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# Predicting fiscal stress events : the role of fiscal, financial and governance indicators

Raif Cergibozan

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Membre de l'université Paris Lumières

## **Raif Cergibozan**

# **La prévision des périodes de stress fiscal : le rôle des indicateurs fiscaux, financiers et de gouvernance**

Thèse présentée et soutenue publiquement le **12 décembre 2018**  
en vue de l'obtention du doctorat de Sciences économiques de l'Université Paris  
Nanterre  
sous la direction de M. Jean-Pierre Allegret (Université de Nice Sophia Antipolis)

### **Jury :**

Rapporteur :	M. Cyriac Guillaumin	Maitre de Conférences HDR, Université Grenoble Alpes
Rapporteur :	M. Alexandru Minea	Professeur des Universités, Université d'Auvergne
Membre du jury :	M. Michel Boutillier	Professeur des Universités, Université de Paris Nanterre
Membre du jury :	Mme. Florence Huart	Maitre de Conférences HDR, Université de Lille 1
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Finally, all the mistakes in this thesis are my own.

## Résumé

L'Europe a subi la crise la plus sévère de sa récente histoire à la suite de la crise financière globale de 2008. C'est pourquoi cette thèse a l'objectif d'identifier de façon empirique les déterminants de cette crise dans le cadre de 15 principaux membres de l'UE (UE-15). Dans ce sens, nous développons d'abord un index de pression fiscale continu, contrairement aux travaux empiriques précédents, afin d'identifier des périodes de crise dans les pays UE-15 de 2003 à 2015. Ensuite, nous utilisons trois différentes techniques d'estimation, à savoir Cartes auto-organisatrices, Logit et Markov.

Nos résultats d'estimation démontrent que notre indicateur de crise identifie le *timing* et la durée de la crise de dette dans chacun des pays de UE-15. Résultats empiriques indiquent également que l'occurrence de la crise de dette dans l'UE-15 est la conséquence de la détérioration de balances macroéconomiques et financières sachant que les variables comme le ratio des prêts non-performants sur les crédits totaux du secteur bancaire, la croissance du PIB, chômage, balance primaire / PIB, le solde ajusté du cycle PIB. De plus, variables démontrant la qualité de gouvernance tel que participation et responsabilisation, qualité de la réglementation, and efficacité gouvernementale, jouent également un rôle important dans l'occurrence et sur la durée de la crise de dette dans le cadre de l'UE-15. En outre, les résultats de prévision des modèles Logit et Markov montrent que nos modèles sont capables de prédire correctement tous les épisodes de crise et non-crise dans la période de 2003-2015.

Etant donné que les résultats économétriques indiquent l'importance de la détérioration fiscale dans l'occurrence de la crise de dette européenne, nous testons la convergence fiscale des pays membre de l'UE. Dans ce sens, nous utilisons deux variables dépendantes basée sur les critères de Maastricht, à savoir le ratio de la dette publique sur le PIB et le ratio du déficit budgétaire sur le PIB, ainsi que des tests de racine unitaire traditionnels (ADF), non-traditionnels de type ruptures structurelles (Zivot-Andrews et Lee-Strazicich) avec des tests non-linéaires (KSS). Les résultats montrent que Portugal, Irlande, Italie, Grèce et Espagne diverge des autres pays de l'UE-15 en termes de dette publique / PIB alors qu'ils convergent, à part la Grèce, avec les autres pays membres de l'UE-15 en termes de déficit budgétaires / PIB. Ceci indique que l'accumulation de la dette publique dans ces pays-là n'est pas liée aux déficits budgétaires, mais autres facteurs comme les déficits commerciaux et/ou courants.

**Mots-clés :** Crise de dette européenne, Index de pression fiscale, Indicateurs d'alerte, Convergence fiscale, Logit, Modèle de Markov à changement de régime, Cartes auto-organisatrices.

## Abstract

Europe went through the most severe economic crisis of its recent history following the global financial crisis of 2008. Hence, this thesis aims to empirically identify the determinants of this crisis within the framework of 15 core EU member countries (EU-15). To do so, the study develops a continuous fiscal stress index, contrary to previous empirical studies that tend to use event-based crisis indicators, which identifies the debt crises in the EU-15 and the study employs three different estimation techniques, namely Self-Organizing Map, Multivariate Logit and Panel Markov Regime Switching models.

Our estimation results show first that the study identifies correctly the time and the length of the debt crisis in each EU-15-member country by developing a fiscal stress index. Empirical results also indicate, via three different models, that the debt crisis in the EU-15 is the consequence of deterioration of both financial and macroeconomic variables such as nonperforming loans over total loans, GDP growth, unemployment rates, primary balance over GDP, and cyclically adjusted balance over GDP. Besides, variables measuring governance quality, such as voice and accountability, regulatory quality, and government effectiveness, also play a significant role in the emergence and the duration of the debt crisis in the EU-15. Moreover, logit and Markov forecast results show that the models could correctly predict nearly all crisis and noncrisis episodes over the period of 2003-2015.

As the econometric results clearly indicate the importance of fiscal deterioration on the occurrence of the European debt crisis, this study also aims to test the fiscal convergence among the EU member countries. To do so, the study employs two dependent variables based on Maastricht Criteria, i.e. public debt over GDP and budget deficit over GDP, and uses traditional unit root tests (ADF), nontraditional one (Zivot and Andrews)- and two-structural breaks (Lee and Strazicich) along with nonlinear unit root tests (KSS). The results indicate that Portugal, Ireland, Italy, Greece, and Spain (PIIGS) diverge from other EU-15 countries in terms of public debt-to-GDP ratio. In addition, results also show that all PIIGS countries except for Greece converge to EU-10 in terms of budget deficit-to-GDP ratio. This result is interesting since the accumulation of public debt is not mainly related to budget deficits but other structural factors like trade and/or current deficits.

**Keywords:** European Debt Crisis, Fiscal Stress Index, Leading Indicators, Fiscal Convergence, Logit, Markov Regime Switching Model, Self-Organizing Maps.

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## Introduction

The global financial crisis that emerged in the United States (US) in 2007 first spread to Europe through strong trade and financial linkages, then other advanced and developing countries, following the failure of Lehman Brothers in September 2008. Consequently, the world economy suffered a significant recession leading to increasing unemployment rates with important social costs. More importantly, massive interventions of governments and central banks to limit the negative impacts of the crisis both on real and financial sectors, i.e. zero-bound or even negative nominal interest rates, expansionary budget policies, and bank rescue plans including measures such as bail-outs, recapitalization and nationalization of illiquid and insolvent banks, resulted in a dramatic rise in public debt stock leading then to sovereign debt crisis in some Eurozone member countries. Hence, researchers have made efforts to understand the emergence of the global financial crisis, but also to find its leading indicators. Besides, the recent debt problem, particularly in some Eurozone countries, has also motivated some economists to identify empirically the determinants of debt crises (e.g. Arellano & Kocherlakota, 2008; Fioramanti, 2008; Candelon & Palm, 2010; Reinhart & Rogoff, 2011; Baldacci et al, 2011a, 2011b).

The study aims to bring a wider perspective to debt crises in the context of the European Union (EU)-15 countries. To do so, the study first tries to identify and date debt crises by defining a new fiscal stress index. Second, the study employs a very large data set composed of 51 leading indicators to explain the debt crises. More importantly, the study includes an important number of governance indicators that have largely been ignored in explaining debt crises. Third, the Self-Organizing Maps (SOM), the Multivariate Logit Model (MLM), and the Panel Markov Regime Switching Model (PMRSM) are used to identify the determinants causing the European debt crisis contrary to the classic estimation methods used in previous studies. Our study, hence, offers the opportunity of a comparative analysis between different model estimations, which has not been done yet in the literature. Fourth, forecast performance for each estimated model is provided. Fifth, the fiscal convergence between EU member states is analyzed using both traditional unit root tests and nontraditional one- and two-structural breaks along with nonlinear unit root tests.

This study is composed of three chapters. The first chapter presents different definitions for fiscal stress indexes. As we demonstrate, early empirical papers tend to use event-based crisis indicators. This leads to important structural problem that we try to resolve by

developing a continuous fiscal stress index for each EU-15 country within the period of 2003-2015. Note that this continuous fiscal stress index, inspired by the currency crisis indicators, offers the opportunity to analyze the data by using different estimation techniques such as the Markov approach. Once the fiscal stress index is constructed, we attempt to determine the optimal threshold values in order to identify periods of debt crisis. In accordance with Candelon et al. (2012), this study uses accuracy measures, sensitivity-specificity graphics, and KLR cut off methods to determine the optimal threshold value. Next, we compare the dates of debt crisis episodes for the EU-15 countries with the results of previous studies for robustness and consistency issues. The empirical results show that our fiscal stress index identifies more ‘debt crisis’ episodes and also indicates a longer crisis period, in particular for the so-called PIIGS, than previous empirical studies applied to debt crises (e.g. Baldacci et al., 2011a; Berti et al., 2012; Hernandez de Cos et al., 2014). Because our index measures the pressure or stress level in a country contrary to other fiscal stress definitions that focus mainly on default events. We think that our fiscal stress index gives more realistic results, at least for some countries, contrary to ‘over-optimistic’ results found in previous studies.

The second chapter first presents 51 explanatory variables that are likely to cause a debt crisis. The set of explanatory variables covers different sectors of the economy and also includes some governance quality measures, often ignored in the past literature. The chapter then presents three estimation methods employed in the study: SOM, Logit, and Markov models. Unlike other econometric approaches, the SOM approach allows the researcher to work with large datasets and has the ability to visually monitor, via crisis maps created for each country for the period of 2003-2015, the transition from noncrisis (tranquil) to crisis states. Besides, through the SOM analysis, we are able to determine the variables’ order of importance in explaining the occurrence of the debt crises in the EU member countries. In other words, the SOM analysis serves us as a filter to determine which indicators should be included into the Logit and Markov model estimations. Note also that this study is the first one that uses the Markov approach in estimations of debt crises. Empirical results obtained from three different models indicate that the debt crisis in the EU-15 is the consequence of deterioration of both financial and macroeconomic variables such as nonperforming loans over total loans, GDP growth, unemployment rates, primary balance over GDP, and cyclically adjusted balance over GDP. Besides, variables measuring governance quality, such as voice and accountability, regulatory quality, and government effectiveness, also play a significant role in the emergence and the duration of the debt crisis in the EU-15. Moreover, logit and

Markov forecast results show that the models could correctly predict nearly all crisis and noncrisis episodes over the period of 2003-2015.

As the econometric results clearly indicate the importance of fiscal deterioration on the occurrence of the European debt crisis, the third chapter of this study aims to test the fiscal convergence among the EU member countries over the period from 1995Q1 to 2017Q2. To do so, the study employs two dependent variables based on Maastricht Criteria, i.e. public debt over GDP and budget deficit over GDP, and uses traditional unit root tests (ADF, Dickey and Fuller, 1979), nontraditional one-structural break (Zivot and Andrews, 1992)- and two-structural breaks unit root tests (Lee and Strazicich, 2003) along with nonlinear unit root tests (KSS). The results indicate that Portugal, Ireland, Italy, Greece, and Spain (PIIGS) diverge from other EU-15 countries in terms of public debt-to-GDP ratio. In addition, results also show that all PIIGS countries except for Greece converge to EU-10 in terms of budget deficit-to-GDP ratio. This result is interesting since the accumulation of public debt is not mainly related to budget deficits but other structural factors like trade and/or current deficits.

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# Chapter 1

## Dating Debt Crises in EU-15

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### 1.1. Introduction

Understanding why and how the financial crises occur has become an important issue since financial crises lead to high social and economic costs both for the public sector and private investors in terms of economic contraction, high unemployment, and high interest rates. Hence, a large number of theoretical and empirical studies have been conducted to understand crises. Empirical papers, frequently called early warning systems (EWS), are generally used to identify crisis episodes, find their determinants, predict their occurrence, and if possible to prevent future crisis episodes.

The empirical studies have employed different parametric and non-parametric techniques. Parametric techniques generally include discrete-choice models (logit and probit), and the Markov approach, while non-parametric techniques have mostly been limited to the signal approach.<sup>1</sup> Whatever the techniques used to generate EWS estimations, identifying crisis episodes is crucial, since they enter EWS models as dependent variables. However, there is no consensus on how to define a crisis which is a source of discrepancies for crisis dates and inconsistencies for the significance of explicative variables in model estimations. This led some researchers to construct crisis indicators or indexes based on economic theory (e.g. Eichengreen et al., 1996).

Although there is a relatively rich literature on currency crisis definitions, there is a limited number of definitions for banking or debt crises. More importantly, debt crises (like banking crises) are usually identified and dated by a combination of events, such as the inability of borrowers to pay the interest or principal on time, large arrears, or large IMF loans to help the borrower avoid a default. In other words, dating debt crises is generally event-based and is typically founded on the available ex post figures (i.e. Detragiache and Spilimbergo, 2001; Baldacci et al., 2011a, 2011b). However, this dating method has several shortcomings. It is based primarily on information about government actions undertaken in response to fiscal stress and depend on information obtained from regulators and international organizations or rating agencies. In addition, the events method identifies crises only when

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<sup>1</sup> There also exist some empirical studies that use other methods based on artificial neural network.



they are severe enough to trigger market events; crises successfully contained by prompt corrective policies are neglected. This means that empirical work suffers from a selection bias. Therefore, in order to fulfill these shortcomings, we develop a fiscal stress index like currency crisis indicators *a la* Eichengreen et al. (1996) or Kaminsky and Reinhart (1999) in order to identify the dates of debt crisis episodes occurred in EU-15 countries over the period of 2003-2015.

Our fiscal stress index identifies more ‘debt crisis’ episodes than previous empirical studies applied to debt crises, since it measures the pressure or stress level in a country contrary to other fiscal stress definitions that focus mainly on default events. To be more precise, our index indicates high fiscal pressure in 14 out of 15 countries included into the sample following the outbreak of the global financial crisis. The only country where the index does not find high fiscal stress is Germany.

The remainder of the chapter is organized as follows. Section 1.2 presents a literature review on crisis definitions. Section 1.3 presents the data and methodology. Section 1.4 presents and evaluates the estimation results. Section 1.5 concludes.

## **1.2. Literature Review**

Different definitions are used in the literature to identify a debt crisis. According to canonical definition, a debt crisis is said to occur when borrowers are unable to pay the principal or interest as planned (Dornbusch, 1989; Cottarelli, 2011). Debt crises also arise when the fiscal authority does not raise tax revenues to pay its current or future debt stock (Bordo & Meissner, 2016). Although there is no consensus on how to define a debt crisis, one can say there exists a common ‘view’: debt crisis is defined as sovereign defaults, large arrears, large IMF loans, and fiscal distress events (Pescatori & Sy, 2007, Correa & Sapriza, 2014).

In general, credit-rating agencies focus on default events for analyzing debt crises. For instance, Moody’s Investor Service (2003) accepts the assumption that countries have failed to pay their debts if one or more of the following criteria are met:

- 1- There is a missed or delayed disbursement of interest and/or principal, even if the delayed payment is made within the grace period, if any.
- 2- A distressed exchange occurs, where:

a) The issuer offers bondholders a new security or package of securities that amount to a diminished financial obligation such as new debt instruments with lower coupon or par value.

b) The exchange had the apparent purpose of helping the borrower avoid a “stronger” event of default (such as a missed interest or principal payment).

Another credit rating agency, Standard and Poor’s (Beers & Chambers, 2002), assumes that default events occur when any of the following conditions occur:

1- For local and foreign currency bonds, notes, and bills, when either each issuer’s debt is considered in default either when a scheduled debt-service payment is not made on the due date or when an exchange offer of new debt contains less favorable terms than the original issue;

2- For central bank currency, when notes are converted into new currency of less than equivalent face value; and

3- For bank loans, when either scheduled debt service is not paid on the due date or a rescheduling of principal and/or interest is agreed to by creditors at less-favorable terms than the original loan. Such rescheduling agreements covering short- and long-term bank debt are considered defaults even where, for legal or regulatory reasons, creditors deem forced rollover of principal to be voluntary.

In addition, many rescheduled sovereign bank loans are ultimately extinguished at a discount from their original face value. Typical deals have included exchange offers (such as those linked to the issuance of Brady bonds), debt/equity swaps related to government privatization programs, and/or buybacks for cash. Standard & Poor’s considers such transactions as defaults because they contain terms less favorable than the original obligation.

As seen, credit rating agencies mainly deal with default events when defining debt crises, but as default events are not so easy to identify, different definitions are given for debt crisis, as mentioned above. For instance, Sy (2004) defines debt crisis as an event that occurs when the average spreads on the most liquid sovereign bonds are above 1,000 basis points (10 percentage points). Detragiache and Spilimbergo (2001) classify an observation as a debt crisis if either or both of the following conditions occur:

1- There are arrears of principal or interest on external obligations toward commercial creditors (banks or bondholders) of more than 5% of the total outstanding commercial debt.

2- There is a rescheduling or debt-restructuring agreement with commercial creditors listed in the World Bank’s Global Development Finance.

Debt crises are defined by the Fiscal Stress Index in the empirical literature. One of the most accepted definitions in the literature for the Fiscal Stress Index belongs to Baldacci et al. (2011a, 2011b). They assume the existence of one of four criteria as a fiscal stress: a) public debt default or restructuring based on Standard & Poor's definition, b) a large IMF-supported program which is access to 100% of quota or more, c) excessively high inflation rate which is an inflation rate greater than 35% per annum for developed countries and greater than 500% per annum for developing countries, and d) exceptionally high sovereign bond yields which is defined as sovereign spreads greater than 1,000 basis points or 2 *SDs* from the country average, both for advanced and developing countries.

