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

Marcos Souto**
Benjamin M. Tabak***
Francisco Vazquez****

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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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** International Monetary Fund, MCM.
*** Banco Central do Brasil: Research Department. Universidade Católica de Brasília. E-mail: benjamin.tabak@bcb.gov.br
**** International Monetary Fund.
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):

\[ E = VN(d_1) - DBe^{-rT}N(d_2), \]

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.
\[ d_1 = \frac{\ln \left( \frac{V}{DB} \right) + \left( r + \frac{1}{2} \sigma_v^2 \right) T}{\sigma_v \sqrt{T}} = \frac{\ln \left( V \exp \left( \left( r + \frac{1}{2} \sigma_v^2 \right) T \right) \right) - \ln(DB)}{\sigma_v \sqrt{T}} , \] (2)

and

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

with \( \sigma_v \) being the implied value of asset volatility.

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

\[ \sigma_E = \frac{\partial E}{\partial V} \sigma_v = N(d_1) \frac{V}{E} \sigma_v , \] (4)

where \( E \) is the value of equity and \( \sigma_E \) 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).

Souto (2008b) shows how to solve numerically this system and shows that the numerical solution of the system converges to a unique pair 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:

\[ DB = STD + \alpha \cdot LTD, \] (5)

where STD represents the short-term liabilities (maturity \( \leq 1 \) year), LTD represents the long-term liabilities (maturity \( > 1 \) year), and \( \alpha \) is a parameter between 0 and 1 (usually around 0.5).\footnote{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 ($D$):

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

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

$$RNDP = N(-D2D).$$ \hspace{1cm} (7)

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

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

§ Moody’s utilizes $\alpha$ 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.

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:

$$\sigma = \sqrt{\frac{\sum_{t=1}^{N} \text{Min}[(\ln(V_t) - \ln(V_{t-1}),0)]^2}{N}}$$

(9)

where \(\text{Min}(\cdot, \cdot)\) 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 shook 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*+φ, where i* is the foreign interest rate (e.g. Libor), and φ is a risk premium (assuming that the uncovered interest 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.

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\(^\text{§§}\). 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.

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

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

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:

\[
EDF_{it} = \alpha_i + \beta_i \cdot X_{it} + \epsilon_{it},
\]

where \( EDF_{it} \) is the time series of expected default frequency for the bank \( i \), \( \alpha_i \) is the constant term, \( \beta_i \) 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 \( \epsilon_{it} \) 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 \( X_{it} = \alpha + \beta_{i-1} \cdot X_{i,t-1} + \beta_{i-2} \cdot X_{i,t-2} + \xi_{it} \), where \( X = \{\text{EDF_book, EDF_market, NPL}\} \)
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):

$$X_t = \alpha + \beta_1 \cdot X_{t-1} + \beta_2 \cdot X_{t-2} + u_t, \quad (11)$$

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)\textsuperscript{†††}. 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.

\textless Place Table 5 and Figure 7 About Here\textgreater

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:

\begin{equation}
EDF_i = \alpha + \beta_i \cdot X_{it} + \nu_i,
\end{equation}

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.

\textless Place Table 6 About Here\textgreater

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

\textsuperscript{†††} 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:

\[ y_u = \Psi_0 + \Psi_1 y_{u-1} + \Psi_2 y_{u-2} + f_i + \epsilon_i, \]  

where \( y_u \) 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.
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.
References


Figure 1: The Merton Framework.
Table 1: Sample size.

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<th>Nmb of Banks</th>
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<th>Perc. of System $</th>
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<tr>
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<td>Top 101 Institutions</td>
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Notes:
1/ In USD Billions, as of September 2007.
2/ Percentages estimated with respect to the top 101 institutions.
Source: Central Bank of Brazil.
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<th>Variable</th>
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<td>Brazilian broad equity index (IBOVESPA)</td>
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<td>J1Y</td>
<td>One-year domestic nominal interest rate</td>
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<td>1-yr non-deliverable forward exchange rate</td>
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<td>Industrial production index</td>
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<td>SP500</td>
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<td>Data Stream</td>
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<td>CPI</td>
<td>Inflation price index 2</td>
<td>Central Bank of Brazil</td>
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<tr>
<td>VIX</td>
<td>US market volatility index</td>
<td>Data Stream</td>
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<td>FEDFUNDS</td>
<td>Federal funds short term nominal interest rate</td>
<td>Data Stream</td>
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<td>DS_Banks</td>
<td>Data Stream equity index for banks</td>
<td>Data Stream</td>
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<td>US YC</td>
<td>US yield curve (30-yrs minus 3-months zero coupon rates)</td>
<td>Bloomberg and authors' calculation</td>
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<td>Commodity prices (including petroleum)</td>
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<td>CBRZ1U5</td>
<td>5-year CDS spreads</td>
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<td>BRUN/TOTR</td>
<td>Brazil unemployment rate</td>
<td>Data Stream</td>
</tr>
<tr>
<td>CreditGr</td>
<td>system credit growth</td>
<td>Central Bank of Brazil</td>
</tr>
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</table>
Figure 2: Aggregated EDF for all banks.

Source: Authors’ estimation.
Figure 3: Aggregated EDFs by ownership.

