

Currency Crises in Argentina

An empirical Investigation

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Abstract

This paper is aimed at studying the determinants of currency crises suffered by Argentina from 1885 to 2003, on one hand, and at characterizing each particular currency crisis, on the other hand.

Firstly, we look for regularities and common factors throughout history. We split the dataset in crises and non-crises years and carried out graphical analysis in order to analyze the behavior of key macroeconomic variables in the neighborhood of currency crises. We complemented it by estimating a *logit* model including a set of variables chosen from the prescriptions of the existing currency crises theories.

Secondly, following Kaminsky (2003) we perform regression tree analysis to classify crises and crashes into different varieties proposed by the theories at stake. We use fifteen financial and macroeconomic variables suggested by the empirical literature.

It is found that fiscal imbalances were always present, which is consistent with the predictions of first generation speculative attack models. All three methods used to characterize currency crises in Argentina show the importance of the fiscal side. Adverse foreign factors had also a key role in explaining crises. Finally, in most of the crises, regularities in the behavior of macroeconomic variables can be detected.

Key Words: Currency Crises, Graphic Analysis, Logit model, Regression Tree Method

JEL Classification Codes: E3, N20

CURRENCY CRISES IN ARGENTINA.

AN EMPIRICAL INVESTIGATION

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For historians each event is unique. Economics, however, maintains that forces in society and nature behave in repetitive ways. History is particular, economics is general.

Charles P. Kindleberger

Manias, Panics, and Crashes: A History of Financial Crises, 1978.

En la historia monetaria argentina, a pesar de su confusa apariencia, nótese una serie de períodos de ilimitada confianza y prosperidad, de expansión en las transacciones, de especulación inmobiliaria y fantasía financiera, seguidos de colapsos más o menos intensos, precipitados en pánicos que originan la liquidación forzada de las operaciones, el relajamiento de la confianza, la postración y el estancamiento de los negocios. Sin duda, cada uno de estos ciclos no se presentan exactamente en las mismas condiciones, ni con idéntico carácter, pero, considerados en conjunto, es posible encontrar en ellos, hechos fundamentales que se repiten, cuyo análisis permite formular síntesis acerca de su evolución ... buscaremos demostrar que en nuestras crisis, aparte de las diferencias de menor cuantía, interviene un factor fundamental, ... y peculiar al grado de formación histórica del país.

Raúl Prebisch

Anotaciones sobre nuestro medio circulante (1921)

I. INTRODUCTION

When it comes to currency crises, Argentina is one the most interesting cases to study. Not only had a larger number of *crises years* than any other developed and emerging country, as documented by Eichengreen and Bordo (2000), but also was the protagonist of some of the more resounding cases of crises and default in the world history. Not only is one of the most

* We thank Gustavo Adler, Horacio Aguirre, Manuel Luis Cordero, Víctor Elías, Lucas Llach, Saúl Lizondo and José Pineda for helpful comments to earlier versions of this paper. All remaining errors are ours. We gratefully acknowledge the support of the Consejo de Investigaciones de la Universidad Nacional de Tucumán (CIUNT) Grant 26/F 204. The views expressed herein are those of the authors and not necessarily those of the CIUNT.

vulnerable countries to international and regional crisis as shown by Kaminsky and Reinhart (2002) but also generated its own currency crisis.

The cost of several crises and crashes for Argentina, in terms of real output losses, has been huge, and possibly one of the largest in the world. The latest crash in 2001/ 2002, known as Tango, brought about a 15% decrease in real GDP and pushed vast sectors of the population below the poverty line. Similarly, the 1989 crash, which ended in hyperinflation, resulted in a 9% fall in real GDP.

According to Cerro and Meloni (2004), who work with monthly data from 1885 to 2003, there were **19** crises in 118 years of history, which implied **32 crisis years**. That is, Argentina had a *crisis year* every 3.7 years. It seems very difficult to match that record.

What are these crises caused by? Do they always recognize the same causes? Which are the “fundamental facts” repeated in every crisis, mentioned by Prebisch in the opening quotation at the epigraph? To put it in another way, did Argentina suffer from the same disease throughout history? Were there different varieties of the same disease? Is there any particular deficiency in the immunological system of Argentina that makes the country prone to currency crises? What was the role of external shocks in the crises?

This paper is not aimed at answering all these questions but at studying the determinants of the 19 currency crises suffered by Argentina from 1885 to 2003, on one hand, and at characterizing each particular currency crisis, on the other hand.

Firstly, we look for regularities and common factors throughout history. We split the dataset in crises and non-crises years and carried out graphical analysis in order to analyze the behavior of key macroeconomic variables in the neighborhood of currency crises. We complemented it by estimating a *logit* model. As in Frankel and Rose (1996) we include four groups of explanatory variables attempting to characterize Argentina’s currency crises. Variables were chosen from the prescriptions of the existing currency crises theories.

Secondly, following Kaminsky (2003) we perform regression tree analysis to classify crises and crashes into different varieties proposed by the theories at stake. We use fifteen financial and macroeconomic variables suggested by the empirical literature.

While the first approach misses the details but highlights the repeated facts, the regularities; the second approach, stresses diversity, the characteristics that make each crisis a unique historic event.

The remainder of the paper is organized as follows. Section II sketches some theoretical issues on currency crises. In Section III we briefly survey the empirical literature on the topic. Section IV explains the empirical results obtained from the graphic analysis, the logit analysis and the regression tree. Finally, section VI presents some conclusions, conjectures and guidelines for further research.

II. MODELS OF CURRENCY CRISES

Since the pioneer contribution of Krugman (1979), the family of currency crises models has grown in such a way that we already have three generations. The first-generation models, associated, precisely, to the name of Krugman showed how inconsistencies between domestic economic conditions and the exchange rate commitment lead to the collapse of the currency peg. In his paper, budget deficit fully monetized is financed by Central Bank expending reserves. With the exchange rate fixed, investors get rid of the excess money supply by exchanging domestic currency for foreign reserves of the central bank. When such reserves fall to a critical threshold, a speculative attack is launched, causing reserves depletion and the abandon of the exchange rate peg.

The speculative attack takes place when the shadow price of exchange rates (the price that would prevail after the speculative attack takes place) equals the exchange rate. At that

moment reserves are driven to zero forcing the abandonment of the fixed exchange rate, and the economy switches to a floating rate regime. With reserves depleted, budget deficit is financed by money creation, which in turn causes an increase in inflation rate.

