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MULTIVARIATE TRANSVARIATION ANALYSIS AND CURRENCY CRISES

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Multivariate Transvariation Analysis and Currency Crises

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Abstract: The aim of this paper is to understand currency crises by selecting the macroeconomic fundamentals with a high predictive power, defining the latter as the variable ability of discriminating between two groups of countries: the sound and the distressed. We consider a sample of over one hundred countries which experienced a currency crash, following Frankel and Rose (1996) and we apply the statistical methodology, transvariation analysis, which measures the amount of overlap between the distributions of the sound and the distressed countries. The result of this methodology is a ranking of the groups of variables who tend to better distinguish the two groups. In order to test the informative power of the selected indicators, we calculate the leave one out predictive error using a transvariation based linear discriminant function. Our results seem to outperform Frankel and Rose (1996) probit analysis.

JEL Classification: G01, C14, F32

Keywords: currency crises; multivariate transvariation analysis; linear discriminant function

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1 Introduction

How can we establish if a country's economic situation is leading to a currency crisis? The best we can do is to monitor a set of variables that can give us some information on the country's economic well being. So the question becomes what variables should we monitor and is there a rigorous and robust methodology that enables us to rank the group of variables that have a higher predictive power?

Economic theory and a vast literature on country crises[2], list a set of useful macroeconomic indicators and the fact that high current account and government deficits, low reserves, high domestic credit may lead to a crisis is not a novelty, but we are suggesting an empirical methodology that helps select the group of variables to monitor, through the use of multivariate discriminant analysis. The application of this methodology to the problem of country crises is the innovative aspect of the paper. The rationale of this analysis is to position two groups of units (the sound and the distressed countries) on a k-dimensional plane (where the k-dimensions represent the economic variables). In order to correctly classify a country, whose group membership is unknown, having some available information on the macroeconomic indicators that characterize that country, we need to select those variables that can best separate the distributions of the two groups (the sound and the distressed). The same concept can be applied if we wished to diagnose diabetes on a new patient. We don't know if the patient belongs to the group of people affected by diabetes or to the healthy group, but if we had to choose one or two variables that would help classify the new patient correctly we would probably select the most informative one, i.e. the one that best discriminates the two groups of patients.

This very intuitive methodology can be relevant for policy analysis, because it is very simple to implement and easy to be interpreted. The policymaker can use this approach in a very flexible way by studying the position of a single country compared to the two groups and by choosing the number of variables. Group separability is the key issue of the paper. There are different ways of measuring it, but we concentrate on one methodology, transvariation analysis, which quantifies the amount of overlap between the two groups' distributions. If the amount of overlap is high the two groups are not separated and the variables have a low discriminative power, on the contrary, if the amount of overlap is low, the two groups are apart and the variables have a high discriminative power.

We are considering currency crises according to the definition of Frankel and Rose (1996), addressing the analysis on a wide sample of countries (over one hundred). In the first part we focus on the concept of group separability, by comparing the different ways of measuring the distance between two groups and by showing that transvariation analysis, which measures the amount of overlap between the groups, is better from a methodological point of view (Calò (2006)). The results corroborate this methodological finding. The second issue that is addressed in this article is linked to the multivariate extension[3]. Gini (1916) at first introduces the synthetic variable approach and Calò (2006) later introduces a sequential procedure to measure the multivariate transvariation probability index. We report and compare both methodologies. Finally, in order to validate this approach we calculate the leave one out predictability error through the use of a linear discriminant function. Even in this case we compare the results using the traditional LDF (Fisher (1936)) and the LDF that minimizes the transvariation probability index proposed by Montanari (2004). In terms of results we notice that our findings outperform the

[2] See Kaminsky *et al.* (1997), Kaminsky (1999),Kaminsky (2006) for a review on Early Warning Systems

[3] See Bragoli *et al.* (2009) for an univariate application of transvariation analysis.

ones obtained by Frankel and Rose. The article is structured as follows. Section 2 highlights two different ways of measuring separation between distributions: the Mahalanobis distance and multivariate transvariation analysis. Section 3 focuses on the definition of univariate and multivariate transvariation and describes the procedure of calculating the transvariation probability index on multiple dimensions. Section 4 introduces two linear discriminant functions. Section 5 applies the methodology to currency crises and shows the rankings of the variables in terms of group separation in a univariate, bivariate and trivariate context. Section 6 compares the prediction error of the best couple of variables using Fisher's linear discriminant function, but also a transvariation based linear discriminant function following Montanari (2004). Section 7 concludes.

2 Two distance based measures of group separability

Variable selection, according to discriminant analysis, consists in choosing the indicators that maximize a distance between two groups of units. The most common distance that we are used to thinking of is the Euclidean distance, but because we would like to measure the distance between two distributions, variability is an important issue (Flury (1997)). It is thus important to introduce the concept of standard distance. In a univariate case the standard distance between two numbers x_1 and x_2, with respect to the random variable X, is given by:

$$\Delta_x(x_1, x_2) = \frac{|x_1 - x_2|}{\sigma} \tag{1}$$

In a multivariate case the standard distance (the Mahalanobis distance) is generalized to a situation where two or more variables are measured simultaneously. The multivariate standard distance between two populations with mean vectors μ_1 and μ_2 and common covariance matrix ψ is given by:

$$\Delta(\mu_1, \mu_2, \psi) = \left[(\mu_1 - \mu_2)' \, \psi^{-1} \, (\mu_1 - \mu_2)\right]^{1/2}. \tag{2}$$

The main assumptions and characteristics of the Mahalanobis distance are the following:

- the distributions are assumed to be homoscedastic (the distance is in fact based on the common covariance matrix ψ);
- the distributions are summarized in terms of their first order and second order moments ($\Delta(\mu_1, \mu_2, \psi)$).

Transvariation analysis measures the amount of overlap between two distributions. Differently from the Mahalanobis distance, this methodology calculates the distance between the two groups starting from distances between individuals. If the two populations are normally distributed with identical covariance matrix, it can be shown that the amount of overlap between them is a function of the Mahalanobis distance, but for skewed distributions the distance may not succeed in distinguishing between separated or overlapping distributions (Calò 2006). Transvariation analysis is a very powerful measure, because it simultaneously takes into account all the characteristics of the distributions of the two groups (location, variability and skewness) without summarizing data with moment statistics. In the next paragraph we are going to focus on the definition of the transvariation probability index in both a univariate and multivariate context.

3 Univariate and multivariate transvariation analysis

Transvariation analysis measures the separability between the distributions of two groups of units with respect to one variable (univariate transvariation) or with respect to multiple variables (multivariate transvariation).

We start by introducing Gini's definition of univariate and multivariate transvariation. In particular we focus on one of the measures of distribution separability: the transvariation probability index.

