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Article

# Self-organizing maps as a tool to compare financial macroeconomic imbalances: The European, Spanish and German case[☆]

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## ARTICLE INFO

## ABSTRACT

The economic recession in the European countries during the current financial crisis and the widespread worsening of the financial situation have resulted in wide macroeconomic differences across countries. In this paper we use the method of self-organizing maps (SOM) to compare the macroeconomic financial imbalances among European countries. We detect different profiles of countries and identify the public expenditure and the saving rate as the most critical variables that impacts on the national financial situation. In addition, since several countries of the European Union have regions with some degree of economic and financial competences, we study the influence of the regions on the whole country. Thus, we classify and compare the Spanish and German regions and we prove the impact of the regional situation on the whole country situation.

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## 1. Introduction

The current financial crisis, although initially a bank-level crisis, has resulted in a situation of generalized illiquidity in financial markets and financial instability. Whereas in the first months the crisis had a microeconomic impact over the firms and the financial intermediaries, it later reached macroeconomic dimensions and the solvency of some countries became under discussion.

The switch from microeconomic financial distress to macroeconomic distress can be verified from 2010 in after. At the beginning of 2010, the European Union (EU), the International Monetary Fund (IMF) and the European Central Bank (ECB) granted 110 billion of euros credit to Greece given the inability of this country to serve its public debt. Some days later, a permanent fund for ransom of 750 billion was created due to the threat of international contagion and in order to reinforce the international reliability of the European currency. Some months later, in November 2010, Ireland received 87 billion of euros as financial help to refinance the public debt. In April 2011, Portugal asked and received from the EU and the IMF financial help amounting to 78 billion of euros. In addition, the implausibility of Greece to serve the interest of the public debt after the first bailout casted new doubts about the stability of the euro area after May 2011. From April 2012, the main European concern has focused on Spain, which has received 100 billion of euros credit line from the EU.[1] More recently, in March 2013, a 10 billion of euros bailout was announced for Cyprus.

In a financial environment so globalized as the current one, the national financial distresses can be transmitted to other countries, be a threat for the global economic recovery and lead to a generalized collapse of the credit flow to the real economy. In spite of the fact that in July 2011 the European Banking Authority (EBA) published the results of the stress tests of the financial institutions[2] with an acceptable result in general terms, financial markets did not rely completely on the States and Governments. In fact, the credit rating of the United States and of many European countries worsened in the summer of 2011.

An implication of these facts is that Europe should have some tools to assure the effective comparability among countries as a means to assure the efficiency of the correctional policies. In addition, early warning systems in the European financial system

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[1] A more in detail presentation of the main yardsticks throughout the financial crisis can be found in the ECB website http://www.ecb.int/ecb/html/crisis.es.html.
[2] http://www.eba.europa.eu/EU-wide-stress-testing/2011/2011-EU-wide-stress-test-results.aspx.

could alleviate the asymmetric impact of the financial crisis among countries and avoid the threat of "two speed Europe" that could put in danger the common currency.

The model we propose is a step forward to have such a tool for the detection and management of divergences among countries to anticipate this danger. The analysis within countries can also provide interesting insights since the regions or the states with economic autonomy can contribute significantly to the (in)stability and growth of the whole country. The earlier the economic unbalances among regions are detected, the easier they could be corrected.

Spain is an interesting case to test our model given the financial problems that it is going through, and the special regional configuration of the Public Administration. The Spanish regional governments (Autonomous Communities or AA.CC. hereinafter) have high levels of financial leverage that cast doubts on the ability of Spain to meet its financial engagements. This is the view of the rating agencies, which have systematically downgraded the credit rating of the AA.CC., and the view of the EU, which has required the Spanish Government to control the financial deficit of the AA.CC. In order to enable the comparability of our model, we apply our model to Germany. Although the German states (*Bundesländer*) are considered NUTS-1 and the Spanish AA.CC. are considered NUTS-2 according to the European classification,[3] both kinds of institutions are comparable in terms of political and economic competences. In addition, the quite different financial situation of Germany and Spain allows us to test the "virtuous or vicious circle" effect of regions on the country as a whole.

Our paper aims to contribute to the literature on national financial balance providing a complete and simple model. Most of the international comparisons until now have been based on one single indicator, which results in the loss of explanatory ability. Our model is self-organizing maps (SOM), a technique based on neural networks (NN) that enables complex international classifications by combining several variables.

