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Linking Financial and Macroeconomic Factors to Credit Risk Indicators of Brazilian Banks*

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Abstract

This study constructs a set of credit risk indicators for 39 Brazilian banks, using the Merton framework and balance sheet information on the banks' total assets and liabilities. Despite the simplifying assumptions, the methodology captures well several stylized facts in the recent history of Brazil. In particular, it identifies deterioration in the credit risk indicators of the banking sector, following the crisis in the early 2000s. The risk indicators were regressed against a number of macro-financial variables at both individual and systemic level, showing that an increase in the system EDF, interest rates, and CDS spreads will lead to a deterioration of the individual expected default probability.
Keywords: structural models, credit risk indicators, stress tests, macro-financial links.
JEL Classification: G21, G33

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I. Introduction

The banking sector of Brazil went through an acute crisis in the early 2000s, following the Russian crisis, the severe deterioration in the exchange rate and the almost complete depletion of foreign reserves. After few years, the banks recovered and have since enjoyed a very benign macro-financial environment, marked with robust profits.

This paper assesses the extent of the vulnerabilities of the Brazilian banking sector using a variant of the Merton framework (1973, 1974). To this end, the study constructs a set of credit risk indicators for 39 Brazilian banks, which are then used to compare banks' risk profile, and examines the impact of potential shocks on the various risk indicators. In contrast to the Merton framework, which uses market data to capture the collective views and expectations of market participants, this paper uses book value data from balance sheets due to the absence of market data for several banks in Brazil. The approach still incorporates volatility into the estimations, a key feature of the Merton framework for capturing non-linearities in the credit risk indicators, especially during periods of distress.

Despite the simplifying assumptions, the methodology captures well several stylized facts in the recent history of Brazil. In particular, it identifies deterioration in the credit risk indicators of the banking sector, following the crisis in the early 2000s. The methodology also points to a substantial improvement in the credit risk indicators since then, in line with the very benign environment under which Brazilian banks have been operating in the last years. It also captures an event of volatility in the exchange rate market in may 2006.

The risk indicators were regressed against a number of macro-financial variables at both individual and systemic level. The regressions show that banks would be impacted differently at the individual level, although the system EDF, real interest rates, and inflation appear to be strong determinant factors for virtually all banks. In general, an increase in these factors will lead to a deterioration of the individual expected default probability. The VAR analysis carried out at the system level, shows similar results, with shocks in interest rates been statistically significant in the first two aftermath periods, and showing a declining trend after the first period. Altogether, we believe the methodology used in this paper appears to have the potential of being a useful toolkit to many economies that lack (or have shallow) equity markets.

The paper has eight sections. Section II briefly describes the Merton framework. Section III describes the data used in this study. Section IV estimates credit risk indicators using the modified Merton framework for a set of 39 Brazilian banks. These risk indicators are regressed against a number of macro-financial variables in Section V. Section VI seeks to explain the expected default dynamics, whereas section VII presents panel-VAR results. Finally, section VIII concludes.

II. A Structural Model for Estimating Credit Risk Indicators

We utilize the Merton (1973, 1974) framework to estimate expected default probabilities for a set of Brazilian banks. The Merton framework combines liability-related balance sheet information with commonly used risk measurement tools to construct marked-to-market overall balance sheets with a view to identify and quantify credit risk. It relies on observable market information about the value and volatility of liabilities (and equity) to derive the value of non-observable quantities, such as the asset value and corresponding volatility. This information is then combined to estimate risk indicators, such as the distance-to-distress, default probability and credit spreads.

The Merton framework offers some distinct advantages over other vulnerability analyses[†]. First, the Merton framework takes balance sheet information and combines it with current and forward-looking financial market prices to compute risk-adjusted marked-to-market balance sheets. It thus incorporates the collective views of all market participants, as all the relevant information is priced into the firm's equity. Second, the Merton framework distinguishes itself from other vulnerability analyses in that it incorporates market volatility when estimating credit risk. Volatility is crucial in capturing nonlinear changes in risk, especially during times of stress when small shocks can gain momentum and trigger systemic repercussions.

The basic idea of the Merton framework is to model a firm's balance sheet by grouping the main accounts into assets, liabilities and 'equity'. Merton shows how a firm's equity can be modeled as a (junior) contingent claim on the residual value of its assets. In the event of default, equity holders receive nothing if the firm's assets are all consumed to pay the senior stakeholders (e.g. debt holders); otherwise equity holders receive the difference between the value of assets and debt. Under this framework, the equity of the firm can be seen as a call option on the residual value of the firm's assets. From Black and Scholes (1973):

$$E = VN(d_1) - DBe^{-rT}N(d_2), \tag{1}$$

where V is the implied value of asset, DB is the value of the distress barrier, r is the (constant) risk-free interest rate, T is the maturity of the option, and d_1 and d_2 are defined as:

[†] See Gapen et al. (2004, 2005) and Dale and Jones (2006) for examples of application of the Merton framework to government, banking, and corporate sectors' balance sheets.

$$d_1 = \frac{\ln\left(\frac{V}{DB}\right) + \left(r + \frac{1}{2}\sigma_V^2\right)T}{\sigma_V\sqrt{T}} = \frac{\ln\left(V\exp\left(\left(r + \frac{1}{2}\sigma_V^2\right)T\right)\right) - \ln(DB)}{\sigma_V\sqrt{T}}, \tag{2}$$

and

$$d_2 = \frac{\ln\left(\frac{V}{DB}\right) + \left(r - \frac{1}{2}\sigma_V^2\right)T}{\sigma_V\sqrt{T}} = \frac{\ln\left(V\exp\left(\left(r - \frac{1}{2}\sigma_V^2\right)T\right)\right) - \ln(DB)}{\sigma_V\sqrt{T}}, \tag{3}$$

with σ_V being the implied value of asset volatility.

Also, using Ito's lemma and the definition of variance, it is easy to show that:

$$\sigma_E = \frac{\partial E}{\partial V}\frac{V}{E}\sigma_V = N(d_1)\frac{V}{E}\sigma_V, \tag{4}$$

where E is the value of equity and σ_E is the volatility of equity.

This framework enables a rich characterization of a firm's (or sovereign's) balance sheet and the derivation of a series of credit risk indicators, in particular the distance to distress, the default probability, and credit spreads. Overall, with information on the market value and volatility of equity and the book value of liabilities, it is possible to estimate the implied value for assets and assets volatility, by solving a system of equations comprised by equations (1) and (4) (See figure 1).

<Place Figure 1 About Here>

Souto (2008b) shows how to solve numerically this system and shows that the numerical solution of the system converges to a unique par of values. After determining the distress barrier, the firm is assumed to default whenever the values of its implied assets fall below this distress barrier. We follow Moody's-KMV and define the distress barrier as:

$$DB = STD + \alpha \cdot LTD^{\ddagger}, \tag{5}$$

where STD represents the short-term liabilities (maturity $\leq$ 1 year), LTD represents the long-term liabilities (maturity $>$ 1 year), and α is a parameter between 0 and 1 (usually around 0.5)[§].