Gerling et al. (2017) added two new sub-criteria to the Baldacci et al.'s (2011a, 2011b) definition for the Fiscal Stress Index. These criteria are the accumulation of domestic arrears and a measure of market-access loss. The main reason for adding the first criterion is said to be the lack of interest, which focuses solely on yields. Loss of market access includes excessive market pressure, and the two sub-criteria for this contain periods of low/no volume and sovereign-yield spikes.

In addition to these approaches, there are also studies that define debt crises as a consequence of banking crises. Reinhart and Rogoff (2011) find banking crises to often lead to debt crises. The main reason why banking crises turn into debt crises stems from the vital importance of banks in the payment system. Thus, a problem that arises in the banking sector can easily be spread to the private and public sectors. If governments attempt to rescue banks, as they have done in Europe following the failure of Lehman Brothers, a debt crisis can easily arise to the extent that systemic bailouts lead to a dramatic deterioration of a country's fiscal situation or balance (Correa & Sapriza, 2014).

### **1.3. Data and Methodology**

The data for variables used for constructing the fiscal stress index (FSI) is gathered from Oxford Economics and IMF International Financial Statistics for the period of 2003-2015. Our fiscal stress index is defined as a continuous variable rather than event-based, contrary to previous studies. The bond yield pressure, imputed interest rate on general government debt minus the real GDP growth rate, public sector borrowing requirements, general government gross debt and cyclically-adjusted primary balance variables have been used in calculating our fiscal stress index. The selection of variables in the construction of the index is based on

Baldacci et al. (2011a, 2011b) and Hernandez de Cos et al. (2014). Note also that the variables are standardized or weighted according to the empirical crisis literature. The weights of the components of the crisis index are chosen to equalize their volatility and thus avoid the possibility of one of the components dominating the index, hence to obtain consistent results concerning dates of debt crises.

However, there is no consensus, in the literature, on how to weight the variables of the crisis index. Von Hagen and Ho (2003) and Eichengreen et al. (1996) divide variables into their respective standard deviations, while Bussierre and Fratzcher (2006) and Bussierre (2013) prefer to weight variables by dividing them into their variances. Another weighting method is to equate the volatility of each variable to the volatility of the exchange rate instead of weighting the variables through their own standard deviations (i.e., Kaminsky et al., 1998; Kaminsky & Reinhart, 1999; Bunda & Ca'Zorri, 2010; Lestano & Jacobs, 2007; Candelon et al., 2012, and Yiu et al., 2009). On the other hand, some authors also utilize arbitrary weights: for instance, in Corsetti et al. (2001) the weights assigned to exchange rate and reserves are, respectively, 0.75 and 0.25. Herrera and Garcia (1999) uses standardized (or equal) weights for each index component

However, all these different weighting procedures may not solve the volatility problem over time because the variables used in the construction of the index do not react to the structural changes occurring in the economy at the same magnitude. In addition, the different fiscal regime preferences applied in the analyzed period may affect the variables used in the construction of the fiscal pressure index at different degrees (Chui, 2002). Aziz et al. (2000), Nitithanprapas and Willett (2000) and Caramazza et al. (2004) use the method of deseasonalizing or detrending the index components to prevent the problem of volatility of the data. Moreover, Eichengreen et al. (1995, 1996) and Nitithanprapas and Willett (2002) also suggest testing different weights for sensitivity issues. But they also conclude that the weighting method does not change significantly dating of crisis episodes. Note also that it is more appropriate to use country-specific weights for the index components as every country has specific economic features, instead of common weights for all the sample countries, as done in Sachs et al. (1996) and Edison (2003). Although these methods are mostly employed in currency crises, our study uses them to construct the fiscal stress index. The fiscal stress index is calculated as follows:

$$FSI_{i,t} = \frac{\Delta BYP_{i,t}}{\sigma_{BYP_{i,t}}} + \frac{\Delta(r-g)_{i,t}}{\sigma_{(r-g)_{i,t}}} + \frac{\Delta PSBR_{i,t}}{\sigma_{PSBR_{i,t}}} + \frac{\Delta GGGD_{i,t}}{\sigma_{GGGD_{i,t}}} - \frac{\Delta CAPB_{i,t}}{\sigma_{CAPB_{i,t}}} \quad (1.1)$$

where *BYP* (Bond Yield Pressure) is government bond spreads (relative to 10-year US Treasury bonds), *r-g* is the imputed interest rate on general government debt minus real GDP growth rate, *GGGD* is General Government Gross Debt, and *CAPB* indicates Cyclically Adjusted Primary Balance/GDP. Sub-indices represent *t* as time, *i* as country, and  $\Delta$  is the differential operator. Increases in *BYP*, *r-g*, *PSBR*, and *GGDD* augment fiscal pressure, while increases in *CAPB* reduce financial pressure. Because the increases in *CAPB* indicate a balanced budget, hence its effect is expected to be negative. The Fiscal Stress Index indicates or signals a debt crisis when it exceeds a certain threshold value. The crisis index then becomes a binary variable which takes the value of 1 if a crisis occurs and 0 otherwise.

$$C_{i,t} = \begin{cases} 1 & \text{if FSI}_{i,t} > \text{optimal threshold} \\ 0 & \text{otherwise} \end{cases} \quad (1.2)$$

What is important here is to choose an ‘optimal’ threshold value. Several papers determine an arbitrary threshold; if the indicator value exceeds this specified threshold, any month, quarter or year is classified as a crisis episode. Note that higher the threshold level is the less the number of detected crisis is, and vice versa. Therefore, this arbitrary threshold method results in different number and effective dates of currency crises as empirically shown by Kamin et al. (2001), Edison (2003), and Lestano and Jacobs (2007) in the cases of currency crises. This actually constitutes one of the biggest problems in the crisis literature. On the other hand, Zhang (2001) and Edison (2003) state that values of threshold for crisis indexes are sample-dependent. Hence, when a severe crisis occurs, which might lead to large movements in the most volatile series in the index, the sample mean and the sample standard deviation can change substantially, causing changes in crisis dates. In other words, the sample-dependent nature of threshold definition implies that future data can affect the identification of past crisis (Abiad, 2003).

In order to avoid problems related to threshold level, we consider different methods based on Candelon et al. (2012) to determine the optimal threshold value for the fiscal stress index of each EU-15 country. For this purpose, we use accuracy measures, sensitivity-specificity graphics and KLR cut-off method (Kaminsky et al., 1998) to select the optimal threshold. The test evaluation matrix describes the threshold methods as shown in Table 1.1.

**Table 1.1.** Test evaluation matrix

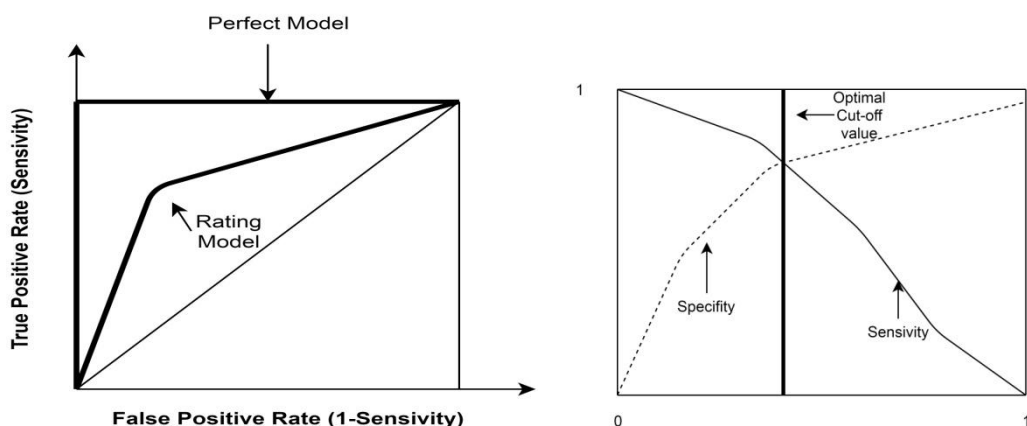
		Actual Value Obtained from FSI			
		Debt Crisis	No Debt Crisis	Total	
		Debt Crisis	True Positive (TP)	False Positive (FP)	TP+FP (A)
Model Estimation Results	No Debt Crisis	False Negative (FN)	True Negative (TN)	FN+TN (B)	
		Total	TP+FN (C)	FP+TN (D)	Obs.

**Note:** A = All predicted debt crises; B = All predicted non-debt crises; C = All actual crises; D = All actual non-debt crises; and Obs. = Observations.

In Table 1.1, the test is called the sensitivity for capturing correct crisis periods and is calculated by  $TP / (TP + FN)$ . In addition, if the test is successful in capturing normal periods, it is said to have specificity calculated by  $TN / (FP + TN)$ . In graphic methods for sensitivity-specificity, the optimal cut-off value is determined so as to maximize sensitivity and specificity simultaneously and conditionally. The definition for optimal threshold and how performance level is determined is presented graphically in Figure 1.1. According to the sensitivity-specificity graphics, the cut-off value is at the intersection of sensitivity and specificity at the right. On the left side of the Figure 1.1., there is the Receiver Operating Characteristic Curve (ROC), which is often used to estimate the predicted model performances. Here, the area under the ROC curve takes a value between 0.5 and 1. Accordingly, the larger the area under the ROC curve, the higher the success rate of the model. The perfect model and the estimated model results are shown in Figure 1.1.

In addition, accuracy measures are calculated as  $(TP + TN) / (TP + FP + FN + TN)$ . Finally, the optimum threshold is obtained by the KLR method to minimize the adjusted noise-to-signal ratio  $(FP / [FP + TN]) / [TP / TP + FN]$ .

**Figure 1.1.** ROC curve and determination of optimal threshold using the sensitivity-specificity graph.



## 1.4. Estimation Results

We first construct a fiscal stress index for each EU-15 country according to the equation (1). In order to identify debt crisis periods, we need to determine optimal threshold (cut-off) values which are calculated by three different ways as mentioned in the previous section (see Table 1.2). Bold figures in the below Table indicate the optimal cut-off values for each country.

Figure 1.2 present the crisis and noncrisis periods for EU-15 countries: shaded zones indicate crisis periods, in other words the period where the index value exceeds the optimal threshold value. As clearly seen from the Figure, all EU-15 countries except for Germany seem to have gone through the debt crisis following the global financial crisis. As expected, the debt crisis in Greece, Ireland, Spain, the United Kingdom, Italy, and Portugal seem to have lasted longer compared to other countries. In addition, Greece seems to not have fully recovered from the debt crisis yet by the end of 2015.

**Table 1.2.** Optimal cut-off values for EU-15

Country	Accuracy measures			Sensitivity-Specificity graphic			KLR	
	Cut-off	Sensitivity	Specificity	Cut-off	Sensitivity	Specificity	Cut-off ( <i>S</i> )	Cut-off ( <i>G</i> )
Austria	<b>0.410</b>	100.0	90.90	<b>0.410</b>	100.0	90.90	2.535	6.381
Belgium	2.376	50.0	90.90	<b>1.298</b>	100.0	90.90	3.343	6.381
Denmark	0.371	100.0	81.80	<b>2.254</b>	100.0	100.0	4.211	6.381
Finland	1.157	100.0	91.70	<b>3.433</b>	100.0	100.0	4.137	6.381
France	1.035	100.0	91.70	<b>1.788</b>	100.0	100.0	2.161	6.381
Germany	1.218	100.0	91.70	<b>3.516</b>	100.0	100.0	6.157	6.381
Greece	0.154	100.0	80.0	<b>0.752</b>	100.0	100.0	9.407	6.381
Ireland	-0.277	100.0	85.70	<b>0.435</b>	100.0	100.0	13.521	6.381
Italy	<b>0.229</b>	100.0	83.30	0.426	85.70	83.30	3.721	6.381
Luxembourg	3.855	100.0	91.70	<b>9.994</b>	100.0	100.0	10.985	6.381
Netherlands	1.058	100.0	90.90	<b>2.523</b>	100.0	100.0	3.972	6.381
Portugal	1.164	100.0	87.50	<b>1.729</b>	100.0	100.0	5.809	6.381
Spain	0.695	100.0	87.50	<b>1.998</b>	100.0	100.0	7.378	6.381
Sweden	-0.231	100.0	90.0	<b>0.275</b>	100.0	100.0	2.071	6.381
United Kingdom	0.991	100.0	90.0	<b>1.753</b>	100.0	100.0	3.748	6.381

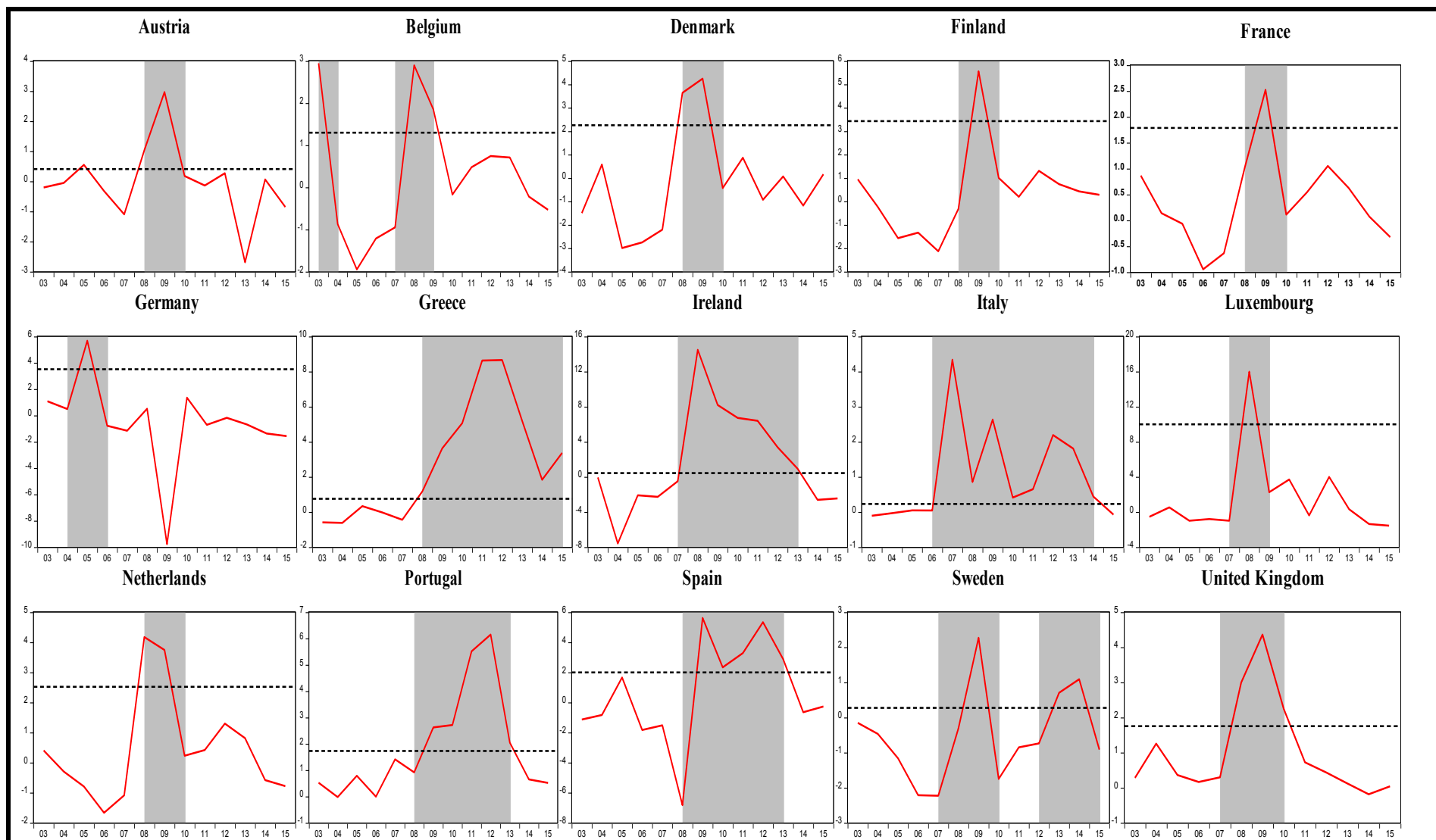
**Note:** *S* and *G* indicate optimal threshold values for specific and all EU-15 countries, respectively.