Definition 1.Two groups G_1 and G_2 of n_1 and n_2 units respectively, are said to transvary on the variable X with respect to their corresponding mean values $m_{1,X}$ and $m_{2,X}$ $(m_{1,X} \neq m_{2,X})$, if the sign of at least one of the differences $x_{1i} - x_{2j}$ (i=1,...,n_1 and j=1,...,n_2), which can be defined between the X values belonging to the groups is opposite to that of $m_{1,X} - m_{2,X}$. Any pair of units ($i \in G_1$,$j \in G_2$) satisfying this condition is said to transvary. The number of transvarying pairs is denoted by:

$$s_{12} = \sum_{n_1}^{i=1} \sum_{n_2}^{j=1} \eta \left(x_{1i}, x_{2j} \right), \quad (3)$$

where
$\eta \left(x_{1i}, x_{2j} \right) = 1$, if $\left(x_{1i} - x_{2j} \right) \left(m_{1,X} - m_{2,X} \right) < 0$;
$\eta \left(x_{1i}, x_{2j} \right) = 0$, if $\left(x_{1i} - x_{2j} \right) \left(m_{1,X} - m_{2,X} \right) > 0$;
$\eta \left(x_{1i}, x_{2j} \right) = 1/2$, if $x_{1i} = x_{2j}$.

By using the median in place of the mean Gini (1916) defines transvariation probability as the ratio between the actual values of transvarying pairs to its maximum:

$$tp = s_{12}/max(s_{12}). \quad (4)$$

If the variable distributions are symmetric it can be shown that $max(s_{12}) = n_1 n_2/2$, which is the maximum number of cases of transvariation ($n_1 n_2$) under the hypothesis that the medians of the two distributions coincide (this justifies the multiplication of the number of cases by 1/2 according to (3)).

Gini and Livada (1959) extend the concept of transvariation to a multivariate framework.

Definition 2.Two groups G_1 and G_2 of n_1 and n_2 units respectively, are said to transvary on the k-dimensional variable X with respect to their corresponding mean vectors $m_{1,X}$ and $m_{2,X}$, if there exists at least one pair (x_{1i}, x_{2j}) where $i \in G_1$ and $j \in G_2$, such that for h=1,...,k the sign of the h-th entry in vector $x_{1i} - x_{2j}$ is opposite to that of the h-th entry in vector $m_{1,X} - m_{2,X}$ (this entry not being null). Any pair of units $(i \in G_1, j \in G_2)$ satisfying this condition are said to jointly transvary.

Given the multivariate definition of transvariation analysis we report two different methodologies for the calculation of the transvariation probability index. The first methodology follows Gini's work 'A synthetic measure of transvariation with respect to n variables', where he calculates the transvariation probability reducing the dimensionality of the problem by creating a synthetic variable. Gini starts from considering the same definition of multivariate transvariation stated above and focuses on two issues. The number of transvariation cases decreases when the number of variables increases. The second aspect refers to the fact that the definition of multivariate transvariation does not consider the intermediate cases in which transvariation is observed with respect to some variables, but not with respect to others. The aim of his work is to find a method to incorporate the intermediate cases in order to find a multivariate transvariation probability index which is independent from the number of dimensions, but that depends on the intensities of the differences between the variables. The procedure that takes these considerations into account can be described as follows. We consider two groups G_1 and G_2 of n_1 and n_2 units respectively. We define x_{1i} the i-th unit of G_1 and $x_{2j}$the j-th unit of G_2. $k$is the number of variables. The first step involves the calculation of the mean differences of each variable (or dimension) k=1,...,p, where the mean differences are defined as follows:

$$\Delta_k = \frac{1}{n_1 n_2} \sum_{i=1}^{n_1} \sum_{j=1}^{n_2} \left| x_{1i,k} - x_{2j,k} \right| . \tag{5}$$

The second step implies the creation of the 'reduced values', defined as follows:

$$x^*_{1i,k} = \frac{x_{1i,k}}{\Delta_k} \tag{6}$$

and

$$x^*_{2j,k} = \frac{x_{2j,k}}{\Delta_k} \tag{7}$$

with i=1,...,n_1 ($i \in G_1$), j=1,...,n_2 ($j \in G_2$) and k=1,...p (k=number of variables). The second step implies the creation of synthetic variables by summing the 'reduced variables' with the 'correct sign'. The synthetic variables are defined as follows:

$$x^{**}_{1i} = \sum_{k=1}^{p} \alpha_k x^*_{1i,k} \tag{8}$$

and

$$x^{**}_{2j} = \sum_{k=1}^{p} \alpha_k x^*_{2j,k}, \tag{9}$$

where

$$\alpha_k = sign(m_{1X,k} - m_{2X,k}) \tag{10}$$

The reduced values of G_1, which are $n_1 p$, through this last step, are synthesized by a vector of n_1 variables. For the i-th unit we have p reduced values that are summed together using the correct sign. The sign is positive if for the k-th variable the median of G_1 is greater than the median of G_2, the sign is negative if the opposite applies. The same is true with G_2. We thus remain with two groups G_1 and G_2 of n_1 and n_2 units of synthesized variables respectively. The last step consists in calculating the univariate transvariation of the synthesized variables. This methodology does not depend on the dimensions of the problem, because they are always reduced to one. It strongly depends on the 'reduced values', in particular on the mean differences which are at the denominator. If the mean difference of a certain variable is high the reduced value looses importance and on the opposite, if the mean difference is low, the 'reduced value' weights more in the determinacy of the composite variable.

Following Calò (2006) [4] we also develop a procedure to calculate the joint transvariation by counting the cases in which the h-th pair of units satisfies jointly the condition for transvariation in all the k-dimensions simultaneously. The procedure is sequential, it focuses on the region where the groups overlap and can be summarized in the following steps:

- at step one the procedure calculates the transvariation probability between G_1 and G_2 on each variable and the variable corresponding to the minimum probability is chosen ($X_{min,1}$);
- at step two the number of transvarying pairs is recorded in order to determine two subsets of G_1 and G_2 that are called G_1' and G_2';
- at step three the transvariation probability is calculated on the subsets G_1' and G_2' with respect to the other variables different from $X_{min,1}$, and a second variable corresponding to the minimum probability is chosen ($X_{min,2}$), the subsets are updated.

The procedure follows definition 2 of. It is quite obvious from the above description that both the definition and the implementation are very restrictive. In particular, we expect to find an inverse relationship between transvariation probability index and the number of variables jointly considered. We report a comparison between the two methods in terms of results in paragraph number 5.

