Economic growth and currency crisis: A real exchange rate entropic approach

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Abstract

We propose a classification of currency crisis consequences based on the entropic analysis of a macroeconomic variable uniquely, without any further assumption. The entropy information carried by the real exchange rate time series serves to order the sampled countries. We show that this ranking is highly correlated with the annual minimum growth of gross domestic product, a proxy used to quantify real currency crisis effects. We compare this criterion against that most currently used, variance based methodology. In addition, cross-country correlations support the hierarchical ordering based on the entropic criterion.

I. Introduction

Prediction and contagion of financial crisis has received much attention in recent years. The financial instability during the Nineties has caused intense exchange and banking crisis in developed and, especially, in developing countries. Most of the empirical literature has focused on identification, prediction and contagion of currency crisis, see Kaminsky, Lizondo and Reinhart (1998) and Abiad (2003) for two comprehensive surveys. In this literature, the macroeconomics effects of currency crisis have sometimes been forgotten in favour of constructing mechanism to anticipate the *events* called currency crisis.

In general, characterization of currency crisis has been focused on the analysis of indicators that use variance of the macroeconomic series, such us real exchange rate, reserves, and/or interest rates for dating and defining the event of crisis. But, as pointed out by Ebrahimi *et al*. (1999), although variance plays a central role in characterizing and ranking economic variables, entropy seems to be a superior measure to extract underlying information in the economic data.

Following the above ideas, we have applied entropy analysis to the real exchange rate (RER) time series with the objective of classifying countries that have suffered currency crisis during the nineties in terms of their *real vulnerability*. We compared ordering results from variance and entropy of the time series showing that entropy is a better statistic to characterize the impact of currency crisis. Our results could be interpreted as a first step in the search for new forms of dating and predicting currency crisis and contagion. In order to do this, we have analysed a sample of 28 countries during the period of 1990-2002, most of which have suffered the effects of financial and currency crisis in the last decade. For a complete list of date and crisis originating countries see for example table 1 and 2 in Kaminsky *et al.* (2003) or appendix B in Pérez (2005).

II. Methodology

Entropy and variance has been widely used in economic literature as measures of dispersion and uncertainty, although variance (and other higher moments) are by far the most popular indexes still used because of their simplicity. Given a time series $\boldsymbol{x} = x_1, x_2, x_3, \ldots, x_i, \ldots, x_n$, where the index i refers to discretized time, the (sample) variance of the time series is defined as:

$$Var(x) = \sigma^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n} \qquad (1)$$

where $\bar{x}$ is the sample mean and σ is the standard deviation. Variance measures average departures of the time series from its mean.

On the other hand, following Shannon (1948), we can construct a probability distribution $P(\boldsymbol{x})$ from the time series $\boldsymbol{x}$ itself, and define the entropy of $P(\boldsymbol{x})$ as:

$$H[P(\boldsymbol{x})] = H(x) = -\sum_{i=1}^{N_{intervals}} p_i \log_2 p_i \qquad (2)$$

where the sum is over the $N_{intervals;}$ intervals that the full range of allowed values of $\boldsymbol{x}$ is partitioned. In this way, p_j is the probability of each interval j of being "occupied", and it is estimated as the number of x_i of the time series that fall in the interval i, divided by the total number of intervals, that is, $N_{interval}$. A value of $N_{intervals} = 50$ has been used in our calculations, although the results reported are rather insensitive to variations in $N_{intervals}$ from 20 to 50. Due to the finite amount of data used in the analysis, we have also estimated errors on observed entropy calculations accordingly with Roulson (1999). The maximum error reported in the entropy calculations is 3 %.

Broadly speaking, entropy describes the extent to which the distribution is concentrated on small sets; thus, it can be regarded as a measure of disparity of the distribution from the uniform one. If entropy is low, the distribution is concentrated at a few values of *x*. Note that entropy gives a very different kind of information than variance. If the distribution is concentrated on *several* small sets, far from each other, the variance can be large, while the entropy is small. We can recast the above paragraph in the particular case of exchange rate movements. For example, rigid exchange rate decisions tend to concentrate variations around small values during tranquil periods, and crisis generally moves these variations toward much higher values. In this sense, variations in RER are concentrated around sets far from each other. On the other hand, more flexible exchange rate decisions allow larger departures, even during tranquil times, and the values taken by the time series are not concentrated, but on the contrary, seem to be more or less continuous. So, entropy could be a good index to classify different exchange rate dynamics in different countries. Moreover, we shall show that an entropic ranking in the real exchange rate is highly correlated with countries economic growth decay after devaluations.