**Table 1.3.** Debt crisis episodes from selected studies

Country	Our results: Crisis dates	Hernandez de Cos et al. (2014): Crisis dates	Baldacci et al. (2011a): Start of crisis	Berti et al. (2012):
Austria	2009	No crisis	No crisis	No crisis
Belgium	2003, 2008-2009	No crisis	No crisis	No crisis
Denmark	2008-2009	n.a.	No crisis	No crisis
Finland	2009	No crisis	No crisis	No crisis
France	2009	No crisis	No crisis	No crisis
Germany	2005	No crisis	No crisis	No crisis
Greece	2008-2015	2008-2010	2008	n.a.
Ireland	2008-2013	2008-2010	2008	n.a.
Italy	2007-2014	2008-2010	2008	No crisis
Luxembourg	2008	n.a.	n.a.	No crisis
Netherlands	2008-2009	No crisis	No crisis	No crisis
Portugal	2009-2013	2008, 2010	2008, 2010	2009-2010
Spain	2009-2013	n.a.	2010	2009, 2012
Sweden	2009, 2013-2014	n.a.	No crisis	No crisis
United Kingdom	2008-2010	n.a.	No crisis	2009

**Note:** "n.a." indicates that the country is not covered in the study.





**Figure 1.2.** Fiscal Stress Indexes and their threshold values for EU-15 countries  
**Note:** Dashed areas indicate crisis periods

When we compare our results with those of Hernandez de Cos et al. (2014), we observe that they do not find any crisis episode in the cases of Austria, Belgium, Finland, France, and the Netherlands in the post-2003 period. On the contrary, our results show that Austria in 2009, Belgium in 2003, 2008, and 2009, Finland in 2009, France in 2009, and the Netherlands in 2008 and 2009 had a debt crisis. Besides, Hernandez de Cos et al. (2014) state that Greece, Ireland, Italy, and Portugal had a debt crisis from 2008 to 2010 while our index indicate that Greece from 2008 to 2015, Ireland from 2008 to 2013, Italy from 2007 to 2014, and Portugal from 2009 to 2013 suffered a debt crisis. Baldacci et al. (2011a) and Berti et al. (2012) have quite similar results when compared to the results of Hernandez de Cos et al. (2014) since they all use similar definitions for debt crisis (see Table 1.3).

Moreover, our fiscal stress index identifies more ‘debt crisis’ episodes than previous empirical studies applied to debt crises, since it measures the pressure or stress level in a country contrary to other fiscal stress definitions that focus mainly on default events. To be more precise, our index indicates high fiscal pressure in 14 out of 15 countries included into the sample following the outbreak of the global financial crisis. The only country where the index does not find high fiscal stress is Germany.

## **1.5. Conclusion**

This chapter aimed to construct a weighted continuous fiscal stress index to identify debt crisis episodes occurred in the EU-15 countries over the period 2003-2015. Besides, we used three different methods to calculate ‘optimal’ threshold values for each country which is used to date debt crises. When the index exceeds the optimal threshold values, it signals a debt crisis and takes the value of 1.

Our results indicate that 14 out of 15 countries suffered a debt crisis following the global financial crisis in 2008. To be more precise, 2008 is the start year of the debt crisis in 7 out of 15 EU member countries, while 2009 is the outbreak date of debt crisis in 6 countries. Besides, our results show that Greece, Ireland, Italy, Portugal, and Spain (so-called PIIGS) spearhead other EU-15 countries in terms of crisis severity and length: 8 years for Greece, 7 years for Italy, 6 years for Ireland, Portugal and Spain.

On the other hand, our fiscal stress index identifies more ‘debt crisis’ episodes and indicates a longer crisis period for the so-called PIIGS than previous empirical studies applied to debt crises (Baldacci et al., 2011a; Berti et al., 2012; Hernandez de Cos et al., 2014).

Because our index measures the pressure or stress level in a country contrary to other fiscal stress definitions that focus mainly on default events. We think that our fiscal stress index gives more realistic results, at least for some countries, contrary to ‘over-optimistic’ results found in previous studies.

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## Chapter 2

# Determinants of The European Sovereign Debt Crisis: Application of Logit, Markov Regime Switching Model and Self Organizing Maps

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### 2.1. Introduction

Over the last decade, the European Union went through the most severe economic and political crisis since its creation following the World War II. Some economists (i.e. Wolf, 2012) stated that the crisis was the result of contagion of the US subprime crisis to Europe: as the crisis spread to Europe, governments and central banks heavily intervened in real and financial sectors to limit the negative impacts of the crisis. These expansionary policies and bank rescue plans (in other words, nationalization of private debt) resulted in a dramatic rise in public debt stock leading then to sovereign debt crisis in some Eurozone member countries.

Some argued that the crisis is related to increasing fiscal deficits and rising public debt stock, but these problems are the consequences of the structural factors associated with the Eurozone. The main argument here is the Eurozone is not an optimum currency area *a la* Mundell (1961), since there is no a risk sharing system such as an automatic fiscal transfer mechanism to redistribute money to areas/sectors which have been adversely affected by the capital and labor mobility. Moreover, Eurozone is a monetary union without a fiscal union: this design, permitting the free riding of fiscal policies within a framework of common monetary policy, led to differences in inflation rates within the Eurozone member countries. Inflation differences in turn caused a decrease in the trade competitiveness of high-inflation countries, i.e., Greece, Spain. As the option of improving the competitiveness of the economy through exchange rate depreciation was not available, because of the common currency, trade deficits steadily rose in the Southern peripheral countries leading then to constant increases in public debt stock (Ari, 2014). This was not an important problem until the outbreak of the global financial crisis. Because with the transition to European Monetary Union (EMU), increasing capital inflows towards peripheral countries resulted in low interest rates facilitating the rollover of the debt stock. In addition, low interest rates led to a decrease in household savings and increased consumption, causing external deficits and an increase in private debt stock.

This chapter aims to empirically identify the determinants of the European debt crisis. To do so, we employ three different estimation techniques, namely SOM, Logit, and Markov models. The main reason to use different methods is the fact that using different methodologies have led to inconsistent results in terms of crisis determinants and crisis prediction (see Berg and Patillo, 1999; Beckman et al., 2006; Comelli, 2014; Ari and Cergibozan, 2018 for further discussion). Hence, we first apply the SOM approach which allows us to visualize, via crisis maps created for each country, the transition from noncrisis to crisis states. Besides, the SOM analysis gives us variables' order of importance in explaining the occurrence of the debt crises in the EU member countries. In other words, the SOM analysis serves us as a filter to determine which indicators should be included into the Logit and Markov model estimations. Then, we estimate logit and Markov models with the variables found to be significant by the SOM approach.

According to the results obtained from different estimation techniques, in addition to financial and macroeconomic variables such as nonperforming loans over total loans, GDP growth, primary balance over GDP, unemployment, cyclically-adjusted balance over GDP, governance variables (i.e. voice and accountability, regulatory quality and government effectiveness) also play a significant role in the emergence of the European debt crisis. Besides, the logit and Markov models could also predict nearly all crisis and noncrisis episodes in EU-15 over the period of 2003-2015.

The remainder of the chapter is organized as follows. Section 2.2 presents a literature review on empirical papers on debt crises. Section 2.3 presents the data for explanatory variables. Section 2.4 describes three different estimation methods used in the chapter. Section 2.5 discusses estimation results and forecast performance of the models. Section 2.6 concludes.

## **2.2. Literature Review**

Although there is a large empirical literature on banking and currency crises, there is a limited number of empirical studies on debt crises. Detragiache and Spilimbergo (2001) examine the determinants of debt crises in sample consisting of 69 countries over the period from 1971 to 1998. Using logit models, they find that the probability of a debt crisis increases with the proportion of short-term debt (public and private) and debt service coming due and decreases with foreign exchange reserves. IMF (2002) analyzes the possible causes of the

relatively high frequency of debt crises in Latin America. The study indicates that although total external debt is not high relative to GDP by international standards, it is concentrated in the public sector and is high relative to exports and relative to tax revenue. This means that devaluation provides a limited boost to economic activity, hence government revenues, but it causes a large increase in debt-service expenditure. Besides, the macroeconomic volatility worsens liquidity problems and increases default risk.

Manasse et al. (2003) test, via Logit and binary recursive tree models, the impact of core macroeconomic indicators on the occurrence of a debt crisis in sample of 47 countries over the period of 1970-2002. Their empirical results indicate that external debt ratios measuring solvency and sustainability (high total external debt to GDP ratio), measures of illiquidity (high short-term debt to reserves ratio) or refinancing risk (periods of tight international liquidity as proxied by the US treasury bill rate), measures of external imbalance (high current deficits as a percentage of GDP), negative domestic developments (low real GDP growth and high inflation rates), and political factors such as elections increase the probability of debt crisis.

Hemming et al. (2003) empirically analyze whether there are systematic patterns in fiscal variables in the periods before and after crises in the cases of 29 emerging market countries over the period of 1970-2000, by employing a Probit model. They find that a high proportion of sovereign debt denominated in foreign currency, short-term debt to reserves, and net claims of the banking sector on central government (as a ratio of GDP) are found to be significant variables in explaining debt crises.

Baldacci et al. (2011a) develop an early warning system based on the signaling approach of Kaminsky et al. (1998) for a large set of 165 countries over the period of 1970-2010. Their results indicate that in advanced countries the top predictors of fiscal stress are gross public financing needs and fiscal solvency risks, while in emerging economies, the best predictors of fiscal stress are risks associated with public debt structure and exposure to spillovers from financial markets. Berti et al. (2012) follow the methodology used in Baldacci et al. (2011a), but in a limited sample consisting of 33 countries over the period from 1970 to 2012. They show that private sector credit flow over GDP, current account over GDP, and yield curve are among the best predictors of fiscal stress.

Hernandez de Cos et al. (2014) use the signaling approach with country-specific thresholds for a limited set of 11 Eurozone countries over the period of 1970-2010. They first indicate that using a country-specific threshold increases the predictive power of early

indicators in the signaling approach. Second, fiscal balance over GDP, real effective exchange rate, short-term debt over GDP, leverage of financial corporations, private sector credit flow over GDP, and real GDP growth are found to have the highest predictive power. Gerling et al. (2017) examine the determinants of fiscal crises for a large sample of 188 IMF member countries for the period of 1970-2015, via fixed effect panel regression. They find that a fiscal crisis tends to be preceded by loose fiscal policy measured by real expenditure growth, hence primary balance deterioration, and by large deterioration in the external current account.

Bruns and Poghosyan (2018) use the extreme bound analysis (based on the pooled logit model) to determine the variables leading to fiscal distress in the cases of 81 developing and advanced countries over the period of 1970-2015. They find that fiscal distress tends to follow a period of overheating in the real sector (widening of output gap) which can be associated with a build-up of financial imbalances, hence detrimental to systemic stability. In addition, adverse developments in the external sector (high current account deficit, low level of reserves/GDP ratio, and higher trade openness) tend to precede fiscal distress episodes. Moreover, foreign exchange debt to GDP ratio, primary and overall fiscal balance to GDP ratios, are robust indicators of debt crises.

Cerovic et al. (2018) adopt two alternative estimation techniques, namely the signal approach and multivariate logit model in order to identify the structural weaknesses leading to debt crises in a sample of 118 countries over the period of 1970-2015. The results show that variables linked to domestic economic activity (large output and credit gaps), fiscal policy (overall or primary deficit, use of central bank credit to finance the fiscal deficit), and external imbalances (current account deficit and degree of openness) increase the probability of a future crisis

### **2.3. Data and Leading Indicators**

This section presents the leading indicators that may have caused the occurrence of the European debt crisis. While many different leading indicators are used in explaining debt crises in the literature, some of them give more meaningful results in explaining debt crises. Hence, having a large set of leading indicators will be useful. For example, in Bussierre and Fratzscher (2006), 28 leading indicators of currency crises were collected in five groups. These groups are external competitiveness, external exposure, domestic real and public sector, domestic financial sector, global factor or contagion indicator. Only six of these indicators are

included in the final model. In our study, a very wide set of leading indicators has been used to explain debt crises like in Bussierre and Fratzscher (2006).

Our dataset consists of 51 leading indicators. The selection of leading indicators is based on the studies by Manasse et al. (2003), Baldacci et al. (2011a, 2011b), Berti et al. (2012), and Hernandez de Cos et al. (2014). Our preferred approach is that all indicators are first used in the SOM analysis to determine which indicators are important in explaining the European debt crisis. Then, significant variables are used in Logit and Markov model estimations. Table 2.1 presents definitions and sources for the selected leading indicators used in the study. Their descriptive statistics are given in Table 2.2. The first set consists of public and real sector variables: GDP, Inflation, Unemployment, Government Expenditure / GDP, Primary Balance / GDP, Cyclically Adjusted Balance / GDP, Revenue / GDP, Interest Payments / Revenue, Interest Payments / Expenses, Cash Surplus / GDP, REER, Savings / Expenditures, Tax Revenue / GDP, and Wages. The second category includes financial indicators that exert an influence on sovereign debt situations: Bank capital / Asset, Non-performing Loans / Total Loans, Banking Sector Leverage, M2 / GDP, and Banking Crisis Index. The study uses Laeven and Valencia's (2013) definition of banking crisis.

Our third set of indicators encompasses different debt ratios: External Debt / Export, External Debt / GDP, External Debt Government / GDP, External Debt Private / GDP, Net Debt / GDP, and Household Debt / GDP. Social indicators constitute our fourth set: Health Expenditure / GDP, Public Health Expenditure / GDP, Gini Coefficient, Gross Enrollment Ratio, Fertility Rate, and Age Dependency Ratio. Excessive increases in health expenditures, deterioration in income distribution, decline in education level, decline in fertility rate, and increase in age dependency ratio are expected to increase the likelihood of debt crisis.

Finally, our fifth and last set includes governance indicators. Only a very small number of studies have examined the effect of governance quality on the likelihood of debt crises (Manessa et al, 2003; Guscina, 2008). The governance indicators used in the study are Political Stability Risk Rating, Credit Rating, Trade-Credit Risk Rating, Government Effectiveness, Political Stability and Freedom from Violence / Terrorism, Regulatory Quality, Rule of Law, and Voice and Accountability. The deterioration of countries' governance indicators is expected to increase the likelihood of a debt crisis. We have used Kaufmann et al. (2011) for defining governance indicators. Accordingly, voice and accountability cover freedom of expression, freedom of association, election of government, and free media for a nation's citizens.



**Table 2.1. Notation, Source, and Expected Sign of Variables**

INDICATOR	ABBREVIATION	SOURCE	EXPECTED SIGN
Current account of balance of payments (% of GDP)	CA/GDP	WB	(-)
GDP, real, annual growth	GDP growth	WB	(-)
Exports, goods & services (% of GDP)	X/GDP	WB	(-)
Inflation, consumer prices index (annual %)	Inflation	WB	(+)
Health expenditure, total (% of GDP)	H. Expenditure (Total)/GDP	WB	(+)
Unemployment rate (%)	Unemployment	WB	(+)
Government expenditure as % of GDP	GOV.EXP/GDP	WB	(+)
Foreign direct investment, inward, share of GDP	FDI/GDP	WB	(+)
Domestic credit to private sector (% of GDP)	CPS/GDP	WB	(+)
Health expenditure, public (% of government expenditure)	H.EXP (Public)/GOV.EXP	WB	(+)
Primary net lending/borrowing (also referred as primary balance) (% of GDP)	Primary Balance/GDP	IMF	(-)
Cyclically adjusted balance (% of potential GDP)	Cyclically Adjusted Balance /GDP	IMF	(-)
Revenue (% of GDP)	Revenue/GDP	IMF	(-)
Reserves, foreign exchange, excluding gold, US\$	Reserves	WB	(-)
Cash surplus/deficit (% of GDP)	Cash Balance/GDP	IMF	(-)
Tax revenue (% of GDP)	Tax Revenue/GDP	WB	(-)
Savings/Expenditures	Savings/Expenditures	WB	(-)
Imports, goods & services (% of GDP)	M/GDP	WB	(+)
Trade balance /GDP	Trade/GDP	WB	(-)
External debt, total, share of exports	EX-DEBT/X	WB	(+)
Political stability risk rating (7=lowest risk)	PSRR	OE	(-)
Credit rating, average	Credit Rating	OE	(-)
Exchange rate, effective real	REER	OE	(+)
External debt, total, share of GDP	EX-DEBT/GDP	WB	(+)
External debt government/GDP	EX-DEBT-GOV/GDP	WB	(+)
External debt private/GDP	EX-DEBT-PRIVATE/GDP	WB	(+)
Foreign direct investment, outward, share of GDP	OFDI/GDP	WB	(+)
Wages, hourly, US\$	WAGE	OE	(-)
Net debt (% of GDP)	NET_DEBT/GDP	IMF	(+)
Bank capital to assets ratio (%)	CAPITAL/ASSETS	WB	(-)
Bank nonperforming loans to total gross loans (%)	NPL/TGL	WB	(+)
Trade credit risk rating (7=lowest risk)	TCRR	OE	(-)
Household Debt/GDP	Household Debt/GDP	OE	(+)
Control of Corruption	Corruption	WB	(-)
Government Effectiveness	GOV.EFFECT	WB	(-)
Political Stability and Absence of Violence/Terrorism	PSAVTT	WB	(-)
Regulatory Quality	Regulatory Quality	WB	(-)
Rule of Law	Rule of Law	WB	(-)
Voice and Accountability	Voice and Accountability	WB	(-)
Gini coefficient	GINI COEFF	WIID, SWIID	(+)
Gross enrolment ratio, tertiary, both sexes (%)	Enrolment Tertiary	WB	(-)
Gross enrolment ratio, primary, both sexes (%)	Enrolment Primary	WB	(-)
Gross enrolment ratio, secondary, both sexes (%)	Enrolment Secondary	WB	(-)
Fertility rate, total (births per woman)	Fertility Rate	WB	(-)
Age dependency ratio, old (% of working-age population)	Age Dependency	WB	(+)
Interest payments (% of revenue)	INT_PAY/REVENUE	WB	(+)
Interest payments (% of expense)	INT_PAY/EXPENSE	WB	(+)
Banking sector leverage	Bank Leverage	WB	(+)
M2/GDP	M2/GDP	OE	(+)
Fiscal Stress Index	FSI	Authors Calculation	
Democracy	Democracy	PP	(-)
Index of Banking Crises	Banking Crises	(Laeven and Valencia, 2013)	(+)

**Note:** Abbrev, Obs, Mis, Val, M, Min and Max denote abbreviation, observations, missing value, mean, minimum and maximum, respectively. WB, IMF, OE, PP, WIID and SWIID indicate World Bank, International Monetary Fund, Oxford Economics, Polity Projects, World Income Inequality Database and Standardized World Income Inequality Database, respectively.