4 Linear discriminant functions to classify a new unit

A distance measure between the two groups is important for variable selection, but we can take a step forward and use the criteria of distance in order to create a model that can classify with a relative low error a new unit whose group membership is unknown. The latter model will help corroborate the validity of the variable selection approach. In classification issues the most commonly used model is the linear discriminant function introduced by Fisher (1936). The linear discriminant function is derived by constructing linear combinations of the multivariate random vector X and by choosing, among all the possible combinations, the one that has a large standard distance. Any linear combination $Y = \beta' X$, with

$$\beta = c \cdot \psi \left(\mu_1 - \mu_2 \right), \tag{11}$$

where $c \neq 0$ is an arbitrary constant, is a linear discriminant function for the two populations. By applying (11) we are choosing the vector beta of linear combinations that maximizes the multivariate distance (2)(the Mahalanobis distance) between the two groups. The linear discriminant function ($Y = \beta' X$) is a linear function that best separates the two groups according to the criterion of distance maximization. It is well known that Fisher's function is not robust against outlying observations and against violations of normality and homoscedasticity. In order to overcome these limitations, following Montanari (2004), we compare Fisher's LDF to a linear discriminant function based on a projection pursuit method, which is the numeric search of 'interesting' low dimensional projections

[4] we consider the median of the $n_1 n_2$ differences instead of the difference between the medians of the two groups in order to count the tranvarying cases. By making this correction the situation of maximum transvariation may be obtained by shifting one of the groups so that the median of the $n_1 n_2$ differences is equal to zero. In this case the $max(s_{12})$ is always equal to $n_1 n_2/2$.

of high dimensional data, using as ‘interesting’ projections the ones that maximize group separation in terms of Gini’s transvariation . Let X be the k-dimensional vector of the variables to be used in order to discriminate between G_1 and G_2, α a k-dimensional unit norm vector defining a projection direction and $y = \alpha' x$ the variable that results projecting x along α. An LDF can be derived, in a projection pursuit framework, as the linear combination ($y = \alpha' x$) which minimizes the transvariation probability index. This new discriminant function is equivalent to Fisher’s linear discriminant function when the optimality conditions (normality, homoscedasticity) for the latter are satisfied and outperforms it when the optimality conditions do not hold (Montanari (2004)).

The main objective of deriving a linear discriminant function is to reduce the k-dimensional problem to one dimension, by projecting the units belonging to the two groups, which are defined by two or more dimensions, on a linear function. Once the linear function is determined either analytically as in Fisher or numerically by minimizing the transvariation measure, we have to set thresholds on it in order to allocate a new unit (in our case a country). The selected threshold divides the two groups, we can compare the new unit with the threshold and establish whether it belongs to one group or the other.

The aim of the next sections is to apply the group distance approach (comparing the transvariation probability index with the Mahalanobis distance) to select the macroeconomic indicators that have a higher predictive power and validate the selection by computing the leave one out error rates comparing Fisher’s linear discriminant function and a transvariation based linear discriminant function.

5 Ranking of the variables

We start with Frankel and Rose (1996) annual data on developed countries from 1971 through 1992 and we define the currency crises as a large change of the nominal exchange rate that is also a substantial increase in the rate of change of nominal depreciation. Differently from Frankel and Rose (1996) we consider the group of distressed countries in the years before the crisis, in particular we use data of three years before and one year before, in order to compare the results as the crisis approaches and we define the control group as the sound developed countries, using year 2000 data. The variables are listed in table 1 and are very similar to the ones proposed by Frankel and Rose (1996).

We consider some debt variables (the ratio of external debt to GDP, short term debt to external debt, government debt to external debt), some current account indicators (the current account as a percentage of GDP, investment as a percentage of GDP), capital account indicators (the variation of the reserves), monetary indicators (M2 growth and inflation), a measure of the overborrowing (domestic credit to GDP) a measure of recession (GDP growth). According to Frankel and Rose (1996) probit analysis, currency crashes tend to occur when FDI inflows dry up, when reserves are low and when domestic credit is high and they also tend to be associated with sharp recessions. Neither current account nor government deficit appear to play an important role in a crash. Our results are partially different from the ones pointed out by Frankel and Rose (1996).

From a univariate point of view, see table (4), inflation, the growth of M2 and the current account deficit are the best variables in terms of a low transvariation probability index, while the worst variables are domestic credit (as a percentage of GDP), the variation of reserves and the short term debt (as a percentage of external debt). In table (5) we show the rankings of the bivariate variables according to the transvariation probability index (according to Calò (2006) and Gini) and the Mahalanobis distance. From the data description (tables 2 and 3), most of the variables are skewed and for this reason the probability of transvariation should be a more robust methodology in measuring the separability between the distributions. Table 5 and tables 6 to 8 report the variables ranking in the bivariate and in the trivariate cases. The first column of each table reports the transvariation probability index according to Calò (2006) methodology, the second column reports the same index but following Gini's methodology and the third reports the Mahalanobis distance. The variables with a low (high) index and a high (low) distance are characterized by a high (low) level of separation between the two groups. We can notice that the three different methodologies produce different rankings of the variables and according to the cograduation index calculated between the two different approaches and the Mahalanobis distance (table 9) Calò's methodology is closer to Mahalanobis distance compared to Gini's. In order to assess which of the two transvariation probability indexes is more useful in terms of group separation we decided to compare the best group against the worst group of variables both on two and three dimension to see which of the two approaches selects the group of variables in the correct way. Figures 1 and 2 compare the two approaches in a bivariate context. Calò (2006) methodology (figure 1) seems to provide the correct couple of variables in terms of group separation. M2 growth and inflation (the best couple of variables) separate the two groups, while external debt and short term debt (the worst couple of variables) don't. On the other hand Gini's methodology (figure 2) gives a worst level of information on group separability. The same applies on a space of three dimensions (figure 3 and 4), even if in this case it is less clear. In the bivariate context (table 7) according to the transvariation probability index (Calò's method) M2 growth (together with inflation, government debt, investment and GDP growth) and CAD (together with external debt, investment and M2 growth) seem to work best in separating the two distributions. The variation of reserves (together with GDP growth, inflation, government debt, and external debt) and the external debt (together with short term debt, government debt and the variation of domestic credit) seem to behave worse in terms of distribution separability. In the trivariate context (table 8) the CAD (together with domestic credit and investment, domestic credit and short term debt, inflation and GDP growth) is characterized by a higher group separation, while GDP growth (together with external debt and short term debt and external debt and government debt) is characterized by the lowest level of group separation.

6 Validation

The selection of the the most informative couple of variables from a discriminative point of view is the first step of our analysis, we are now ready to measure the predictability power of the low transvariation couple of variables (M2 growth and inflation) comparing them with the couple characterized by the highest Mahalanobis distance between the two groups (M2 growth and government debt). In tables 10 and 11 we report the predictability error of both couple using Fisher's linear discriminant analysis and the transvariation based linear discriminant analysis described in section 4.

We construct a thousand bootstrap training samples from the two groups of countries, considering for the distressed group the third year before the crisis and for the sound group year 2000. We calculate for each sample the leave one out predictability error and we report the mean values in tables 10 and 11. While in both tables the training sample of the distressed is based on three years before the crisis, table 10 classifies the 50 countries (34 distressed and 16 sound) considering the same years of the training sample, while table 11 classifies the distressed countries considering the data one year before the crisis.

We notice that the predictability error diminishes in all cases as the currency crisis approaches. The couple of variables M2 growth and inflation, which are first ranked according to the transvariation probability index, have the lowest predictability error when the classifying model is the transvariation based LDF (18 p.c. three years before the crisis and 10 p.c one year before). The couple of variables M2 growth and government debt as a percentage on external debt, which are first ranked according to the Mahalanobis distance, have a lower predictability error when Fisher's LDF is used, but still relatively high (26 p.c. three years before and 20 p.c one year before the crisis). Comparing these results with Frankel and Rose (1996) probit analysis we find that while the overall leave one out predictability error is very close (10 p.c. against 8.8 p.c), if we compare the partial errors, we notice that the probability of predicting crash instead of tranquility is 6 p.c. with the transvariation analysis methodology (against 0.82 p.c. Frankel and Rose (1996)), whilst predicting tranquility instead of crash is 11.7 p.c. (against 92 p.c.Frankel and Rose (1996)).