III. Empirical Analysis

We have used returns from the monthly real exchange rates (rRER) time series, in 28 countries, calculated as:

$rRER_i = (RER_{i+1} - RER_i)/ RER_i$

where $rRER_i$ is the monthly real exchange rate (return) at month i. The period 1990-2002 has been used, yielding a total of 156 data points for each country. RER is computed as the ratio of domestic consumer price to foreign price proxied by USA consumer price, and the result is multiplied by the nominal exchange rate of the domestic currency with US dollar. Data, including real Gross Domestic Product (GDP), has been drawn from International

Financial Statistics form the IMF database available on-line (http://ifs.apdi.net/imf/logon.aspx).

We have calculated entropy and variance in rRER in the 28 selected countries (see Appendix). Results are displayed in Figure 1, where countries in the x-axis are ordered following an increasing entropy criterion. The upper panel of Figure 1 shows entropy values (with error bars), as calculated by using Equation 2. The lower panel in the same figure shows variance calculations (Equation 1). Comparing both upper and lower panels in this figure, it is clear that a direct relation between both measures does not exist, although in some cases local similarities exist. For instance, Argentina is at the first place in both cases, with the lowest entropy and highest variance. Other countries seem to share both criteria; Indonesia, Brazil and Venezuela also are placed in the lower part of the plots, that is, they share high variance and low entropy.

In general, we can see that lower values of entropy correspond to the principal originating crisis countries in the last decade (Argentina, Thailand, Mexico) and, on the other side, countries of the EU, and Australia, have the highest entropies. In fact, one may divide the x-axis in developing countries, from Argentina to Philippines, and developed countries, from The United Kingdom to Australia with the unique exception of Chile, right in the middle of the EU group. Looking at the lower panel of Figure 1 it is evident that following a variance-ordering criterion will not yield the same results. So, variance and entropy, unless similar, orders this group of countries in a quite different fashion. Is the entropic ordering information useful for the currency crisis empiric literature? And, in what sense?

We have tried to answer partially these questions in two directions.

Firstly, ordering countries by rRER entropy solely, automatically create clusters of countries with similar exchange rate behavior, even though they are not always time correlated. This fact may be demonstrated by calculating any appropriate measure of “distance” between the variables, as for example cross-correlation coefficient.

In Figure 2 we have calculated Pearson’s correlation coefficient between rRER among pairs of countries, also ordered in both axis accordingly with the entropy criterion. High correlations (white squares) between countries in the upper and right corner of the graph are clearly seen, as is expected in those countries belonging to the EU. However, the last country, Australia, although with a similar entropy value to the EU countries, shows no correlation at all with them, as also in the case of Ireland and Chile. Ireland, although a country belonging to the EU has no correlation with these countries, but noneless, it is placed in this cluster by its entropy value. Chile, on the other hand, seems unexplained however from this unique analysis.

Outside the EU cluster, one may identify several clusters of correlations, as is the case Asian countries, that is, Malaysia, Thailand, Korea and Indonesia, in the lower and left part of Figure 2. Noteworthy is the case of Singapore, an Asian country, which however is placed just besides the EU countries accordingly with its entropy value. Looking at its correlations, it is easy to conclude that its position is mainly due to its high correlation with the EU countries. As it the case of Chile, Philippines however, remains also in an unexplainable position.

Most of the Latin American countries seem to be isolated with few correlations, with the exceptions of Brazil, correlated with Argentina, Colombia and Chile.

One may conclude from the above analysis that the particular entropy value, although a univariate statistic, seems to correctly order countries regarding its economic liaisons, even though in some cases there no exist time correlations.

In second place, real exchange rate movements are at the heart of the economic activity, and in this way, it is expected that any appropriate ordering criterion in the exchange rate movement will be reflected in the overall economic performance.

Currency and financial crisis have produced severe consequences in the economic activity in the group of countries we study. For instance, Argentine gross domestic product (GDP) dropped 11% after exchange rate collapse in 2002 and has shown a very low economic growth rate in the analyzed sample (around 2%). Indonesia dropped more than 13% during 1998 after bath collapse in 1997, but its economic growth rate in period analyzed is above 4%. In Europe, we can see that economic growth consequences of currency crisis are quite different. For instance, Spanish GDP dropped only 1% in 1993 after the peseta devaluation or Greece and Portugal in the same year with economic growth contraction around 1,5% (table 1).

Empirical literature of currency crisis has no tried to explain relationships between the proper crisis and the intensity of its macroeconomic effects. In table 2, we have calculated the correlation coefficient between the minimum of the annual GDP in the time series of each country and its order in our two ordering criteria, variance and entropy. We have found that the entropic criteria better fits a direct relation between drops in the GDP and rRER entropy, with lower entropy directly related with major GDP losses.