Political stability and the freedom from violence/terrorism demonstrate the possibility of government destabilization or overthrow through unconstitutional political violence or terrorism. The government effectiveness indicator is the government's policy-making and implementation quality and the credibility of its commitment to such policies as well as the degree to which public services are independent of political repression. Rule of law shows the implementation of contracts in addition to opportunities for crime and violence; the quality of

the police, courts, and property rights; and the level of trust and compliance of individuals with society. Control of corruption refers to the use of public power for special gains, with small or large corruption in addition to elite and private interests seizing public power. Political stability refers to the stability of the current government and the entire political system. Trade-credit risk rating means that the trading partner cannot fulfill its obligations. The democracy index refers to the country's level of democracy.

**Table 2.2.** Descriptive Statistics of the Data Set

INDICATOR	OBS	MIS.VAL.	MEAN	STD.DEV.	MIN	MAX
Current account of balance of payments (% of GDP)	195	0(0%)	0.94	5.48	-14.43	11.93
GDP, real, annual growth	195	0(0%)	1.17	2.82	-9.17	8.40
Exports, goods & services (% of GDP)	195	0(0%)	54.52	39.96	18.54	213.85
Inflation, consumer prices index (annual %)	195	0(0%)	1.79	1.36	-4.46	4.93
Health expenditure, total (% of GDP)	180	15(7.69%)	9.52	1.20	6.80	11.97
Unemployment rate (%)	195	0(0%)	8.46	4.65	2.33	27.51
Government expenditure as % of GDP	195	0(0%)	48.11	5.90	32.96	65.65
Foreign direct investment, inward, share of GDP	193	2(1.02%)	37.58	138.23	-6.75	1,144.76
Domestic credit to private sector (% of GDP)	195	0(0%)	110.77	35.83	54.56	202.19
Health expenditure, public (% of government expenditure)	180	15(7.69%)	15.11	2.14	9.29	20.86
Primary net lending/borrowing (also referred as primary balance) (% of GDP)	195	0(0%)	-0.94	3.71	-29.73	6.04
Cyclically adjusted balance (% of potential GDP)	195	0(0%)	-2.53	3.39	-18.61	4.01
Revenue (% of GDP)	195	0(0%)	45.03	6.18	32.79	57.44
Reserves, foreign exchange, excluding gold, US\$	195	0(0%)	25,169.38	24,607.29	143.55	119,026
Cash surplus/deficit (% of GDP)	179	16(8.20%)	-3.51	4.23	-32.37	4.11
Tax revenue (% of GDP)	179	16(8.20%)	22.22	5.85	0.31	35.08
Savings/Expenditures	194	1(0.51%)	0.28	0.14	0.08	0.85
Imports, goods & services (% of GDP)	195	0(0%)	50.45	31.81	22.92	177.65
Trade balance /GDP	195	0(0%)	4.08	9.10	-12.55	36.20
External debt, total, share of exports	190	5(2.56%)	673.46	498.41	258.78	2,807.26
Political stability risk rating (7=lowest risk)	195	0(0%)	5.81	0.62	4.26	6.83
Credit rating, average	195	0(0%)	17.88	4.15	0.00	20.00
Exchange rate, effective real	195	0(0%)	101.52	5.46	88.99	127.40
External debt, total, share of GDP	190	5(2.56%)	511.16	983.55	82.98	5,490.03
External debt government/GDP	179	16(8.20%)	41.96	25.61	1.65	152.47
External debt private/GDP	177	18(9.23%)	214.75	195.45	33.51	1,067.07
Foreign direct investment, outward, share of GDP	182	13(6.67%)	39.26	128.79	-3.95	833.68
Wages, hourly, US\$	182	13(6.67%)	32.44	10.10	8.19	51.67
Net debt (% of GDP)	164	21(10.77%)	42.88	47.10	-69.74	176.57
Bank capital to assets ratio (%)	170	25(12.82%)	5.77	1.51	3.00	13.97
Bank nonperforming loans to total gross loans (%)	187	8(4.10%)	4.58	5.93	0.08	34.67
Trade credit risk rating (7=lowest risk)	152	23(11.79%)	5.32	1.99	0.00	7.00
Household Debt/GDP	125	70(35.90%)	84.16	36.15	46.78	217.51
Control of Corruption	195	0(0%)	1.54	0.71	-0.25	2.55
Government Effectiveness	195	0(0%)	1.51	0.51	0.21	2.36
Political Stability and Absence of Violence/Terrorism	195	0(0%)	0.81	0.46	-0.47	1.66
Regulatory Quality	195	0(0%)	1.43	0.38	0.34	1.92
Rule of Law	195	0(0%)	1.49	0.48	0.24	2.12
Voice and Accountability	195	0(0%)	1.35	0.24	0.56	1.83
Gini coefficient	135	60(30.77%)	36.66	3.09	28.51	44.56
Gross enrolment ratio, tertiary, both sexes (%)	156	39(20%)	67.44	16.33	10.33	110.26
Gross enrolment ratio, primary, both sexes (%)	172	23(11.79%)	103.98	4.86	95.71	120.90
Gross enrolment ratio, secondary, both sexes (%)	172	23(11.79%)	110.46	13.14	91.39	164.81
Fertility rate, total (births per woman)	180	15(7.69%)	1.64	0.24	1.21	2.06
Age dependency ratio, old (% of working-age population)	195	0(0%)	25.90	3.99	15.25	35.08
Interest payments (% of revenue)	195	16(8.20%)	6.77	3.79	0.27	17.29
Interest payments (% of expense)	179	16(8.20%)	6.16	3.13	0.28	14.20
Banking sector leverage	180	15(7.69%)	16.03	9.52	3.89	51.56
M2/GDP	182	13(6.67%)	81.31	22.09	41.62	133.32
Fiscal Stress Index	195	0(0%)	0.72	2.83	-9.78	15.99
Democracy	195	0(0%)	9.84	0.48	8.00	10.00
Index of Banking Crises (Laeven and Valencia, 2013)	195	0(0%)	0.58	0.49	0.00	1.00

**Note:** Obs, Mis. Val, M, Min and Max denote observations, missing value, mean, minimum and maximum, respectively.

## **2.4. Methodology**

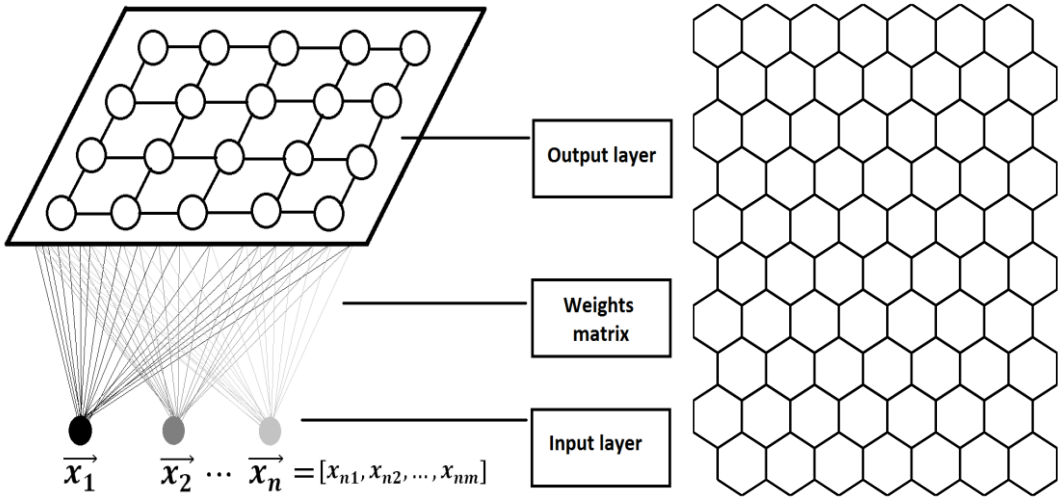
This section presents the three different methods used to determine the indicators that play a role in the emergence of the European debt crisis. The methods used in the study are Self Organizing Maps (SOMs) or Kohonen Maps, Multivariate Logit Model (MLM), and Panel Markov Regime Switching Model (PMRSM). The previous literature testing the likelihood of a debt crisis rests on models such as Logit-Probit, Signal Approach, and Markov Regime Switching. In this study, the results of SOM, Logit, and are given in a comparative way. In addition, we test the stability of estimates. Last but not least, predicting performance of each method is presented. The first method used in the study is the SOM. This model allows the simultaneous use of more variables compared to other methods, and the error based on omitted variables is reduced to a minimum by including many of the variables that can cause debt crisis. The SOM results help determine the important factors that played a role in the emergence of the European debt crisis. After determining the significant variables via the SOM, we use these variables in Logit and estimations.

### **2.4.1. Self-Organizing Map**

The SOM, or Kohonen map, is a very effective tool for analyzing existing patterns in high-dimensional datasets. SOM basically shows the relationship between input data much easier by visually simplifying relationships that are hard to see in large datasets. SOM does this by offering low-dimensional images of high-dimensional data. In other words, SOM size reduction tools provide the researcher with the convenience of complex datasets. SOM is an unsupervised competitive learning methodology introduced in the artificial neural network literature by Kohonen (1982). SOM is a nonlinear and nonparametric method, unlike other methods used in economics and does not rely on rigid assumptions. Based on this, SOM provides important advantages for researchers. For instance, including too many variables at the same time in the majority of econometric methods results in multicollinearity where too many parameters cannot be predicted due to observation constraints. Although the SOM method has been used extensively in a large number of scientific fields since it first appeared in the literature, its use economics is very rare. Some examples of the use of SOM in economic studies include Serrano-Cinca (1996), Kiviluoto (1998), Lee et al. (2005), Shanmuganathan et al. (2006), Giovanis (2010), Sarlin (2011a), Sarlin and Peltonen (2013),

Louis et al. (2013), Claveria et al. (2016), and Deichmann et al. (2017). Applied examples of SOM in economics are Sarlin (2011a, 2011b, 2013) and Sarlin and Marghescu (2011). The topological structure of SOM networks is shown in the Figure 2.1.

**Figure 2.1.** The topology of the SOM network.



Each circle in the left graph shows neurons. Neurons are represented by rectangles or hexagons. A SOM network consists of two-layers of nodes: the input and the output. Note that high-dimensional inputs are transformed into a two-dimensional map. The main purpose of the SOM is to reflect this similarity to the output layer, preserving its similarity with the input data. At this point, the whole relationship can be preserved at first, and this can be transformed into more easily explainable visuals. As seen in the Figure 2.1, each of the input neurons is connected to the output neurons with specific weights. These weights are randomly determined at the beginning of process, but the most successful neuron is activated by SOM's competitive learning algorithm, and the similarity between input and output layers is maintained at the highest level; this means that these weights are learned and adjusted. Here, the winning neuron is known as the best matching unit (BMU). The important point here is that each output layer has a single coordinate and that the distance between the output layers can be easily calculated. On this count, each output layer will be positioned in a two-dimensional map based on the similarity of the weights of the output layers. While neurons with similar weights are positioned closer, non-similar neurons will be located further away. In SOM, each input data is basically expressed by an  $n$ -dimensional input vector  $X = [X_1, X_2, \dots, X_n]^T \in R^n$ , where each element represents the property value of the input data. In addition, each input in the SOM depends on the specific weight  $m_{ij}$  of each node. This

weight is expressed by  $m_{ij} = [m_{ij}^1, m_{ij}^2, \dots, m_{ij}^n]^T \in R^n$  usually as a codebook vector. Here the size of the codebook vector is obviously equal to the number of inputs (Stefanovic & Kurasova, 2011). The SOM process has four basic elements: initialization, competition, cooperation, and adaptation, realized in five steps by the SOM algorithm (Vesanto & Alhoniemi, 2000; Sarlin & Peltonen, 2013):

**Step 1. Initialization:** All connections are provided with an initial weight.

**Step 2. Competition:** By using Euclidean distances, compare each input vector  $x_j$  with each output vector  $m_i$  and find the best match  $m_b$ . The winning node is commonly known as the Best Matching Unit (BMU).

$$\|x - m_b\| = \min_i \|x - m_i\| \quad (2.1)$$

Here, the smallest Euclidean distance may be defined as the BMU.

**Step 3. Cooperation and adaptation:** In the input space, the BMU and its topological neighbors are closely located to the input vector. The update rule for the prototype vector of unit  $i$  is

$$m_i(t+1) = m_i(t) + \alpha(t)h_{bi}(t)[x(t) - m_i(t)] \quad (2.2)$$

where  $t$  is the number of iterations,  $\alpha(t)$  is the adaptation coefficient, and  $h_{bi}(t)$  denotes the neighborhood Kernel centered on the BMU. Neighborhood function is often calculated using the Gaussian neighborhood function:

$$h_{bi(j)} = \exp\left(-\frac{\|r_b - r_i\|^2}{2\sigma^2(t)}\right) \quad (2.3)$$

where  $r_b$  and  $r_i$  are two-dimensional coordinates of the reference vectors,  $m_b$  and  $m_i$ , respectively, and the radius of the neighborhood  $\sigma(t)$  is the monotonically decreasing learning factor at time  $t$ .

**Step 4.** Repeat Steps 2 and 3 for sufficient iterations and convergence.

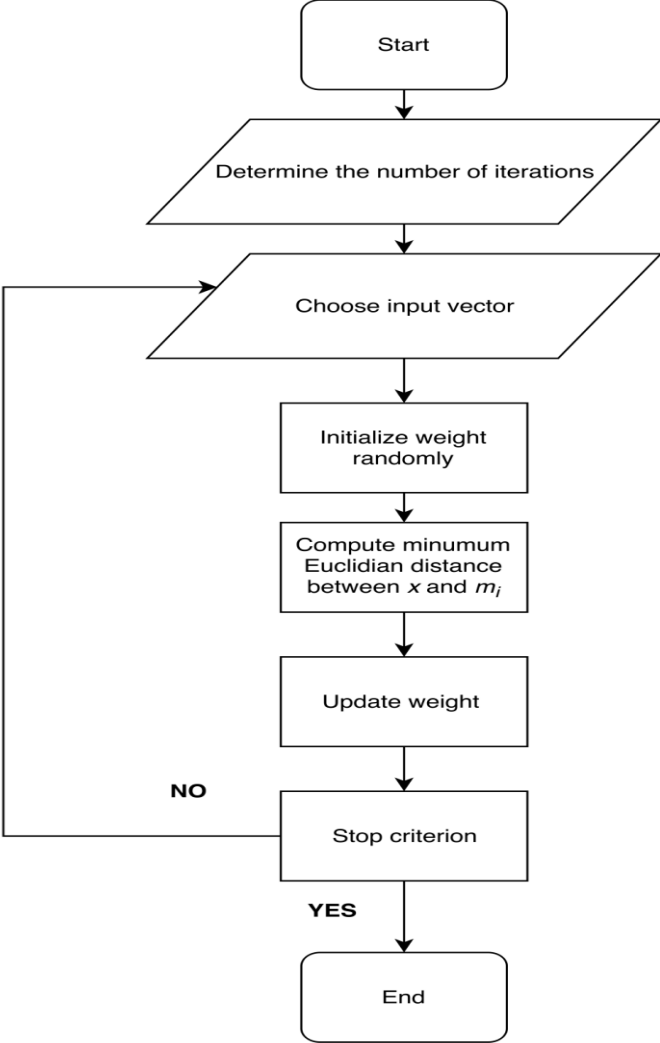
**Step 5.** By using the SOM-based  $K$ -means clustering method, gather the nodes into a small number of clusters.

The flow chart for the SOM used in this study is shown in Figure 2.2.

Giving a simple numerical example for a better understanding of SOM's algorithm would be appropriate. Suppose there are 30 countries that have four qualities to be analyzed. The main purpose of using the SOM in this sample is to separate the homogeneous subgroups

by considering the four basic characteristics of these 30 heterogeneous countries. In this respect, countries with similar characteristics will be gathered in the same groups. The sample data is also shown in Table 2.3. The four characteristics of the 30 countries are identified by  $A_1, A_2, A_3,$  and  $A_4,$  respectively.