Two important aspects of this model should be remarked: the first one is that speculative attacks are not only possible, but also inevitable when fiscal policy is not consistent with the exchange rate regime. The time in which the speculative attack will take place is perfectly known forehand, so nobody is taken by surprise. Secondly, there is no incompatibility between rational behavior and the (apparent) arbitrariness of currency attacks. Rational economic behavior, characterized by smoothly evolution over time, can be associated with dramatic attacks and changes in the exchange rate regimes.

Second-Generation Models

The so-called second generation models developed by Flood and Garber (1984b) and Obstfeld (1986, 1994) became widely recognized after the canonical crisis model failed to explain the European Monetary System crises (1992-1993). Second generation models are based on the existence of multiple equilibria. When investors anticipate that a successful attack will alter policy (even if they agree that currency policy may be consistent with the currency peg) it will be expected that future fundamentals (conditional on an attack's taking place) be incompatible with the peg. In this case, government might defend the currency, but the costs (high interest rate, high unemployment rate) can be so onerous that government finally devaluates, so the market anticipates that action and acts in advance.

The government compares the net benefits from changing the exchange rate versus defending it. Policymakers usually have as many good reasons to defend the fixed exchange rate but also to abandon it. For example, if government has a large debt burden denominated in domestic currency, devaluation would evaporate part of the debt. Or, if the country is suffering high unemployment rates, and nominal wages are rigid, devaluation would diminish real wages. But, on the other hand, in inflation-prone countries a nominal anchor is a guarantee against high inflation rates, so defending the currency keeps inflation under control. Another argument put forward to resist devaluations is that a fixed exchange rate facilitates investment and international trade. Crucially, the cost of defending a fixed exchange rate increases when people expect that the regime will be abandoned.

Models of self-fulfilling attacks imply that good fundamentals are not enough neither to prevent attacks, nor to avoid a currency crisis. The state of fundamentals determines the existence and multiplicity of attack equilibrium. In Krugman's model fundamentals may be consistent with exchange rate or not. In second generation models the same is true for extreme values of fundamentals, but there's also a large middle ground over which fundamentals are neither so strong as to make crises inevitable nor so weak as to make an attack impossible. An important difference between this two models is that in the first the moment of the depletion of reserves can be anticipated, while in the second the timing is undetermined, so it can happens unexpectedly, and that is why they are considered so dangerous.

Third Generation Models

The Southeast Asian currency crisis in 1997 was the starting point for a new theory of currency crises. As Krugman (1998) points out, none of the fundamentals that led to a first generation crisis were present in the Asian economies. Asian economies did not face severe unemployment when the crisis begun, nor had any incentive to abandon the peg to carry out expansive monetary policy. Besides, in all countries were present a boom-bust cycle in the asset markets. Financial intermediaries had a central role in the crisis. A mismatch in the deposits of the banking and non-banking system was present: the institutions borrowed short-term money, often in foreign currency, and lent that money in long-term domestic currency.

The conventional currency crisis theories associated with inconsistency in present or future fundamentals missed the role played by financial intermediaries whose liabilities were

perceived to have government guarantee, but were essentially unregulated and therefore subject to moral hazard problems.

The evidence seems to suggest that Asian crisis was neither the consequence of fiscal imbalances, nor were the incentives to follow an expansive monetary policy, but were the problems with financial intermediaries that drove the crisis. The excessive risk lending led to inflation in the asset prices. When the crisis burst, the asset prices fall, the insolvency of intermediaries were visible, forcing them to cease operations, which in turn implied further deflation in asset prices.

Sudden Stop Models

The sudden stop theory of currency crises emphasizes the liquidity problem in emerging economies due to a sudden stop, that is, episodes of sudden and massive reversal in capital inflows. The reversions generally happen in countries that have experienced heavy capital inflows and consequently important current account deficits. To face this sudden capital outflow, governments spend reserves, which increases financial vulnerability and finally devaluates its currency. The resulting reverse in current account deficit impacts on economic activity and employment. This line of research is only recent and is associate to the works of Calvo (1998), Calvo and Reinhart (2000) and Calvo, Izquierdo and Talvi (2002)

III. EMPIRICAL LITERATURE

The numerous empirical researches on currency crises focused on two types of studies: (a) the analysis of specific events or particular countries and, (b) cross-country analysis. They are mainly dedicated to:

- Analysis of the probability of crises
- Test for contagion and determining the channels through which contagion occurs
- Establish the relationship between currency and banking crisis
- Comparison of historic and recent crises
- Test for specific theories of what causes crises in a given country or group of countries.

Table 1 summarizes some of the most relevant papers in the recent empirical literature.

In general, the empirical literature works with stylized models having the following as main predictions:

- In first-generation models, previous to the speculative attack we should observe an expansive fiscal and monetary policy, and a decline in international reserves for long periods.
- On the other hand, second generation models imply that speculative attacks should be followed by expansive monetary and fiscal policies.
- Third generation models emphasize the role played by financial intermediaries, so they analyze variables related to them, such as the liquidity coefficient, solvency of the financial sector, external debt maturity, and assets denomination versus liabilities.