‡ Usually this expression also incorporates one-year interest payments. To compensate for that, we use $\alpha = 0.7$, slightly larger than the value used by Moody's.

We can also estimate:

(1) Distance to distress ($D2D$): which gives the number of standard deviations that the asset value is away from the distress barrier (D):

$$D2D = \frac{\ln(V) + \left(r - \frac{1}{2}\sigma^2\right)T - \ln(D)}{\sigma\sqrt{T}}. \tag{6}$$

(2) Risk neutral default probability ($RNDP$):

$$RNDP = N(-D2D). \tag{7}$$

(3) Credit default spread ($spread$):

$$spread = \frac{-1}{t}\ln\left(\frac{V}{De^{-rt}}N(d_1) + N(d_2)\right). \tag{8}$$

III. The Data

III.1. Banking Data

We have collected monthly book value data[**] for a sample of 39 banks, including some of the largest banks, going back to January of 2001[††]. These banks represent 72.9 percent of total assets for the banking system (Table 1). Our sample includes government (11), domestic private (17), and foreign private banks (11). Foreign private banks are defined as those with at least 50 percent of foreign ownership. Otherwise, they are classified as domestic private banks. This data is available in the Central Bank of Brazil website.

<Place Table 1 About Here>

[§] Moody's utilizes α in the range 0.5-0.6, based on the calibration of their model, so as to match model and historical probabilities of default. We use $\alpha = 0.7$, to compensate for the lack of information on 1-year interest rate expenses.

[**] For each individual bank, we have information on total assets, short-term liabilities, long-term liabilities, total loans and credits, non-performing loans (NPL) as percentage of total loans, and return on equity (ROE).

[††] The balance sheet data used in this study was adjusted to account for banks' operations that were 'double-counted'. This data is available starting only in January 2001.

Few of these banks trade equity frequently in the Brazilian stock exchange and for them we can estimate credit risk indicators using equity market data. In addition, there is also data available on the expected default probability for some banks, as estimated by Moody's-KMV and available in their database.

III.2. Macro-financial variables

To construct the regression model linking the credit risk indicator to macro-financial factors, we have selected a number of variables that could describe the main dynamics recently observed in both global and domestic markets. We adapted some of the suggested factors from Gray and Walsh (2008) to the Brazilian reality. We list these factors in Table 2 below, along with their source and their definitions. All variables are available at least at a monthly frequency, and most cover the same period as for the banking data, with exception of the time series for USD interest rates in Brazil (known as *Cupom Cambial*), since this time series have a shorter time span.

<Place Table 2 About Here>

IV. Estimating Default Probabilities for Brazilian Banks

We use the structural Merton framework as outlined in Section 2, to estimate expected default probabilities for Brazilian banks. In the case of Brazil, market data is not available for several banks and it is thus not possible to obtain marked-to-market risk indicators for them. However, it is still possible to incorporate volatility, using book value data, into the estimation of credit risk indicators. As mentioned above, factoring in volatility makes it possible to capture non-linearities that are important particularly when a company or bank enters a period of distress. While losing the 'collective view' feature that characterizes the Merton framework, book value balance sheet data still possesses relevant information.

In this context, estimating risk indicators using book value balance sheet data, it is not necessary to estimate expressions (2) and (3) (to obtain implied value of assets and assets volatility). Instead, the book value of assets and volatility of assets are used to estimate the risk indicators in expressions (6) – (8). To estimate the volatility for the book value of total assets, we use the definition for downside risk volatility, which places greater weight to negative shocks than to positive shocks, as in the formula below:

$$\sigma = \sqrt{\sum_{t=1}^{N} Min\left(\ln(V_t) - \ln(V_{t-1}), 0\right)^2} \,, \tag{9}$$

where $Min(\cdots)$ is the minimum function.

The intuition for this choice for volatility modeling relies on the fact that usually the negative shocks are the source of concern, rather than the positive ones. It has also helped to deal with many cases where the volatility was rather a reflex of a steady growth. In the particular case of this study, this measure of volatility has helped us obtain reasonable estimates for default probabilities, consistent with the main stylized facts observed in the recent history of Brazil.

All book value information was converted to US dollars and we use a Brazilian short-term interest rate, in US Dollars (the "*cupom cambial*")[‡‡], to estimate the expected default probability. We used Dollar denominated values in order to be able to contrast our results with the Moody's-KMV results. In figures 2 and 3 below, we present the expected default probability aggregated (by total assets) for the system and for groups of banks (government, domestic private, and foreign private banks) and few comments are in place. First, despite the fact that it uses only book value data, the estimated EDFs capture the main events of recent history in Brazil reasonably well. For example, the high (but decreasing) EDFs in the beginning of 2003 reflect the end of the period crisis that shaked the Brazilian banking system in the early 2000's. Then, more recently (April 2006), an episode of volatility in the foreign exchange market again provokes deterioration in the banks' credit risk profile, having affected the government banks more acutely. Second, in general, private domestic banks perform better than government and private foreign banks. Government banks perform the worse, in general. This is also consistent with the observed stylized facts, with domestic private banks presenting to his stakeholders very profitable results (more profitable than foreign banks). Finally, after the crisis in the early 2000's, Brazilian banks credit risk profile improved significantly (perhaps easier to be seen in Figure 4 below), reflecting the very benign environment under which they have been operating since then.

<Place Figures 2 and 3 About Here>

IV.1. One Interesting Case: Recent Failure of a Large Sized Bank

Established in 1969 as a small investment fund this bank became a commercial bank in 1989 and continued to grow steadily until 2004, to become the eighth largest private domestic bank in Brazil, managing over USD 6 Billions in assets. However, the Central Bank of Brazil placed this bank in a monitoring list in late 2002, declaring the fragility of the bank's capital structure to be 'fragile'. In late 2003, both Standard and Poor's and Fitch, downgraded this bank ratings, reflecting deterioration in its credit portfolio and inadequate loan provisioning. In mid 2004 the bank suffered a bank run that eventually lead the bank to be intervened in November 2004.

[‡‡] The "cupom cambial" is defined as the sum $i^*+\varphi$, where i^* is the foreign interest rate (e.g. Libor), and φ is a risk premium (assuming that the uncovered interst rate parity holds).

Figures 4 and 5 below present the evolution of the estimated default frequency for the bank during the period of March 2002 to November 2004, as well as the evolution of the bank's total assets volatility and distance-to-distress. Figure 4 shows an acute deterioration of the EDF in May, 2004, which continue to deteriorate until achieving a maximum point in June 2006. After that, EDF bounced around high levels until September 2009. The deterioration in EDF was mainly associated with an increase in asset volatility (Figure 5) stemming from the bank run in mid 2004. Despite the early warnings made by the Central Bank of Brazil, the estimated EDF is consistent with a number of credit reports by rating agencies that highlighted the relative good performance of this bank as late as April/May 2004. The results also highlight the usefulness of this tool for off-site supervision applications, as the methodology captures the deterioration in the credit risk indicator few months before the BCB intervention took place..