**Figure 2.2.** Flowchart of the SOM method



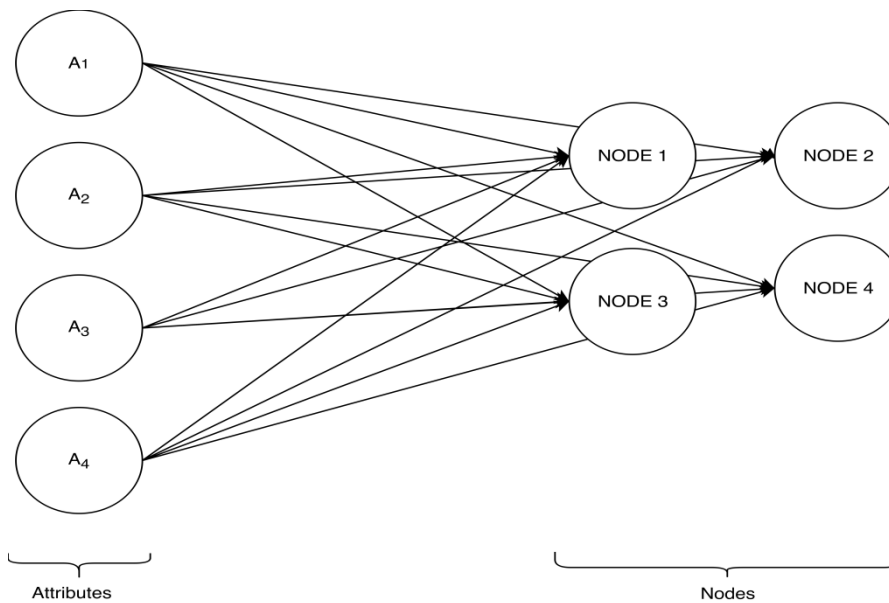
In this example, the SOM network consists of four input nodes and four output nodes. Small numbers of input and output nodes are chosen for the simplicity of calculation. An example of the SOM architecture is represented in Figure 2.3.

**Table 2.3.** Sample Dataset

Country	Attributes			
	$A_1$	$A_2$	$A_3$	$A_4$
1	0.81	0.70	0.75	0.07
2	0.90	0.03	0.25	0.05
3	0.12	0.27	0.50	0.53
4	0.91	0.04	0.69	0.77
...	...	...	...	...
30	0.17	0.22	0.56	0.44

**Note:** Due to the space constraint, the entire table is not included. The numbers are derived randomly between 0 and 1.

**Figure 2.3.** An example of SOM architecture



As emphasized above in the SOM analysis, initial weights must be determined at random (see Table 2.4).

**Table 2.4.** Initial Weights

Attributes	$W_1$	$W_2$	$W_3$	$W_4$
1	0.18	0.81	0.25	0.10
2	0.26	0.86	0.80	0.96
3	0.14	0.08	0.43	0.01
4	0.13	0.39	0.91	0.77

**Note:**  $W$  indicates initial weights. Different weight values are selected for the four nodes.

Suppose that our first calculation is made for the randomly chosen second country. In this case  $x(0) = (0.90, 0.03, 0.25, 0.05)$  shows the response of the second country, or its qualification. The Euclidian distances calculated for the four output nodes in the model for determining the node that gives the best result for the second country are listed below:

$$d_1(0) = \sqrt{(0.90 - 0.18)^2 + (0.03 - 0.26)^2 + (0.25 - 0.14)^2 + (0.05 - 0.13)^2} = 0.768$$

$$d_2(0) = \sqrt{(0.90 - 0.81)^2 + (0.03 - 0.86)^2 + (0.25 - 0.08)^2 + (0.05 - 0.39)^2} = 0.917$$

$$d_3(0) = \sqrt{(0.90 - 0.25)^2 + (0.03 - 0.80)^2 + (0.25 - 0.43)^2 + (0.05 - 0.91)^2} = 1.337$$

$$d_4(0) = \sqrt{(0.90 - 0.10)^2 + (0.03 - 0.96)^2 + (0.25 - 0.01)^2 + (0.05 - 0.77)^2} = 1.443$$

The results show the node in  $d_1(0) = 0.768$  to have the minimum Euclidean distance. Accordingly, the first output node gives the most similar result to the input data. In the other 30 countries, the best matching output node can be identified in the same way. Now that the BMU has been identified, the neighbors' weights can be updated accordingly. To make it simple from the beginning, let's assume that the learning rate ( $\alpha$ ) is 0.9, which is close to 1, meaning the best value. If the learning rate is zero, there will be no remaining updates as if the weights of the vectors had been predicted. For the BMU, the current weights calculated according to Equation 2.2 will be:

$$\begin{bmatrix} w_{11}(1) \\ w_{12}(1) \\ w_{13}(1) \\ w_{14}(1) \end{bmatrix} = \begin{bmatrix} 0.18 \\ 0.26 \\ 0.14 \\ 0.13 \end{bmatrix} + 0.9 \left( \begin{bmatrix} 0.90 \\ 0.03 \\ 0.25 \\ 0.05 \end{bmatrix} - \begin{bmatrix} 0.18 \\ 0.26 \\ 0.14 \\ 0.13 \end{bmatrix} \right) = \begin{bmatrix} 0.83 \\ 0.05 \\ 0.24 \\ 0.06 \end{bmatrix}$$

As observed, the higher the learning rate is, the higher the similarity with the input. The updated weights for the neighboring units as calculated according to the Gaussian neighborhood function in Equation 2.3 are shown below at  $t = 0$ :



$$h_{12}(0) = \exp\left(-\frac{0.910^2}{2 \cdot (1)^2}\right) = 0.662$$

$$h_{13}(0) = \exp\left(-\frac{0.994^2}{2 \cdot (1)^2}\right) = 0.611$$

$$h_{14}(0) = \exp\left(-\frac{0.961^2}{2 \cdot (1)^2}\right) = 0.631$$

where

$$d_{12} = \sqrt{(0.18-0.81)^2 + (0.26-0.86)^2 + (0.14-0.08)^2 + (0.13-0.39)^2} = 0.910$$

$$d_{13} = \sqrt{(0.18-0.25)^2 + (0.26-0.80)^2 + (0.14-0.43)^2 + (0.13-0.91)^2} = 0.994$$

$$d_{14} = \sqrt{(0.18-0.10)^2 + (0.26-0.96)^2 + (0.14-0.01)^2 + (0.13-0.77)^2} = 0.961$$

The calculated weights for output node 2 are:

$$\begin{bmatrix} w_{21}(1) \\ w_{22}(1) \\ w_{23}(1) \\ w_{24}(1) \end{bmatrix} = \begin{bmatrix} 0.81 \\ 0.86 \\ 0.08 \\ 0.39 \end{bmatrix} + 0.9(0.662) \left( \begin{bmatrix} 0.90 \\ 0.03 \\ 0.25 \\ 0.05 \end{bmatrix} - \begin{bmatrix} 0.81 \\ 0.86 \\ 0.08 \\ 0.39 \end{bmatrix} \right) = \begin{bmatrix} 0.86 \\ 0.37 \\ 0.18 \\ 0.19 \end{bmatrix}$$

The calculated weights for output node 3 are:

$$\begin{bmatrix} w_{31}(1) \\ w_{32}(1) \\ w_{33}(1) \\ w_{34}(1) \end{bmatrix} = \begin{bmatrix} 0.25 \\ 0.80 \\ 0.43 \\ 0.91 \end{bmatrix} + 0.9(0.611) \left( \begin{bmatrix} 0.90 \\ 0.03 \\ 0.25 \\ 0.05 \end{bmatrix} - \begin{bmatrix} 0.25 \\ 0.80 \\ 0.43 \\ 0.91 \end{bmatrix} \right) = \begin{bmatrix} 0.61 \\ 0.05 \\ 0.01 \\ 0.44 \end{bmatrix}$$

The calculated weights for output node 4 are:

$$\begin{bmatrix} w_{41}(1) \\ w_{42}(1) \\ w_{43}(1) \\ w_{44}(1) \end{bmatrix} = \begin{bmatrix} 0.10 \\ 0.96 \\ 0.01 \\ 0.77 \end{bmatrix} + 0.9(0.631) \left( \begin{bmatrix} 0.90 \\ 0.03 \\ 0.25 \\ 0.05 \end{bmatrix} - \begin{bmatrix} 0.10 \\ 0.96 \\ 0.01 \\ 0.77 \end{bmatrix} \right) = \begin{bmatrix} 0.55 \\ 0.43 \\ 0.15 \\ 0.41 \end{bmatrix}$$

Finally, as the weights have been determined for all output nodes, the adjusted weight vectors of the winning node and its neighborhood are given below:

$$\begin{aligned}
w_1(1) &= (0.83 \ 0.05 \ 0.24 \ 0.06)' \\
w_2(1) &= (0.86 \ 0.37 \ 0.18 \ 0.19)' \\
w_3(1) &= (0.61 \ 0.05 \ 0.01 \ 0.44)' \\
w_4(1) &= (0.55 \ 0.43 \ 0.15 \ 0.41)'
\end{aligned}$$

Figure 2.4 shows the distance matrix, Unified Distance Matrix (U-Matrix) and clustering results based on SOM. The U-Matrix is formulated as follows (Stefanovic and Kurasova, 2011):

$$U - Matrix = \begin{pmatrix} u_{11} & u_{1|1|22} & u_{12} & u_{12|13} & \cdots & u_{1k_y} \\ u_{1|1|21} & & u_{1|1|22} & & \cdots & u_{1k_y|2k_y} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ u_{k_x1} & u_{k_x1|k_x2} & u_{k_x2} & u_{k_x2|k_x3} & \cdots & u_{k_xk_y} \end{pmatrix} \quad (2.4)$$

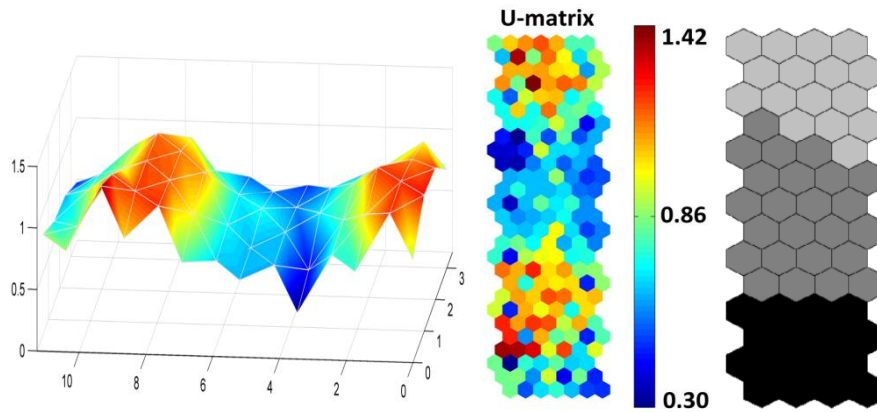
where  $u_{ij|i(j+1)}$   $u_{ij|j(i+1)}$ ,  $M_{ij}$ , and  $M_{i(j+1)}$  refer to the distance between neighboring neurons. First, the U-Matrix in the middle of Figure 2.4 shows the distance between neurons, while the scale displays the distance between neurons. The convergence of the scale to red indicates increases in the distance between neurons, while the convergence of the scale to blue indicates decreases in the distance between neurons. Blue and near blue scale values shows similar cluster groups, and scale values of red and near red indicate the separation point of the clusters. On the left side of Figure 2.4, there is the distance matrix which is the 3D representation of the U-Matrix. This representation clearly shows the distances and proximities between neurons. Similar neurons are located in the same clusters, and different clusters pass from the point where the distance increases. High values in the distance matrix indicate the borders of different cluster groups, while low values show the groups. The size of the low values indicates that the factors belonging to that group are also large. As emphasized in Mostafa's (2010) study, the U-Matrix is used in many studies to be able to see the clusters' structure. But classifying via the U-Matrix is very difficult due to the lack of clarity in clusters' visuality. In order not to encounter such a problem in the study, we use the SOM-based  $K$ -means clustering method. The right side of the Figure shows the clusters obtained based on SOM. Here, the Davies-Bouldin Validity Index (DBVI) is used to select the best among the differences. At this point, an attempt is made to determine the optimal number of clusters. DBVI is obtained as follows (Vesanto & Alhoniemi, 2000):

$$\frac{1}{G} \sum_{m=1}^G \max_{n \neq m} \left\{ \frac{S_G(Q_m) + S_G(Q_n)}{d_{GE}(Q_m, Q_n)} \right\} \quad (2.5)$$

where  $S_G$  represents the internal cluster distance,  $d_{GE}$  stands for cluster distance, and  $G$  indicates cluster number. DBVI is a very convenient way to determine the optimal number of clusters because it gives the lowest values that indicate the best clustering results.

Accordingly, the U-Matrix result shows the two regions are very close to red, so all the data have two different cluster boundaries. The three different clusters obtained by dividing all the data by two cut points are shown on the right. Note that, unlike the U-Matrix, borders and clusters are quite noticeable. Thus, different clusters are seen more clearly.

**Figure 2.4.** Distance matrix, U-Matrix, and SOM-based clusters.



**Note:** From left to right: distance matrix, U-matrix and the SOM based clusters.

Once SOM estimates are made, the quality of the estimates should be tested. This is a very important factor for the success of the estimation results. Two measurement methods are used for this, namely Quantization Error (QE) and Topographic Error (TE). QE is an important tool used to show how compatible the input data is with the generated map. Basically, this method is based on calculating the mean distance from the best matching input vector (Asan & Ercan, 2012). QE is calculated as follows:

$$E_{QE} = \frac{1}{T} \sum_t \|X(t) - m_b(t)\| \quad (2.6)$$

where  $X$  is the input vector and  $m_b$  is the winning neuron. The second method used to measure SOM quality is TE. As the map is a protected map, TE expresses how well the properties of the input data are preserved. Accordingly, TE is calculated as follows:

$$E_{TE} = \frac{1}{T} \sum_t u(X(t)) \quad (2.7)$$

where  $T$  is the number of inputs. In addition, when the winning vector of vector  $X$  is closer to the neuron,  $u(X(t)) = 0$ . Otherwise,  $u(X(t))=1$  (Stefanovic & Kurasova, 2011).

No clarity exists on determining the importance of variables in studies using the SOM method in economics. The components of SOM are interpreted without any definite relationship is established. However, some techniques are used in natural sciences to identify more clearly the significance of variables in SOM analysis. These are structuring index (SI), relative importance index (RI), cluster description index (CD), and Spearman rank correlation index (SRC) (Ki et al., 2016).

The SI index is originally developed and used by Park et al (2005) and Tison et al (2004, 2005). A variable used in the model with a low SI value indicates that the effect of that variable on the cluster of the SOM map is also low. Therefore, variables with high SI values explain a significant portion of the differentiation between cluster groups. The SI value of variable  $i$  can be calculated as follows:

$$SI_i = \frac{\sum_{j=1}^S \sum_{k=1}^{j-1} |w_{ij} - w_{ik}|}{\|r_j - r_k\|} \quad (2.8)$$

where the nominator and denominator respectively show the weight and topological differences between  $j$  and  $k$  map units, while  $S$  represents the total number of map units.

Another index used to determine the significance level of variables in the emergence of SOM-based clusters is the Relative Importance Index. In RI indexes, each variable is expressed based on the distance matrix as a pie chart proportional to the sum of the variables. In addition, the sum of these effects is standardized at 100. In other words, the importance of the variables in the model depends on what size they have in the pie chart. Accordingly,  $i$  is expected to have a high RI value if it is to have a high effect on the SOM structure.

Vesanto (2002) uses the CD index which expresses the variation in each cluster. Thanks to the CD index, the internal properties of each cluster can be displayed. The CD index is calculated as follows:

$$CC_i = \sum_{l=1}^C S_{li}^D = \sum_{l=1}^C \frac{(C-1)S_{li}^C}{\sum_{m=1, m \neq l}^C S_{mi}^C} \quad \text{where } S_{li}^C = \frac{\sigma_{li}}{\sigma_i} \quad (2.9)$$

where  $\sigma_{li}$  and  $\sigma_i$  respectively indicate the standard deviations of the variable in cluster  $l$  and the whole data set, while  $C$  shows the total number of clusters. A high CD value calculated for a variable means that the variable has high significance when it occurs in different clusters.

However, these methods can give quite different order of importance in estimates. In other words, while a variable is found to be important for an index, it may have a lower

significance for other indexes. This inconsistency poses problems in interpreting the estimation results. Hence, we use all four techniques mentioned above, namely SI, RI, CD, and SRC following the literature. Then, we also calculate two different overall to avoid any contradictory results. The Overall Index (1) is calculated with the following steps:

- 1- First, four different index values are converted into percentage values. For this, the highest value of each index is accepted as 100 and all other values are calculated based on this value. The main purpose of doing this is to get a chance to compare different indices from the same unit.
- 2- As each index is expressed as a percentage, the following calculation is made so that each index has an overall weight equal to:

$$Overall\ Index(1) = \frac{X_i(SI) + X_i(RI) + X_i(CD) + X_i(SRC)}{4} \quad (2.10)$$

where  $X_i$  represents the SI, RI, CD and SRC values of the variable  $i$ .

The Overall Index (2) is calculated as follows:

$$Overall\ Index(2) = \frac{SI - \mu_{SI}}{\sigma_{SI}} + \frac{RI - \mu_{RI}}{\sigma_{RI}} + \frac{CD - \mu_{CD}}{\sigma_{CD}} + \frac{SRC - \mu_{SRC}}{\sigma_{SRC}} \quad (2.11)$$

where  $\sigma_{SI}$ ,  $\sigma_{RI}$ ,  $\sigma_{CD}$  and  $\sigma_{SRC}$  show the standard deviations for the SI, RI, CD and SRC indexes, respectively.  $\mu_{SI}$ ,  $\mu_{RI}$ ,  $\mu_{CD}$  and  $\mu_{SRC}$  indicate the means of the SI, RI, CD and SRC indexes, respectively. Here the main purpose of dividing the indices into their standard deviations by subtracting their averages is to standardize the indices and ensure that no factor dominates the overall index. In other words, the effect of extreme results is minimized with the aim of obtaining more consistent results. Similarly, indexing is a frequently used method in the crisis literature.<sup>2</sup>

Finally, the SOM's performance matrix is used to determine the factors that cause the European Debt Crisis. The SOM forecast performance matrix is expressed as follows: The success of predicting crisis and noncrisis episodes after SOM estimates are expressed using the above matrix. According to this, the percentage of correctly estimated debt crisis periods is calculated as  $TP / (TP + TN)$ , while the percentage of correctly estimated non-debt crisis periods is calculated as  $TN / (FP + TN)$ .