Source: Authors’ estimation.
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

<table>
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<tr>
<th>Dependent</th>
<th>Independent</th>
<th>$\chi^2$</th>
<th>Prob &gt; $\chi^2$</th>
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<tr>
<td>NPL</td>
<td>Log(EDFₐₙ)</td>
<td>7.10</td>
<td>2.9%</td>
</tr>
<tr>
<td>NPL</td>
<td>Log(EDFₐₕ)</td>
<td>0.53</td>
<td>76.9%</td>
</tr>
<tr>
<td>Log(EDFₐₙ)</td>
<td>NPL</td>
<td>1.41</td>
<td>49.3%</td>
</tr>
<tr>
<td>Log(EDFₐₙ)</td>
<td>Log(EDFₐₕ)</td>
<td>2.76</td>
<td>25.2%</td>
</tr>
<tr>
<td>Log(EDFₐₕ)</td>
<td>NPL</td>
<td>1.18</td>
<td>55.4%</td>
</tr>
<tr>
<td>Log(EDFₐₕ)</td>
<td>Log(EDFₐₙ)</td>
<td>0.95</td>
<td>62.3%</td>
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</table>
Table 4A: Stepwise OLS regressions.\(^1\)

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

Note: Variables that are statistically significant at 1, 5, or 10 percent, are marked by *, **, or *** respectively.
Table 5: Aggregated Data VAR

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>z</th>
<th>Prob(&gt;z)</th>
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<tbody>
<tr>
<td>log(EDF):</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lag 1</td>
<td>0.58</td>
<td>0.16</td>
<td>3.63</td>
<td>0.0%</td>
</tr>
<tr>
<td>Lag 2</td>
<td>0.09</td>
<td>0.16</td>
<td>0.56</td>
<td>57.8%</td>
</tr>
<tr>
<td>5-yrs CDS spreads:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lag 1</td>
<td>4.93</td>
<td>16.69</td>
<td>0.3</td>
<td>76.8%</td>
</tr>
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<td>12.89</td>
<td>-1.17</td>
<td>24.3%</td>
</tr>
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<td>1-yr expected inflation</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>36.52</td>
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</tr>
<tr>
<td>Lag 2</td>
<td>-12.08</td>
<td>34.57</td>
<td>-0.35</td>
<td>72.7%</td>
</tr>
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<td>Brazil equity index:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lag 1</td>
<td>-1.19</td>
<td>1.67</td>
<td>-0.72</td>
<td>47.4%</td>
</tr>
<tr>
<td>Lag 2</td>
<td>-2.72</td>
<td>1.60</td>
<td>-1.17</td>
<td>8.9%</td>
</tr>
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<td>Domestic nominal interest rate (ST):</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lag 1</td>
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<td>428.49</td>
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<td>391.83</td>
<td>-0.84</td>
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<td>Domestic nominal interest rate (LT)</td>
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<td></td>
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<tr>
<td>Lag 1</td>
<td>176.35</td>
<td>227.70</td>
<td>0.77</td>
<td>43.9%</td>
</tr>
<tr>
<td>Lag 2</td>
<td>36.38</td>
<td>234.95</td>
<td>0.15</td>
<td>87.7%</td>
</tr>
<tr>
<td>Constant</td>
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<td>0.42</td>
<td>-2.94</td>
<td>0.3%</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td></td>
<td></td>
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<td>68.4%</td>
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</table>
Figure 7: Impulse reaction functions for the VAR
Table 6: Dynamic Panel Results\textsuperscript{1/}

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

Overall R\textsuperscript{2}      | 4.58%    |

Notes:

\textsuperscript{1/} Variables that are statistically significant at 1, 5, or 10 percent, are marked by *, **, or *** respectively.
Table 7: Panel-VAR results.

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

<table>
<thead>
<tr>
<th></th>
<th>S</th>
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<th>EDF</th>
<th>CDS</th>
<th>IR</th>
<th>ER</th>
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</thead>
<tbody>
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<tr>
<td>NPL</td>
<td>10</td>
<td>99.0%</td>
<td>1.0%</td>
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<td>EDF</td>
<td>10</td>
<td>2.9%</td>
<td>97.1%</td>
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</tr>
<tr>
<td>Panel B: 5-var model</td>
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<td>NPL</td>
<td>10</td>
<td>95.6%</td>
<td>2.2%</td>
<td>0.3%</td>
<td>1.8%</td>
<td>0.1%</td>
</tr>
<tr>
<td>EDF</td>
<td>10</td>
<td>1.3%</td>
<td>91.0%</td>
<td>4.1%</td>
<td>1.4%</td>
<td>2.2%</td>
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<td>CDS</td>
<td>10</td>
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<td>7.0%</td>
<td>78.5%</td>
<td>1.9%</td>
<td>11.0%</td>
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<tr>
<td>IR</td>
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<td>2.4%</td>
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<tr>
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<td>41.0%</td>
<td>5.6%</td>
<td>48.5%</td>
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Banco Central do Brasil

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   Eduardo Lundberg
   Monetary Policy and Banking Supervision Functions on the Central Bank
   Eduardo Lundberg
   Jul/2000

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4 An Information Theory Approach to the Aggregation of Log-Linear Models
   Pedro H. Albuquerque
   Jul/2000

5 The Pass-Through from Depreciation to Inflation: a Panel Study
   Ilan Goldfajn and Sérgio Ribeiro da Costa Werlang
   Jul/2000

6 Optimal Interest Rate Rules in Inflation Targeting Frameworks
   José Alvaro Rodrigues Neto, Fabio Araújo and Marta Baltar J. Moreira
   Jul/2000