<Place Figures 4 and 5 About Here>

V. Book vs. Market Data: Some Important Stylized Facts

In this section we compare the EDF for the three largest banks in Brazil estimated using book value information, as laid out in Section II above, with the EDFs estimated by Moody's-KMV, using market value data. We focus on these three largest banks because their stocks are fairly liquid. In Figure 6, we plot the weighted average EDF (by total assets) for the two cases and few comments are in order. First, there is a high degree of correlation between the two series (72.7%) and they both seem to capture the main peaks and valleys in the recent history in Brazil. This is a fairly high degree of correlation particularly considering that the market EDF imbeds other information in addition to what is in the financial statements. This is a very important point, as both market and book EDFs capture the main trends in the EDFs. When there is no reliable market data (or no market data at all), it is crucial to know that book EDF can work as a very good proxy for market EDF. This may also represent the fact that banks' financial statements are probably the most important piece of information when forming market expectations about the likelihood of banks' default. Second, the book EDF is considerably higher than the EDF. In the particular case of these three large banks, book value EDF is about 9 times bigger than the market EDF[§§]. This is a result of the total assets (book) volatility, which is significantly larger than the implied market asset volatility. Despite the observed book total assets fluctuations, the market still considers these banks to be fairly stable and equity volatility is not so high.

<Place Figure 6 About Here>

A second interesting question is whether the credit risk indicators (book or market EDFs) could be any useful in forecasting NPLs and/or vice-versa. That is, whether the banks' credit risk deteriorates in expectation for a deterioration in the borrowers' credit

[§§] For this purpose, we estimated the regression $EDF_{Book,t} = \beta \cdot EDF_{Market,t} + \varepsilon_t$, producing $\beta = 8.90$, significantly different than zero (t-stat=8.18), Adj.-R^2=53.9% and F-stat=66.9.

profile, or the other way around. We tried to address this question by running a 2-lag VAR, comprised by book and market EDF and NPL[***]. Results are presented in Table 3. The only statistically significant Granger causality is from NPL to log(EDF_M). Interestingly, there is no statistical significant Granger causality from NPL to log(EDF_B), which may be only indicating that a deterioration in Borrowers' credit quality (increase in borrowers' default) does not necessarily leads to a deterioration in the banks' credit risk (increase in the likelihood that the bank will default), particularly at the low levels of NPLs observed in these three large banks. There is no Granger causality from log(EDF_M) to log(EDF_B) or vice-versa and there seems to be no dominance of log(EDF_M) over log(EDF_B) or vice-versa, as far as forecasting capability is concerned.

<Place Table 3 About Here>

VI. Explaining the EDF Dynamics

In this section we try to establish a relationship between the expected default probabilities to a number of macro-financial variables, in an effort to construct a framework that can be used for stress testing. We start with simple OLS regressions at the individual bank level and then we move to a structural VAR, applied to the aggregated risk indicator and to a panel, including the available data for all banks in our sample. To avoid problems with unit root, we used the first difference for the variables.

VI.1. Individual Banks

To identify the main drivers for individual banks expected default probabilities, we utilize simple OLS stepwise regressions:

$$EDF_{it} = \alpha_i + \underset{\sim}{\beta}_i \cdot X_{it} + \varepsilon_{it}, \tag{10}$$

where EDF_{it} is the time series of expected default frequency for the bank i, α_i is the constant term, $\underset{\sim}{\beta}_i$ is the vector of coefficients for the variables X_{it}, X_{it} is the set of macro and financial variables (some of them bank-specific, such as NPLs), and ε_{it} is the bank-specific time series of residuals.

We used a backward elimination, which involves starting with all candidate variables (as in Table 2) and then eliminating the ones whose coefficient's significant level is higher than 10%. So, each bank may end up with a different set of covariates, X_{it}. Results for this analysis are presented in Table 4.

[***] We use the model $X_t = \alpha + \underset{\sim}{\beta}_1 \cdot X_{t-1} + \underset{\sim}{\beta}_2 \cdot X_{t-2} + \xi_t$, where $X_t = \{\mathrm{EDF}_{\mathrm{book}}, \mathrm{EDF}_{\mathrm{market}}, \mathrm{NPL}\}$

<Place Table 4 About Here>

Several points are worth highlighting in Table 4. First, the individual banks EDFs are explained by different factors, which can be due to their diverse portfolio composition, maturity structure, and risk exposures. Second, the simple OLS regressions also had reasonably good fits, with Adjusted R^2 ranging from 38 percent to 84.6 percent, while the F-Statistics was significant at the 1 percent level for all banks. Finally, despite the diversity of the explanatory variables in each bank regression, there were a few common factors to most of them.

The system expected default probability was significant for all banks with the exception of bank 9. The positive sign indicates that an increase in the system probability of default also induces an increase in the individual bank probability of default, which is quite intuitive and stresses the importance of examining a systemic risk event. The short-term nominal domestic interest rate was also significant for several banks, with two counterbalancing factors. In general, the negative sign could be taken as an evidence that diminishing the domestic interest rate may have a significant impact on banks interest income (over which Brazilian banks rely heavily), and thus increasing the individual bank probability of default. However, for banks 1, 7, 9 and 10, the positive sign is evidencing the increase in credit risk from the borrowers, with the increase in interest rate, provoking an increase in the individual banks probability of default. Finally, inflation (12-month expected inflation) was very significant for four banks, with a positive sign for three of them, indicating that a surge in inflation will impose additional burden to borrowers, increasing their credit risk and the associated banks' probability of default.

VI.2. Aggregated Banks

In addition to the simple OLS for individual banks, we also investigate the impact of variables over the entire sample, using aggregated data. The idea is to identify the main risk drivers that could have adverse effect over the entire system. For this exercise, we use a structural VAR, as we are also interested in visualizing the reaction functions to shocks in the main factors. To determine which variables to utilize, we run a stepwise OLS regression over the aggregated data (as in Equation (10) above) and find that short-term and long-term domestic real interest rate are the most significant factors. Next, we estimate the VAR with two lags only (because of the number of available data – 44 observations):

$$X_t = \alpha + \underset{\sim}{\beta}_1 \cdot X_{t-1} + \underset{\sim}{\beta}_2 \cdot X_{t-2} + u_t \,, \tag{11}$$

The results are presented in Table 5. In general, we obtained good fits with two-lags VAR: the adjusted R^2 was reasonably high (68.4 percent). Increases in the first lag values for 5-years CDS spreads and interest rates are associated with an increase in the contemporaneous system EDF, while decreases in expected inflation and the Brazilian broad market index are also associated with an increase in the system EDF. Additional tests show that VAR residuals are normal (Jarque-Bera test) and have no autocorrelation (Lagrange-multiplier test), and that the VAR satisfies the stability conditions (Eigenvalue stability condition)[†††]. Despite their large margins, the first two periods of the impulse reaction functions (Figure 7) are significant at the 95 percent confidence level for 5-years CDS spreads and SELIC, and indicate that a positive shock in interest rates and CDS spreads would be provoke a spike in the system EDF (in the first period), followed by a gradual decrease in EDF, as the system accommodates the shocks and makes the appropriate adjustments in their portfolios.