7 Conclusions

In this chapter we use Frankel and Rose (1996) dataset to apply a statistical methodology to analyze currency crises. The strength of transvariation analysis is its simple interpretation. We define informative, for the sake of crises predictability, those variables that have a high discriminative power, that can separate the group of distressed countries from the sound. The transvariation probability index is a robust measure of the separation between the distributions even when the optimality conditions of homoscedasticity and normality do not hold. We calculate the bivariate and the trivariate transvariation probability indexes to rank the group of variables that have a high predictive power and test through the use of a transvariation based linear discriminant function their predictability. From a methodological point of view we are in line with Calò (2006) and Montanari (2004) by assessing that transvariation analysis is a more robust methodology in a discriminant analysis context, compared to the Mahalanobis distance and the linear discriminant function gives lower predictability errors if it is based on the minimization of the probability of transvariation, rather than on the maximization of the multivariate distance. From an economic point of view our empirical results that follow from a non structural investigation of the data, are partially different from the ones pointed out by Frankel and Rose (1996). The growth of M2 together with inflation, government debt, investment, GDP growth, but also the Current Account Deficit together with the external debt and investment seem to be the most predictive variables. The growth of M2 and inflation, which are the first ranked according to the transvariation probability index, predict currency crises with an error of 18 p.c three years before and 10 p.c one year before. This methodology seem to outperform Frankel and Rose (1996) probit analysis in terms of the leave one out predictability errors.

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Table 1: *Variables considered*

Variable Name	Variable abbreviation
Variation of Domestic credit	dcredit
M2 growth	M2growth
External debt (p.c.of GDP index on year before)	extdebt
Short Term Debt (p.c. of external debt index on year before)	shortdebt
Government Debt (p.c of external debt index on year before)	gdebt
Current account deficit (p.c of GDP)	CAD
Reserves growth	reserves
Inflation	inflation
GDP growth	ggrowth
Investment (p.c. of GDP index on year before)	invest

Table 2: *Distressed countries descriptive statistics*

	min	1q	Me	3q	max
Variation of Domestic credit (in p.c. terms)	-37.0	6.7	20.0	30.0	79.0
M2 growth (in p.c. terms)	-15.0	9.7	17.0	23.2	81.0
External debt (p.c.of GDP index on year before)	-60.0	-2.2	7.0	21.2	159.0
Short Term Debt (p.c. of external debt index on year before)	-80.0	-25.0	0.0	17.0	117.0
Government Debt (p.c of external debt index on year before)	-55.0	-6.0	-1.0	3.2	18.0
Current account (p.c of GDP)	-26.0	-11.0	-4.0	-2.7	5.0
Reserves growth (in p.c. terms)	-69.0	-31.2	-10.0	30.2	142.0
Inflation (in p.c. terms)	-12.0	4.0	8.0	15.2	48.0
GDP growth (in p.c. terms)	-26.0	-4.2	0.0	4.2	18.0
Investment (p.c. of GDP index on year before)	-40.0	-12.2	0.0	9.5	64.0

Table 3: *Developed countries descriptive statistics*

	min	1q	Me	3q	max
Variation of Domestic credit (in p.c. terms)	-6.0	10.5	15.0	18.5	30.0
M2 growth (in p.c. terms)	0.8	5.1	8.2	11.2	16.0
External debt (p.c.of GDP index on year before)	-2.0	10.5	16.0	19.0	22.0
Short Term Debt (p.c. of external debt index on year before)	-8.0	-1.0	0.5	6.0	15.0
Government Debt (p.c of external debt index on year before)	-27.0	-11.5	-8.5	1.5	16.0
Current account (p.c of GDP)	-11.1	-4.8	0.2	4.4	8.6
Reserves growth (in p.c. terms)	-42.0	-4.5	5.5	18.5	68.0
Inflation (in p.c. terms)	-1.0	1.0	2.0	3.0	4.0
GDP growth (in p.c. terms)	1.0	2.0	3.0	3.0	6.0
Investment (p.c. of GDP index on year before)	0.0	3.0	6.0	9.0	15

Table 4: *Univariate transvariation probability index*

	index
Inflation	0.19817
M2 growth	0.41311
CAD	0.53354
Investment	0.57317
GDP Growth	0.61585
Government debt	0.68293
External debt	0.78963
Domestic credit	0.78963
Variation of Reserves	0.83232
Short-term debt	0.85823

Table 5: *Ranking of variables (the bivariate case)*

(Calò)		(Gini)		Mahalanobis distance	
M2growth-inflation	0.04	M2growth-dcredit	0.02	M2growth-gdebt	0.038
M2growth-gdebt	0.11	M2growth-inflation	0.02	inflation-gdebt	0.034
M2growth-invest	0.12	dcredit-inflation	0.03	M2growth-ggrowth	0.034
M2growth-ggrowth	0.13	CAD-M2growth	0.05	CAD-inflation	0.032
CAD-extdebt	0.13	CAD-inflation	0.08	CAD-gdebt	0.032
CAD-invest	0.15	CAD-dcredit	0.09	M2growth-invest	0.031
CAD-M2growth	0.16	M2growth-invest	0.17	dcredit-gdebt	0.029
invest-inflation	0.16	M2growth-ggrowth	0.18	CAD-extdebt	0.028
CAD-ggrowth	0.16	reserves-M2growth	0.20	CAD-M2growth	0.028
CAD-gdebt	0.16	M2growth-shortdebt	0.21	reserves-inflation	0.028
dcredit-ggrowth	0.17	ggrowth-extdebt	0.22	M2growth-inflation	0.028
M2growth-extdebt	0.18	M2growth-gdebt	0.23	CAD-ggrowth	0.027
CAD-inflation	0.18	extdebt-gdebt	0.28	M2growth-extdebt	0.027
dcredit-inflation	0.19	invest-extdebt	0.29	inflation-ggrowth	0.027
CAD-shortdebt	0.21	inflation-shortdebt	0.30	ggrowth-gdebt	0.026
dcredit-gdebt	0.21	dcredit-shortdebt	0.32	CAD-invest	0.026
dcredit-invest	0.22	reserves-dcredit	0.36	reserves-gdebt	0.025
reserves-M2growth	0.23	dcredit-gdebt	0.36	inflation-extdebt	0.025
invest-gdebt	0.23	dcredit-ggrowth	0.36	dcredit-inflation	0.025
inflation-gdebt	0.23	reserves-extdebt	0.38	invest-inflation	0.025
ggrowth-gdebt	0.23	dcredit-invest	0.41	gdebt-shortdebt	0.025
CAD-reserves	0.23	extdebt-shortdebt	0.42	reserves-M2growth	0.024
invest-ggrowth	0.24	invest-inflation	0.43	invest-gdebt	0.025
inflation-ggrowth	0.24	reserves-inflation	0.44	inflation-shortdebt	0.024
M2growth-dcredit	0.25	ggrowth-gdebt	0.50	CAD-reserves	0.023
CAD-dcredit	0.25	M2growth-extdebt	0.54	CAD-dcredit	0.023
M2growth-shortdebt	0.27	dcredit-extdebt	0.54	M2growth-shortdebt	0.023
invest-shortdebt	0.29	CAD-shortdebt	0.60	extdebt-gdebt	0.022
ggrowth-shortdebt	0.29	inflation-gdebt	0.63	M2growth-dcredit	0.022
reserves-shortdebt	0.29	reserves-gdebt	0.64	reserves-ggrowth	0.021
inflation-shortdebt	0.29	inflation-ggrowth	0.64	CAD-shortdebt	0.020
invest-extdebt	0.30	invest-gdebt	0.64	dcredit-ggrowth	0.020
reserves-dcredit	0.30	CAD-reserves	0.66	ggrowth-extdebt	0.018
gdebt-shortdebt	0.31	invest-ggrowth	0.67	invest-ggrowth	0.016
reserves-invest	0.31	CAD-extdebt	0.71	ggrowth-shortdebt	0.016
ggrowth-extdebt	0.31	CAD-invest	0.75	reserves-invest	0.015
inflation-extdebt	0.32	reserves-ggrowth	0.76	dcredit-invest	0.014
dcredit-shortdebt	0.32	reserves-invest	0.76	reserves-dcredit	0.014
reserves-inflation	0.32	gdebt-shortdebt	0.77	invest-extdebt	0.014
reserves-gdebt	0.33	ggrowth-shortdebt	0.82	reserves-extdebt	0.014
reserves-extdebt	0.34	CAD-ggrowth	0.83	dcredit-extdebt	0.014
extdebt-gdebt	0.35	invest-shortdebt	0.86	reserves-shortdebt	0.011
reserves-ggrowth	0.36	inflation-extdebt	0.95	invest-shortdebt	0.011
dcredit-extdebt	0.38	CAD-gdebt	1.08	extdebt-shortdebt	0.010
extdebt-shortdebt	0.40	reserves-shortdebt	1.11	dcredit-shortdebt	0.010

