BRAZILIAN REAL CRISIS REVISITED: A LINEAR PROBABILITY MODEL TO IDENTIFY LEADING INDICATORS

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Abstract

This article aims at identifying the indicators of the Brazilian real crisis through building a probit model incorporating 20 monthly macroeconomic, political, and financial sector indicators from 1980:1 – 1999:1. Results indicate that the significant variables are inflation (1-month lag), real exchange rate (1-month lag), import growth (1-month lag), US interest rates (2-month lag), public debt/GDP (2-month lag), and current account/GDP (3-month lag). Evidence further indicates that the signs of the variables are in line with our expectations, with the exception of US interest rates.

JEL Classification: C51, O54

Keywords: Mexican peso crisis, financial crises, probit model, Brazil

I. Introduction

The Brazilian real's fall in January 1999 was the result of an ill-conceived currency and inflation policy. Brazil had long had severe difficulties with inflation. In 1994 Brazil began implementing the Real Plan, which was an economic stabilization plan that involved temporary indexation. The indexation was tied, through the exchange rate, to the number of dollars required to purchase a product rather than to measures of inflation and the currency. Hence, despite its success in reducing inflation below zero by the end of 1998, the controlled devaluation built into Brazil's crawling peg failed to offset the effects of earlier differences between US and Brazilian inflation rates under the Real Plan. During this period, Brazil's currency had been widely considered to be overvalued by 15 to 25 percent (Gruben

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and Welch, 2001). In January 1999, Minas Gerais Governor Itamar Franco's announced that he would suspend his state's debt payment to Brazil's national government. This declaration was followed by similar statements from six other governors, who demanded to suspend their own debt. Due to this political turmoil, billions of dollars in capital flowed out of the country, and the Brazilian equities fell in value. Within a week, the head of Brazil's central bank resigned and the central bank announced changes in the nation's exchange rate band to allow a 9% devaluation. Only two days after Brazil's new devalued exchange rate band was announced, the Brazilian Central Bank announced that the real would no longer be pegged to the US dollar and would be allowed to float. However, immediately after the devaluation, the government tightened its monetary policy and managed to stabilized the currency within a period of less than six months.

This article aims at identifying the indicators of the Brazilian real crisis through building a linear probability model incorporating 20 monthly macroeconomic, political, and financial sector indicators from 1980:1 – 1999:1. This article is structured as follows. The next section provides an overview of the literature. Section III introduces the data and the methodology. Section IV presents the findings and Section V points out the conclusions that emerge from the study.

2. Literature Review

Literature on financial crises is categorized into three mainstream models, namely first-generation models, second-generation models, and third-generation models. In the "first-generation" models (Krugman 1979; Flood and Garber 1984), a government with persistent money-financed budget deficits is assumed to use a limited stock of reserves to peg its exchange rate and the attempts of investors to anticipate the inevitable collapse generates a speculative attack on the currency when reserves fall to some critical level.

In "second-generation" models (Obstfeld 1994, 1996, Ozkan and Sutherland 1995, Radelet and Sachs 1998) policy is less mechanical: a government chooses whether or not to defend a pegged exchange rate by making a tradeoff between short-run macroeconomic

flexibility and longer-term credibility. The crisis then arises from the fact that defending parity is more expensive as it requires higher interest rates. Should the market believe that defense will ultimately fail, a speculative attack on a currency develops either as a result of a predicted future deterioration in macro fundamentals, or purely through self-fulfilling prediction.

The need for third generation models became apparent in 1990s with Mexican Tequila crisis of 1994 and the East Asian crisis of 1997. A number of new approaches have emerged to explain how these crises evolved and how they spread from country to country. Third-generation models (Dooley 1997, Krugman 1998, Radelet and Sachs 1998) are categorized into three different groups such as herd-behavior, contagion, and moral hazard. There have been numerous studies in the literature on EWS of financial crises**.** Although studies differ in terms of the econometric method followed, variables employed, definition of financial crisis, and the time span on which the EWS is built, the literature can conveniently be categorized into two main groups. The first group consists of studies based on a model known as Signals Approach, which involves observing the behavior of a number of indicators as they issue signals when they exceed certain threshold values. The second approach is based on a logit or probit model and uses lagged values of early warning indicators and a crisis dummy variable designed to predict crises.