Table 1. Empirical literature

Authors	Period	Countries
Blanco and Garber (1986)	1973-1982	Mexico
Cumby and Wijnbergen (1989)	Dec 1978- -April 1981	Argentina
Eitchengreen, Rose and Wyplosz (1994)	1967-1992	22 Emerging and developed countries suffering a crisis
Klein and Marion (1994)	1957-1991 -Monthly data	Panel data for 16 Latin American countries
Pazarbasioğlu and Ötker (1994)	1979-1993 - Monthly data	Denmark, Ireland, Norway, Spain and Sweden
Calvo and Mendoza (1996)	1994-1995	Mexico
Eitchengreen, Rose and Wyplosz (1996)	1959-1993 –quarterly data	20 industrialized countries
Frankel and Rose (1996)	1971-1992	105 countries
Sachs, Tornell and Velasco (1996)	1994/1995	20 emerging economies
Flood and Marion (1997)	January 1957-January 1991	80 episodes of fixed exchange rate in 17 Latin American countries
Burnside, Eichenbaum and Rebelo (1998)	July 1995-May 1998	Indonesia, Malaysia, Thailand, Korea, Philippines, Hong Kong, Singapore and Taiwan
Chang and Velasco (1998)	1987-1997	Indonesia, Korea, Malaysia, Philippines, Thailand, Mexico, Argentina, Brazil and Chile
IMF (1998)	1975-1997	50 industrialized and emerging countries
Kaminsky, Reinhart and Lizondo (1998)	1970-1995	15 developed and 5 developing countries
Berg and Pattillo (1999)	1997	Asian countries
Glick and Rose(1999)	1971, 1973, 1992-1993, 1994-1995, 1997-1998	161 countries affected by crises
Kaminsky and Reinhart (1999)	Crisis 1997	Asian countries
Tornell (1999)	1985-1995	Hong Kong and 22 emerging countries
Kaminsky and Reinhart (2000)	1997-1999 - daily data	35 countries
Moreno and Trehan (2000)	1974-1997 post Bretton Woods	121 countries
Eichengreen and Bordo (2002)	1883-1998	21 emerging and developed countries
Kaminsky, Reinhart and Vegh (2002)	1826-2002	Countries affected by different crises
Kaminsky (2003)	1970-2002	20 countries

Crises in Argentina

Cerro and Meloni (2003) dated **19** crises throughout **118** years of history. *Five* crises were rated as “crashes”, *nine* as “mild” and *five* as minor turbulences. Interestingly, the number and magnitude of the crises increases through time (see Table 2). The five “deep crises” identified correspond to the years, 1890-91, 1929-32, 1975-76, 1989-91 and 2001-02.

Crises were determine by means of a Market Turbulence Index (MTI) which is the sum of changes in three variables: the exchange rate, international reserves and the interest rates weighted by the inverse of their variability. The index stems from the idea that market pressure increases when exchange rate devaluates (rises), when interest rates increase and when international reserves fall. Under a floating exchange rate regime, we expect abrupt increases in the exchange rate as crisis develops, while under a fixed exchange rate, prior to devaluation, interest rates increase and international reserves diminish.

Whenever the MTI is greater than the mean (μ) plus k standard deviations (STD), a “signal” or “turbulent episode”. is identified. An episode is considered a deep crisis or “crash” when two “close” months with *MTI* greater than the mean value plus three STD is observed. On the other hand, If the *MTI* is greater than μ plus two STD but less than μ plus three STD, we call it “mild crisis”. If *MTI* exceeds its mean value in a half STD at least twice the episode is considered “minor turbulence”. The remaining episodes, i.e. when the index departs less

than one half standard deviation from the average are termed as “non- crisis” or tranquility times.

Table 2. **Crisis Summary**

Period	Years (1)	Number of crises (2)	Number of crises years (3)	Crisis Years as % of total years (3)/(1)	GDP Growth (annual average in%)	Type of Crisis		
						Deep (crash)	Mild	Minor Turbulence
1885 - 1913	29	2	4	13.8	5.4*	1	1	0
1914- 1945	32	4	8	25.0	3.1	1	1	2
1946 – 1976	31	7	10	32.3	3.8	1	4	2
1977 – 1991	15	4	9	60.0	0.4	1	2	1
1992- 2002	11	2	3	27.3	2.1	1	1	0
Total	118	19	34	28.8	3.3	5	9	5

The 19 crises implied 34 *crisis years*. That is, 29% of the 118 were *crisis years*, which meant one *crisis year* every 3.5 years. A given year is considered a *crisis year* if the market turbulence index exceeds one standard deviation from the average in at least 2 months, consecutive or alternate (no more than six months apart).

According to the Market Turbulence Index, the most turbulent period of Argentina’s history was 1977 – 1991, not only because it registered 4 crises in 15 years, but also because nine of those years were *crisis years*, which meant 60% of these years in crisis (see Appendix, Table 2 A for details).

IV. EMPIRICAL RESULTS

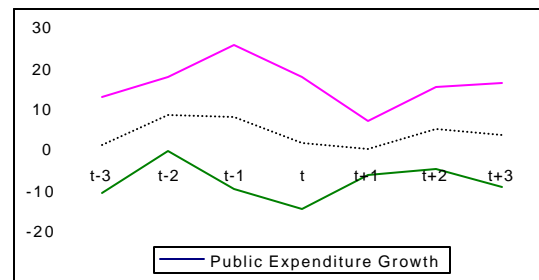
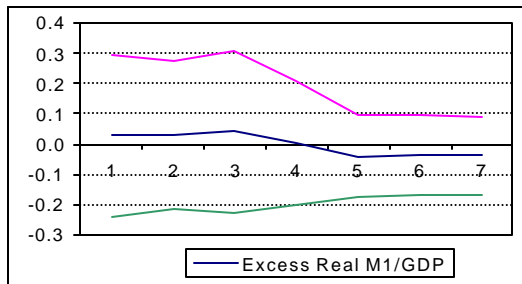
Macro variables Behavior in the Neighborhood of the crisis: Graphic Analysis

How did the Argentine economy perform in the neighborhood of crises? Is there any regularity in the behavior of the macroeconomic variables around these extreme episodes? In order to approach to the answer of these questions we carried out *Graphic Analysis* for several macroeconomic variables. That is, we put a magnifier on the behavior of macro variables three years before and three years after each crisis. That is, for each of the 19 crises identified for Argentina, we normalize all the variables in the dataset in seven periods: ***t-3; t-2; t-1; t; t+1; t+2; t+3***, with *t* standing for the peak of the crisis. We report the average value of the variables and the intervals (in color lines) resulting from adding and subtracting one standard deviation.

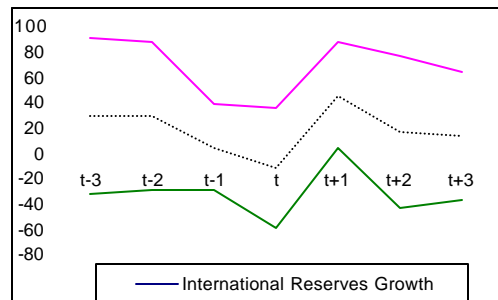
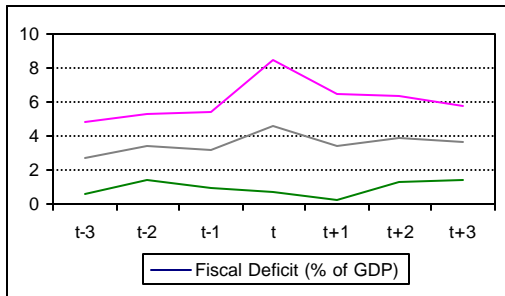
As Frankel and Rose (1996) point out, a graphical approach has advantages and disadvantages. Among the first, it imposes no parametric structures on the data, it makes only a few assumptions that are necessary in inference statistics, and it is often more accessible and informative than tables with estimations of coefficients. On the other hand, the graphic analysis is informal, and intrinsically univariate.

