

Systemic Bank Risk in Brazil: An Assessment of Correlated Market, Credit, Sovereign, and Inter-Bank Risk in an Environment with Stochastic Volatilities and Correlations

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Purpose I

Develop a forward-looking portfolio simulation methodology for assessing the *correlated* impacts of:

- market risk,
- private sector credit risk,
- Sovereign default risk,
- and inter-bank default risk,

for both:

- individual banks, and
- groups of banks (i.e. systemic risk)

Purpose II

Estimate:

- the probability of individual and multiple banks failing, and
- the monetary costs for recapitalizing the banking system.

Important Risk Drivers

- (1) Sovereign default rate,
- (2) credit risk distributions of the banks' loan portfolios credit risk distributions,
- (3) loan portfolio sector, region, and Sovereign concentrations in the banks' loan portfolios,
- (4) initial bank capital ratios,
- (5) economic environment volatilities and correlations, of important financial and economic variables,
- (6) asset and liability and maturity and currency mismatches,
- (7) banks' net interest margins, and
- (8) banks' operating expense ratios.

Simulation Sample

- 28 of the largest Brazilian banks:
 - Typically well capitalized;
 - Very concentrated portfolio (Government loans);
 - High operating expenses;
 - Very high interest rate spreads;
 - High profitability;
 - Almost zero investments in equity and real estate.

Portfolio Simulation Approach

- Simulate future financial and economic environment as a set of *correlated* random variables (interest rates, FX rates, equity returns)
- Revalue each bank asset and liability (model uses approx. 450 securities per bank) as a function of the simulated environment
- Recalculate the bank's net worth and capital ratio in the simulated environment,
- Repeat the simulation a large number of times
- Analyze the distribution of simulated bank capital ratios to estimate the probability of restricted market access

Credit Risk Methodology

- Extensive empirical analysis of publicly traded companies in Brazil identified:
(1) typical debt to value ratios, (2) beta coefficients, and (3) firm specific equity return volatilities for firms with various credit ratings.
- For each run of the simulation the return on a firm's equity is estimated to be a function of the simulated return on an equity market index plus a firm specific random change.
- This simulated equity return allows the estimation of a new debt to value ratio and credit rating (including default) for each firm in the bank's loan portfolio

Credit Risk Methodology

- Simulated and historical credit transition probabilities are remarkably close.
- The GOB is modeled as a very large Corporate Borrower whose risk of default is systematically related to the returns on the Ibovespa (the broad Brazilian equity market index).
- Private sector and Sovereign credit risk is correlated through their systematic relationships to equity market returns.

Results I

- Individuals banks, no government default, higher volatilities (economic environment):
 - Compare means and standard deviations of ROAA and ROAE between historical reported values (2000-2004) and simulated values (Dec.-2004), for a set of 13 banks.
 - Finding: simulated ROAA and ROAE are unbiased estimators for historical ROAA and ROAE.

	β	Adj. R ²	Wald Stat.
<u>Panel A: ROAE Regressions</u>			
Mean	0.84 (9.32)	0.89	2.97
St. Dev.	1.48 (5.71)	0.74	3.39
<u>Panel B: ROAA Regressions</u>			
Mean	1.13 (8.88)	0.88	1.03
St. Dev.	1.75 (3.67)	0.53	2.48
<u>Panel C: Pooled Observations</u>			
All	0.90 (15.95)	0.83	2.98

Results II

- Individuals banks, no government default, lower volatilities (economic environment):
 - Simulated capital ratios for a set of 28 banks, using parameters estimated over the 2003-2004 period.
 - Banks face no solvency problems and remain well-capitalized even at 99% VaR level. This result is driven significantly by high bank profitability
 - Standard deviations of simulated capital ratios are small