Signals approach was developed by Kaminsky *et al*. (1998) and consists of a bilateral model where a set of high frequency economic variables during a specified period is compared, one at a time, with a crisis index so that when one of these variables deviates from its normal level beyond a specific threshold value prior to a crisis, it issues binary signals for a possible currency crisis. The model devised by Kaminsky *et al*. (1998) consists of 15 variables with optimal thresholds estimated for each country in relation to percentiles of the distribution of observations of the indicator maximizing the correct signals and minimizing the false ones. They set their signal horizon at 24 months and defined a currency crisis as a sharp depreciation of the currency or a large decline in international

reserves that exceeds the mean by more than three standard deviations. The percentage of correct signals to the percentage of false signals, on the other hand, gives an indication of the accuracy of each indicator. They used monthly data of 15 developing and 5 industrial countries from 1970 to 1995 and detected an average of 61 crises during this period. Their best indicators, based on noise-to-signal ratio, are real exchange rate, banking crises dummy, exports, stock prices, and M2/international reserves. This model was later improved by Kaminsky and Reinhart (1999), who used the same sample as in Kaminsky *et al.* (1998). Their model identified a total of 26 banking and 76 currency crises, 18 of which were twin crises.

They found that the occurrence of both types of crises has increased sharply since the early 1980s with only one twin crisis taking place before 1980. In their study Kaminsky and Reinhart (1999) also found out that banking and currency crises had common causes with the former usually preceding the latter and following a particular pattern where the peaks of banking crises follows the currency crises. Probit and logit models, pioneered by Frankel and Rose (1996), use limited dependent variable models known as probit or logit regressions to identify the causes of crises and to predict future crises.

This approach defines a crisis indicator equal to one or zero depending on whether a currency crisis does or does not occur within the specified time period. Frankel and Rose (1996) attempted to find out how international debt structure and external factors affected the probability of currency crises. They used a number of external, internal and foreign macroeconomic variables in a multivariate probit model specified for 105 developing countries, covering annual data from 1971 to 1992. They defined a crisis as at least 25% depreciation of the nominal exchange rate that also exceeds the previous year's depreciation level by at least 10% and constructed a dummy crisis variable according to that rule. Results of their model indicate that the significant variables are output growth, foreign direct investment/total debt, reserves, domestic credit growth, external debt and foreign interest rates. Sachs, Tornell and Velasco (1996) also used a probit model to analyze currency crises, particularly the

Mexican Tequila Crisis of 1995, using a sample of 20 emerging countries that were vulnerable to contagion effect. They used the weighted sum of the percent decrease in reserves and the percent depreciation of the exchange rate as their crisis index. They found that crises happened only in the countries with weak fundamentals such as low reserves**,** fragile banking systems and overvalued exchange rate. They also found evidence showing that short-term capital inflows do not matter when reserves and fundamentals are strong whilst government consumption and current account deficits matter only in the countries with weak fundamentals and weak reserves. Berg and Pattillo (1999) tested models offered by Kaminsky, Lizondo and Reinhart (1998), Frankel and Rose (1996) and Sachs, Tornell, Velasco (1996) to see if these models could predict the Asian Crisis using information available at the end of 1996. They found out that the models offered by Sachs, Tornell, Velasco (1996) and Frankel and Rose (1996) were ineffective in forecasting the Asian Crisis. The Kaminsky, Lizondo and Reinhart (1998) model, on the other hand, proved to be successful.

Crisis probabilities generated by this model for the period between May 1995 and December 1996 were statistically significant predictors of actual crisis occurrence over the following 24 months. Berg and Pattillo (1999) also found out that in all three approaches, the probability of a currency crisis increases when domestic credit growth is high, the real exchange rate is overvalued relative to trend, and the ratio of M2 to reserves is high. In a recent study, Komulainen and Lukkarila (2003) examined the causes of financial crises in 31 emerging market countries during 1980-2001 using a probit model based on 23 variables. Their findings show that financial crises occur together with banking crises and an increase in private sector liabilities, public debt, foreign liabilities of banks, unemployment, inflation, and US interest rates raises the probability of a crisis. Table 1 summarizes the empirical literature on financial crises.