The various graphs show dramatic differences in the behavior of all variables examined before, during and after the crises¹. A brief comment on each variable follows.

- *Excess real M1 as percentage of the GDP* peaks in **t-1** (4.1% on average), falls during crisis at 0.5% and reaches a trough at **t+1**, averaging -3.9. This variable was built as deviations from the estimated demand for money (in real terms) as % of GDP.
- *Public Expenditure Growth*: peaks two periods before the crises (on average, increases 8.7%) and the trough at **t+1** with an average value of 0.4% (which means a fall of 8.3%)

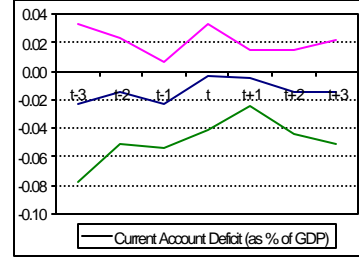
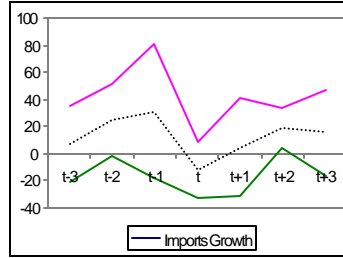
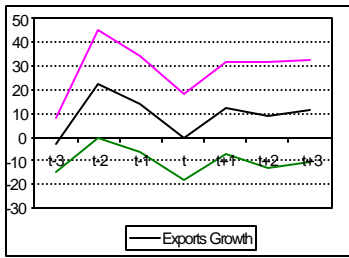


- *Fiscal Deficit (as % of GDP)* starts its upward path before crises and peaks during crises at an average level greater than 4%, showing the lack of funds (both, external as well as internal) to finance the fiscal gap.
- *International Reserve Growth*: increases at **t-3** (about 30%), then starts to fall and reaches a minimum at **t** with a fall of -11%

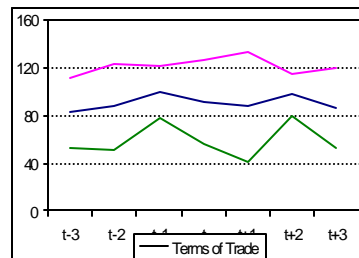
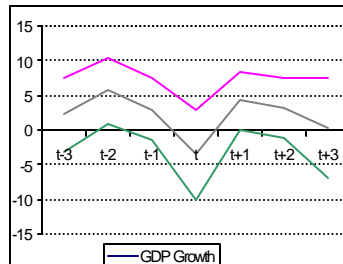
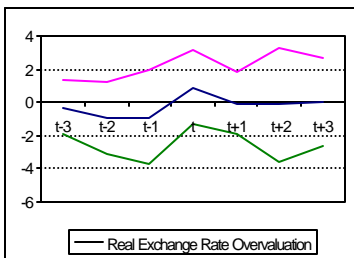


- *Exports growth* reaches a peak two years before crises (on average 22.5%), while the trough happens at the moment of the crises with a value of -0.2%. The fall at t might be the result of unfavorable TOT but also a consequence of uncertainty about future rules of the game.
- ♦ *Imports growth* is highly correlated with GDP movements. its maximum rate of growth is reached one period before crises, with 31.2% and its minimum during crises, with a negative rate of growth of -11.7%.
- ♦ *Current Account Deficit (as % of GDP)* reaches a peak at **t-1** (average -2.3) and a trough at **t** (-0.38%), i.e. an improvement of 2%. That is, during crises the lack of capital inflows leaves the country with no other alternative than adjusting aggregate demand.

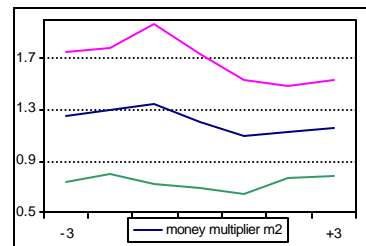
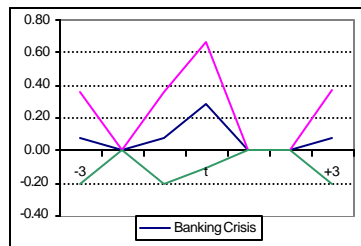
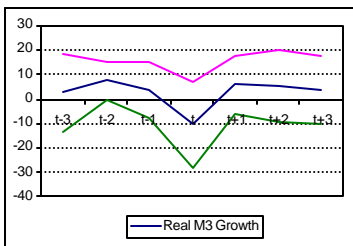
¹ Similar conclusions are drawn by Cerro and Meloni (2003) by means of non-parametric tests, such as Kolmogorov—Smirnov, that tests for the equality of distribution and Kruskal-Wallis, Wilcoxon, Median Chi-Square and Van der Waerden testing for equality of population between crisis and tranquil periods.



- *GDP growth* reaches a peak two years before the beginning of crises (on average 5.7%) and the trough at the moment of the crises (-3.6% on average). The difference between peak and trough is 9.3% on average.
- *Real Exchange Overvaluation*, built as deviation from the RER trend, accumulates pressure during $t-2$ and $t-1$ and overshoots at t right after the devaluation.