Table 6: *Ranking of variables (the trivariate case (1))*

Calò		Gini		Mahalanobis distance	
cad-dcredit-invest	0.002	m2growth-dcredit-inflation	0.006	m2growth-ggrowth-gdebt	0.046
cad-dcredit-shortdebt	0.002	cad-dcredit-inflation	0.021	m2growth-invest-gdebt	0.044
cad-inflation-ggrowth	0.003	cad-m2growth-dcredit	0.024	cad-m2growth-gdebt	0.043
cad-reserves-m2growth	0.003	cad-m2growth-inflation	0.031	cad-inflation-gdebt	0.043
cad-reserves-inflation	0.003	cad-m2growth-extdebt	0.040	m2growth-inflation-gdebt	0.042
cad-reserves-dcredit	0.005	cad-dcredit-extdebt	0.040	m2growth-dcredit-gdebt	0.040
cad-m2growth-dcredit	0.006	cad-inflation-extdebt	0.049	cad-m2growth-ggrowth	0.040
cad-dcredit-extdebt	0.006	m2growth-dcredit-gdebt	0.049	reserves-m2growth-gdebt	0.039
cad-dcredit-ggrowth	0.006	m2growth-dcredit-ggrowth	0.061	cad-m2growth-invest	0.039
cad-inflation-gdebt	0.006	m2growth-dcredit-invest	0.067	cad-dcredit-gdebt	0.039
cad-reserves-extdebt	0.006	m2growth-inflation-gdebt	0.070	dcredit-inflation-gdebt	0.039
reserves-dcredit-extdebt	0.006	cad-growthm2-ggrowth	0.073	reserves-m2growth-ggrowth	0.039
reserves-dcredit-inflation	0.006	cad-inflation-ggrowth	0.076	m2growth-gdebt-shortdebt	0.038
cad-invest-inflation	0.008	m2growth-dcredit-shortdebt	0.085	m2growth-extdebt	0.038
cad-m2growth-extdebt	0.009	m2growth-inflation-shortdebt	0.085	m2growth-ggrowth-extdebt	0.038
cad-m2growth-inflation	0.009	m2growth-inflation-ggrowth	0.092	reserves-inflation-gdebt	0.038
cad-m2growth-shortdebt	0.009	cad-m2growth-invest	0.095	cad-m2growth-extdebt	0.038
cad-dcredit-gdebt	0.009	m2growth-invest-inflation	0.098	m2growth-invest-ggrowth	0.038
cad-extdebt-shortdebt	0.009	reserves-m2growth-dcredit	0.113	inflation-gdebt-shortdebt	0.037
cad-gdebt-shortdebt	0.009	dcredit-inflation-gdebt	0.122	cad-inflation-extdebt	0.037
cad-ggrowth-shortdebt	0.009	reserves-dcredit-extdebt	0.134	cad-reserves-inflation	0.036
cad-inflation-shortdebt	0.009	reserves-m2growth-extdebt	0.146	m2growth-inflation-ggrowth	0.036
cad-ggrowth-extdebt	0.011	reserves-m2growth-inflation	0.149	m2growth-invest-extdebt	0.036
cad-invest-ggrowth	0.011	dcredit-inflation-shortdebt	0.152	inflation-ggrowth-gdebt	0.036
cad-invest-shortdebt	0.011	cad-m2growth-shortdebt	0.159	cad-ggrowth-gdebt	0.036
cad-reserves-ggrowth	0.011	cad-m2growth-gdebt	0.174	m2growth-dcredit-ggrowth	0.035
cad-reserves-invest	0.011	cad-dcredit-invest	0.174	cad-inflation-ggrowth	0.035
cad-reserves-shortdebt	0.011	reserves-dcredit-inflation	0.174	m2growth-ggrowth-shortdebt	0.035
cad-m2growth-ggrowth	0.012	cad-dcredit-ggrowth	0.180	cad-invest-gdebt	0.035
cad-inflation-extdebt	0.012	reserves-inflation-extdebt	0.192	inflation-extdebt-gdebt	0.035
reserves-dcredit-shortdebt	0.012	cad-dcredit-shortdebt	0.195	invest-inflation-gdebt	0.035
reserves-invest-inflation	0.012	dcredit-inflation-ggrowth	0.198	cad-invest-inflation	0.035
cad-dcredit-inflation	0.014	dcredit-invest-inflation	0.198	cad-m2growth-inflation	0.034
reserves-dcredit-invest	0.017	cad-inflation-shortdebt	0.210	cad-reserves-gdebt	0.034
cad-extdebt-gdebt	0.018	invest-inflation-extdebt	0.223	cad-gdebt-shortdebt	0.034
cad-ggrowth-gdebt	0.018	reserves-m2growth-invest	0.229	cad-extdebt-gdebt	0.034
cad-reserves-gdebt	0.018	cad-dcredit-gdebt	0.232	cad-dcredit-inflation	0.033
m2growth-dcredit-extdebt	0.018	reserves-m2growth-ggrowth	0.232	reserves-m2growth-invest	0.033
reserves-m2growth-dcredit	0.021	m2growth-dcredit-extdebt	0.241	cad-invest-extdebt	0.033
reserves-invest-shortdebt	0.021	m2growth-inflation-extdebt	0.296	dcredit-ggrowth-gdebt	0.033