Although NN have been widely used in business and finance domains, the analysis of country financial issues is a relatively unexplored field and has promising avenues for research (Herrero et al., 2011; Yim and Mitchell, 2005). The SOM method has been previously used to classify regions (Alfaro Cortés et al., 2003). These authors show the validity of the SOM method for the socio-economic classification of the European NUTS-2 regions. Unlike these authors' research, which focuses on social issues, our paper is concerned with financial and economic factors.

Our objective is twofold. First, we use the SOM method to perform a classification of the European countries depending on their solvency using the most common variables in the literature. The identification of the similarities and differences among countries is relevant information to detect imbalances in order to take correcting measures to avoid the propagation of financial crises. Our second aim is to relate the financial situation of the country as a whole with the financial situation of its regions. Recent concerns about the impact of the financial situation of the regions on the solvency of the whole country advice for a more in-depth analysis. Accordingly, we perform a classification analysis of the German and Spanish regions. Germany and Spain are two countries with an analogous territorial organization but with diametrically different financial situation, so that our analysis can cast some light on to which extent the national distress is due to the regional macroeconomic imbalance.

Our paper is divided into six sections. After the introduction, in the second Section we present the foundations of the neural

networks as methods for financial analysis and prediction; we also describe the SOM methodology. In Section 3 we apply our model to the European countries in order to have an international classification and to identify the most determinant variables of the financial situation. We compare our results with the ones from previously used techniques as the *K*-means and the Factor/*K*-means clustering procedures In Sections 4 and 5 we reply an analogous analysis for the Spanish AA.CC. and the German *Länder*. In Section 6 we conclude with the most remarkable ideas and we point out some applications of our model for the design of economic policies.

## 2. The neural network method

### 2.1. Foundations of neural networks in business and finance

NN are one the most widely used models among the intelligence techniques. They have mathematical and algorithmic elements that mimic the biological neural networks of the human nervous system, so that they have similarities with the functioning of the human brain (Kohonen, 1993). NN take into account the relations among different groups of artificial neurons and processes the information about them using a so-called connectionist approach, in which network units are connected by a flow of information.

Neural networks are a powerful set of algorithms whose objective is to find a pattern of behavior (Moreno and Olmeda, 2007) and that have two main advantages compared to more traditional multivariate statistical techniques. First, NN do not require any kind of assumption about the statistical distribution of the data. Second, NN are not limited by linear specifications as many of the traditional techniques are. So, a successful NN implementation generates a system of relationships that has been learnt from observing past examples and is able to generalize these lessons to new examples.

As shown by Vellido et al. (1999) and Wong and Selvi (1998), NN have been profusely used in several domains of business, management, marketing and production. These applications usually involve the interaction of many diverse variables that are highly correlated, frequently assumed to be nonlinear, unclearly related, and too complex to be described by a mathematical model.

The use of neural networks in finance applications has been previously investigated in a number of areas such as loan segmentation, country investment risk, forecasting market movement, and credit scoring (Baesens et al., 2005; Becerra-Fernandez et al., 2002; Falavigna, 2012; Huang et al., 2005). NN have been used even in accounting issues to examine the occurrence of earnings management in various contexts (Höglund, 2012). By far, the main application of NN is bankruptcy and insolvency prediction, which accounts for around 30% of contributions (Vellido et al., 1999).

The general outcome of such works is that in the credit industry, neural networks have been considered to be accurate tool for credit analysis (Min and Lee, 2008). Similarly, Guresen et al. (2011) show that in most of the cases NN models give better result than other methods in forecasting stock markets movements.

Dutta and Shekhar (1988) pioneered the use of NN for corporate bond ratings. According to their results, the predictive success rate of NN was 88.3% compared to 64.7% for the regression model. Such significant results motivated further implementations of NN for bond ratings. Surkan and Singleton (1990) compare the NN against the multivariate discriminant analysis and find that the former perform significantly better. Kim et al. (1993), Lee and Choi (2013) and Maher and Sen (1997) also compare the performance of the regression analysis, the multivariate discriminant analysis, the logistic regression and the rule-based methods with NN for the classification of debt ratings. In all the cases the highest percentage of correctly classified bonds was achieved with NN. Likewise, Ravi Kumar and Ravi (2007) comprehensively review the methods

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[3] http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NUTS_33&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=HIERARCHIC.