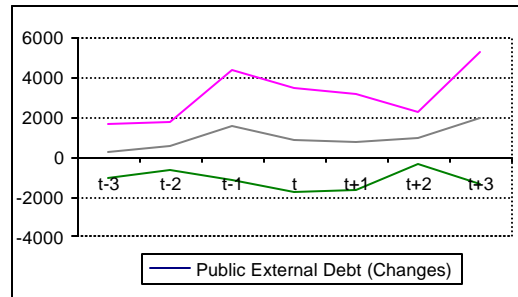
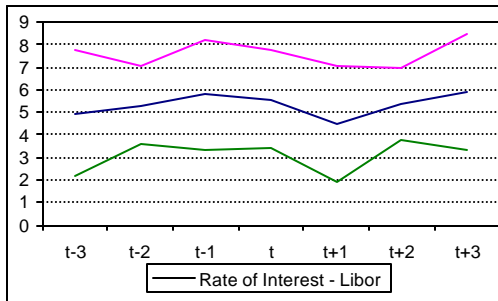


- *Real M3 growth* falls abruptly during crises reaching a value of -10.5% on average, after peaking two periods before crises with a value of 7.6% on average
- *Banking crises*, taken from Kaminsky and Reinhart (2000), always precede or coincide with currency crises.
- *Money Multiplier m2*, reaches a peak two periods before crises and troughs two periods after crises with values of 1.11 and 1.03 respectively.



- *International Rate of Interest*: it reaches a peak one period before the crises begin. For emerging economies, the increase in the international interest rate is very important for two reasons. Firstly, it is key to explain the capital inflow and outflow to emerging countries as pointed out by Calvo, Reinhart and Leiderman (1992). Secondly, it impacts on the service of external debt. An increase in the rate of interest is associated with

worsening in quasi fiscal deficit and consequently in fiscal accounts. In most severe crisis adverse external conditions were present.



Finally, the components of the Market Turbulence Index behave as expected. That is. Exchange rate depreciates very slowly in **t-2** and **t-1** and explodes at **t**.

Regression Analysis

Following Frankel and Rose (1996), we try to characterize Argentina's currency crises rather than testing specific theories of crises.

We estimate a *logit* model whose binary dependent variable takes the value 0 for no-crisis years, and 1 for crisis years. Independent variables were classified into three groups: (i) **Domestic Macroeconomic Indicators**: real public expenditure growth, GDP growth, Real M3 growth. (ii) **External Indicators**: CAD, Reserves/Imports Ratio, Real Exchange Rate Overvaluation, External Debt. (iii) **Foreign Variables** TOT, International Rate of Interest. Three alternative models were estimated using maximum likelihood². Results are tabulated in Table 3. Since logit coefficients are not directly interpretable, we report the effect of a change in variables on the probability of crisis. We also tabulated zstatistics with null hypothesis of no effect and report McFadden R squared.

Most of the variables included are statistically significant at usual levels. It is found that the probability of crisis increases when GDP, real M3 growth, and the ratio reserves to imports fall. Crises are also more likely when the local currency appreciates (lagged once), and TOT impairs (although this variable is not statistically significant at standard values in models 2 and 3).

On the other hand, an increase in public expenditure growth, in the current account deficit (lagged one period), in the external debt (not significant in Model 1), and an increase in the international rate of interest also increase the probability of crisis.

Interestingly enough, the results of the regression let us conclude that fiscal variables have an important role in determining the probability of crisis. The domestic macroeconomic effects, measured by GDP growth and real M3 growth are very strong. An appreciation of the currency (lagged once) also increases the probability of a crisis, but contemporaneously it has the opposite sign as expected, since during crisis devaluation has already taken place. However we can also see that an impairing of external conditions (measured by an increase in international rate of interest or by a worsening in TOT) makes a crisis more probable.

Table 3. **Regression Results.**

² We also estimated by probit and Linear Probability Model, but results do not differ significantly

Variable	Model 1	Model 2	Model 3
C	3.90 (1.18)	-0.93 (-0.27)	-0.85 (0.25)
GDP growth	-0.17 (-2.99)	-0.17 (-2.76)	-0.17 (2.76)
Public expenditure growth	0.05 (2.55)	0.04 (2.29)	0.04
Real M3 growth	-0.08 (-2.79)	-0.09 (-2.60)	-0.08 (2.60)
External Debt	-6.05E-06 (-0.06)	1.45E-05 (0.13)	
Terms of Trade (TOT)	-0.06 (-2.10)	-0.03 (-1.14)	-0.03 (-1.18)
Current Account Deficit	-4.90 (-0.78)		
Current Account Deficit (-1)		-22.41 (-2.39)	-22.22 (-2.41)
LIBOR	0.23 (1.19)		
LIBOR (-1)		0.56 (2.37)	0.55 (2.36)
Reserves /Imports	-1.62 (-2.13)	-1.42 (-2.07)	-1.41 (-2.04)
Real Exchange Rate overvaluation	0.41 (2.51)	0.44 (2.59)	0.44 (2.60)
Real Exchange Rate overvaluation (-1)	-0.47 (-2.31)	-0.48 (-2.28)	-0.48 (-2.28)
LR statistic (11 df)	52.67285	60.28001	60.26328
Probability (LR stat)	8.56E-08	3.21E-09	1.19E-09
Mcfadden R-squared	0.42324	0.484366	0.484
Obs with Dep=0	92	92	92
Obs with Dep=1	26	26	26

Note: Z statistic in parenthesis below coefficient

Regression Tree Analysis

Regression Tree Analysis is a non-parametric device, aimed at identifying the characteristics of each crisis separately. This well-known method in many disciplines (see details in Appendix), was introduced in the analysis of currency crises by Kaminsky (2003).

The regression tree method applied to currency crises has a couple of advantages when compared to other traditional methods. First, it does not impose the same functional form to all crises such as logit and probit models. Second, the probability of crises augments as the number of variables indicating vulnerability increase. For example, an expanding domestic credit may be explosive with convertibility and with capital inflow reversal.

The output of regression tree method is a set of terminal nodes, each one characterizing a crisis or a group of crises. The method considers an initial split of the data into two subgroups according to the rule of minimum node. Many different criteria can be defined for selecting the best split at each node. However, the properties of the final tree selected are insensitive to the choice of splitting rule. Variable misclassification costs and prior distributions can be incorporated into the splitting structure in a natural way.

This split is repeated in sequential form until each subset terminates either when there is no impurity reduction from splitting or when the number of observations in the cell is less than a specified number of rows.

The classification tree resembles the one obtained using the Akaike information criterion (Venables and Ripley, 1996). The key features of the tree approach are: (1) Splits are sequential, so that only a subset of all possible splits is examined. (2) Cross-validation is used to assess model fit. (3) No penalty value is assigned a priori; rather, all possible penalties are considered. (4) It makes powerful use of conditional information in handling nonhomogeneous relationships. (5) It does automatic stepwise variable selection and complexity reduction. (6) It is invariant under all monotone transformations of individual ordered variables. (7) It is extremely robust with respect to outliers and misclassified points in the learning sample. (8) It handles missing values through the use of surrogate splits.