<Place Table 5 and Figure 7 About Here>

VI.2. Panel Regression

In order to benefit from all the available information, which included bank level data, with monthly frequency, to assess the impact of macroeconomic variables on the EDFs, and considering that we have an unbalanced panel, we employ the following panel regression specification:

$$EDF_{it} = \alpha + \underset{\sim}{\beta} \cdot X_{it} + \upsilon_t \,, \tag{12}$$

The results are presented in Table 6 and few comments are in order. Only long-term domestic nominal interest rate, 1-year NDF, S&P 500 index, FED Funds interest rate, Banks index, CDS spreads and unemployment rate are statistically significant at 1 % level. At 5 % level there is the IBOVESPA index, and at 10% there are commodity prices (including oil) and the US yield curve. The signs are generally consistent with our expectations. A decrease in interest rate will reduce banks interest income, which is fairly large in the case of Brazilian banks. The deterioration in the Brazilian equity index (IBOVESPA), indicates an increase in borrowers' credit risk, which leads to an increase in banks' credit risk. An increase in the US S&P 500 index, may divert foreign investors' capital, leading to a drop in the IBOVESPA and, consequently, an increase in the banks' EDF, through the same channel we have just explained above. An increase in the US interest rate is generally associated with a Brazilian currency depreciation, which increases borrowers' and banks' exposures to foreign currency risk.

< Place Table 6 About Here>

The sign in the banks' index works in through the very same channel as the sign for IBOVESPA. Increases in commodity prices impose inflationary pressures on customers' and corporations budgets, making them more prone to credit risk and increasing the

[†††] Test results can be provided upon request.

likelihood of a bank credit event. An increase in the US yield curve, meaning that investors expect an increase in the US long-term interest rate, will work through the same channel as the US FED Funds. Finally, increases in the Sovereign CDS spreads (one of the main borrowers of Brazilian banks) will obviously increase banks' credit risk and increases in Brazil unemployment rates (which could be seen as a proxy for customers' credit risk) is also associated with a deterioration of banks' EDFs.

VII. A VAR Panel approach

We apply a vector autoregression (VAR) to bank-level data to study the dynamic relationship between bank's non-performing loans (NPL) and one-year default probability (EDF) following the approach developed by Love and Zicchino (2006). We specify a second-order VAR model as follows:

$$y_{it} = \Psi_0 + \Psi_1 y_{it-1} + \Psi_2 y_{it-2} + f_i + \varepsilon_t \,, \tag{13}$$

where y_{it} is a two-variable vector {NPL, EDF}, the f_i are fixed effects that are included to allow for individual heterogeneity[‡‡‡]. We also perform an additional test incorporating changes in the Brazilian domestic exchange rate (ER), short-term real interest rates (IR) and the credit default spreads (5-year tenure) in order to assess the impact of these variables on bank's NPL and EDF.

The results are presented in Table 7. Empirical results suggest that the relationship between NPL and EDF is positive, although it is not necessarily statistically significant. Nonetheless, we also present the impulse-response figures using a 5% confidence interval, which suggests that the NPL responds positively to shocks in the EDF.

< Place Table 7 About Here>

The results presented in figures 8 and 9 suggest that the EDF measure is sensitive to shocks in CDS, ER and IR, with the expected positive sign. The increase in these variables would imply that financial markets conditions are worsening and we would expect the risk indicator EDF to signal this.

<Place Figures 8 and 9 About Here >

Table 8 presents the variance decomposition results. The variables explain most of their own variation 10 periods ahead in most cases. The EDF explains only 2.9% of total variation in NPL, whereas the NPL explains 2.9% of EDF. The CDS, IR and ER explain about 7.7% of total variation in the EDF.

[‡‡‡] It is worth noticing that since the fixed effects are correlated with the regressor due to lags of the dependent variables the common mean-differencing procedure cannot be employed. Therefore, a forward mean-differencing procedure is used instead.

< Place Table 8 About Here>

VIII. Conclusion

The results of a modified Merton framework, applied to the case of the Brazilian banking system, appear to be promising for countries without liquid equity markets. While the methodology is based on balance sheet information, and not on market valuations, the estimated asset volatility and default probability time series seem quite sensible. In particular, they track well the deteriorated credit condition of the system after the crisis in the early 2000s. In addition, the framework proves useful to simulate the effects of possible changes in macroeconomic conditions to individual banks and to the banking system. More specifically, it improves upon conventional portfolio stress tests that rely only on asset and liability levels by incorporating explicitly volatility into the analysis.

There are many directions to which this paper can be extended This would provide a far richer laboratory for analyzing the dynamics of the banks EDFs. It would be useful to explore further the relationships between book and market indicators. It would also be interesting to investigate the reverse causality, that is, the impact on the real sector from a shock in the credit risk indicator.

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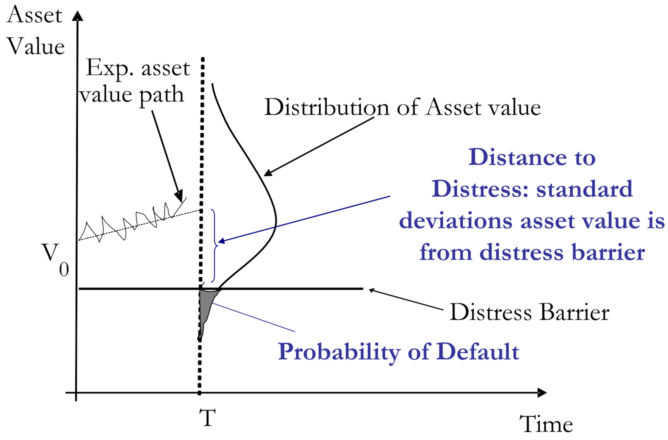


Figure 1: The Merton Framework.

Table 1: Sample size.