7 Leading Indicators of Inflation for Brazil
   Marcelle Chauvet
   Sep/2000

8 The Correlation Matrix of the Brazilian Central Bank’s Standard Model for Interest Rate Market Risk
   José Alvaro Rodrigues Neto
   Sep/2000

9 Estimating Exchange Market Pressure and Intervention Activity
   Emanuel-Werner Kohlscheen
   Nov/2000

10 Análise do Financiamento Externo a uma Pequena Economia
    Carlos Hamilton Vasconcelos Araújo and Renato Galvão Flóres Júnior
    Mar/2001

11 A Note on the Efficient Estimation of Inflation in Brazil
    Michael F. Bryan and Stephen G. Cecchetti
    Mar/2001

12 A Test of Competition in Brazilian Banking
    Márcio I. Nakane
    Mar/2001
13 Modelos de Previsão de Insolvência Bancária no Brasil
Marcio Magalhães Janot
Mar/2001

14 Evaluating Core Inflation Measures for Brazil
Francisco Marcos Rodrigues Figueiredo
Mar/2001

15 Is It Worth Tracking Dollar/Real Implied Volatility?
Sandro Canesso de Andrade and Benjamin Miranda Tabak
Mar/2001

16 Avaliação das Projeções do Modelo Estrutural do Banco Central do Brasil para a Taxa de Variação do IPCA
Sergio Afonso Lago Alves
Mar/2001

17 Estimando o Produto Potencial Brasileiro: uma Abordagem de Função de Produção
Tito Nícias Teixeira da Silva Filho
Abr/2001

18 A Simple Model for Inflation Targeting in Brazil
Paulo Springer de Freitas and Marcelo Kfoury Muinhos
Apr/2001

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Marcelo Kfoury Muinhos, Paulo Springer de Freitas and Fabio Araújo
May/2001

20 Credit Channel without the LM Curve
Victorio Y. T. Chu and Márcio I. Nakane
May/2001

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Pedro H. Albuquerque
Jun/2001

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Paulo Coutinho and Benjamin Miranda Tabak
Jun/2001

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Sérgio Mikio Koyama e Márcio I. Nakane
Jul/2001

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Joel Bogdanski, Paulo Springer de Freitas, Ilan Goldfajn and Alexandre Antonio Tombini
Aug/2001

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Pedro Fachada
Aug/2001

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Marcelo Kfoury Muinhos
Aug/2001