The method can uncover general forms of nonlinearity in data; Brieman et al. (1984) shows that the classification tree method is consistent in the sense that, under suitable regularity conditions, the risks of partition-based predictors and classifiers converge to the risk of the corresponding Bayes rules.

Empirical Results

Previous to running the *Regression Tree* method, we classified years of crises and non-crises during 118 years of Argentine history according to the MTI. We did not distinguish among crises intensity, i.e. deep, mild and minor turbulences. Indicators of crises were grouped according to the prescription of the first, second, third generation models and sudden stops. A total of fifteen indicators were used.

Table 4. **Indicators of Currency Crises Models**

Model of Currency Crises	Variables
First Generation Models	Fiscal Deficit (% GDP)
	Public Expenditure Growth
	Excess Real M1 Balances/GDP
Second Generation Models	Exports Growth
	GDP Growth
	Real Exchange Rate Overvaluation
	Current Account Deficit
Third Generation Models	M2/Reserves Growth
	M2 Multiplier Growth
	M2/Reserves
	M2 Multiplier
	Bank Deposits Growth
Debt	External Debt/Exports
Sudden Stop	Nominal Libor
	Nominal Libor Growth

The results of *regression tree* are reported in Figure 1. They show the criteria for splitting the sample. The 34 years of crises were classified in different varieties of currency crises according to only five indicators (among the fifteen listed in table 4): Fiscal Deficit, Real Deposits, Overvaluation, Exports and Current Account Deficit. The overall importance of variables is presented in Table 1A.

It is found that observations are assigned to six terminal nodes, which let us classify the crises into three different groups. The first split of the data is carried out on the *fiscal deficit as percentage of GDP*, with a threshold of 6.6. For values greater than that, we identify eight crisis years. This variety of crises is consistent with first generation models.

For values minor than 6.6, there is a new split in the subgroup, performed by *real total deposits*. If its rate of growth is greater than -12.7, the new split comes from exports, and we have another final node with four crises.

If real deposits grow less than -12.7%, the sample is split again by the variable *overvaluation*. If there is a RER overvaluation greater than -2.6, and changes in Current Account Deficit are less than 0.4, we find another terminal node with eight crises.

Table 2A describes the characteristics of the final group. There we can identify indicators of vulnerability. In the first node (number 3) the only indicator of vulnerability is fiscal deficit, there are eight years of crises where fiscal deficit as percentage of GDP is greater than 6.6%. These crises correspond to the following years (see Table 3A): 1958, 1962, 1975 and 76 and 1981 to 1985.

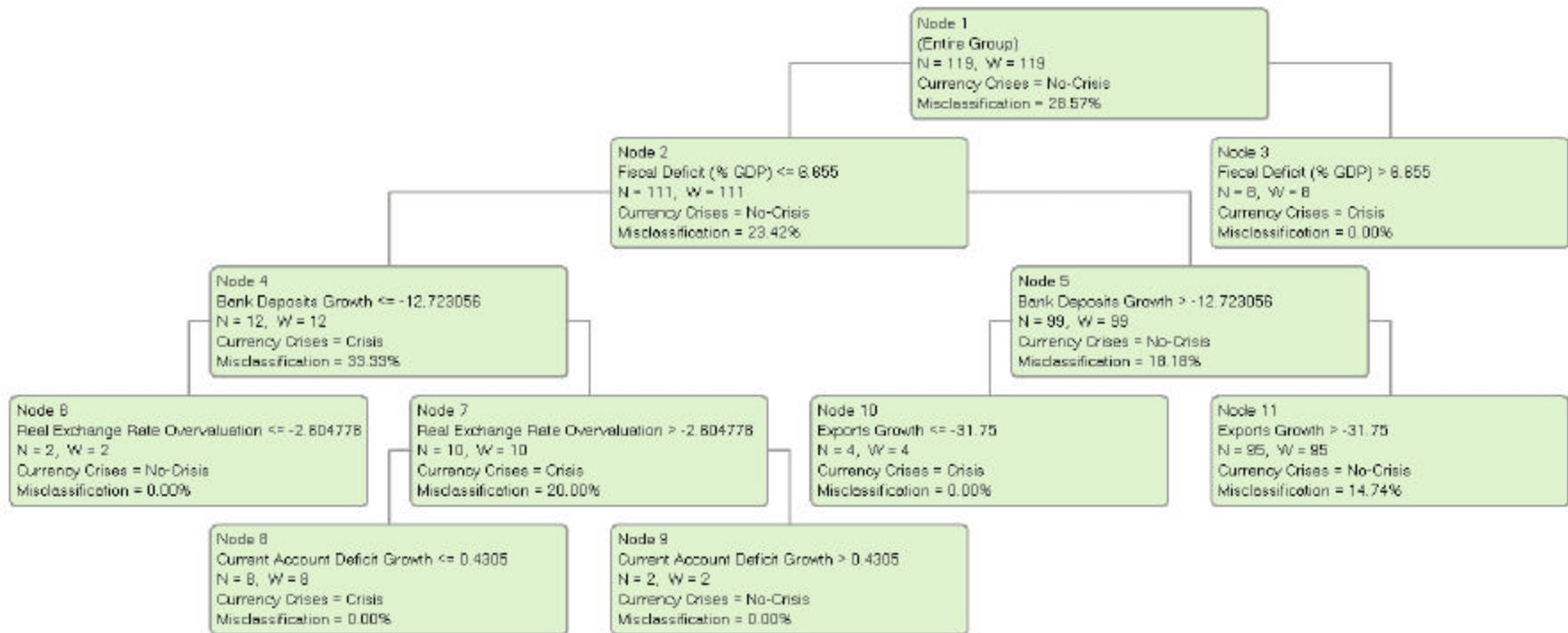
Node 8 is related to an important fall in real deposits jointly with an impairing in current account deficit not greater than 0.43 and an overvaluation greater than -2.6. In that final node we find the following crises years: 1890, 1891, 1914, 1951, 1989, 1990, 1995 and 2001. Notice that node 8 includes the most severe crises Argentina went throughout its history.