Table 7: *Ranking of variables (the trivariate case (2))*

Calò		Gini		Mahalanobis distance	
cad-m2growth-invest	0.023	reserves-ggrowth-extdebt	0.296	cad-ggrowth-extdebt	0.033
m2growth-invest-extdebt	0.024	invest-ggrowth-extdebt	0.314	m2growth-invest-inflation	0.033
reserves-m2growth-invest	0.024	m2growth-invest-shortdebt	0.323	cad-inflation-shortdebt	0.032
cad-m2growth-gdebt	0.027	reserves-dcredit-ggrowth	0.323	reserves-inflation-ggrowth	0.032
m2growth-dcredit-gdebt	0.027	reserves-invest-inflation	0.332	cad-dcredit-ggrowth	0.032
dcredit-extdebt-shortdebt	0.029	extdebt-gdebt-shortdebt	0.335	m2growth-dcredit-invest	0.031
reserves-inflation-shortdebt	0.029	invest-inflation-ggrowth	0.338	reserves-m2growth-inflation	0.031
reserves-invest-extdebt	0.032	cad-inflation-gdebt	0.348	m2growth-invest-shortdebt	0.031
cad-invest-extdebt	0.034	dcredit-inflation-extdebt	0.348	reserves-dcredit-gdebt	0.031
cad-invest-gdebt	0.034	ggrowth-extdebt-shortdebt	0.348	cad-dcredit-extdebt	0.031
reserves-m2growth-extdebt	0.034	reserves-invest-extdebt	0.348	cad-reserves-ggrowth	0.031
reserves-inflation-extdebt	0.035	reserves-inflation-ggrowth	0.378	cad-reserves-m2growth	0.031
reserves-m2growth-inflation	0.037	reserves-dcredit-invest	0.384	m2growth-inflation-extdebt	0.031
reserves-m2growth-shortdebt	0.037	m2growth-ggrowth-shortdebt	0.390	dcredit-gdebt-shortdebt	0.031
invest-inflation-shortdebt	0.038	reserves-m2growth-shortdebt	0.396	dcredit-invest-gdebt	0.030
reserves-extdebt-shortdebt	0.038	m2growth-invest-ggrowth	0.424	cad-reserves-extdebt	0.030
m2growth-inflation-extdebt	0.040	reserves-extdebt-shortdebt	0.430	cad-m2growth-dcredit	0.029
m2growth-dcredit-shortdebt	0.043	reserves-dcredit-shortdebt	0.448	cad-m2growth-shortdebt	0.029
invest-inflation-ggrowth	0.043	m2growth-invest-gdebt	0.460	dcredit-extdebt-gdebt	0.029
m2growth-invest-shortdebt	0.044	reserves-m2growth-gdebt	0.463	reserves-dcredit-inflation	0.029
dcredit-invest-shortdebt	0.046	invest-extdebt-shortdebt	0.473	reserves-ggrowth-gdebt	0.029
dcredit-invest-gdebt	0.047	m2growth-ggrowth-gdebt	0.476	reserves-invest-inflation	0.029
m2growth-invest-ggrowth	0.049	m2growth-gdebt-shortdebt	0.479	cad-dcredit-invest	0.029
reserves-gdebt-shortdebt	0.049	dcredit-invest-shortdebt	0.482	cad-invest-ggrowth	0.029
m2growth-invest-gdebt	0.055	cad-reserves-dcredit	0.485	dcredit-inflation-ggrowth	0.029
m2growth-dcredit-ggrowth	0.056	cad-reserves-m2growth	0.488	cad-extdebt-shortdebt	0.029
dcredit-gdebt-shortdebt	0.056	invest-inflation-shortdebt	0.497	reserves-inflation-extdebt	0.028
dcredit-ggrowth-gdebt	0.056	dcredit-gdebt-shortdebt	0.506	cad-reserves-invest	0.028
reserves-ggrowth-extdebt	0.056	ggrowth-extdebt-gdebt	0.506	ggrowth-gdebt-shortdebt	0.028
m2growth-invest-inflation	0.058	ggrowth-gdebt-shortdebt	0.546	reserves-m2growth-extdebt	0.028
dcredit-invest-extdebt	0.058	cad-invest-gdebt	0.561	m2growth-dcredit-inflation	0.028
reserves-extdebt-gdebt	0.058	dcredit-ggrowth-shortdebt	0.564	m2growth-inflation-shortdebt	0.028
reserves-inflation-gdebt	0.058	cad-reserves-gdebt	0.570	reserves-inflation-shortdebt	0.028
reserves-invest-ggrowth	0.058	reserves-dcredit-gdebt	0.598	m2growth-extdebt-shortdebt	0.028
m2growth-dcredit-inflation	0.060	dcredit-invest-ggrowth	0.607	inflation-ggrowth-extdebt	0.028
m2growth-dcredit-invest	0.060	invest-gdebt-shortdebt	0.613	cad-ggrowth-shortdebt	0.027
ggrowth-gdebt-shortdebt	0.060	dcredit-invest-gdebt	0.616	invest-gdebt-shortdebt	0.027
dcredit-inflation-shortdebt	0.061	reserves-inflation-shortdebt	0.616	m2growth-dcredit-extdebt	0.027
reserves-invest-gdebt	0.061	cad-ggrowth-gdebt	0.619	inflation-ggrowth-shortdebt	0.027
m2growth-inflation-shortdebt	0.063	cad-ggrowth-extdebt	0.622	invest-inflation-ggrowth	0.027