	Bank 11	Bank 12	Bank 13	Bank 14	Bank 15	Bank 16	Bank 17	Bank 18	Bank 19
Initial	0.091	0.252	0.132	0.062	0.103	0.065	0.094	0.200	0.201
Mean	0.110	0.251	0.150	0.074	0.150	0.070	0.112	0.240	0.200
St. Dev.	0.003	0.004	0.007	0.002	0.004	0.002	0.007	0.004	0.001
Maximum	0.121	0.266	0.181	0.081	0.167	0.078	0.140	0.257	0.209
Minimum	0.096	0.235	0.123	0.068	0.136	0.060	0.083	0.215	0.196
<u>VaR Levels:</u>									
99.0%	0.103	0.242	0.136	0.070	0.142	0.064	0.096	0.227	0.197
97.5%	0.104	0.244	0.137	0.071	0.144	0.065	0.098	0.231	0.198
95.0%	0.106	0.245	0.139	0.072	0.145	0.066	0.101	0.232	0.198
90.0%	0.107	0.246	0.141	0.072	0.146	0.067	0.104	0.234	0.199
75.0%	0.108	0.249	0.145	0.073	0.148	0.069	0.108	0.237	0.199
50.0%	0.110	0.252	0.149	0.074	0.150	0.070	0.112	0.240	0.200
25.0%	0.111	0.254	0.154	0.075	0.152	0.072	0.116	0.242	0.201
10.0%	0.113	0.256	0.159	0.076	0.155	0.073	0.120	0.245	0.202
5.0%	0.114	0.257	0.162	0.077	0.156	0.074	0.122	0.246	0.203
2.5%	0.115	0.258	0.166	0.077	0.158	0.075	0.124	0.248	0.203
1.0%	0.116	0.260	0.170	0.078	0.160	0.076	0.127	0.250	0.204

Results III

- Individuals banks, government default, lower volatilities (economic environment):
 - Government may default with an average 4.5% default rate consistent with Fitch's Sovereign Credit Rating for Brazil (i.e. B).
 - Assume several scenarios of losses (additional defaults on corporate and individuals' loans and different losses level on the market value of government loans).

Results III (cont.)

- Incremental defaults on corporate and customers' loans resulting from a Sovereign default generally have marginal impacts on banks' portfolios.
- Several banks start having solvency problem if they suffer losses of 10% or higher in the market value of government loans. A larger number face significant solvency problems if losses reach 25% of government loan's market value.

Probability of Default

Losses on Government Loans	Defaults on Business and consumer Loans	Bank 1	Bank 2	Bank 3	Bank 4	Bank 5	Bank 6	Bank 7	Bank 8	Bank 9	Bank 10	Bank 11	Bank 12	Bank 13	Bank 14
10%	0	0.000	0.000	0.001	0.000	0.038	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.050
10%	+ 1 times the average historical default rates	0.000	0.000	0.001	0.000	0.045	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.050
10%	+ 2 times the average historical default rates	0.000	0.000	0.001	0.000	0.048	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.050
25%	0	0.000	0.000	0.046	0.000	0.048	0.000	0.000	0.034	0.000	0.060	0.045	0.000	0.003	0.050
25%	+ 1 times the average historical default rates	0.000	0.000	0.046	0.000	0.048	0.000	0.000	0.038	0.000	0.060	0.045	0.000	0.004	0.050
25%	+ 2 times the average historical default rates	0.000	0.000	0.046	0.002	0.048	0.000	0.000	0.041	0.000	0.060	0.045	0.000	0.005	0.050
Losses on Government Loans	Defaults on Business and consumer Loans	Bank 15	Bank 16	Bank 17	Bank 18	Bank 19	Bank 20	Bank 21	Bank 22	Bank 23	Bank 24	Bank 25	Bank 26	Bank 27	Bank 28
10%	0	0.000	0.041	0.000	0.000	0.000	0.000	0.050	0.050	0.000	0.000	0.000	0.000	0.000	0.000
10%	+ 1 times the average historical default rates	0.000	0.041	0.000	0.000	0.000	0.000	0.050	0.050	0.000	0.000	0.000	0.000	0.000	0.000
10%	+ 2 times the average historical default rates	0.000	0.041	0.000	0.000	0.000	0.000	0.050	0.050	0.000	0.000	0.000	0.000	0.000	0.000
25%	0	0.045	0.041	0.034	0.000	0.049	0.000	0.050	0.050	0.051	0.000	0.048	0.000	0.000	0.046
25%	+ 1 times the average historical default rates	0.045	0.041	0.035	0.000	0.049	0.000	0.050	0.050	0.051	0.000	0.048	0.000	0.000	0.046
25%	+ 2 times the average historical default rates	0.045	0.041	0.037	0.000	0.049	0.000	0.050	0.050	0.051	0.000	0.048	0.001	0.000	0.046