Table 1. Literature Review on Financial Crises

Study	Kaminsky, Lizondo, Reinhart (1998)	Sachs. Tornell, Velasco (1996)	Kaminsky, Reinhart (1999)	Berg, Patillo (1999)	Frankel, Rose (1996)	Komulainen and Lukkarila (2003)
Appr.	Signals	Probit	Signals	Both	Probit	Probit Model
Data	1970-1975 monthly data from 15 developing and 5 industrial countries	Monthly data from 20 emerging markets.	Same sample as Kaminsky, Lizondo, Reinhart (1998)	Same variables as Kaminsky, Lizondo, Reinhart (1998) plus M2/ reserves and CA/GDP	1971-1992 annual data from 105 developing countries	1980-2001 monthly data from 31 emerging and developing countries
Crisis Index	Weighted average of exchange rate and reserve changes with a threshold of mean +3 standard deviation.	Weighted sum of percent decrease in reserves and the percent depreciation of the exchange rates	Weighted average of exchange rate changes and reserves	Same as Kaminsky, Lizondo, Reinhart (1998)	Exchange rate change over 25%, at least 10% higher than previous year	Equally weighted exchange rate depreciation and loss of reserves with a threshold of +2 standard deviations
Signif. Var.	Real exchange rate, exports, banking crises dummy, stock prices, M2/ international reserves	Low reserves, fragile banking systems, overvalued exchange rate	Banking and currency crises have common causes	Real exchange rate, current account, reserve, export, and M2/ reserves	Output growth, foreign direct investment/ total debt, reserves, domestic credit growth, external debt and foreign interest rates	Private sector liabilities, public debt, foreign liabilities of banks, unemployment, inflation, and US interest rates

3. Data and Methodology

The linear probability model used in this study is built based on monthly, end-of-month observations from 1980:1 – 1999:1. Most data are gathered from DataStream. The data for government debt figures come from several sources, including IFS, the World Bank's WDI and IMF country reports. The tested 20 indicators are selected on the basis of currency crisis theories and previous empirical literature, and are transformed into log returns to achieve mean reverting properties and to make statistical testing procedures valid. In addition to the traditional macroeconomic variables, we include several indicators describing the vulnerability of domestic banks.

These indicators include the growth of bank deposits, the ratio of the lending rate to the deposit rate, and the ratio of bank reserves to assets. We also employ variables that indicate vulnerability to a sudden stop of capital inflows. These variables are public debt, broad money to reserves, and private sector liabilities. We also include an index[1] that proxies the political instability. To study foreign influences on crises, we include the US interest rate. Since we study all these variables simultaneously, we hope to distinguish those indicators that reflect actual causes of the Brazilian real crisis of 1999. Table 2 shows the explanatory variables, their expected signs and explanations. Linear probability models traditionally define a currency crisis as a discrete event. One common technique is to construct an index of exchange market pressure as a weighted average of exchange rate changes and reserves changes (as well as interest rates in some cases). The crisis is said to occur when the index exceeds a particular threshold level. At this point, we calculate an exchange market pressure index (EMP). The index includes exchange rate depreciation and loss of reserves, which are weighted

[1] This index consists of a binary dummy variable that takes the value of 1 or zero depending on whether an event adversely effecting political stability does or does not occur during a particular month. If an event such as the assassination or resignation of a prominent political figure, or unrest in the country, takes place, the dependent variable takes the value of 1. Otherwise it remains 0.

to influence equally. Our exchange market pressure index takes the form:

$$EMP = ?e - (s_e/s_r)*?r \quad (1)$$

where ?e denotes the change in exchange rate and ?r in international reserves, s_e and s_r denote the standard deviation of exchange rate alteration and reserves, respectively. We determine the values of the EMP index more than three standard deviations above the mean as a crisis. Since macroeconomic variables often worsen prior to the actual crisis, we define a crisis not only the crisis month but also the four months before. In other words, we use a four-month window for our variables.

Table 2. Explanatory Variables

Indicator & Expected Sign		Explanation
Inflation	+	Inflation is associated with high nominal interest rates and may proxy macroeconomic mismanagement that adversely affects the economy and the banking system (Demirguc-Kunt and Detragiache 1997).
Real Exchange Rate	-	Currency overvaluation may lead to deteriorations in the current account and have historically been associated with currency crises (Berg et al. 1999).
Export Growth	-	Weak exports may lead to deteriorations in the current account and have often been associated with currency crises (Dowling and Zhuang, 2000).
Import Growth	+	Excessive import growth could lead to worsening in the current account and have been related with currency crises (Berg and Patillo 1999)
M1	+	Growth of M1 indicates excess liquidity, which may invoke speculative attacks on the currency thus leading to a currency crisis (Eichengreen et al. 1995).