27 Complementaridade e Fungibilidade dos Fluxos de Capitaís Internacionais
Carlos Hamilton Vasconcelos Araújo e Renato Galvão Flôres Júnior
Set/2001
<table>
<thead>
<tr>
<th></th>
<th>Title</th>
<th>Authors</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Using a Money Demand Model to Evaluate Monetary Policies in Brazil</td>
<td>Pedro H. Albuquerque and Solange Gouvêa</td>
<td>Nov/2001</td>
</tr>
<tr>
<td>30</td>
<td>Testing the Expectations Hypothesis in the Brazilian Term Structure of Interest Rates</td>
<td>Benjamin Miranda Tabak and Sandro Canesso de Andrade</td>
<td>Nov/2001</td>
</tr>
<tr>
<td>31</td>
<td>Algumas Considerações sobre a Sazonalidade no IPCA</td>
<td>Francisco Marcos R. Figueiredo e Roberta Blass Staub</td>
<td>Nov/2001</td>
</tr>
<tr>
<td>32</td>
<td>Crises Cambiais e Ataques Especulativos no Brasil</td>
<td>Mauro Costa Miranda</td>
<td>Nov/2001</td>
</tr>
<tr>
<td>35</td>
<td>Uma Definição Operacional de Estabilidade de Preços</td>
<td>Tito Nícolas Teixeira da Silva Filho</td>
<td>Dez/2001</td>
</tr>
<tr>
<td>38</td>
<td>Volatilidade Implícita e Antecipação de Eventos de Stress: um Teste para o Mercado Brasileiro</td>
<td>Frederico Pechir Gomes</td>
<td>Mar/2002</td>
</tr>
<tr>
<td>40</td>
<td>Speculative Attacks on Debts, Dollarization and Optimum Currency Areas</td>
<td>Aloísio Araújo and Márcia Leon</td>
<td>Apr/2002</td>
</tr>
<tr>
<td>41</td>
<td>Mudanças de Regime no Câmbio Brasileiro</td>
<td>Carlos Hamilton V. Araújo e Getúlio B. da Silveira Filho</td>
<td>Jun/2002</td>
</tr>
<tr>
<td>42</td>
<td>Modelo Estrutural com Setor Externo: Endogenização do Prêmio de Risco e do Câmbio</td>
<td>Marcelo Kfoury Muinhos, Sérgio Afonso Lago Alves e Gil Riella</td>
<td>Jun/2002</td>
</tr>
<tr>
<td>43</td>
<td>The Effects of the Brazilian ADRs Program on Domestic Market Efficiency</td>
<td>Benjamin Miranda Tabak and Eduardo José Araújo Lima</td>
<td>Jun/2002</td>
</tr>
<tr>
<td>No.</td>
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<td>Authors</td>
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</tr>
<tr>
<td>44</td>
<td>Estrutura Competitiva, Produtividade Industrial e Liberação Comercial no Brasil</td>
<td>Pedro Cavalcanti Ferreira e Osmani Teixeira de Carvalho Guillén</td>
<td>Jun/2002</td>
</tr>
<tr>
<td>45</td>
<td>Optimal Monetary Policy, Gains from Commitment, and Inflation Persistence</td>
<td>André Minella</td>
<td>Aug/2002</td>
</tr>
<tr>
<td>46</td>
<td>The Determinants of Bank Interest Spread in Brazil</td>
<td>Tarsila Segalla Afanasieff, Priscilla Maria Villa Lhacer and Márcio I. Nakane</td>
<td>Aug/2002</td>
</tr>
<tr>
<td>47</td>
<td>Indicadores Derivados de Agregados Monetários</td>
<td>Fernando de Aquino Fonseca Neto e José Albuquerque Júnior</td>
<td>Set/2002</td>
</tr>
<tr>
<td>49</td>
<td>Desenvolvimento do Sistema Financeiro e Crescimento Econômico no Brasil: Evidências de Causalidade</td>
<td>Orlando Carneiro de Matos</td>
<td>Set/2002</td>
</tr>
<tr>
<td>50</td>
<td>Macroeconomic Coordination and Inflation Targeting in a Two-Country Model</td>
<td>Eui Jung Chang, Marcelo Kfoury Muinhos and Joanílio Rodolpho Teixeira</td>
<td>Sep/2002</td>
</tr>
<tr>
<td>51</td>
<td>Credit Channel with Sovereign Credit Risk: an Empirical Test</td>
<td>Victorio Yi Tson Chu</td>
<td>Sep/2002</td>
</tr>
<tr>
<td>52</td>
<td>Generalized Hyperbolic Distributions and Brazilian Data</td>
<td>José Fajardo and Aquiles Farias</td>
<td>Sep/2002</td>
</tr>
<tr>
<td>54</td>
<td>Stock Returns and Volatility</td>
<td>Benjamin Miranda Tabak and Solange Maria Guerra</td>
<td>Nov/2002</td>
</tr>
<tr>
<td>55</td>
<td>Componentes de Curto e Longo Prazo das Taxas de Juros no Brasil</td>
<td>Carlos Hamilton Vasconcelos Araújo e Osmani Teixeira de Carvalho de Guillén</td>
<td>Nov/2002</td>
</tr>
<tr>
<td>56</td>
<td>Causality and Cointegration in Stock Markets: the Case of Latin America</td>
<td>Benjamin Miranda Tabak and Eduardo José Araújo Lima</td>
<td>Dec/2002</td>
</tr>
<tr>
<td>57</td>
<td>As Leis de Falência: uma Abordagem Econômica</td>
<td>Aloisio Araújo</td>
<td>Dez/2002</td>
</tr>
<tr>
<td>59</td>
<td>Os Preços Administrados e a Inflação no Brasil</td>
<td>Francisco Marcos R. Figueiredo and Thaís Porto Ferreira</td>
<td>Dez/2002</td>
</tr>
<tr>
<td>60</td>
<td>Delegated Portfolio Management</td>
<td>Paulo Coutinho and Benjamin Miranda Tabak</td>
<td>Dec/2002</td>
</tr>
</tbody>
</table>
61 O Uso de Dados de Alta Frequência na Estimação da Volatilidade e do Valor em Risco para o Ibovespa
João Maurício de Souza Moreira e Eduardo Facó Lemgruber
Dez/2002

62 Taxa de Juros e Concentração Bancária no Brasil
Eduardo Kiyoshi Tomooka e Sérgio Mikio Koyama
Fev/2003

63 Optimal Monetary Rules: the Case of Brazil
Charles Lima de Almeida, Marco Aurélio Peres, Geraldo da Silva e Souza and Benjamin Miranda Tabak
Feb/2003

64 Medium-Size Macroeconomic Model for the Brazilian Economy
Marcelo Kfoury Muinhos and Sergio Afonso Lago Alves
Feb/2003

65 On the Information Content of Oil Future Prices
Benjamin Miranda Tabak
Feb/2003

66 A Taxa de Juros de Equilíbrio: uma Abordagem Múltipla
Pedro Calhman de Miranda e Marcelo Kfoury Muinhos
Fev/2003

67 Avaliação de Métodos de Cálculo de Exigência de Capital para Risco de Mercado de Carteiras de Ações no Brasil
Gustavo S. Araújo, João Maurício S. Moreira e Ricardo S. Maia Clemente
Fev/2003

68 Real Balances in the Utility Function: Evidence for Brazil
Leonardo Soriano de Alencar and Márcio I. Nakane
Feb/2003

69 r-filters: a Hodrick-Prescott Filter Generalization
Fabio Araújo, Marta Baltar Moreira Areosa and José Alvaro Rodrigues Neto
Feb/2003

70 Monetary Policy Surprises and the Brazilian Term Structure of Interest Rates
Benjamin Miranda Tabak
Feb/2003

71 On Shadow-Prices of Banks in Real-Time Gross Settlement Systems
Rodrigo Penaloza
Apr/2003

72 O Prêmio pela Maturidade na Estrutura a Termo das Taxas de Juros Brasileiras
Ricardo Dias de Oliveira Brito, Angelo J. Mont’Alverne Duarte e Osmani Teixeira de C. Guilhen
Maio/2003

73 Análise de Componentes Principais de Dados Funcionais – uma Aplicação às Estruturas a Termo de Taxas de Juros
Getúlio Borges da Silveira e Octavio Bessada
Maio/2003

74 Aplicação do Modelo de Black, Derman & Toy à Precificação de Opções Sobre Títulos de Renda Fixa
Octavio Manuel Bessada Lion, Carlos Alberto Nunes Cosenza e César das Neves
Maio/2003