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<sup>2</sup> For more information on the different indexing methods, see Ari and Cergibozan (2016).

**Table 2.5.** SOM Forecast Performance Matrix

		Actual Value Obtained from FSI		Total
		Debt Crisis	No Debt Crisis	
	Debt Crisis	True Positive ( <i>TP</i> )	False Positive ( <i>FP</i> )	<i>TP + FP</i> (A)
SOM Predicted Results	No Debt Crisis	False Negative ( <i>FN</i> )	True Negative ( <i>TN</i> )	<i>FN + TN</i> (B)
	Total	<i>TP + FN</i> (C)	<i>FP + TN</i> (D)	

**Note:** A: All predicted debt crises, B: All predicted non-debt crises, C: All actual crises, D: All actual non-debt crises

### 2.4.2. Multivariate Logit Model

This sub-section presents the logit model which is used to test the statistical significance of the variables found to be significant in the SOM analysis in explaining the emergence of the European debt crisis. Logit method is widely used in crisis literature (e.g. Eliasson and Kreuter, 2001; Kumar et al., 2003; Lestano et al., 2005; Bussiere and Fratzscher, 2006; Candelon et al., 2012). Since crises have a nonlinear structure, logit models, nonlinear by nature, are frequently used in crisis estimations. As a dependent variable in the logit model, the Fiscal Stress Index is converted into a binary variable. According to this, the Fiscal Stress Index has a value of "1" for values above the threshold and "0" for other cases. "1" refers to debt crisis periods while "0" means normal periods.

Logit models are known as binary selection or qualitative response models, and the resultant  $Y$  of these models is "1" when the event occurs, and "0" otherwise. In this study, the event can be expressed as the occurrence or non-occurrence of a debt crisis. The linear probability model is the simplest binary-choice model, and in these models the likelihood of an occurrence of event is defined as a linear function depending on  $p$ , an explanatory variable or variables (Dougherty, 2007):

$$p_i = p(Y_i = 1) = \beta_1 + \beta_2 X_i \quad (2.12)$$

Here, the  $p$  value cannot be observed. In this case, the only data is the model's result,  $Y$ . In linear probability models, a dummy variable is used for this dependent variable. Unfortunately, linear probability models have significant shortcomings. The first shortcoming is confronted as problems related to the error term. Generally, there are two non-statistical and random parts of the dependent variable  $Y_i$  for observation  $i$ . The non-stochastic part depends on the  $X_i$  variable and the parameters and is equal to the conditional expected value of  $Y_i$ ,  $E(Y_i | X_i)$ . Here the random part is the error term.

$$Y_i = E(Y_i | X_i) + u_i \quad (2.13)$$

Calculating the non-stochastic part for observation  $i$  is quite simple because  $Y$  can only take two values, 1 with  $p_i$  probability and 0 with  $(1 - p_i)$  probability:

$$E(Y_i) = 1 \times p_i + 0 \times (1 - p_i) = p_i = \beta_1 + \beta_2 X_i \quad (2.14)$$

The expected value of observation  $i$  is  $\beta_1 + \beta_2 X_i$ , meaning that the model can be rewritten as follows:

$$Y_i = \beta_1 + \beta_2 X_i + u_i \quad (2.15)$$

The probability function is, thus, the simultaneous non-stochastic part of the relationship between  $Y$  and  $X$ . From this perspective, the error term must be  $(1 - \beta_1 - \beta_2 X_i)$  in order for the  $Y_i$  result to take the value 1. For the model result to be 0, the error term must be  $-\beta_1 - \beta_2 X_i$ . So, the distribution of the error term consists of only two values, and this distribution is not normal or even continuous. This means that standard errors and general test statistics are invalid. In addition to this, the two values for error distribution vary with  $X$ , so the distribution is also heteroscedastic. The population variance of  $u_i$  can be shown as  $(\beta_1 + \beta_2 X_i)(1 - \beta_1 - \beta_2 X_i)$  which varies with  $X_i$  (Dougherty, 2007).

Both the logit and probit model approaches can overcome the limitation of the linear probability model whose negative and positive estimates values are greater than 1. This constraint is overcome by using a function that effectively transforms the regression function. After this transformation, values adjusted to the model are limited to range between 0 and 1. The visually adjusted regression model is S-shaped as opposed to linear probability models. The logistic function  $F$ , which is the function of any  $z$ , is expressed as follows (Brooks, 2014):

$$F(z_i) = \frac{e^{z_i}}{1 + e^{z_i}} = \frac{1}{1 + e^{-z_i}} \quad (2.16)$$

where  $e$  is exponential under the logit approach. The main reason for naming the model this way is that the  $F$  function is a cumulative logistic distribution. Thus, the predicted logistic model is as follows:

$$P_i = \frac{1}{1 + e^{-(\beta_1 + \beta_2 x_{2i} + \dots + \beta_k x_{ki} + u_i)}} \quad (2.17)$$

where  $P_i$  is the probability that the result is  $\gamma_i = 1$ . In the framework of the logistic model, 0 and 1 are the function's asymptotes. Hence, even if the probabilities never drop to exactly 0 or reach 1, they can converge. In Equation 2.16, when  $z_i$  approaches infinity,  $e^{-z_i}$  approaches zero and  $1/(1 + e^{-z_i})$  approaches 1; when  $z_i$  approaches negative infinity,  $e^{-z_i}$  approaches

infinity and  $1/(1+e^{-z_i})$  approaches 0. This model is not explicitly linear and cannot be linearized with any transformation. Therefore, it cannot be predicted using the ordinary least squares (OLS), but with maximum likelihood estimation (Brooks, 2014). Note that Logit and probit regressions often produce similar results (Stock & Watson, 2010).

Some important problems are encountered when using the logit model in empirical studies. The first one is to determine the optimal threshold for the fiscal stress index to transform it into binary crisis variable. Another problem is how to determine the critical value (cut-off) used to assess the predictive performance of the estimated model. Choosing a lower threshold value would raise the number of correctly predicted crises, but at the expense of increasing the number of false alarms (Type II errors). By contrast, choosing a higher threshold value would reduce the number of false alarms, but at the expense of increasing the number of missed crises (Type I errors). Here, the modeler solves this trade-off problem by defining a threshold probability according to the relative importance given to Type I versus Type II errors (Bussierre & Fratzscher, 2006). Researchers often set a value of 0.5 as the critical value. However, as stated by Chui (2002) the sample is relatively unbalanced in favor of noncrisis periods. Therefore, choosing a threshold value of 0.5 would underestimate the predictive power of the EWS model (Esquivel & Larrain, 1998). For this reason, lower critical values (i.e. 0.25 and 0.2) are used to evaluate the predictive performance of the models

Finally, the performance evaluation matrix of the logit model is used to determine the factors that have led to the European debt crisis. The logit forecast performance matrix is similar to that of SOM. The success of the logit model is calculated by taking into account the different cut-off values (0.50, 0.25, 0.20) as noted above, unlike the SOM. However, the correct percent estimate of the crisis periods is calculated as  $TP / (TP + FN)$  and the estimated percentage of normal periods as  $TN / (FP + TN)$ .

**Table 2.6.** Logit Forecast Performance Matrix

		Actual Value Obtained from FSI		Total
		Debt Crisis	No Debt Crisis	
Logit Results	Debt Crisis	True Positive ( <i>TP</i> )	False Positive ( <i>FP</i> )	<i>TP + FP</i> (A)
	No Debt Crisis	False Negative ( <i>FN</i> )	True Negative ( <i>TN</i> )	<i>FN + TN</i> (B)
	Total	<i>TP + FN</i> (C)	<i>FP + TN</i> (D)	

**Note:** A: All predicted debt crisis, B: All predicted non-debt crisis, C: All actual crisis, D: All actual non-crisis



### 2.4.3. Panel Markov Regime-Switching Model

The Markov model is the third method used in this chapter. This estimation technique is also frequently used in recent papers on financial crises (i.e. Martinez-Peria, 2002; Arias and Erlandsson, 2004, Alvarez-Plata and Schrooten, 2006; Brunetti et al., 2008; Candelon et al., 2012). One of the main reasons that motivate economists to employ the Markov approach is due to the transformation of the continuous crisis indicator into a binary variable through arbitrary threshold values. Because, this transformation may lead to a loss of information regarding crisis duration. The Markov model addresses this issue, as the crisis index is used in a continuous format, unlike the logit model. In other words, the Markov model does not require a prior dating of crises; instead, identifying crisis periods are determined within the model itself (Abiad, 2007). Therefore, event-based studies still use logit/probit models. Besides, the Markov model in which the regimes (crisis and noncrisis) are modeled within the model without an arbitrary cut-off value.

In addition, as stated in Fratzscher (2003) and Alvarez-Plata and Schrooten (2006), the Markov model allows measuring the impact of non-observed factors such as shifts in investors' expectations on the occurrence of crises. Therefore, the Markov method is preferred to logit model in order to include the factors that cannot be observed but that have an effect on debt crises in estimations. The Markov model may be written as follows for the purpose of the study:

$$\begin{aligned}
 y_t &= \alpha_{S_t} + x_t' \beta_{S_t} + u_t & t = 1, \dots, T \\
 u_t &\sim i.i.d.(0, \sigma_{S_t}^2) & \alpha_{S_t} = \alpha_0(1 - S_t) + \alpha_1 S_t \\
 \beta_{S_t} &= \beta(1 - S_t) + \beta_1 S_t & \sigma_{S_t}^2 = \sigma_0^2(1 - S_t) + \sigma_1^2 S_t
 \end{aligned} \tag{2.18}$$

where  $y$  shows the fiscal stress index, and  $x$  is the matrix of explanatory variables.  $\alpha$ ,  $\beta$  and  $\sigma$  are assumed to depend on the invisible state variable.

Let  $s_t$  be a random variable that can take only integer values between  $\{1, 2, \dots, N\}$ . Assuming that the probability of  $s_t$  being equal to a certain value  $j$  depends only on the value of  $s_{t-1}$  (Hamilton, 1994), we have:

$$P\{s_t = j \mid s_{t-1} = i, s_{t-2} = k, \dots\} = P\{s_t = j \mid s_{t-1} = i\} = p_{ij} \tag{2.19}$$

Such a process  $\{p_{ij}\}_{i,j=1,2,\dots,N}$  is an  $N$ -state Markov chain. Transition probability  $p_{ij}$  gives the probability of occurrence of  $j$  following  $i$ . Note that:

$$p_{i1} + p_{i2} + \dots + p_{iN} = 1 \tag{2.20}$$

Generally, it is easy to show the transition probabilities ( $N \times N$ ) as the transition matrix  $P$ :

$$P = \begin{bmatrix} p_{11} & p_{21} & \cdots & p_{N1} \\ p_{12} & p_{22} & \cdots & p_{N2} \\ \vdots & \vdots & \cdots & \vdots \\ p_{1N} & p_{2N} & \cdots & p_{NN} \end{bmatrix} \quad (2.21)$$

The transition probability of the element corresponding to row  $j$  and column  $i$  of matrix  $p$  is  $p_{ij}$ . Autoregressive processes, in which the autoregressive parameters are variable, are considered to be a consequence of a regime-switching variable. Here, the regime itself is defined as a result of an unobserved Markov chain. Note that the special case of these processes is independent and identically distributed.

Let  $s_t$  ( $s_t = 1, 2, \dots, \text{or } N$ ) be an unobserved random variable that defines the regime at time  $t$  for a given period of time with  $N$  possible distributions. While the process is in regime 1, observed variable  $y_t$  has  $N(\mu_1, \sigma_1^2)$  distribution; when the process is in regime 2, the observed variable  $y_t$  has  $N(\mu_2, \sigma_2^2)$  distribution, and so on. Thus, for the  $j$  value of the  $s_t$  variable, the conditional density function of  $y_t$  (Hamilton, 1994) is:

$$f(y_t | s_t = j; \theta) = \frac{1}{\sqrt{2\pi}\sigma_j} \exp \left\{ \frac{-(y_t - \mu_j)^2}{2\sigma_j^2} \right\} \quad (2.22)$$

for  $j = 1, 2, \dots, N$  where  $\theta$  is the vector of population parameters including  $\mu_1, \dots, \mu_N$  and  $\sigma_1^2, \dots, \sigma_N^2$ . The unobservable regime is based on a probability distribution of  $\{s_t\}$  and the unconditional probability of  $s_t$  being  $\pi_j$  at the  $j$  value is:

$$P\{s_t = j; \theta\} = \pi_j \text{ for } j = 1, 2, \dots, N. \quad (2.23)$$

$\pi_1, \dots, \pi_N$  probabilities are also defined for  $\theta$ :

$$\theta = (\pi_1, \dots, \pi_N, \sigma_1^2, \dots, \sigma_N^2, \pi_1, \dots, \pi_N)'. \quad (2.24)$$

For example, to find the combined event of probabilities at  $s_t = j$  and  $y_t$  between  $[c, d]$ :

$$p(y_t, s_t = j; \theta) = f(y_t | s_t = j; \theta) \cdot P\{s_t = j; \theta\} \quad (2.25)$$

In this case, one must integrate  $y_t$  according to all values between  $c$  and  $d$ . Equation 2.25 is called the combined density distribution function of  $y_t$  and  $s_t$ . According to Equations 2.22 and 2.23, this function is rewritten as follows:

$$p(y_t, s_t = j; \theta) = \frac{\pi_j}{\sqrt{2\pi}\sigma_j} \exp \left\{ \frac{-(y_t - \mu_j)^2}{2\sigma_j^2} \right\} \quad (2.26)$$

The unconditional density function of  $y_t$  can be found through Equation 2.26 for all values of  $j$ :

$$\begin{aligned}
f(y_t; \theta) &= \sum_{j=1}^N p(y_t, s_t = j; \theta) \\
&= \frac{\pi_1}{\sqrt{2\pi}\sigma_1} \exp\left\{-\frac{(y_t - \mu_1)^2}{2\sigma_1^2}\right\} \\
&\quad + \frac{\pi_2}{\sqrt{2\pi}\sigma_1} \exp\left\{-\frac{(y_t - \mu_2)^2}{2\sigma_2^2}\right\} + \dots \\
&\quad + \frac{\pi_N}{\sqrt{2\pi}\sigma_N} \exp\left\{-\frac{(y_t - \mu_N)^2}{2\sigma_N^2}\right\}
\end{aligned} \tag{2.27}$$

As the  $s_t$  regime is not observed, the corresponding density function describing the observed real data  $y_t$  is the function of Equation 2.27. If distributions of the regime variable  $s_t$  at time  $t$  are independent and identically distributed, the loglikelihood function of the observed data can be calculated as follows from Equation 2.27:

$$\ell(\theta) = \sum_{t=1}^T \log f(y_t; \theta) \tag{2.28}$$

The maximum likelihood estimation of  $\theta$  for  $j = 1, 2, \dots, N$  according to constraints  $\pi_1 + \pi_2 + \dots + \pi_N = 1$  and  $\pi_j \geq 0$  is obtained by maximizing Equation 2.28. This calculation can be done by numerical methods or EM algorithms (Hamilton, 1994).

Our study calculates the LR test upper bound probabilities while examining linear models against the regime switching model (Cevik et al., 2014; Davies, 1987). One can test whether the number of regimes and the use of the nonlinear model are correct. The Panel-Markov regime switching model is preferred over time series regime switching models in determining the factors that cause debt crisis. The main reason for this is that crisis regimes in the Europe ensure that each country is included simultaneously. We also choose the Panel-Markov regime switching model in our study because it has not been used in studies dealing with financial crises yet. Following Asea and Blomberg (1998) and Chen (2007a, 2007b, 2008), we estimate the Panel Markov model where  $T$  ( $t = 1, \dots, T$ ) indicates the time period,  $i$  ( $i = 1, \dots, N$ ) the individual, and  $K$  ( $k = 1, \dots, K$ ) the properties of countries. To estimate the model, we consider the following equation:

$$y_{it} = c_i + \sum_{k=1}^K \beta_k X_{kit} + \varepsilon_{it} \tag{2.29}$$

In the equation,

$$y_i = \begin{bmatrix} y_{i1} \\ y_{i2} \\ \vdots \\ y_{iT} \end{bmatrix}, \quad P = \begin{bmatrix} X_{1i1} & X_{2i1} & \cdots & X_{ki1} \\ X_{1i2} & X_{2i2} & \cdots & X_{ki2} \\ \vdots & \vdots & \cdots & \vdots \\ X_{1iT} & X_{2iT} & \cdots & X_{kiT} \end{bmatrix}, \quad j_T = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}, \quad \varepsilon_i = \begin{bmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \\ \vdots \\ \varepsilon_{iT} \end{bmatrix} \quad (2.30)$$

where  $y_i$ ,  $j_T$  and  $\varepsilon_i$  are the  $T \times 1$  dimensional row matrix and  $X_i$  the  $T \times K$  dimensional matrix. If Equation 2.29 is rewritten:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} j_T & 0 & \cdots & 0 \\ 0 & j_T & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & j_T \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_N \end{bmatrix} + \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_N \end{bmatrix} \beta + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_N \end{bmatrix} \quad (2.31)$$

Or, we have:

$$Y = Dc + X\beta + \varepsilon \quad (2.32)$$

where

$$D = [d_1 \ d_2 \ \cdots \ d_N] = \begin{bmatrix} j_T & 0 & \cdots & 0 \\ 0 & j_T & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & j_T \end{bmatrix} \quad (2.33)$$

where  $\beta = [\beta_1 \ \beta_2 \ \cdots \ \beta_N]$  is the  $K \times 1$  dimensional row vector and  $D$  is the  $NT \times N$  dimensional matrix. Therefore, the above equation is called the Dummy Variable Least Squares Model. To obtain the panel Markov, the regime switching mechanism needs to be added to the least squares model with the dummy variable. Accordingly, the panel Markov can be written as follows:

$$Y = Dc(j) + X\beta(j) + \varepsilon(j), \text{ for } S_t = j \quad (2.34)$$

where  $\varepsilon(j) \sim N(0, \sigma^2(j))$  and  $S_t$  indicates the unobservable state variable.

$$G = \begin{bmatrix} \text{prob}(S_t = 1 | S_{t-1} = 1) & \text{prob}(S_t = 1 | S_{t-1} = 2) \\ \text{prob}(S_t = 2 | S_{t-1} = 1) & \text{prob}(S_t = 2 | S_{t-1} = 2) \end{bmatrix} \quad (2.35)$$

In this study, a normal period for  $S_t$  has a value of 1, or periods when there is no debt crisis, whereas “2” means a debt crisis period. In order to evaluate the performance of the panel Markov model in predicting debt crises, the average filtered probabilities have to be calculated among  $N$  individuals:

$$\text{ave Pr}(S_t = j | \Phi^t) = \frac{1}{N} \sum_1^N \text{Pr}(S_t = j | \Phi^t) \quad (2.36)$$

where  $\Phi^t$  is the information set consisting of the history of all variables up to time  $t$ .