Also in table 2, we have calculated the same correlation coefficient but using this time the economic growth average rate to test if currency crisis affects to the capability of countries economic growth in the medium term. Results of this correlation show that by only using exchange rate time series we are able to say little about the potential real economic growth in the medium and long term. These results are coincident with that reported by Chou and Chao (2001), and clearly in contrast with Christopoulos (2004), unless we have used different methodology. Nevertheless, in our analysis signs in entropy and variance are what we expected and, again, explanation capability of the entropy as information measure is better than the variance in the exchange rate time series analysis[1].

[1] We expected that low entropy coefficients, which have shown an important relationship with the intensity of

IV. Conclusions

We have introduced a new criterion to characterize the effects of currency crisis based solely in the analysis of the real exchange rate returns time series. We used entropy to order a group of 28 developed and developing countries. As we have shown, ranking countries accordingly with the entropy value of the real exchange rate is highly correlated with the intensity of economic growth drops in periods with currency crisis events. We have tested the entropy against the variance order. As a conclusion regarding this point, entropy seems to be a good measure for analyzing *real vulnerability* consequences in currency crisis events, with low values of entropy in cases of countries that have suffered severe currency crisis in terms of output growth dropped. Moreover, our results give firm signs about which exchange rate dynamics are more prone to suffer currency crisis. In addition, we have shown that the ordering proposed also gives important information regarding economic liaisons between groups of countries, and may shed new light in the contagion issue, although there remains much more research to do on this issue.

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the dropped in GDP, were related with low economic growth rate in the medium term. So, we expected a negative correlation sign. In variance order, we expected a positive correlation sign.

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Appendix

The 28 countries included in this work are as follows (order by increasing entropy):

Argentine (ARG), Malaysia (MAL), Thailand (THA), Mexico (MEX), Korea (KOR), Indonesia (INDO), Brazil (BRA), Venezuela (VEN), Peru (PER), India (INDI), Ecuador (ECU), Turkey (TUR), Colombia (COL), Singapore (SIN), Philippines (PHI), United Kingdom (U_K), Sweden (SWE), Italy (ITA), Ireland (IRE), Finland (FIN), Chile (CHI), Greece (GRE), Portugal (POR), Switzerland (SWI), Denmark (DEN), Spain (SPA), Norway (NOR), Australia (AUS)

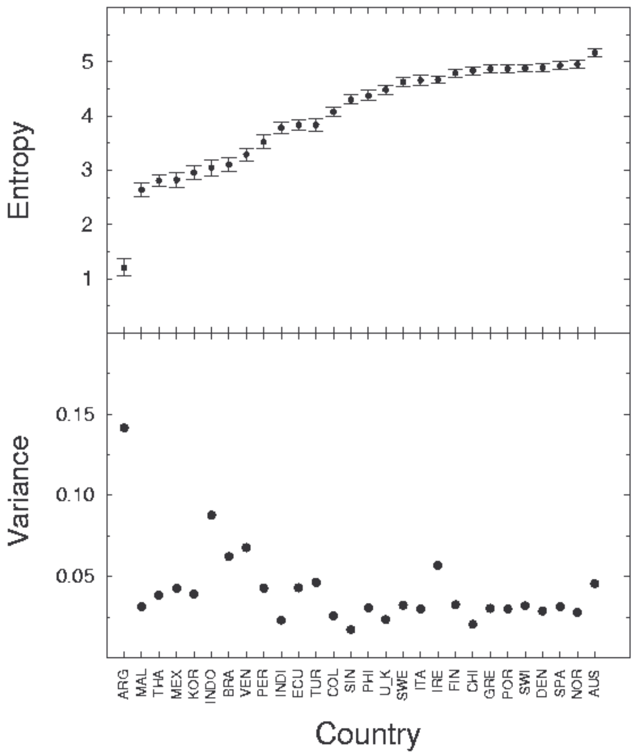
Table 1. Entropy, Variance, Gross Domestic Product (GDP), 1990-2002