75 Brazil’s Financial System: Resilience to Shocks, no Currency Substitution, but Struggling to Promote Growth
Ilan Goldfajn, Katherine Hennings and Helio Mori
Jun/2003
76 Inflation Targeting in Emerging Market Economies
Arminio Fraga, Ilan Goldfajn and André Minella
Jun/2003

77 Inflation Targeting in Brazil: Constructing Credibility under Exchange Rate Volatility
André Minella, Paulo Springer de Freitas, Ilan Goldfajn and Marcelo Kfouri Munhos
Jul/2003

78 Contornando os Pressupostos de Black & Scholes: Aplicação do Modelo de Precificação de Opções de Duan no Mercado Brasileiro
Gustavo Silva Araújo, Claudio Henrique da Silveira Barbedo, Antonio Carlos Figueiredo, Eduardo Facó Lemgruber
Out/2003

79 Inclusão do Decaimento Temporal na Metodologia Delta-Gama para o Cálculo do VaR de Carteiras Compradas em Opções no Brasil
Claudio Henrique da Silveira Barbedo, Gustavo Silva Araújo, Eduardo Facó Lemgruber
Out/2003

80 Diferenças e Semelhanças entre Países da América Latina: uma Análise de Markov Switching para os Ciclos Econômicos de Brasil e Argentina
Arnildo da Silva Correa
Out/2003

81 Bank Competition, Agency Costs and the Performance of the Monetary Policy
Leonardo Soriano de Alencar and Márcio I. Nakane
Jan/2004

82 Carteiras de Opções: Avaliação de Metodologias de Exigência de Capital no Mercado Brasileiro
Cláudio Henrique da Silveira Barbedo e Gustavo Silva Araújo
Mar/2004

83 Does Inflation Targeting Reduce Inflation? An Analysis for the OECD Industrial Countries
Thomas Y. Wu
May/2004

84 Speculative Attacks on Debts and Optimum Currency Area: a Welfare Analysis
Aloisio Araujo and Marcia Leon
May/2004

André Soares Loureiro and Fernando de Holanda Barbosa
May/2004

86 Identificação do Fator Estocástico de Descontos e Algumas Implicações sobre Testes de Modelos de Consumo
Fabio Araujo e João Victor Issler
Maio/2004

87 Mercado de Crédito: uma Análise Econométrica dos Volumes de Crédito Total e Habitacional no Brasil
Ana Carla Abrão Costa
Dez/2004

88 Ciclos Internacionais de Negócios: uma Análise de Mudança de Regime Markoviano para Brasil, Argentina e Estados Unidos
Arnildo da Silva Correa e Ronald Otto Hillbrecht
Dez/2004

89 O Mercado de Hedge Cambial no Brasil: Reação das Instituições Financeiras a Intervenções do Banco Central
Fernando N. de Oliveira
Dez/2004
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Authors</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>Bank Privatization and Productivity: Evidence for Brazil</td>
<td>Márcio I. Nakane and Daniela B. Weintraub</td>
<td>Dec/2004</td>
</tr>
<tr>
<td>92</td>
<td>Steady-State Analysis of an Open Economy General Equilibrium Model for Brazil</td>
<td>Mirta Noemi Sataka Bugarin, Roberto de Goes Ellery Jr., Victor Gomes Silva, Marcelo Kfoury Muinhos</td>
<td>Apr/2005</td>
</tr>
<tr>
<td>93</td>
<td>Avaliação de Modelos de Cálculo de Exigência de Capital para Risco Cambial</td>
<td>Claudio H. da S. Barbedo, Gustavo S. Araújo, João Maurício S. Moreira e Ricardo S. Maia Clemente</td>
<td>Abr/2005</td>
</tr>
<tr>
<td>95</td>
<td>Comment on Market Discipline and Monetary Policy by Carl Walsh</td>
<td>Maurício S. Bugarin and Fábia A. de Carvalho</td>
<td>Apr/2005</td>
</tr>
<tr>
<td>96</td>
<td>O que É Estratégia: uma Abordagem Multiparadigmática para a Disciplina</td>
<td>Anthero de Moraes Meirelles</td>
<td>Ago/2005</td>
</tr>
<tr>
<td>99</td>
<td>Adequação das Medidas de Valor em Risco na Formulação da Exigência de Capital para Estratégias de Opções no Mercado Brasileiro</td>
<td>Gustavo Silva Araújo, Claudio Henrique da Silveira Barbedo, Eduardo Facó Lemgruber</td>
<td>Set/2005</td>
</tr>
<tr>
<td>100</td>
<td>Targets and Inflation Dynamics</td>
<td>Sérgio A. L. Alves and Waldyr D. Areosa</td>
<td>Oct/2005</td>
</tr>
<tr>
<td>101</td>
<td>Comparing Equilibrium Real Interest Rates: Different Approaches to Measure Brazilian Rates</td>
<td>Marcelo Kfoury Muinhos and Márcio I. Nakane</td>
<td>Mar/2006</td>
</tr>
<tr>
<td>102</td>
<td>Judicial Risk and Credit Market Performance: Micro Evidence from Brazilian Payroll Loans</td>
<td>Ana Carla A. Costa and João M. P. de Mello</td>
<td>Apr/2006</td>
</tr>
<tr>
<td>103</td>
<td>The Effect of Adverse Supply Shocks on Monetary Policy and Output</td>
<td>Maria da Glória D. S. Araújo, Mirta Bugarin, Marcelo Kfoury Muinhos and Jose Ricardo C. Silva</td>
<td>Apr/2006</td>
</tr>
</tbody>
</table>
104 Extração de Informação de Opções Cambiais no Brasil
Eui Jung Chang e Benjamin Miranda Tabak
Abr/2006

