), Banking Regulation and Supervision: What Works Best?, *World Banking*, WP 2725.

Barth, J., G. Caprio, and R. Levine (1999), Banking Systems Around the Globe: Do Regulation and Ownership Affect Performance and Stability?, *World Banking*, Policy Research WP 2325.

Beron, K., J. Murdoch, and W. Vijverberg (2003), Why Cooperate? Public Goods, Economic Power, and the Montreal Protocol, *Review of Economics and Statistics* 85, 286-297.

Boyd, J. and B. Champ (2006), Inflation and Financial Market Performance: What Have We Learned in the Last Ten Years?, *Federal Reserve Banking of Cleveland*, WP 03-17.

Caprio, G., and D. Klingebiel (2003), Episodes of Systemic and Borderline Financial Crises, *World Bank*.

Degryse, H. and G. Nguyen (2004), Interbanking Exposures: An Empirical Examination of Systemic Risk in the Belgian Banking System, *National Banking of Belgium*, WP 43.

Demirgüç-Kunt, A. and E. Detragiache (2000), Does Deposit Insurance Increase Bankinging System Stability? An Empirical Investigation, *World Banking*, Policy Research WP 2247.

Demirgüç-Kunt, A. and E. Detragiache (1999), Monitoring Bankinging Sector Fragility: A Multivariate Logit Approach with na Application to the 1996-97 Banking Crises, *World Banking*, Policy Research WP 2085.

Demirgüç-Kunt, A. and E. Detragiache (1997), The Determinants of Banking Crises: Evidence from Developed and Developing Countries, *International Monetary Fund*, WP 97/106.

Domaç, I. and M. Peria (2000), Banking Crises and Exchange Rate Regimes: Is There a Link?, *World Banking*, Policy Research WP 2489.

Dornbusch, R., Y. Park, and S. Claessens (2000), Contagion: Understanding How It Spreads, *The World Banking Research Observer* 15, 177-197.

Eichengreen, B. and A. Rose (1998), Staying Afloat When the Wind Shifts: External Factors and Emerging-Market Banking Crises, *National Bureau of Economic Research*, WP 6370

Wells, S. (2002), UK Interbanking Exposures: Systemic Risk Implications, *Financial Stability Review* 19 175-82.