	Nmb of Banks		Total Assets[1/]	Perc. of System[2/]
Government	11	$	340.73	29.1%
Private Domestic	17	$	399.25	34.1%
Private Foreign	11	$	113.59	9.7%
All 39 Banks	39	$	853.57	72.9%
Top 101 Institutions	101	$	1,171.18	100.0%

Notes:

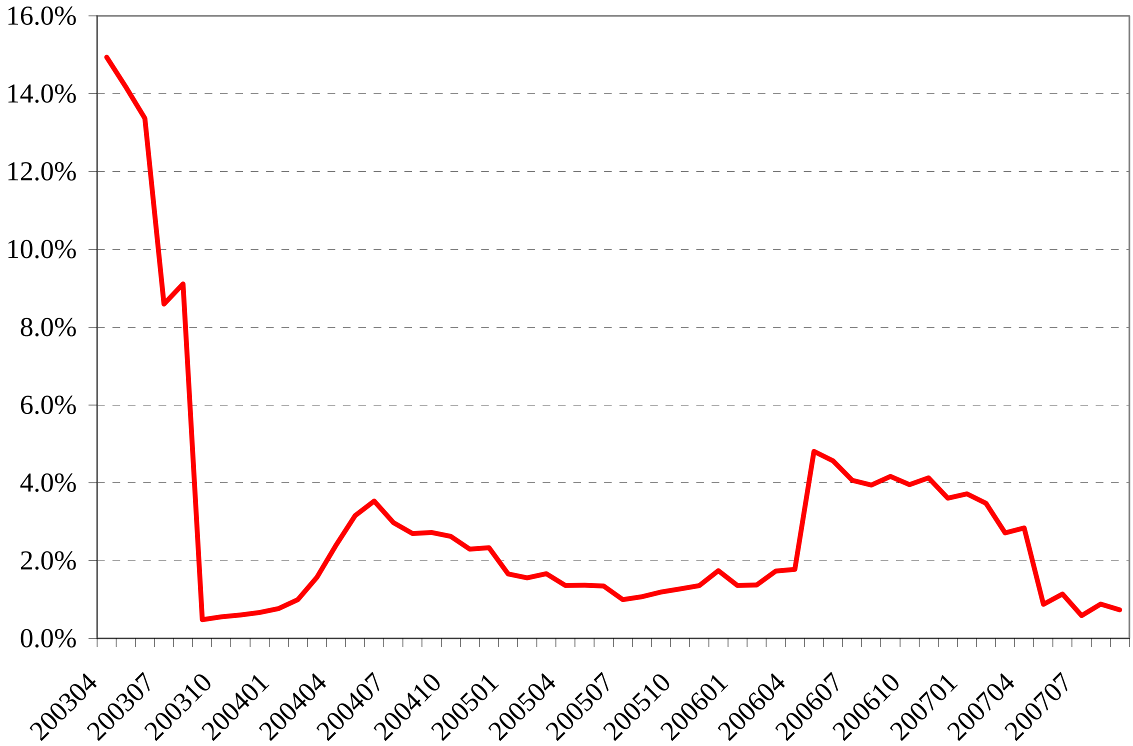
1/ In USD Billions, as of September 2007.

2/ Percentages estimated with respect to the top 101 institutions.

Source: Central Bank of Brazil.

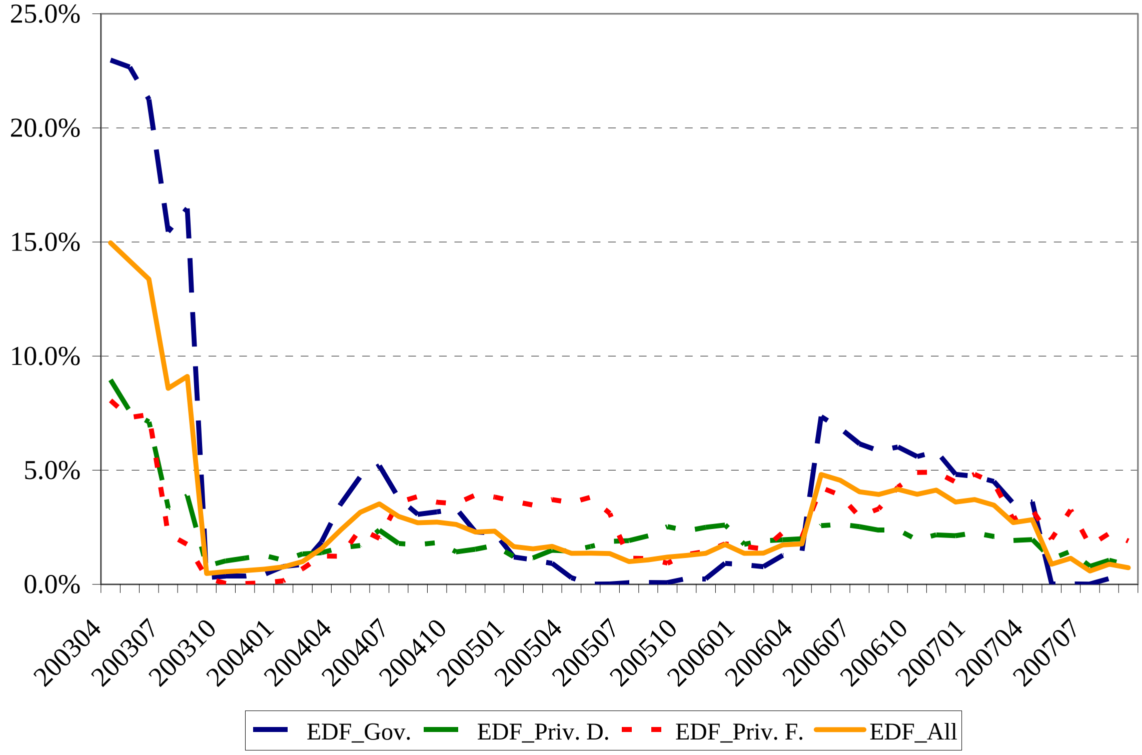
Table 2: Macro-financial variables.

Variable	Description	Source
BnkCrGr	Bank credit growth	Authors' calculation
NPL	Non performing loans, as percentage of total loans	Central Bank of Brazil
Ret(TA - US$)	Return on total assets (continuously compounded)	Central Bank of Brazil
Bank_EDF	Bank's expected default frequency	Central Bank of Brazil
EDF	System's expected default frequency	Central Bank of Brazil
SELIC	Brazilian broad equity index (IBOVESPA)	Data Stream
J1Y	One-year domestic nominal interest rate	Data Stream
EXPINF12m	1-yr expected inflation	Central Bank of Brazil
IBOV	Brazil broad equity index	Central Bank of Brazil
NDF12m	1-yr non-deliverable forward exchange rate	Data Stream
IP	Industrial production index	Brazilian Institute of Applied Economic Research (IPEA)
SP500	Brazil broad equity index	Data Stream
CPI	Inflation price index 2	Central Bank of Brazil
VIX	US market volatility index	Data Stream
FEDFUNDS	Federal funds short term nominal interest rate	Data Stream
DS_Banks	Data Stream equity index for banks	Data Stream
US YC	US yield curve (30-yrs minus 3-months zero coupom rates	Bloomberg and authors' calculation
CommPr1	Commodity prices (including petroleum)	International Financial Statistics - I
CBRZ1U5	5-year CDS spreads	Bloomberg
BRUN%TOTR	Brazil unemployment rate	Data Stream
CreditGr	system credit growth	Central Bank of Brazil



Source: Authors' estimation.

Figure 2: Aggregated EDF for all banks.