105 Representing Roommate's Preferences with Symmetric Utilities
José Alvaro Rodrigues Neto
Apr/2006

106 Testing Nonlinearities Between Brazilian Exchange Rates and Inflation Volatilities
Cristiane R. Albuquerque and Marcelo Portugal
May/2006

107 Demand for Bank Services and Market Power in Brazilian Banking
Márcio I. Nakane, Leonardo S. Alencar and Fabio Kanczuk
Jun/2006

108 O Efeito da Consignação em Folha nas Taxas de Juros dos Empréstimos Pessoais
Eduardo A. S. Rodrigues, Victorio Chu, Leonardo S. Alencar and Tony Takeda
Jun/2006

109 The Recent Brazilian Disinflation Process and Costs
Alexandre A. Tombini and Sergio A. Lago Alves
Jun/2006

110 Fatores de Risco e o Spread Bancário no Brasil
Fernando G. Bignotto e Eduardo Augusto de Souza Rodrigues
Jul/2006

111 Avaliação de Modelos de Exigência de Capital para Risco de Mercado do Cupom Cambial
Alan Cosme Rodrigues da Silva, João Maurício de Souza Moreira and Myrian Beatriz Eiras das Neves
Jul/2006

112 Interdependence and Contagion: an Analysis of Information Transmission in Latin America's Stock Markets
Angelo Marsiglia Fasolo
Jul/2006

113 Investigação da Memória de Longo Prazo da Taxa de Câmbio no Brasil
Sergio Rubens Stancato de Souza, Benjamin Miranda Tabak e Daniel O. Cajueiro
Ago/2006

114 The Inequality Channel of Monetary Transmission
Marta Areosa and Waldyr Areosa
Aug/2006

115 Myopic Loss Aversion and House-Money Effect Overseas: an Experimental Approach
José L. B. Fernandes, Juan Ignacio Peña and Benjamin M. Tabak
Sep/2006

116 Out-Of-The-Money Monte Carlo Simulation Option Pricing: the Join Use of Importance Sampling and Descriptive Sampling
Jaqueline Terra Moura Marins, Eduardo Saliby and Josète Florencio dos Santos
Sep/2006

117 An Analysis of Off-Site Supervision of Banks’ Profitability, Risk and Capital Adequacy: a Portfolio Simulation Approach Applied to Brazilian Banks
Theodore M. Barnhill, Marcos R. Souto and Benjamin M. Tabak
Sep/2006

118 Contagion, Bankruptcy and Social Welfare Analysis in a Financial Economy with Risk Regulation Constraint
Aloísio P. Araújo and José Valentim M. Vicente
Oct/2006
<table>
<thead>
<tr>
<th>Issue</th>
<th>Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out/2006</td>
<td>A Central de Risco de Crédito no Brasil: uma Análise de Utilidade de Informação</td>
<td>Ricardo Schechtman</td>
</tr>
<tr>
<td>Oct/2006</td>
<td>Forecasting Interest Rates: an Application for Brazil</td>
<td>Eduardo J. A. Lima, Felipe Luduvice and Benjamin M. Tabak</td>
</tr>
<tr>
<td>Nov/2006</td>
<td>The Role of Consumer’s Risk Aversion on Price Rigidity</td>
<td>Sergio A. Lago Alves and Mirta N. S. Bugarin</td>
</tr>
<tr>
<td>Nov/2006</td>
<td>A Neoclassical Analysis of the Brazilian “Lost-Decades”</td>
<td>Flávia Mourão Graminho</td>
</tr>
<tr>
<td>Nov/2006</td>
<td>The Dynamic Relations between Stock Prices and Exchange Rates: Evidence for Brazil</td>
<td>Benjamin M. Tabak</td>
</tr>
<tr>
<td>Nov/2006</td>
<td>Herding Behavior by Equity Foreign Investors on Emerging Markets</td>
<td>Barbara Alemanni and José Renato Haas Ornelas</td>
</tr>
<tr>
<td>Dec/2006</td>
<td>Risk Premium: Insights over the Threshold</td>
<td>José L. B. Fernandes, Augusto Hasman and Juan Ignacio Peña</td>
</tr>
<tr>
<td>Dec/2006</td>
<td>Uma Investigação Baseada em Reamostragem sobre Requerimentos de Capital para Risco de Crédito no Brasil</td>
<td>Ricardo Schechtman</td>
</tr>
<tr>
<td>Dec/2006</td>
<td>Term Structure Movements Implicit in Option Prices</td>
<td>Caio Ibsen R. Almeida and José Valentim M. Vicente</td>
</tr>
<tr>
<td>Dec/2006</td>
<td>Brazil: Taming Inflation Expectations</td>
<td>Afonso S. Bevilaqua, Mário Mesquita and André Minella</td>
</tr>
<tr>
<td>Mar/2007</td>
<td>Credit Risk Monte Carlo Simulation Using Simplified Creditmetrics’ Model: the Joint Use of Importance Sampling and Descriptive Sampling</td>
<td>Jaqueline Terra Moura Marins and Eduardo Saliby</td>
</tr>
<tr>
<td>Apr/2007</td>
<td>Amostragem Descritiva no Apreçamento de Opções Européias através de Simulação Monte Carlo: o Efeito da Dimensionalidade e da Probabilidade de Exercício no Ganho de Precisão</td>
<td>Eduardo Saliby, Sergio Luiz Medeiros Proença de Gouvêa e Jaqueline Terra Moura Marins</td>
</tr>
</tbody>
</table>
135 Evaluation of Default Risk for the Brazilian Banking Sector
Marcelo Y. Takami and Benjamin M. Tabak
May/2007