Table 8: *Ranking of variables (the trivariate case (3))*

Calò		Gini		Mahalanobis distance	
m2growth-gdebt-shortdebt	0.064	cad-invest-extdebt	0.622	reserves-m2growth-shortdebt	0.026
dcredit-ggrowth-extdebt	0.064	invest-extdebt-gdebt	0.625	cad-invest-shortdebt	0.026
invest-extdebt-gdebt	0.064	m2growth-extdebt-shortdebt	0.634	reserves-invest-gdebt	0.026
reserves-dcredit-gdebt	0.064	reserves-invest-ggrowth	0.640	dcredit-invest-inflation	0.026
reserves-dcredit-ggrowth	0.066	dcredit-ggrowth-gdebt	0.646	reserves-gdebt-shortdebt	0.026
reserves-inflation-ggrowth	0.067	reserves-extdebt-gdebt	0.671	cad-reserves-dcredit	0.026
m2growth-extdebt-shortdebt	0.069	cad-invest-inflation	0.683	dcredit-inflation-extdebt	0.026
reserves-ggrowth-gdebt	0.069	dcredit-extdebt-shortdebt	0.707	invest-ggrowth-gdebt	0.026
dcredit-extdebt-gdebt	0.070	m2growth-ggrowth-extdebt	0.720	ggrowth-extdebt-gdebt	0.026
dcredit-ggrowth-shortdebt	0.070	inflation-ggrowth-shortdebt	0.732	invest-inflation-extdebt	0.026
dcredit-invest-ggrowth	0.070	cad-reserves-inflation	0.735	reserves-dcredit-ggrowth	0.025
invest-extdebt-shortdebt	0.070	dcredit-invest-extdebt	0.741	invest-inflation-shortdebt	0.025
invest-ggrowth-extdebt	0.072	invest-inflation-gdebt	0.741	reserves-m2growth-dcredit	0.025
reserves-m2growth-gdebt	0.073	reserves-inflation-gdebt	0.741	reserves-extdebt-gdebt	0.025
m2growth-inflation-gdebt	0.076	m2growth-invest-extdebt	0.756	inflation-extdebt-shortdebt	0.025
reserves-m2growth-ggrowth	0.078	reserves-gdebt-shortdebt	0.762	dcredit-inflation-shortdebt	0.025
reserves-ggrowth-shortdebt	0.078	reserves-ggrowth-shortdebt	0.768	extdebt-gdebt-shortdebt	0.025
m2growth-ggrowth-extdebt	0.079	reserves-invest-shortdebt	0.777	invest-extdebt-gdebt	0.024
dcredit-inflation-ggrowth	0.079	cad-reserves-extdebt	0.802	cad-reserves-shortdebt	0.024
inflation-ggrowth-gdebt	0.079	cad-reserves-shortdebt	0.805	m2growth-dcredit-shortdebt	0.023
invest-ggrowth-shortdebt	0.079	inflation-gdebt-shortdebt	0.805	cad-dcredit-shortdebt	0.023
m2growth-inflation-ggrowth	0.082	dcredit-ggrowth-extdebt	0.808	dcredit-ggrowth-extdebt	0.022
inflation-ggrowth-shortdebt	0.082	m2growth-extdebt-gdebt	0.814	reserves-ggrowth-extdebt	0.022
invest-gdebt-shortdebt	0.088	inflation-extdebt-gdebt	0.814	reserves-invest-ggrowth	0.021
dcredit-invest-inflation	0.090	invest-ggrowth-shortdebt	0.823	reserves-ggrowth-shortdebt	0.021
m2growth-extdebt-gdebt	0.092	cad-invest-shortdebt	0.829	dcredit-invest-ggrowth	0.021
invest-ggrowth-gdebt	0.092	cad-extdebt-shortdebt	0.838	dcredit-ggrowth-shortdebt	0.020
dcredit-inflation-gdebt	0.096	dcredit-extdebt-gdebt	0.842	reserves-dcredit-invest	0.019
invest-inflation-gdebt	0.096	inflation-ggrowth-gdebt	0.842	invest-ggrowth-extdebt	0.018
dcredit-inflation-extdebt	0.101	cad-ggrowth-shortdebt	0.869	ggrowth-extdebt-shortdebt	0.018
inflation-extdebt-shortdebt	0.101	cad-gdebt-shortdebt	0.896	dcredit-invest-extdebt	0.018
invest-inflation-extdebt	0.101	inflation-ggrowth-extdebt	0.921	reserves-invest-extdebt	0.017
inflation-ggrowth-extdebt	0.102	invest-ggrowth-gdebt	0.924	reserves-dcredit-extdebt	0.017
inflation-gdebt-shortdebt	0.105	cad-extdebt-gdebt	0.957	invest-ggrowth-shortdebt	0.017
m2growth-ggrowth-gdebt	0.110	cad-reserves-ggrowth	0.967	reserves-invest-shortdebt	0.015
m2growth-ggrowth-shortdebt	0.116	inflation-extdebt-shortdebt	0.973	reserves-dcredit-shortdebt	0.015
inflation-extdebt-gdebt	0.124	cad-reserves-invest	0.979	invest-extdebt-shortdebt	0.015
extdebt-gdebt-shortdebt	0.130	reserves-invest-gdebt	0.979	dcredit-invest-shortdebt	0.015
ggrowth-extdebt-gdebt	0.131	reserves-ggrowth-gdebt	0.988	reserves-extdebt-shortdebt	0.014
ggrowth-extdebt-shortdebt	0.136	cad-invest-ggrowth	0.997	dcredit-extdebt-shortdebt	0.014

Table 9: *Cograduation index (the trivariate case).*

cograduation index (Calò)	0.17
cograduation index (Gini)	0.11

Table 10: *Predictability error three years before*

M2 growth - inflation (best transvariation)							
	tranquility	crash	total		tranquility	crash	total
Predicted tranquility	14	9	23	Predicted tranquility	15	8	23
Predicted crash	2	25	27	Predicted crash	1	26	27
Total	16	34	50	Total	16	34	50
Total error (Fisher)	22.00 p.c.			Total error (transv. based)	18.00 p.c.		
M2 growth - gdebt (best Mahalanobis)							
	tranquility	crash	total		tranquility	crash	total
Predicted tranquility	12	9	21	Predicted tranquility	13	11	24
Predicted crash	4	25	29	Predicted crash	3	23	26
Total	16	34	50	Total	16	34	50
Total error (Fisher)	26.00 p.c			Total error (transv. based)	28.00 p.c.		

Table 11: *Predictability error one year before*

M2 growth - inflation (best transvariation)							
	tranquility	crash	total		tranquility	crash	total
Predicted tranquility	14	5	19	Predicted tranquility	15	4	19
Predicted crash	2	29	31	Predicted crash	1	30	31
Total	16	34	50	Total	16	34	50
Total error (Fisher)	14.00 p.c.			Total error (transv. based)	10.00 p.c.		
M2 growth - gdebt (best Mahalanobis)							
	tranquility	crash	total		tranquility	crash	total
Predicted tranquility	12	6	18	Predicted tranquility	13	9	22
Predicted crash	4	28	32	Predicted crash	3	25	28
Total	16	34	50	Total	16	34	50
Total error (Fisher)	20.00 p.c			Total error (transv. based)	24.00 p.c.		