Recapitalization Cost

Losses on Government Loans	Defaults on Business and consumer Loans	Bank 1	Bank 2	Bank 3	Bank 4	Bank 5	Bank 6	Bank 7	Bank 8	Bank 9	Bank 10	Bank 11	Bank 12	Bank 13	Bank 14
10%	0	0.000	0.000	0.051	0.000	0.064	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.061
10%	+ 1 times the average historical default rates	0.000	0.000	0.054	0.000	0.068	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.061
10%	+ 2 times the average historical default rates	0.000	0.000	0.056	0.000	0.074	0.000	0.000	0.000	0.000	0.061	0.000	0.000	0.000	0.061
25%	0	0.000	0.000	0.102	0.000	0.163	0.000	0.000	0.059	0.000	0.150	0.073	0.000	0.055	0.173
25%	+ 1 times the average historical default rates	0.000	0.000	0.105	0.000	0.170	0.000	0.000	0.060	0.000	0.153	0.076	0.000	0.055	0.173
25%	+ 2 times the average historical default rates	0.000	0.000	0.108	0.052	0.178	0.000	0.000	0.062	0.000	0.156	0.076	0.000	0.055	0.173
Losses on Government Loans	Defaults on Business and consumer Loans	Bank 15	Bank 16	Bank 17	Bank 18	Bank 19	Bank 20	Bank 21	Bank 22	Bank 23	Bank 24	Bank 25	Bank 26	Bank 27	Bank 28
10%	0	0.000	0.084	0.000	0.000	0.000	0.000	0.088	0.095	0.000	0.000	0.000	0.000	0.000	0.000
10%	+ 1 times the average historical default rates	0.000	0.085	0.000	0.000	0.000	0.000	0.091	0.095	0.000	0.000	0.000	0.000	0.000	0.000
10%	+ 2 times the average historical default rates	0.000	0.086	0.000	0.000	0.000	0.000	0.094	0.095	0.000	0.000	0.000	0.000	0.000	0.000
25%	0	0.158	0.233	0.060	0.000	0.083	0.000	0.239	0.278	0.085	0.000	0.065	0.000	0.000	0.168
25%	+ 1 times the average historical default rates	0.158	0.234	0.062	0.000	0.083	0.000	0.243	0.278	0.086	0.000	0.068	0.000	0.000	0.168
25%	+ 2 times the average historical default rates	0.158	0.234	0.062	0.000	0.084	0.000	0.248	0.278	0.087	0.000	0.070	0.050	0.000	0.168

99% VaR Simulated Capital Ratio

Losses on Government Loans	Defaults on Business and consumer Loans	Bank 1	Bank 2	Bank 3	Bank 4	Bank 5	Bank 6	Bank 7	Bank 8	Bank 9	Bank 10	Bank 11	Bank 12	Bank 13	Bank 14
10%	0	0.175	0.115	0.051	0.128	0.011	0.335	-0.001	0.084	0.210	0.040	0.077	0.213	0.108	0.018
10%	+ 1 times the average historical default rates	0.174	0.114	0.048	0.125	0.005	0.334	-0.002	0.083	0.208	0.038	0.077	0.211	0.107	0.018
10%	+ 2 times the average historical default rates	0.173	0.113	0.045	0.122	-0.002	0.333	-0.003	0.080	0.206	0.035	0.077	0.210	0.106	0.018
25%	0	0.126	0.051	-0.026	0.058	-0.092	0.248	-0.121	0.018	0.190	-0.081	0.003	0.134	0.038	-0.094
25%	+ 1 times the average historical default rates	0.124	0.050	-0.029	0.055	-0.100	0.247	-0.123	0.016	0.188	-0.085	0.003	0.131	0.036	-0.094
25%	+ 2 times the average historical default rates	0.122	0.050	-0.032	0.052	-0.108	0.245	-0.124	0.013	0.186	-0.088	0.003	0.129	0.035	-0.094
Losses on Government Loans	Defaults on Business and consumer Loans	Bank 15	Bank 16	Bank 17	Bank 18	Bank 19	Bank 20	Bank 21	Bank 22	Bank 23	Bank 24	Bank 25	Bank 26	Bank 27	Bank 28
10%	0	0.086	-0.006	0.081	0.208	0.135	0.139	-0.012	-0.016	0.080	0.136	0.073	0.132	0.177	0.040
10%	+ 1 times the average historical default rates	0.086	-0.007	0.080	0.207	0.135	0.137	-0.015	-0.016	0.079	0.134	0.071	0.131	0.175	0.040
10%	+ 2 times the average historical default rates	0.086	-0.008	0.079	0.206	0.134	0.134	-0.019	-0.016	0.079	0.133	0.069	0.130	0.173	0.040
25%	0	-0.080	-0.156	0.017	0.137	-0.005	0.087	-0.164	-0.199	-0.011	0.113	0.010	0.046	0.112	-0.095
25%	+ 1 times the average historical default rates	-0.080	-0.157	0.015	0.134	-0.006	0.084	-0.169	-0.199	-0.012	0.110	0.007	0.045	0.110	-0.095
25%	+ 2 times the average historical default rates	-0.080	-0.158	0.014	0.132	-0.006	0.081	-0.173	-0.199	-0.013	0.107	0.005	0.043	0.107	-0.095