Finally, as in other models, the performance matrix is used for determining the indicators that cause the European debt crisis given by the Markov model (see Table 2.7). Following the Markov estimates, we assess the prediction performance of model which is expressed using this matrix. Like the logit model, the Markov model forecast performance is calculated by considering different cut-off values. Here again, the percent correction estimate of the crisis periods is calculated as  $TP / (TP + FN)$  and the corrected estimate of the normal periods as  $TN / (FP + TN)$ .

**Table 2.7.** MRSM Forecast Performance Matrix

		Actual Value Obtained from FSI		Total
		Debt Crisis	No Debt Crisis	
	Debt Crisis	True Positive ( $TP$ )	False Positive ( $FP$ )	$TP + FP$ (A)
MRSM Results	No Debt Crisis	False Negative ( $FN$ )	True Negative ( $TN$ )	$FN + TN$ (B)
	Total	$TP + FN$ (C)	$FP + TN$ (D)	

**Note:** A: All predicted debt crisis, B: All predicted non-debt crisis, C: All actual crisis, D: All actual non-crisis

## 2.5. Estimation Results

SOM is the first estimation technique that we employ in this chapter and it allows us to consider a large number of 51 indicators. The results obtained from the SOM analysis are shown in Figures 2.5, 2.6, 2.7, 2.8, and 2.9. As seen in below Figures, each variable has its own component matrix with two-dimensional visuality. One can then easily observe, via temperature maps, the value that each variable takes in crisis and noncrisis periods, obtained from the Davies-Bouldin Index, and the scale on the right-hand side of each graph (component matrix) increases the readability. To be more precise, each graph in Figures 2.5, 2.6, 2.7, 2.8, and 2.9 represents the values for the different neurons of the respective variable using a color code ranging from dark blue (low values) to dark red (high values).

Figure 2.5 suggests that countries in debt crisis have low growth rates, low export-to-GDP ratio, high inflation and unemployment rates, and high budget deficit-to-GDP ratios. On the other hand, FDI over GDP, the ratio of health expenditures to public expenditures, and total health expenditures do not seem to have a significant impact on debt crisis in EU-15 countries. Figure 2.6 indicates that countries in crisis have high budget deficits, low reserves, low shares of public revenues and taxes to GDP, low credit ratings, and low political stability

risk-rating values. Savings/expenditures, the ratio of imports to GDP, and the ratio of foreign trade balance to GDP do not seem to have a effect on the occurrence of the European debt crisis.

Figure 2.7 indicates that higher public and private external debt as the share of GDP, higher household debt, and higher non-performing loans lead to debt crisis in EU-15. However, it seems that there is no relationship between the occurrence of debt crisis and OFDI over GDP, Capital over Asset, and TCRR. Figure 2.8 shows the impact of governance indicators on the outbreak of the European debt crisis. We observe in the Figure that high income inequality, high corruption, low government effectiveness, low political stability (PSVATT), low Regulatory Quality, low Rule of Law, and low Voice and Accountability are increase the crisis probability. On the other hand, indicators related to education do not seem to have an impact on debt crisis. Hence, one may argue that the EU-15 have a similar structure in terms of education level. Finally, Figure 2.9 shows that the likelihood of the debt crisis jumps with an increase in age dependency ratio, bank leverage, M2 over GDP, banking crisis index, interest payments, and financial pressure index.

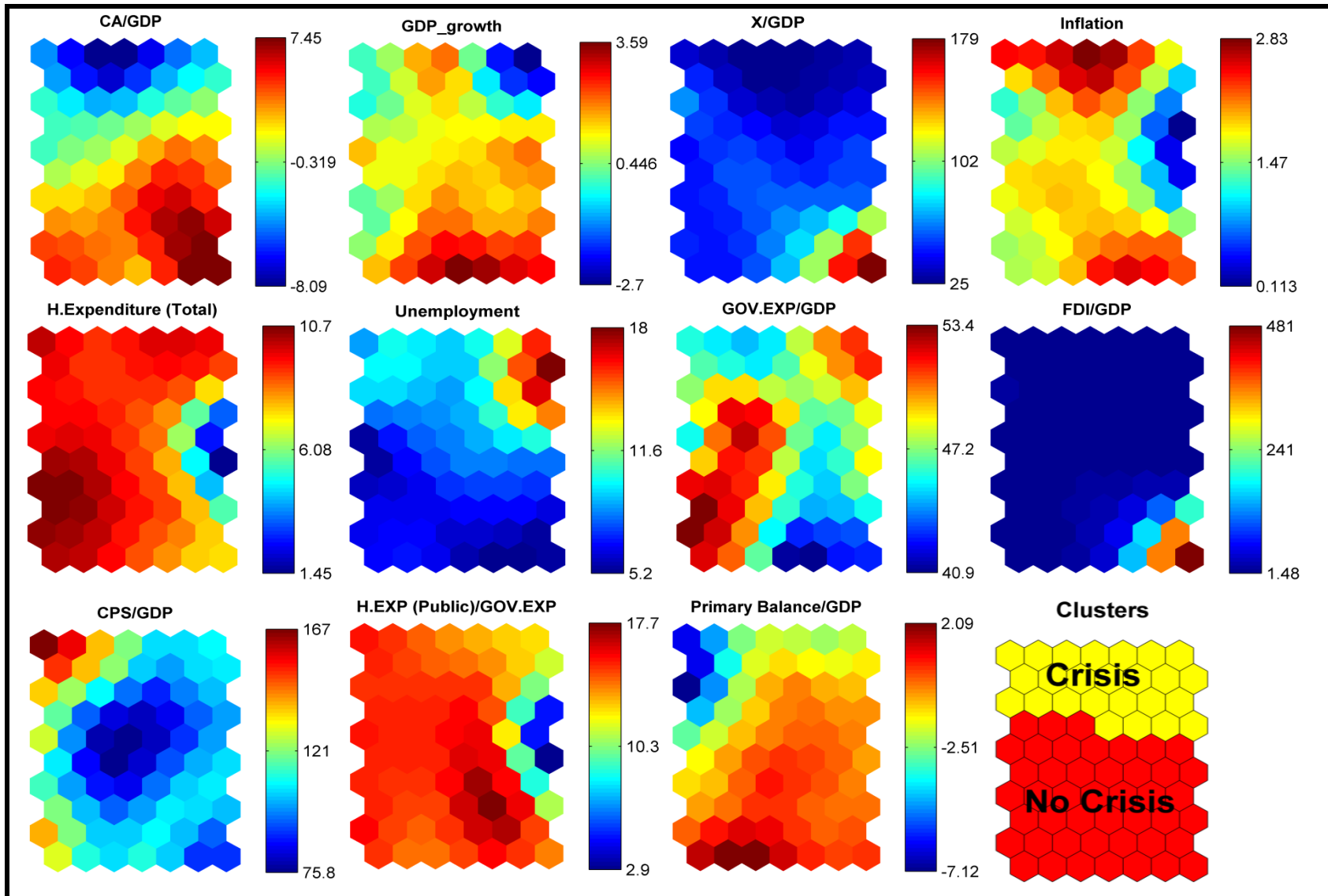
We can clearly claim that the SOM results are consistent with the economic expectations. In order to clearly reveal the unobserved relationships of the component matrixes, we present in Table 2.8 the mean and standard deviation of each leading indicator in crisis and noncrisis periods. Overall, results from the SOM analysis are consistent with the results presented in Table 2.8. for instance, the growth rates of countries in crisis zone tend to be low. The fact that these countries have low growth rates has brought two main problems. The first is the decrease in these countries' tax revenues and the second is increasing unemployment which led to a rise in both social transfers and unemployment benefits that resulted in higher budget deficits. This is indeed confirmed by the SOM results since the indicators related to the budget balance clearly deteriorated before and during the crisis period and the debt ratios of both public and private sectors increased.

Besides, with the decline in growth rates and the increase in unemployment rates, income level and savings rate also decreased in these countries. Along with a decline in income levels, import expenditures and export revenues also decreased, since intra-EU trade in goods and services is quite high. Moreover, economic slowdown is also associated with a dramatic increase in the ratio of nonperforming loans over total loans. As a result, the deterioration of banking balance sheets can trigger a banking crisis that in turn leads to massive bailout programs that exert severe constraints on public finances. Specifically, the

banking crisis index rises to high levels before and during debt crisis episodes. In such periods, the increase in risk premiums leads to higher interest rates, implying a vicious cycle for crisis countries.

Our results show that the governance indicators do matter in the occurrence of debt crises. This is why some European countries (i.e. France) that have experienced significant deterioration in macroeconomic and financial variables have been affected from the crisis to a lower extent and also could exit from the crisis more quickly than Greece, Italy, Spain, Portugal, and Ireland which had exhibited bad performances in their governance indicators.

Table 2.9 presents the ranking of 51 explanatory variables according to six different indexes. When we check the results of two overall indexes in Table 2.9, we observe that the ratio of nonperforming loans over total loans, primary balance over GDP, public sector borrowing requirement, Corruption, Cash Balance over GDP, Unemployment, Voice and Accountability, Regulatory Quality, Rule of Law, GDP growth, Government Effectiveness, and Cyclically Adjusted Balance over GDP are the most important 10 indicators in explaining the outbreak of the European debt crisis. These 10 variables will be used in both logit and Markov estimation.



**Figure 2.5.** Net output of a SOM analysis: clusters based on unified distance matrix (U-matrix) and component matrixes for 11 variables.



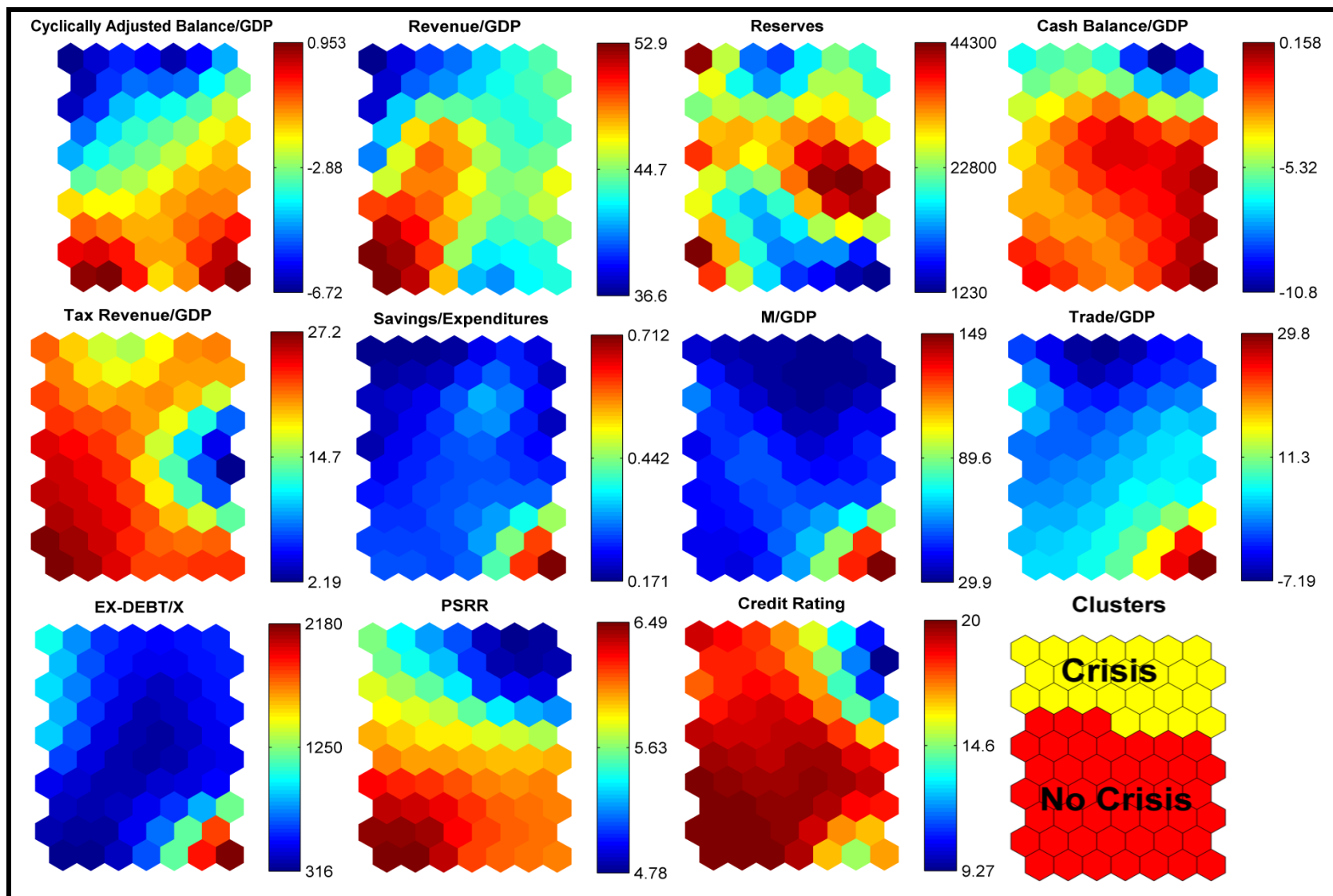


Figure 2.6. Net output of a SOM analysis: clusters based on unified distance matrix (U-matrix) and component matrixes for 11 variables.

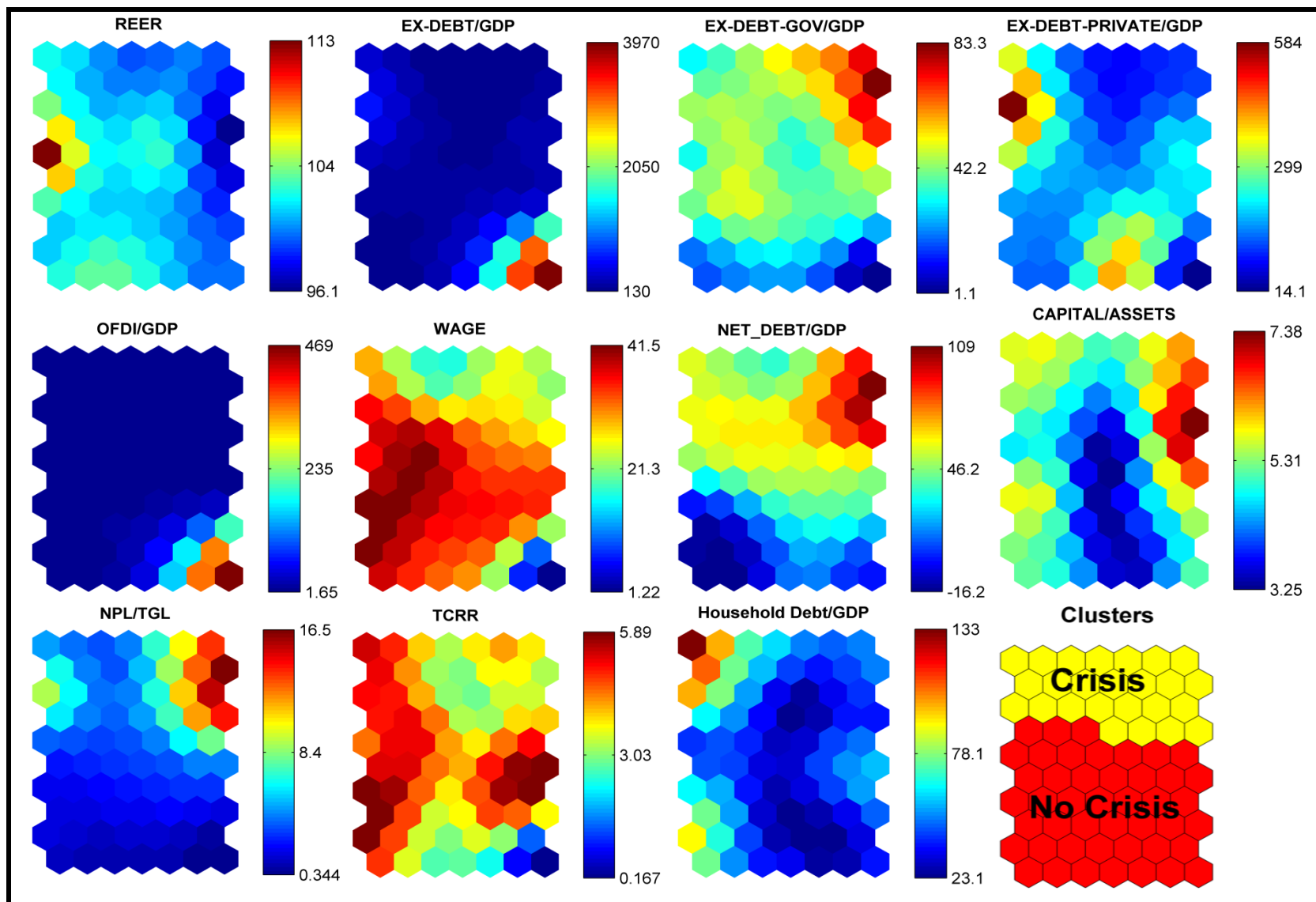


Figure 2.7. Net output of a SOM analysis: clusters based on unified distance matrix (U-matrix) and component matrixes for 11 variables.