Node 10 is related with a considerable fall in exports. We identify this node with the following crises: 1921, 1930, 1938 and 1949. These crises are also consistent with a fall in Terms of Trade, which worsen the prices of exports, a fall of the international demand for Argentineans products or with a fall in production of primary goods, associated with climatological phenomenon.

The results obtained so far are quite preliminaries. Future research is necessary, basically in improving the data set in two directions. The first one is related to increase the number of indicators variables to be used, for example we need better indicators of external debt, domestic credit, among others. The second one is related to broaden the period or periodicity of the data. One possibility is to look for date during XX century; other possibility is to find quarterly data for the whole period. The increase in the sample would be necessary to assure consistency.

However, even preliminary, some conclusions may be drawn. The first one is that extremely high fiscal deficit is responsible for eight currency crisis in Argentina. The second one is that worsen in external conditions may have deleterious consequences in Argentina, mainly when domestic imbalances are present. The third one, when many indicators of vulnerability are signaling crises, they are almost inevitable.

Figure 1
Regression Tree Analysis



VI. CONCLUSIONS

This paper explores the determinants and characteristics of currency crises in Argentina throughout 118 years of history. Taken the 19 crises dated by Cerro and Meloni (2004) as a group, the graphic analyses favor the predictions of the first generation model of currency crisis. In fact, the observed behavior of Real Public Expenditure, Fiscal Deficit, the Rate of growth of International Reserves and Excess Real M1 coincide with the ones expected from the Krugman model. However, the behaviors of the other variables analyzed suggest that some factors associated to second-generation models like the overvaluation of the domestic currency, and the fall in GDP and exports before crises were also important. Likewise, the expansion of Money Multiplier M2 and the precedence of Banking Crisis to currency crises speak about the presence of variables related to third-generation model. Similarly, the behavior of LIBOR and the reversion in the current account supports the sudden stop theory.

The logit estimation confirmed that domestic macroeconomic effects, measured by GDP Growth and Real M3 Growth, and Public Expenditure Growth were very strong. An appreciation of the currency (lagged once) increases the probability of crisis and impairing of external conditions also make a crisis more probable.

The regression tree method classifies argentine crises into three subgroups: one with Fiscal Deficit as a key variable, which supports the first-generation model prediction and reinforces our previous findings. Another subgroup features, besides Fiscal Deficit, RER overvaluation, and a fall in Real Deposits, which indicates a complex mix of factors associated to first, second and third generation models. The last subgroup is characterized by RER overvaluation, diminishing Real Deposits and reversal in capital flows captured by the variable Current Account Deficit.

With all this evidence at hand, some preliminary conclusions can be drawn:

- Fiscal imbalances were always present, which is consistent with the predictions of first generation speculative attack models. All three methods used to characterize currency crises in Argentina show the importance of the fiscal side.
- In most of the crises, regularities in the behavior of macrovariables can be detected. In that sense, Prebisch was right
- Adverse foreign factors had also a key role in explaining crises: an increase in international rate of interest that affects the direction of capital flows and an impairing in TOT increases the probability of crisis.

Although most of the evidence presented here supports mainly the first generation speculative attack models or *à la Krugman*, we also detect some elements of sudden stop theory and third generation models.

The severity and persistence of currency crises in Argentina, the high vulnerability to external shocks regardless of the type of government (*de facto* or constitutional) and the political party in office, seem to reveal problems at the roots of the country rather than associated to particular economic policies or specific adverse shocks. It all seems to point out at the institutional design.

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APPENDIX

CLASSIFICATION TREES.

This appendix describes the construction of a classification tree. The method can uncover general forms of nonlinearity in data; Brieman et al. (1984) shows that the classification tree method is consistent in the sense that, under suitable regularity conditions, the risks of partition-based predictors and classifiers converge to the risk of the corresponding Bayes rules.

Define the measurements (x_1, x_2, \dots, x_r) made on a case as the measurement vector x corresponding to the case. Take the measurement space X to be defined as containing all possible measurement vectors. Suppose that the cases or objects fall into J classes; that is, $C = \{1, \dots, J\}$. Based on these measurements, the goal is to find a systematic way of predicting what class is in. A systematic way of predicting class membership is a rule that assigns a class membership in C to every measurement vector x in X . That is, given any $x \in X$, the rule assigns one of the classes $\{1, \dots, J\}$ to x . A classifier or classification rule is a partition of X into J disjoint subsets A_1, \dots, A_J , $X = \cup_j A_j$ such that for every $x \in A_j$ the predicted class is j .

The first problem in the construction is how to use a learning sample to determine the binary splits of X into smaller and smaller pieces, beginning with X itself. The fundamental idea is to select each split of a subset so that the data in each of the descendant subsets are "purer" than the data in the parent subset. Various criteria have been proposed for evaluating splits, but they have all the same basic goal which is to favor homogeneity within each node child and heterogeneity between the child nodes. The goal of splitting is to produce child nodes with minimum impurity.

The classification tree algorithm is as follows:

(1) For each of the variables x_i , $i = 1, \dots, r$, consider an initial split of the data into two subgroups according to the rule minimum node, or equivalently tree, impurity with estimated class probabilities $p(j/t)$, $j = 1, \dots, J$

$$i(t) = \sum_{j=1}^J p(j/t) \ln p(j/t) \quad (1)$$

Many different criteria can be defined for selecting the best split at each node, i.e. Gini and towing. However, the properties of the final tree selected are insensitive to the choice of splitting rule. The Gini criterion, considered slightly better than towing by Brieman et al (1984), has the form

$$i(t) = \sum_{j=1}^J p(j/t) p(i/t)$$

where variable misclassification costs and prior distributions can be incorporated into the splitting structure in a natural way. The x and the split that minimize (1) define the initial split of the data into two subgroups which we call S_1 y S_2 ; denote this set of splits as T_1 .

(2) Repeat step 1 on each of the two sets S_1 and S_2 . The minimum impurity for observations in S_1 will define two new groups S_{11} y S_{12} ; S_{21} and S_{22} are constructed for observations in S_2 . Notice that new splits may occur on different variables, i.e. $j \neq k$. Denote this new set of splits $S_3 \dots S_6$ as T_2 . Repeat again for each of these new subsets and generate a new set of splits T_3 . As before, the splits in T_3 define disjoint subgroups of data. Sequential splitting of each subset terminates either when there is no impurity reduction from splitting or when the number of observations in the cell is less than a specified number of rows.