Results IV

- We group banks according to their 99% VaR level capital ratios (credit risk rating) into three categories:
 - 1 and 2 (speculative grade),
 - 3 (investment grade),
- Our bank risk assessments are generally quite consistent with ratings provided by Moody's and Standard and Poor's and somewhat conflicting with Fitch ratings.

Panel A: Ratings distributions by rating grade.

	Fitch	Moody's	Standard and Poor's	Barnhill and Souto
Investment Grade	18	1	0	9
Speculative Grade	0	15	10	19

Panel B: Ratings intersection.

	Fitch	Moody's	Standard and Poor's	Barnhill and Souto
Fitch	-	1 (12)	0 (7)	9 (18)
Moody's			10 (10)	12 (16)
Standard and Poor's				7 (10)
All 4 ratings methodologies		0 (7)		

Results V

- Systemic Risk, one single bank.
 - Aggregated all 28 banks as one single bank, to model systemic risk.
 - With no government default, single-bank is very healthy.
 - With government default, single bank face potential solvency problems if losses on government loans reach 25% of their market value.

Panel A: No government default.

	All 28 No_Gov. Default
Initial Value	0.154
Mean	0.154
St. Dev.	0.003
Maximum	0.163
Minimum	0.144
<u>VaR Levels:</u>	
99.0%	0.147
97.5%	0.148
95.0%	0.149
90.0%	0.150
75.0%	0.152
50.0%	0.154
25.0%	0.156
10.0%	0.158
5.0%	0.159
2.5%	0.160
1.0%	0.161

Panel B: Government default.

Losses on Government Loans	10%	10%	10%	25%	25%	25%
	+ 1 times	+ 2 times		+ 1 times	+ 2 times	
Incremental Defaults on Business and consumer Loans	the average historical default 0 rates	the average historical default rates		the average historical default 0 rates	the average historical default rates	
<u>Default Probabilities:</u>						
All 28 banks	0.000	0.000	0.000	0.010	0.015	0.022
<u>Bail-Out' Cost:</u>						
All 28 banks	0.000	0.000	0.000	0.055	0.055	0.055
<u>99% VaR Level:</u>						
All 28 banks	0.113	0.111	0.108	0.030	0.027	0.024

Results VI

- Systemic Risk, three groups simulated individually:
 - No government default: all groups are very healthy.
 - Government default: group 3 (investment grade) remains very healthy even with a loss of 25% of government loans market value. Groups 2 and 1 have solvency problems with 25% losses on government loans and group 1 is the most affected under such scenario.

Sovereign Default Risk Not Considered

	<u>Group 1</u>	<u>Group 2</u>	<u>Group 3</u>
Initial	0.081	0.106	0.219
Mean	0.094	0.128	0.227
St. Dev.	0.002	0.004	0.004
Maximum	0.101	0.143	0.241
Minimum	0.082	0.107	0.210
<u>VaR Levels:</u>			
99.0%	0.087	0.117	0.216
97.5%	0.089	0.119	0.218
95.0%	0.090	0.120	0.220
90.0%	0.091	0.122	0.221
75.0%	0.093	0.125	0.224
50.0%	0.095	0.128	0.227
25.0%	0.096	0.131	0.229
10.0%	0.097	0.133	0.232
5.0%	0.098	0.135	0.233
2.5%	0.098	0.136	0.235
1.0%	0.099	0.138	0.236