<u>Source</u>: Authors' estimation.

Figure 3: Aggregated EDFs by ownership.

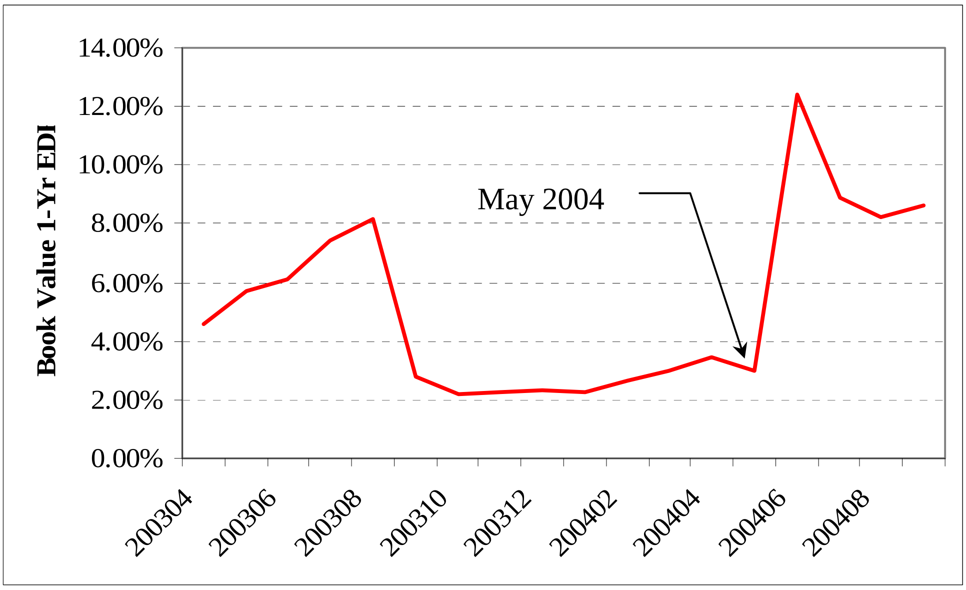


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Figure 4: Estimated EDF for a large Brazilian bank.

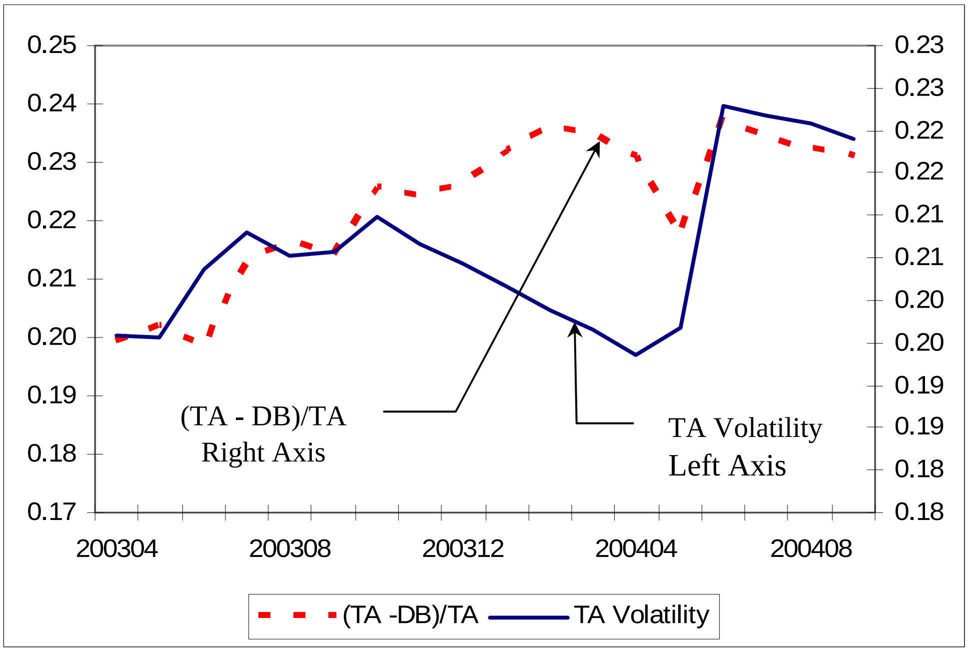
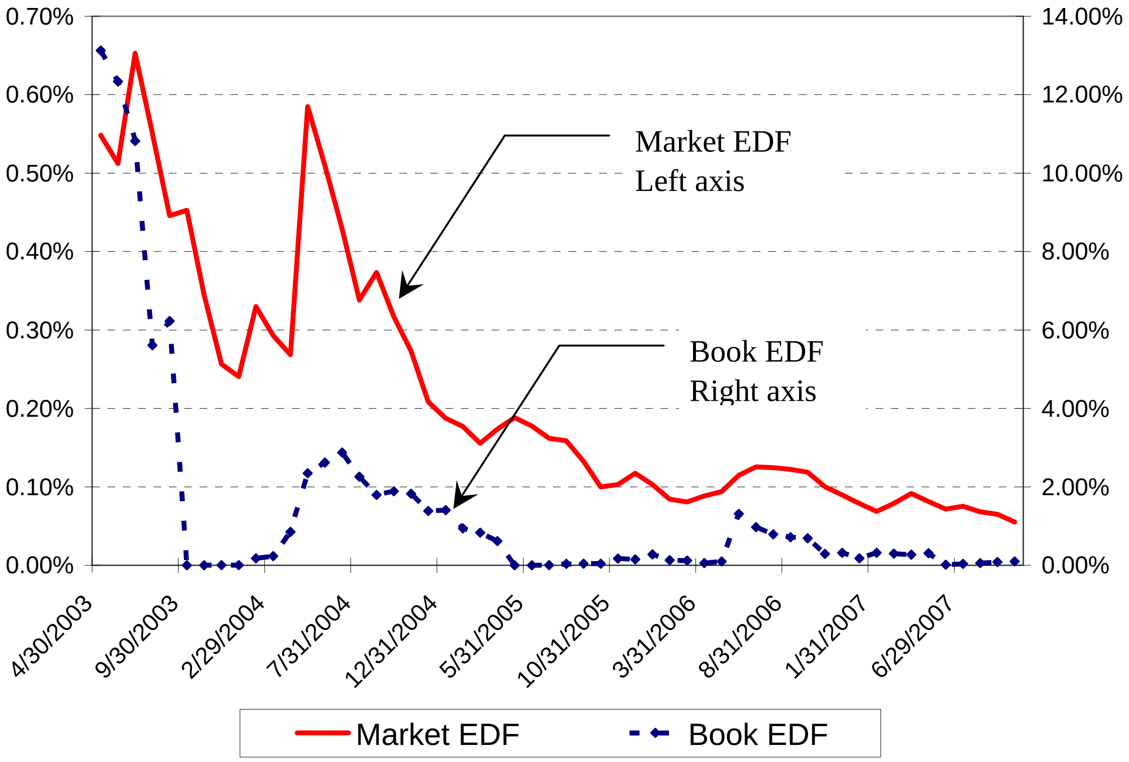


Figure 5: Distance to Distress and TA Volatility for a large Brazilian bank.