Domestic Credit/GDP	+	High levels of domestic credit indicate the fragility of a banking system (Kaminsky and Reinhart, 1998).
Stock Prices	-	Recessions and a burst in asset price bubbles often precede currency crises (Kaminsky and Reinhart, 1999).
Public Debt/GDP	+	Higher indebtedness is expected to raise vulnerability to a reversal in capital inflows, and hence to raise the probability of a crisis (Lanoie and Lemarbre, 1996).
Foreign direct investment/GDP	+	Shows net inflows in the reporting economy. East Asian countries had been dependent on net capital inflows over the decade preceding the crisis
US Interest rates	+	International interest rate increases are often associated with capital outflows (Edison, 2003)
Bank Reserves/Bank Assets	-	Shows the liquidity of the banking system. Adverse macroeconomic shocks are less likely to lead to crises in countries where the banking system is liquid (Demirguc-Kunt and Detragiache, 1997).
Lending Rate-Deposit Rate	+	An increase of this indicator reflects a deterioration in credit risk as banks are unwilling to lend or decline in loan equity (Kaminsky et al. 1998)
Real interest rate	+	Used as a proxy of financial liberalization. Liberalization process itself tends to lead to high real rates. High real interest rates have been increased to repel a speculative attack (Kaminsky et al. 1998).
Foreign exchange reserves	-	Most currency collapses are preceded by a period of increased efforts to defend the exchange rate, which are market by declining foreign exchange reserves (Kaminsky et al. 1998).

Current Account/GDP	-	An increase in the current account is associated with large capital inflows which indicate a diminished probability to devalue and thus to lower the probability of a crisis (Berg and Patillo 1999).
M2/Foreign Exchange reserves	+	Indicates to what extent the liabilities of the banking system are backed by foreign reserves. It also captures the ability of the central bank to meet sudden domestic foreign exchange demands (Berg and Patillo 1999).
Fiscal Balance/GDP	+	Higher fiscal deficits are expected to raise the probability of crisis since they increase the vulnerability to shocks and investor's confidence (Demirguc-Kunt and Detragiache, 1997).
Political Instability	+	Frequent change in the political regime may reduce the willingness of the international financial community to provide financing for a current account deficit. Moreover, political instability may lead to larger budget and current account deficits.
GDP per capita	-	Deterioration of the domestic economic activity is expected to increase the likelihood of crises (Lanoie and Lemarbre 1996).
National Saving Growth	-	High national savings may be expected to lower the probability of debt rescheduling (Lanoie and Lemarbre 1996).

Given the aforementioned indicators and the crisis index, the linear probability model estimates the probability for financial crises. A linear probability model is built where the dependent variable y is a dichotomous variable assuming the value of 1 when a crisis takes place and 0 if otherwise.

$$? = \begin{cases} 0 \text{ if the peg is in effect} \\ 1 \text{ otherwise} \end{cases} \quad (2)$$

The dependent variable is then regressed on the explanatory variables based on the form:

$$? _i = a_i + ß_i x_i + e_i \qquad (3)$$

In this study, one-, two-, and three-month lagged values are initially used in the same regression to identify significant and insignificant variables, and in case of significant variables, to distinguish the most significant lags, ie. the lags with the highest Z-statistic or lowest p-value. These variables are then used in the final regression after removing the insignificant ones. This is done using a backward stepwise regression, which starts with including all variables and their three lags, in our model. Next, the insignificant variables are dropped until only significant ones remain. Then, the most significant lag for each variable is identified and used in the final regression. Table 3 shows the expected signs of the coefficients of the variables. For individual variables, a positive coefficient means that an increase in this explanatory variable increase in dependent variable, that is, dummy dependent variable gets close to 1 signaling a crisis. A negative coefficient, on the other hand, would mean that an increase in this variable would cause a decrease in the dummy dependent variable indicating a tranquil time.

4. Empirical Results

Table 4 summarizes the results of the first pass regression. The most significant lags of each variable are then used in a second regression, and then, in a third regression. The results of these consecutive regressions are given in table 5 and 6, respectively. Results of the final regression are reported in table 7. Strong evidence emerges that the significant variables are inflation (1-month lag), real exchange rate (1-month lag), import growth (1-month lag), US interest rates (2-month lag), public debt/GDP (2-month lag), and current account/GDP (3-month lag). The signs of these variables are in line with our expectations, with the exception of US interest rates which has a negative coefficient.