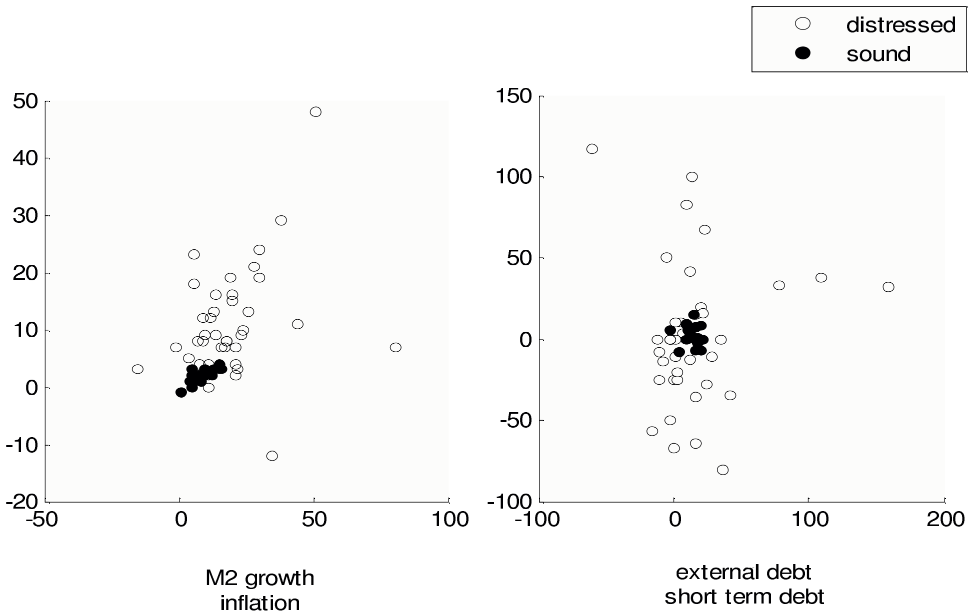

Figure 1: The best and the worst group of variables (Calò)

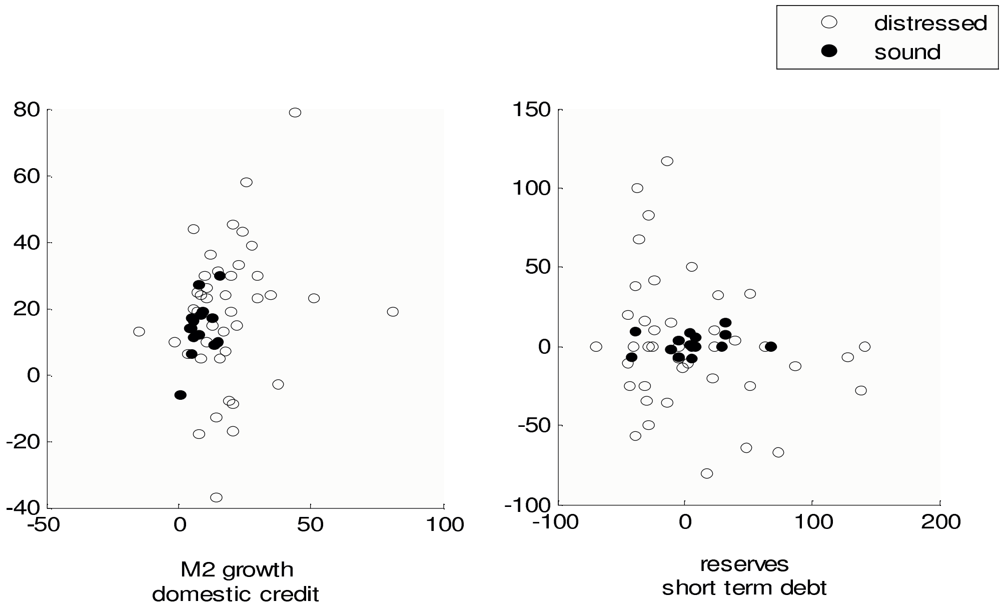

Figure 2: The best and the worst group of variables (Gini)

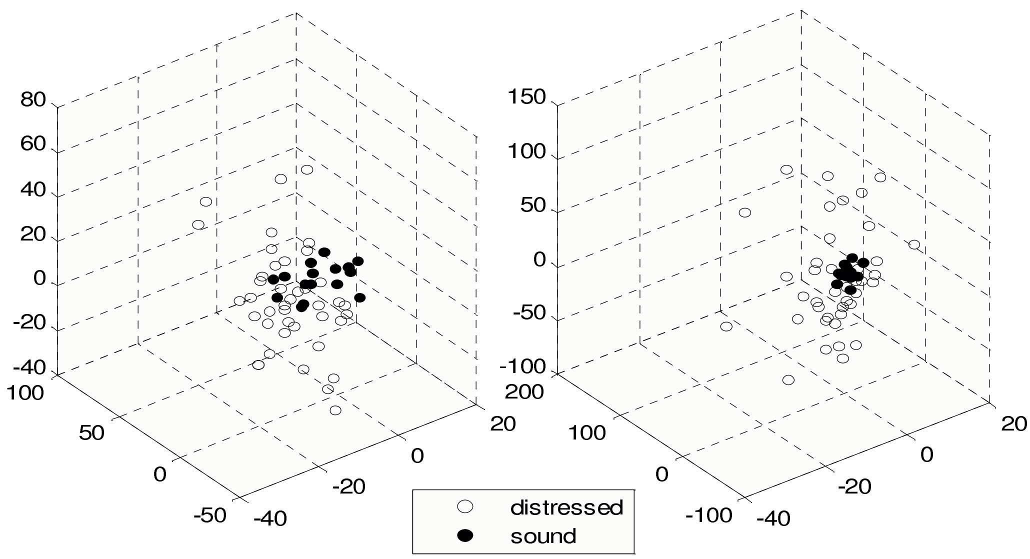

Figure 3: The best and the worst group of variables (Calò)

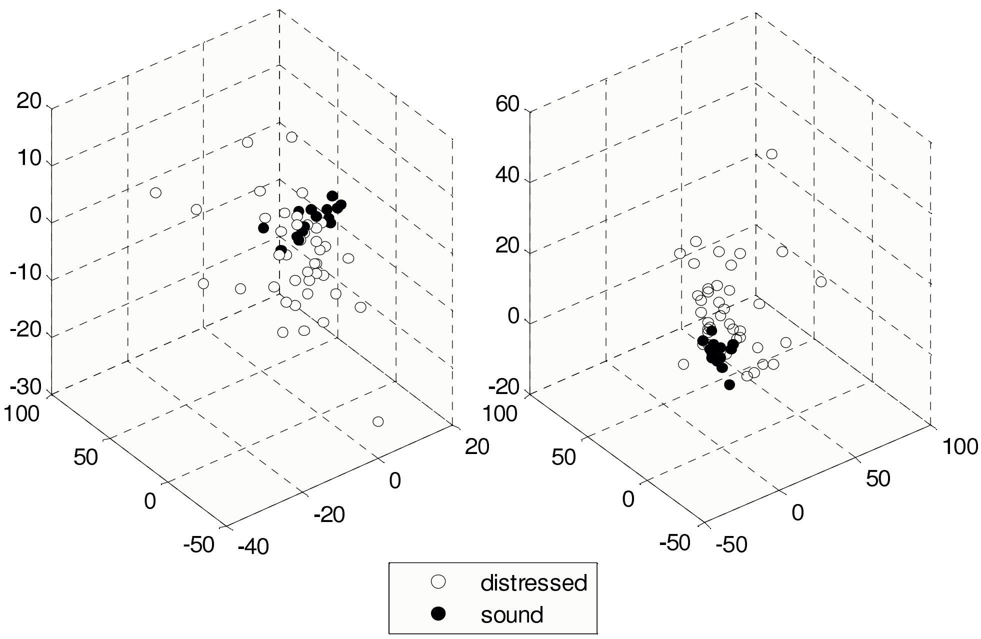

Figure 4: The best and the worst group of variables (Gini)