136 Identifying Volatility Risk Premium from Fixed Income Asian Options
Caio Ibsen R. Almeida and José Valentim M. Vicente
May/2007

137 Monetary Policy Design under Competing Models of Inflation Persistence
Solange Gouvea e Abhijit Sen Gupta
May/2007

138 Forecasting Exchange Rate Density Using Parametric Models: the Case of Brazil
Marcos M. Abe, Eui J. Chang and Benjamin M. Tabak
May/2007

139 Selection of Optimal Lag Length in Cointegrated VAR Models with Weak Form of Common Cyclical Features
Carlos Enrique Carrasco Gutiérrez, Reinaldo Castro Souza and Osmani Teixeira de Carvalho Guillén
Jun/2007

140 Inflation Targeting, Credibility and Confidence Crises
Rafael Santos and Aloísio Araújo
Aug/2007

141 Forecasting Bonds Yields in the Brazilian Fixed Income Market
José Vicente and Benjamin M. Tabak
Aug/2007

142 Crises Análise da Coerência de Medidas de Risco no Mercado Brasileiro de Ações e Desenvolvimento de uma Metodologia Híbrida para o Expected Shortfall
Alan Cosme Rodrigues da Silva, Eduardo Facó Lemgruber, José Alberto Rebello Baranowski and Renato da Silva Carvalho
Ago/2007

143 Price Rigidly in Brazil: Evidence from CPI Micro Data
Solange Gouvea
Sep/2007

144 The Effect of Bid-Ask Prices on Brazilian Options Implied Volatility: a Case Study of Telemar Call Options
Claudio Henrique da Silveira Barbedo and Eduardo Facó Lemgruber
Oct/2007

145 The Stability-Concentration Relationship in the Brazilian Banking System
Benjamin Miranda Tabak, Solange Maria Guerra, Eduardo José Araújo Lima and Eui Jung Chang
Oct/2007

146 Movimentos da Estrutura a Termo e Critérios de Minimização do Erro de Previsão em um Modelo Paramétrico Exponencial
Caio Almeida, Romeu Gomes, André Leite e José Vicente
Out/2007

Adriana Soares Sales and Maria Eduarda Tannuri-Pianto
Oct/2007

148 Um Modelo de Fatores Latentes com Variáveis Macroeconômicas para a Curva de Cupom Cambial
Felipe Pinheiro, Caio Almeida e José Vicente
Out/2007

149 Joint Validation of Credit Rating PDs under Default Correlation
Ricardo Schechtman
Oct/2007
150 A Probabilistic Approach for Assessing the Significance of Contextual Variables in Nonparametric Frontier Models: an Application for Brazilian Banks

Roberta Blass Staub and Geraldo da Silva e Souza

Oct/2007

151 Building Confidence Intervals with Block Bootstraps for the Variance Ratio Test of Predictability

Eduardo José Araújo Lima and Benjamin Miranda Tabak

Nov/2007

152 Demand for Foreign Exchange Derivatives in Brazil: Hedge or Speculation?

Fernando N. de Oliveira and Walter Novaes

Dec/2007

153 Aplicação da Amostragem por Importância à Simulação de Opções Asiáticas Fora do Dinheiro

Jaqueline Terra Moura Marins

Dez/2007

154 Identification of Monetary Policy Shocks in the Brazilian Market for Bank Reserves

Adriana Soares Sales and Maria Tannuri-Pianto

Dec/2007

155 Does Curvature Enhance Forecasting?

Caio Almeida, Romeu Gomes, André Leite and José Vicente

Dec/2007

156 Escolha do Banco e Demanda por Empréstimos: um Modelo de Decisão em Duas Etapas Aplicado para o Brasil

Sérgio Mikio Koyama e Márcio I. Nakane

Dez/2007

157 Is the Investment-Uncertainty Link Really Elusive? The Harmful Effects of Inflation Uncertainty in Brazil

Tito Nícias Teixeira da Silva Filho

Jan/2008

158 Characterizing the Brazilian Term Structure of Interest Rates

Osmani T. Guillen and Benjamin M. Tabak

Feb/2008

159 Behavior and Effects of Equity Foreign Investors on Emerging Markets

Barbara Alemanni and José Renato Haas Ornelas

Feb/2008

160 The Incidence of Reserve Requirements in Brazil: Do Bank Stockholders Share the Burden?

Fábia A. de Carvalho and Cyntia F. Azevedo

Feb/2008

161 Evaluating Value-at-Risk Models via Quantile Regressions

Wagner P. Gaglianone, Luiz Renato Lima and Oliver Linton

Feb/2008

162 Balance Sheet Effects in Currency Crises: Evidence from Brazil

Marcio M. Janot, Márcio G. P. Garcia and Walter Novaes

Apr/2008

163 Searching for the Natural Rate of Unemployment in a Large Relative Price Shocks’ Economy: the Brazilian Case

Tito Nícias Teixeira da Silva Filho

May/2008

164 Foreign Banks’ Entry and Departure: the recent Brazilian experience (1996-2006)

Pedro Fachada

Jun/2008

165 Avaliação de Opções de Troca e Opções de Spread Européias e Americanas

Giuliano Carrozza Uzêda Iorio de Souza, Carlos Patrício Samanez e Gustavo Santos Raposo