Source: Moody's-KMV and authors' estimation.

Figure 6: Book vs. Market EDF for the 3 Largest Brazilian Banks.

Table 3: Granger tests

Dependent	Independent	χ^2	Prob > χ^2
NPL	Log(EDF$_M$)	7.10	2.9%
NPL	Log(EDF$_B$)	0.53	76.9%
Log(EDF$_M$)	NPL	1.41	49.3%
Log(EDF$_M$)	Log(EDF$_B$)	2.76	25.2%
Log(EDF$_B$)	NPL	1.18	55.4%
Log(EDF$_B$)	Log(EDF$_M$)	0.95	62.3%

Table 4A: Stepwise OLS regressions.[1/]

	Bank1	Bank2	Bank3	Bank4	Bank5	Bank6	Bank7	Bank8	Bank9	Bank10
Constant										
Bank credit growth										
NPL										
Return on total assets	-0.07 **							-0.03 **		
System EDF	1.53 *	0.64 *	0.61 *	0.13 *	0.25 *	1.76 *	1.20 *	0.35 *		3.20 *
Domestic nominal int. rate (ST)		6.13 *		-1.60 *			5.92 *	-7.10 *		
Domestic nominal int. rate (LT)	-13.13 *					-6.77 **			2.93 **	11.57 *
1-year expected inflation		0.27 *	0.16 **		0.17 *					-0.91 **
Brazil equity index	-0.13 *	0.03 *					0.03 **		0.03 *	
NDF 1 Y						0.08 **			-0.03 **	
Industrial prodution										
S&P 500		-0.06 *	-0.08 *	-0.04 *					-0.05 **	0.25 **
VIX	-6.85 *		-0.92 ***	-0.41 **						4.46 **
FED Funds int. rate								2.17 ***		
Brazilian banks equity index			0.01 **	0.01 *		0.04 ***				-0.06 ***
US yield curve		0.57 ***			-0.41 ***	-3.02 *	0.95 ***			
Commodity prices										
5-yrs CDS spread					0.03 ***		0.15 *		0.10 *	-0.27 ***
Brazil unemployment rate	-0.96 **									
System credit growth										
US CPI	1.74 ***									
Brazilian IPCA		-0.21 ***						0.45 **		
Adj R-squared	50.6%	81.7%	74.8%	60.0%	58.3%	69.2%	84.6%	38.0%	55.8%	73.6%
F Stat.	11.09 *	44.97 *	41.86 *	21.78 *	25.15 *	32.04 *	76.9 *	9.45 *	15.50 *	28.42 *

Note:

1/ Variables that are statistically significant at 1, 5, or 10 percent, are marked by *, **, or *** respectively.

Table 5: Aggregated Data VAR

Variables	Coefficient	Standard Error	z	Prob(>z)
log(EDF):				
Lag 1	0.58	0.16	3.63	0.0%
Lag 2	0.09	0.16	0.56	57.8%
5-yrs CDS spreads:				
Lag 1	4.93	16.69	0.3	76.8%
Lag 2	-15.04	12.89	-1.17	24.3%
1-yr expected inflation				
Lag 1	-15.32	36.52	-0.42	67.5%
Lag 2	-12.08	34.57	-0.35	72.7%
Brazil equity index:				
Lag 1	-1.19	1.67	-0.72	47.4%
Lag 2	-2.72	1.60	-1.7	8.9%
Domestic nominal interest rate (ST):				
Lag 1	551.20	428.49	1.29	19.8%
Lag 2	-327.69	391.83	-0.84	40.3%
Domestic nominal interest rate (LT)				
Lag 1	176.35	227.70	0.77	43.9%
Lag 2	36.38	234.95	0.15	87.7%
Constant	-1.23	0.42	-2.94	0.3%
Adjusted R^2	68.4%			

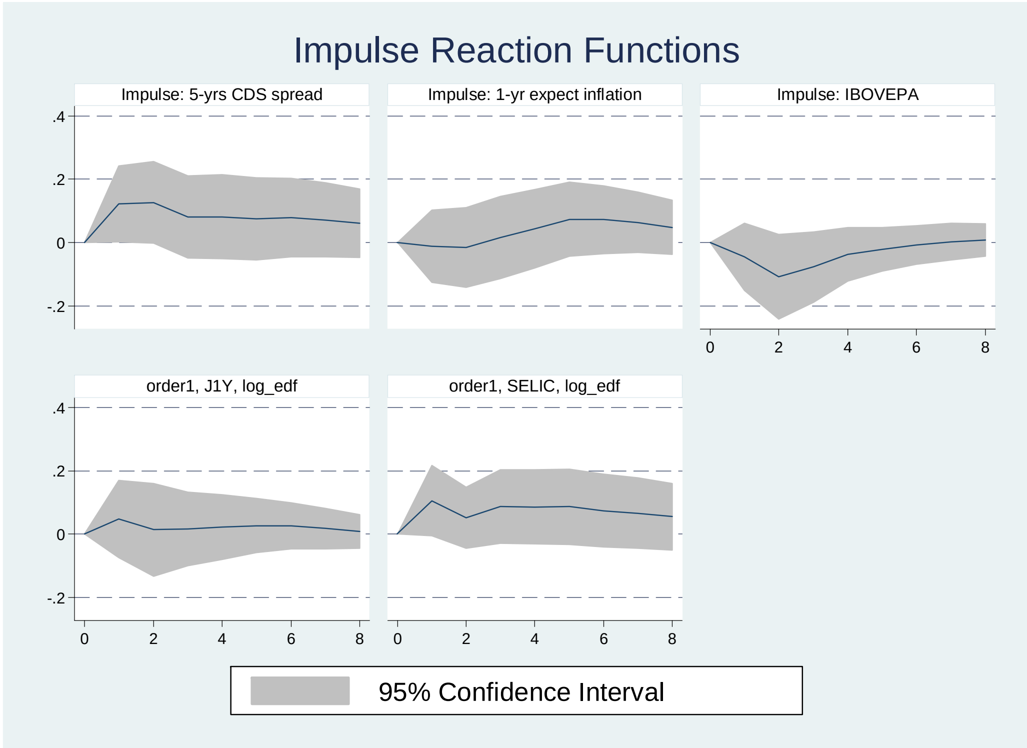


Figure 7: Impulse reaction functions for the VAR

Table 6: Dynamic Panel Results[1/]

	Coeff.	Prob > z	
NPL	-24.97	62.2%	
Return on assets (USD)	-6.20	11.0%	
Domestic nominal interest rate (ST):	2810.94	11.2%	
Domestic nominal interest rate (LT)	-4850.81	0.0%	*
1-year NDF	62.55	0.1%	*
IBOVESPA	-23.53	1.3%	**
1-year expected inflation	86.17	60.9%	
Industrial production	0.05	87.4%	
S&P 500	101.86	0.0%	*
VIX	472.22	18.7%	
FED Funds interest rate	3273.78	0.1%	*
Data Stream banks index	-36.83	0.0%	*
Commodity prices (including oil)	32.74	8.3%	***
US yield curve	37.33	6.7%	***
5-years CDS spread	-210.59	0.5%	*
Brazil unemployment rate	239.94	0.1%	*
Bank credit growth	15.41	30.2%	
Constant	-7.44	0.0%	*
Overall R^2	4.58%		

Notes:
1/ Variables that are statistically significant at 1, 5, or 10 percent, are marked by *, **, or *** respectively.