	Entropy coefficients	Variance coefficients	MIN GDP (1)	AVM GDP (2)	MAX GDP (3)	STAD DEV GDP (4)
ARGENTINE	1,16	0,141	-10,89	1,928	10,58	6,427
MALAYSIA	2,58	0,031	-7,36	6,602	10	5,047
THAILAND	2,77	0,038	-10,51	5,001	11,17	5,738
MEXICO	2,77	0,043	-6,17	3,146	6,77	3,46
KOREA	2,90	0,039	-6,85	6,146	9,49	4,331
INDONESIA	2,98	0,088	-13,13	4,236	8,22	5,636
BRAZIL	3,04	0,062	-0,54	2,337	5,85	2,035
VENEZUELA	3,22	0,068	-8,88	1,688	9,73	5,305
PERU	3,45	0,043	-3,67	3,209	12,82	4,391
INDIA	3,72	0,023	0,91	5,434	7,59	1,846
ECUADOR	3,76	0,043	-6,3	2,592	5,12	2,903
TURKEY	3,76	0,047	-7,32	3,575	9,26	5,811
COLOMBIA	4,01	0,026	-4,2	2,699	5,71	2,616
SINGAPORE	4,22	0,017	-1,9	6,695	12,26	4,39
PHILIPPINES	4,28	0,031	-0,58	3,138	5,85	2,212
UNITED KINGDOM	4,39	0,024	-1,37	2,209	4,42	1,569
SWEDEN	4,53	0,033	-1,74	1,869	6,76	2,686
ITALY	4,55	0,030	-0,88	1,546	3,03	1,049
IRELAND	4,57	0,057	1,93	7,102	11,57	3,117
FINLAND	4,69	0,033	-6,26	1,875	6,29	3,684
CHILE	4,73	0,021	-0,76	5,682	12,28	3,523
GREECE	4,76	0,030	-1,6	2,417	4,39	1,774
PORTUGAL	4,76	0,030	-1,37	2,884	8,45	2,291
SWITZERLAND	4,78	0,032	-0,83	1,21	3,8	1,446
DENMARK	4,78	0,029	0	2,071	5,47	1,414
SPAIN	4,81	0,032	-1,03	2,731	4,91	1,547
NORWAY	4,84	0,028	1,11	3,326	5,26	1,335
AUSTRALIA	5,04	0,046	-0,59	3,285	5,3	1,57

(1) Minimum annual GDP growth in the period sample
(2) Annual average GDP growth in the period sample
(3) Maximum GDP growth in the period sample
(4) Standard Deviation of GDP in the period sample

Table 2. Entropic and variance ordering correlation coefficient

	Annual GDP minimum		Annual GDP average	
	Entropy Ordering	Variance Ordering	Entropy Ordering	Variance Ordering
Correlation coefficient	0.7211	0.5599	-0.2667	0.1436
Slope	0.3551	0.2757	-0.0558	0.0301



<u>Figure 1</u>: Entropy (upper panel) and variance (lower panel) in 28 countries.
Countries are ordered by increasing entropy. Errors bars have been calculated in entropy as explained in the text.

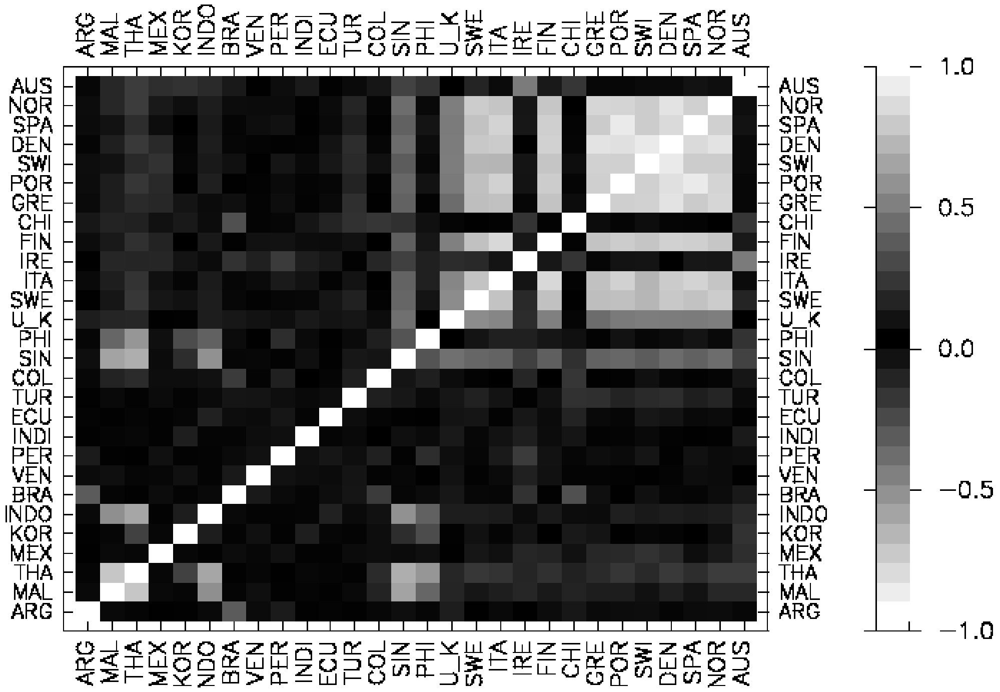


Figure 2: Cross-correlation coefficient between rRER in pairs of countries.
White squares means perfect linear correlation (r=-1 or r=1) and black squares means absence of linear correlation (r=0). The x-axis and y-axis are countries ordered by the entropy criterion. Coefficients data could be obtained from the authors.