(3) The initial tree generated by step 2 is larger than as the data splits were costless. We now "prune" the tree by incorporating a cost to data splits. Let the cost of splitting equal $\alpha \#(N)$, where $\#(N)$ is the number of terminal nodes in a tree. For each $\alpha \geq 0$, one determines which set of terminal nodes minimizes

$$R_{\alpha}(T) = R(T) + \alpha \#(N)$$

Thus, $R_{\alpha}(T)$ is formed by adding to the misclassification cost of the tree a cost penalty for complexity. If α is small, the penalty for having a large number of terminal nodes is small and $T(\alpha)$ will be large. As the penalty α per terminal node increases, the minimizing subtrees $T(\alpha)$ will have fewer terminal nodes. Finally, for α sufficiently large, the minimizing subtree $T(\alpha)$ will consist of the root node only, and the tree T_{max} will have been completely pruned. Although α runs through a continuum of values, there are at most a finite number of subtrees of T_{max} . Thus, the pruning process produces a finite sequence of subtree T_1, T_2, T_3, \dots with progressively fewer terminal nodes.

(4) Calculate a cross-validated estimate of the $R(T)$ for each subtree T_1, T_2, T_3, \dots . Then, the subtree with the smallest cross-validated $R(T)$ produces the right sized tree.

The classification tree resembles one which chooses among different splits using the Akaike information criterion (Venables and Ripley, 1996). The key features of the tree approach are: (1) Splits are sequential, so that only a subset of all possible splits is examined. (2) Cross-validation is used to assess model fit. (3) No penalty value is assigned a priori; rather, all possible penalties are considered. (4) It makes powerful use of conditional information in handling nonhomogeneous relationships. (5) It does automatic stepwise variable selection and complexity reduction. (6) It is invariant under all monotone transformations of individual ordered variables. (7) It is extremely robust with respect to outliers and misclassified points in the learning sample. (8) It handles missing values through the use of surrogate splits.

Program

The program used to build the right tree was DTREG (Decision Tree Regression Analysis For Data Mining and Modeling) by Phillip H. Sherrod. Copyright © 2003-2004. All rights reserved. www.dtreg.com

Variables

Target: Currency Crisis (Deep, Mild and Turbulence)

Predictors:

Fiscal Deficit (% GDP)
 Public Expenditure Growth
 Excess Real M1 Balances/GDP
 Bank Deposits Growth
 Real Exchange Rate Overvaluation
 M2/Reserves Growth
 M2 Multiplier Growth
 M2/Reserves
 M2 Multiplier
 GDP Growth
 Exports Growth
 External Debt/Exports
 Current Account Deficit
 Current Account Deficit Growth
 Nominal Labor
 Nominal Labor Growth

Tree fitting algorithm: Gini.

Assumed prior probabilities for target categories: $P(\text{Crisis}) = 0.25$

Misclassification costs: Equal misclassification costs for all categories (crisis and no-crisis).

How to classify rows with missing predictor values: Surrogate predictors

Method for testing and pruning the tree: 10-fold cross-validation.

The pruning control: Prune to minimum cross-validated error.

Table 1A. Overall Importance of Variables

Variable	Importance
Fiscal Deficit (% GDP)	100%
Exports Growth	71%
Bank Deposits Growth	65%
Current Account Deficit Growth	45%
M2 Multiplier Growth	33%
M2 Multiplier	33%
M2/Reserves	26%
Real Exchange Rate Overvaluation	22%
Libor Growth	16%
Current Account Deficit	14%
M2/Reserves Growth	13%
GDP Growth	10%
Public Expenditure Growth	5%

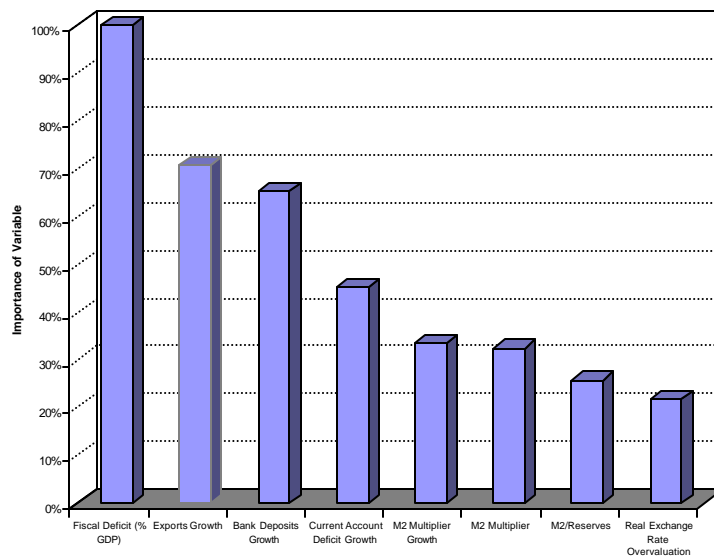


Table 2A. Varieties of Currency Crises

Node	Characteristics	Group 1	Group 2	Group 3	Predicted Value	Misclassification
3	Fiscal Deficit (% GDP) > 6.65	*			Crisis	0%
8	Fiscal Deficit (% GDP) <= 6.65 Bank Deposits Growth <= -12.72 Real Exchange Rate Overvaluation > -2.6 Current Account Deficit Growth <= 0.43			*	Crisis	0%
10	Fiscal Deficit (% GDP) <= 6.65 Bank Deposits Growth > -12.72 Exports Growth <= -31.75		*		Crisis	0%
9	Fiscal Deficit (% GDP) <= 6.65 Bank Deposits Growth <= -12.72 Real Exchange Rate Overvaluation < -2.6 Current Account Deficit Growth > 0.43				No-Crisis	0%
6	Fiscal Deficit (% GDP) <= 6.65 Bank Deposits Growth <= -12.72 Real Exchange Rate Overvaluation <= -2.6				No-Crisis	0%
11	Fiscal Deficit (% GDP) <= 6.65 Bank Deposits Growth > -12.72 Exports Growth > -31.75				No-Crisis	14.74%

Notes: The * indicates to which variety of crises each group belongs.

Table 3A. Crises in each Node

Node Number	Crisis Year
3	1958
	1962
	1975
	1976
	1981
	1982
	1983
	1984
8	1890
	1891
	1914
	1951
	1989
	1990
	1995
2001	
10	1921
	1930
	1938
	1949