Jul/2008
<table>
<thead>
<tr>
<th>Article Number</th>
<th>Title</th>
<th>Authors</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>166</td>
<td>Testing Hyperinflation Theories Using the Inflation Tax Curve: a case study</td>
<td>Fernando de Holanda Barbosa and Tito Nícias Teixeira da Silva Filho</td>
<td>Jul/2008</td>
</tr>
<tr>
<td>167</td>
<td>O Poder Discriminante das Operações de Crédito das Instituições Financeiras Brasileiras</td>
<td>Clodoaldo Aparecido Annibal</td>
<td>Jul/2008</td>
</tr>
<tr>
<td>168</td>
<td>An Integrated Model for Liquidity Management and Short-Term Asset Allocation in Commercial Banks</td>
<td>Wenersamy Ramos de Alcântara</td>
<td>Jul/2008</td>
</tr>
<tr>
<td>170</td>
<td>Política de Fechamento de Bancos com Regulador Não-Benevolente: Resumo e Aplicação</td>
<td>Adriana Soares Sales</td>
<td>Jul/2008</td>
</tr>
<tr>
<td>171</td>
<td>Modelos para a Utilização das Operações de Redesconto pelos Bancos com Carteira Comercial no Brasil</td>
<td>Sérgio Mikio Koyama e Márcio Issso Nakane</td>
<td>Ago/2008</td>
</tr>
<tr>
<td>172</td>
<td>Combining Hodrick-Prescott Filtering with a Production Function Approach to Estimate Output Gap</td>
<td>Marta Areosa</td>
<td>Aug/2008</td>
</tr>
<tr>
<td>173</td>
<td>Exchange Rate Dynamics and the Relationship between the Random Walk Hypothesis and Official Interventions</td>
<td>Eduardo José Araújo Lima and Benjamin Miranda Tabak</td>
<td>Aug/2008</td>
</tr>
<tr>
<td>174</td>
<td>Foreign Exchange Market Volatility Information: an investigation of real-dollar exchange rate</td>
<td>Frederico Pechir Gomes, Marcelo Yoshio Takami and Vinicius Ratton Brandi</td>
<td>Aug/2008</td>
</tr>
<tr>
<td>176</td>
<td>Fiat Money and the Value of Binding Portfolio Constraints</td>
<td>Mário R. Páscoa, Myriam Petrassi and Juan Pablo Torres-Martínez</td>
<td>Dec/2008</td>
</tr>
<tr>
<td>177</td>
<td>Preference for Flexibility and Bayesian Updating</td>
<td>Gil Riella</td>
<td>Dec/2008</td>
</tr>
<tr>
<td>178</td>
<td>An Econometric Contribution to the Intertemporal Approach of the Current Account</td>
<td>Wagner Piazza Gaglianone and João Victor Issler</td>
<td>Dec/2008</td>
</tr>
<tr>
<td>179</td>
<td>Are Interest Rate Options Important for the Assessment of Interest Rate Risk?</td>
<td>Caio Almeida and José Vicente</td>
<td>Dec/2008</td>
</tr>
<tr>
<td>180</td>
<td>A Class of Incomplete and Ambiguity Averse Preferences</td>
<td>Leandro Nascimento and Gil Riella</td>
<td>Dec/2008</td>
</tr>
<tr>
<td>181</td>
<td>Monetary Channels in Brazil through the Lens of a Semi-Structural Model</td>
<td>André Minella and Nelson F. Souza-Sobrinho</td>
<td>Apr/2009</td>
</tr>
<tr>
<td>No.</td>
<td>Title</td>
<td>Authors</td>
<td>Date</td>
</tr>
<tr>
<td>-----</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>182</td>
<td>Avaliação de Opções Americanas com Barreiras Monitoradas de Forma Discreta</td>
<td>Giuliano Carrazza Uzêda Iorio de Souza e Carlos Patrício Samanez</td>
<td>Abr/2009</td>
</tr>
<tr>
<td>184</td>
<td>Behavior Finance and Estimation Risk in Stochastic Portfolio Optimization</td>
<td>José Luiz Barros Fernandes, Juan Ignacio Peña and Benjamin Miranda Tabak</td>
<td>Apr/2009</td>
</tr>
<tr>
<td>185</td>
<td>Market Forecasts in Brazil: performance and determinants</td>
<td>Fabia A. de Carvalho and André Minella</td>
<td>Apr/2009</td>
</tr>
<tr>
<td>186</td>
<td>Previsão da Curva de Juros: um modelo estatístico com variáveis macroeconômicas</td>
<td>André Luís Leite, Romeu Braz Pereira Gomes Filho e José Valentim Machado Vicente</td>
<td>Maio/2009</td>
</tr>
<tr>
<td>188</td>
<td>Pricing Asian Interest Rate Options with a Three-Factor HJM Model</td>
<td>Claudio Henrique da Silveira Barbedo, José Valentim Machado Vicente and Octávio Manuel Bessada Lion</td>
<td>Jun/2009</td>
</tr>
</tbody>
</table>