Table 4. First pass regression						
	1-month lag		2-month lag		3-month lag	
Variable	Coef,	Z-stat	Coef.	Z-stat	Coef.	Z-stat
Inflation	10.57	2.85***	3.52	0.72	3.02	-1.91*
RER	-7.02	1.75*	-2.34	0.62	-2.00	1.16
Export G.	8.12	0.67	2.70	0.32	2.32	0.32
Import G.	11.62	2.38**	3.87	0.65	3.32	0.35
M1	-16.89	0.59	-5.63	0.86	-4.82	0.44
Domestic credit / GDP	-11.89	-2.21**	-3.96	1.08	-3.39	0.56
Stock prices	-6.82	-0.85	-2.27	0.76	-1.95	0.65
Political Instability	8.12	0.91	3.52	1.32	1.81	1.65
Lending and deposit rate spread	11.62	-0.18	2.34	0.62	3.25	0.88
BR /BA	16.89	1.29	2.70	1.32	2.40	0.75
US interest rates	-11.89	1.42	-3.87	2.26**	-2.34	0.72
FDI / GDP	-6.82	0.76	-5.63	0.09	-2.44	0.62
National savings	6.34	0.76	3.96	1.35	2.32	0.32
RIR	11.38	0.88	2.27	0.76	3.32	1.75*
PD / GDP	0.89	0.75	2.11	2.76***	4.82	0.67
Current account/GDP	-11.89	1.45	-3.79	0.24	-2.40	2.38**
GDP p.c.	6.82739	0.76	0.29	0.26	-2.34	2.59***
FB / GDP	6.34	2.30**	2.11	0.09	2.44	1.22
M2 / FER	-11.38	1.42	-8.79	1.77*	-3.25	0.85
FER	0.89	0.75	0.29	1.36	0.25	1.41

* Significant at the 10% level.** Significant at the 5% level. *** Significant at the 1% level. BR/BA=Bank Reserves/Bank Assets.FB= Fiscal Balance. FER= Foreign Exchange Rate. G. = Growth. PD=Public Debt. RER= Real Exchange Rate. RIR=Real Interest Rate.

Table 5. Second pass regression

Variable	Coefficient	Z-statistic
Inflation (-1)	10.57	2.85***
Real exchange rate (-1)	-7.02	1.75*
Import growth (-1)	11.6	2.38**
Domestic credit / GDP (-1)	-11.89	-2.21**
US interest rates (-2)	-3.87	2.26**
Real interest rate (-3)	3.32	1.75*
Public debt / GDP (-2)	2.11	2.76***
Current account/GDP (-3)	-2.40	2.38**
GDP per capita (-3)	-2.34	2.59***
Fiscal balance / GDP (-1)	6.34	2.30**

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

Table 6. Third pass regression

Variable	Coefficient	Z-statistic
Inflation (-1)	14.54	1.73*
Real exchange rate (-1)	-11.83	0.31
Import growth (-1)	7.93	1.72*
Domestic credit / GDP (-1)	-9.12	0.25
US interest rates (-2)	-6.88	2.22**
Real interest rate (-3)	6.56	0.72
Public debt / GDP (-2)	4.02	1.76*
Current account/GDP (-3)	-5.82	2.71***
GDP per capita (-3)	-6.88	0.33
Fiscal balance / GDP (-1)	11.92	0.65

* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

Table 7. Fourth pass regression

Variable	Coefficient	Z-statistic
Inflation (-1)	23.5459	2.3323**
Import growth (-1)	47.2458	2.3765**
US interest rates (-2)	-11.8154	1.6427*
Public debt / GDP (-2)	11.6349	2.3657**
Current account/GDP (-3)	-8.6578	2.2975**

* Significant at the 10% level, ** Significant at the 5% level
*** Significant at the 1% level

5. Conclusions

This study analyzed the causes of the Mexican peso crisis using data from 1970:1 – 1995:1. It estimated a probit model using 20 macroeconomic, political, and financial sector indicators. Results indicate that the significant variables are inflation (1-month lag), real exchange rate (1-month lag), import growth (1-month lag), US interest rates (2-month lag), public debt/GDP (2-month lag), and current account/GDP (3-month lag). Evidence further indicates that the signs of the variables are in line with our expectations, with the exception of US interest rates which has a negative coefficient. These results are not surprising. It was particularly expected that Brazil's chronic inflation would play a role in the real crisis of 1999. High levels of import growth, public debt, and current account deficits have widely been accepted to be associated with financial crises as explained in section II. Therefore, in light of this study, we may conclude that the Brazilian real crisis of 1999 was caused by the suspected macroeconomic fundamentals.

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