Table 7: Panel-VAR results.

Response to	NPL t	EDF t
Panel A: 2-var model		
NPL t-1	0.68	0.36
	(3.09)	(1.77)
EDF t-1	0.02	0.13
	(1.10)	(1.75)
Panel B: 5-var model		
NPL t-1	0.65	0.15
	(2.79)	(1.03)
EDF t-1	0.03	0.12
	(1.30)	(1.64)
CDS t-1	0.01	0.12
	(0.20)	(1.56)
IR t-1	0.03	0.11
	(1.49)	(1.18)
ER t-1	0.00	0.14
	(0.13)	(3.29)

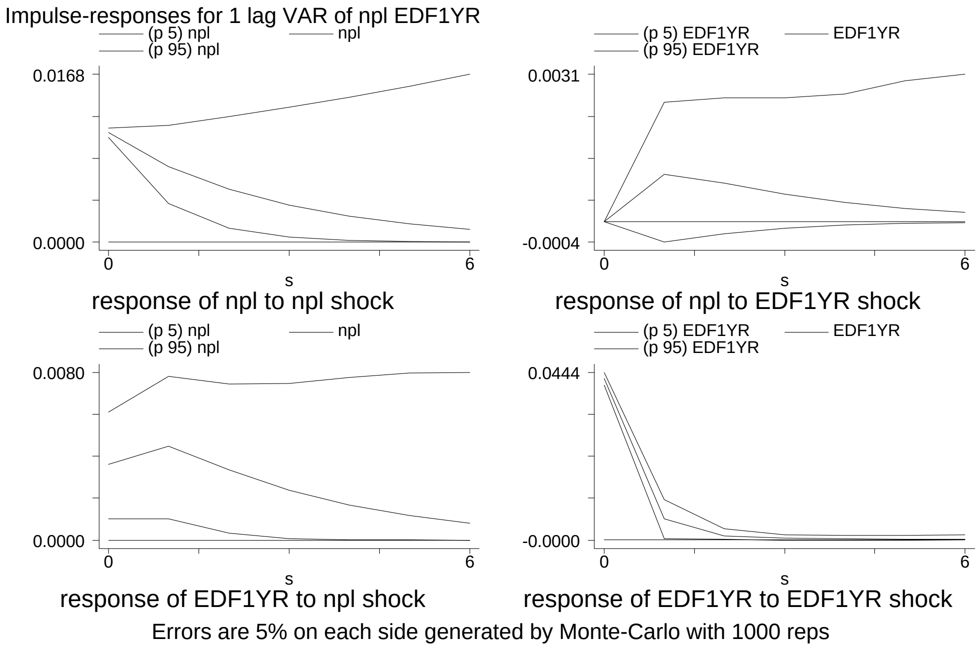


Figure 8. Impulse-responses in a 2-VAR model (EDF x NPL).

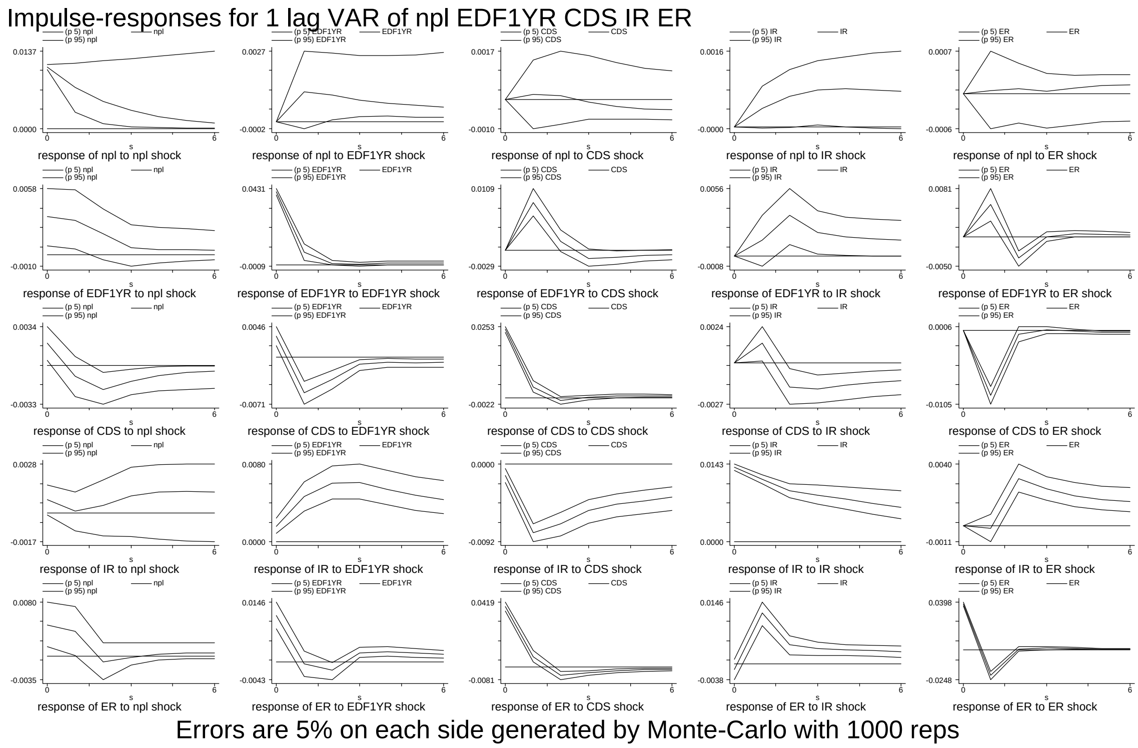


Figure 9. Impulse-responses in a 5-VAR model.

Table 8. Variance Decomposition

	S	NPL	EDF	CDS	IR	ER
Panel A: 2-var model						
NPL	10	99.0%	1.0%			
EDF	10	2.9%	97.1%			
Panel B: 5-var model						
NPL	10	95.6%	2.2%	0.3%	1.8%	0.1%
EDF	10	1.3%	91.0%	4.1%	1.4%	2.2%
CDS	10	1.6%	7.0%	78.5%	1.9%	11.0%
IR	10	0.8%	17.1%	19.6%	60.1%	2.4%
ER	10	0.9%	4.0%	41.0%	5.6%	48.5%

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