Sovereign Default Risk Considered

Losses on Government Loans	0%	0%	0%	10%	10%	10%	25%	25%	25%
	+ 1 times the average historical default rates	+ 2 times the average historical default rates		+ 1 times the average historical default rates	+ 2 times the average historical default rates		+ 1 times the average historical default rates	+ 2 times the average historical default rates	
<u>Default Probabilities:</u>									
Group 1	0.000	0.000	0.000	0.000	0.000	0.000	0.047	0.047	0.047
Group 2	0.000	0.000	0.000	0.000	0.000	0.000	0.031	0.038	0.046
Group 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<u>Bail-Out' Cost:</u>									
Group 1	0.000	0.000	0.000	0.000	0.000	0.000	0.123	0.126	0.128
Group 2	0.000	0.000	0.000	0.000	0.000	0.000	0.058	0.059	0.061
Group 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<u>99% VaR Level:</u>									
Group 1	0.088	0.087	0.086	0.047	0.045	0.043	-0.047	-0.049	-0.052
Group 2	0.116	0.116	0.115	0.093	0.090	0.087	0.021	0.017	0.014
Group 3	0.216	0.216	0.216	0.196	0.194	0.192	0.124	0.121	0.119

Results VII

- Systemic Risk, three groups simulated simultaneously:
 - Banks default simultaneously only when facing significant losses on government loans market value.
 - When they default simultaneously, cost for recapitalizing the banks is very high.

Panel A: Probability of Groups 2 and 3 defaulting at the same time and associated cost (given default), to bring both banks' capital ratios to 0.08.

		<u>Incremental Defaults on Business and Consumers' Loans</u>		
		0	+ 1 times the average historical default rates	+ 2 times the average historical default rates
Losses on Government Loans	0%	0.000	0.000	0.000
	10%	0.000	0.000	0.000
	25%	0.016 (0.109)	0.023 (0.109)	0.029 (0.111)
	40%	0.048 (0.234)	0.048 (0.246)	0.048 (0.256)
	50%	0.048 (0.358)	0.048 (0.362)	0.048 (0.367)

Panel B: Probability of all groups defaulting at the same time and associated cost (given default), to bring all banks' capital ratios to 0.08.

		<u>Incremental Defaults on Business and Consumers' Loans</u>		
		0	+ 1 times the average historical default rates	+ 2 times the average historical default rates
Losses on Government Loans	0%	0.000	0.000	0.000
	10%	0.000	0.000	0.000
	25%	0.000	0.000	0.000
	40%	0.048	0.048	0.048
		(0.163)	(0.173)	(0.180)
	50%	0.048	0.048	0.048
	(0.270)	(0.274)	(0.278)	

Conclusion I

- Methodology provides consistent results:
 - Simulated ROAA and ROAE are unbiased estimators of historical ROAA and ROAE.
 - Simulated credit transition matrix (CTM) is very similar to historical CTM (Brazilian Credit Risk Bureau).
 - Credit ratings are generally consistent with ratings provided by Moody's and Standard and Poor's.

Conclusion II

- With no government default, Brazilian banks appear to have low default risk over a 1-year horizon.
- This low default risk is in part due to high profits resulting from very high interest rate spreads.
- When government default risk is modeled, and banks begin suffering losses on the market value of their government loan portfolios, then banks start facing potential solvency problem.

Conclusion III

Results also show that in a stress period the Brazilian government may face debt management constraints.

- Decisions that reduce the market value of domestic government debt by 10% would cause several individual banks to have simultaneous solvency problems.
- With a 25% loss in market value of government loans a large number of banks could have simultaneous solvency problems.

Conclusions

“All models are wrong some are useful.”

Modeling correlated sovereign and systemic bank risk is a challenging problem.

All models have significant limitations.

With more work the portfolio simulation model presented here has the potential to be “useful” and to:

- Do a better job of modeling correlated Sovereign risk (see Barnhill, 2006),**
- Deal with many correlated risk variables,**
- Deal with detailed bank portfolios,**
- Account for periodic structural breaks that greatly increase risk levels,**