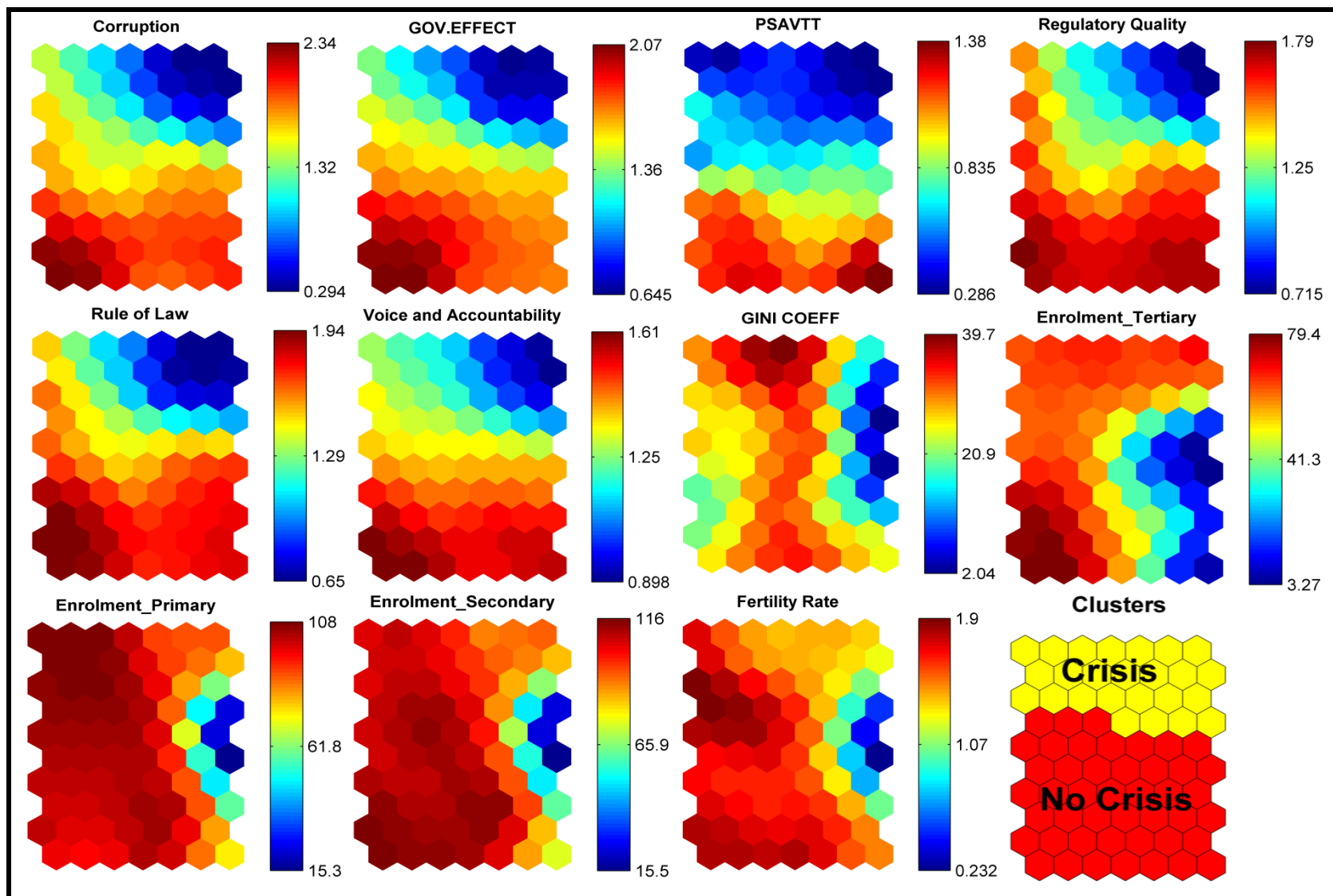


Figure 2.8. Net output of a SOM analysis: clusters based on unified distance matrix (U-matrix) and component matrixes for 11 variables.

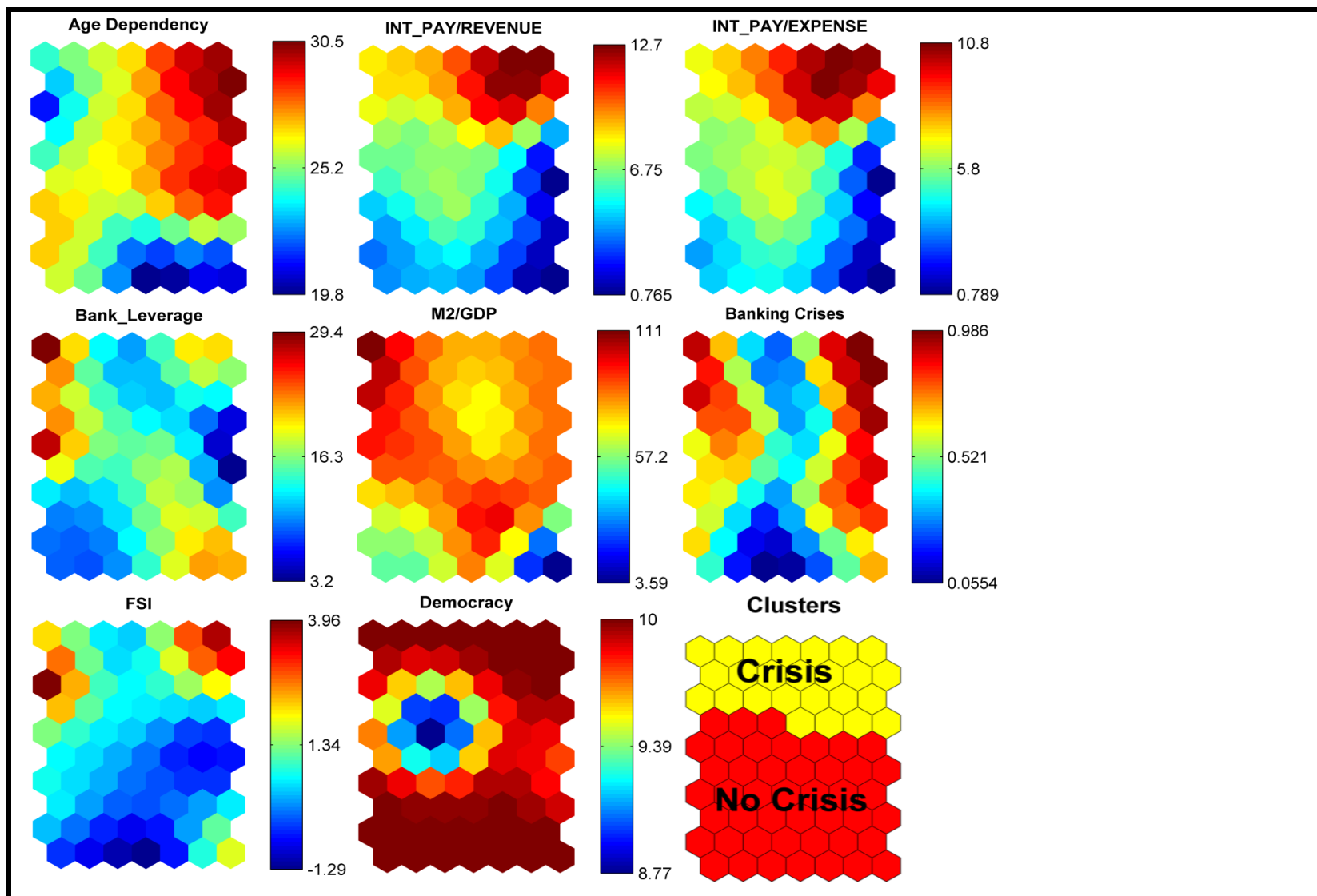


Figure 2.9. Net output of a SOM analysis: clusters based on unified distance matrix (U-matrix) and component matrixes for 8 variables.

**Table 2.8.** Self-Organizing Map-Based Cluster Results

VARIABLES	NO CRISIS ( <i>M</i> )	CRISIS ( <i>M</i> )	NO CRISIS ( <i>SD</i> )	CRISIS ( <i>SD</i> )
Frequency (%)	64.290	35.710	64.290	35.710
CA/GDP	3.566	-3.874	3.852	4.569
GDP Growth	1.754	0.066	2.527	3.017
X/GDP	64.514	35.858	43.348	23.399
Inflation	1.725	1.918	1.125	1.711
H. Expenditure (Total)/GDP	9.547	9.475	1.109	1.345
Unemployment	6.705	11.762	2.009	6.175
GOV.EXP/GDP	48.450	47.522	6.285	5.095
FDI/GDP	55.846	3.998	169.145	6.140
CPS/GDP	104.953	121.710	34.557	35.854
H.EXP (Public)/GOV.EXP	15.651	14.096	2.0931	1.941
Primary Balance/GDP	0.115	-2.949	2.264	4.919
Cyclically Adjusted Balance /GDP	-1.184	-5.046	2.289	3.683
Revenue/GDP	47.309	40.774	5.796	4.403
Reserves	27,640.150	20,564.050	24,962.110	23,407.870
Cash Balance/GDP	-1.956	-6.317	2.271	5.378
Tax Revenue/GDP	23.469	19.660	5.451	6.406
Savings/Expenditures	0.308	0.218	0.147	0.117
M/GDP	57.648	36.955	35.300	17.497
Trade/GDP	6.866	-1.097	8.773	7.232
EX-DEBT/X	674.356	670.413	588.113	269.289
PSRR	6.154	5.171	0.303	0.530
Credit Rating	19.254	15.310	3.091	4.645
REER	102.214	100.212	6.097	3.733
EX-DEBT/GDP	644.485	266.116	1188.315	257.153
EX-DEBT-GOV/GDP	34.552	54.269	19.030	30.138
EX-DEBT-PRIVATE/GDP	216.908	211.008	149.895	254.582
OFDI/GDP	60.280	4.005	159.224	6.483
WAGE	37.241	24.375	6.667	9.795
NET_DEBT/GDP	23.572	77.249	40.604	37.454
CAPITAL/ASSETS	5.532	6.149	1.567	1.330
NPL/TGL	2.177	8.817	1.874	7.942
TCRR	5.945	4.367	1.708	2.025
Household Debt/GDP	71.747	108.856	27.480	39.372
Corruption	1.922	0.817	0.367	0.631
GOV.EFFECT	1.790	0.981	0.246	0.445
PSAVTT	1.011	0.421	0.333	0.423
Regulatory Quality	1.615	1.082	0.218	0.378
Rule of Law	1.752	1.014	0.213	0.476
Voice and Accountability	1.483	1.109	0.138	0.205
GINI COEFF	35.677	38.523	2.752	2.888
Enrollment Tertiary	66.145	69.360	17.513	13.812
Enrollment Primary	103.028	105.829	4.228	5.458
Enrollment Secondary	111.447	108.453	14.072	11.030
Fertility Rate	1.714	1.508	0.197	0.266
Age Dependency	25.413	26.806	3.725	4.334
INT_PAY/REVENUE	4.695	10.524	2.241	3.072
INT_PAY/EXPENSE	4.571	9.026	2.100	2.607
Bank Leverage	15.474	17.058	8.312	11.362
M2/GDP	77.711	87.144	23.254	18.801
FSI	0.038	1.981	2.394	3.154
Democracy	9.772	9.971	0.566	0.170
Banking Crises	0.520	0.691	0.502	0.465

**Table 2.9.** List of Significant Variables Ranked Based on Four Indices (SI—Structuring Index, RI—Relative Importance, CD—Cluster Description, and SRC—Spearman’s Rank Correlation) in a SOM

Rank	SI	Values	RI	Values	CD	Values	SRC	Values
1	GOV.EFFECT	1328.206	Primary Balance/GDP	2.487	NPL/TGL	4.238	GDP growth	-0.639***
2	PSRR	1320.574	EX-DEBT-GOV/GDP	2.370	Unemployment	3.074	Primary Balance/GDP	-0.527***
3	Voice and Accountability	1313.764	PSRR	2.347	Cash Balance/GDP	2.368	Cash Balance/GDP	-0.428***
4	Rule of Law	1313.293	Corruption	2.329	Rule of Law	2.235	Cyclically Adjusted Balance /GDP	-0.398***
5	Corruption	1310.869	NET_DEBT/GDP	2.283	Primary Balance/GDP	2.173	NPL/TGL	0.386***
6	Regulatory Quality	1282.465	Unemployment	2.231	GOV.EFFECT	1.805	Banking Crises	0.373***
7	CA/GDP	1241.308	Regulatory Quality	2.194	PSRR	1.746	EX-DEBT/X	0.341***
8	INT_PAY/REVENUE	1215.579	M2/GDP	2.194	Regulatory Quality	1.736	CA/GDP	-0.324***
9	PSAVTT	1192.348	CAPITAL/ASSET	2.182	Corruption	1.722	Bank Leverage	0.323***
10	INT_PAY/EXPENSE	1176.359	INT_PAY/EXPENSE	2.181	EX-DEBT-PRIVATE/GDP	1.698	GOV.EFFECT	-0.313***
11	NET_DEBT/GDP	1097.219	Cash Balance/GDP	2.168	Cyclically Adjusted Balance /GDP	1.609	PSRR	-0.306***
12	Trade/GDP	1048.616	GINI COEFF	2.136	EX-DEBT-GOV/GDP	1.584	Voice and Accountability	-0.302***
13	Age Dependency	1023.416	Reserves	2.132	Inflation	1.522	NET_DEBT/GDP	0.302***
14	Cyclically Adjusted Balance /GDP	992.023	Enrollment Tertiary	2.131	Credit Rating	1.503	Savings/Expenditures	-0.295***
15	WAGE	983.387	CPS/GDP	2.127	Voice and Accountability	1.491	EX-DEBT-GOV/GDP	0.280***
16	Revenue/GDP	927.769	Bank Leverage	2.120	WAGE	1.469	INT_PAY/REVENUE	0.269***
17	Enrollment Tertiary	927.575	Banking Crises	2.114	Household Debt/GDP	1.433	Rule of Law	-0.268***
18	NPL/TGL	926.662	Voice and Accountability	2.097	INT_PAY/REVENUE	1.371	TCRR	-0.267***
19	Unemployment	908.386	GDP growth	2.085	Bank Leverage	1.367	Trade/GDP	-0.262***
20	X/GDP	907.778	EX-DEBT/GDP	2.078	Fertility Rate	1.350	OFDI/GDP	-0.260***
21	Tax Revenue/GDP	904.0651	Trade/GDP	2.057	FSI	1.317	Corruption	-0.255***
22	Fertility Rate	892.051	Enrollment Secondary	2.046	Enrollment Primary	1.291	Credit Rating	-0.255***
23	M/GDP	868.569	NPL/TGL	2.016	PSAVTT	1.270	M2/GDP	0.249***
24	Cash Balance/GDP	865.003	FDI/GDP	1.98	INT_PAY/EXPENSE	1.242	PSAVTT	-0.247***
25	Democracy	853.076	TCRR	1.977	H. Expenditure (Total)/GDP	1.213	Household Debt/GDP	0.231***
26	EX-DEBT-GOV/GDP	852.431	H.EXP (Public)/GOV.EXP	1.917	GDP growth	1.194	Unemployment	0.229***
27	GOV.EXP/GDP	833.429	H. Expenditure (Total)/GDP	1.908	CA/GDP	1.186	GOV.EXP/GDP	0.223***
28	EX-DEBT/X	822.099	Inflation	1.903	TCRR	1.185	Regulatory Quality	-0.211***
29	M2/GDP	813.392	OFDI/GDP	1.881	Tax Revenue/GDP	1.175	X/GDP	-0.192***
30	Credit Rating	810.121	Enrollment Primary	1.873	Age Dependency	1.163	Enrollment Primary	0.186**
31	Banking Crises	787.017	Age Dependency	1.854	GINI COEFF	1.045	M/GDP	-0.173**
32	H. Expenditure (Total)/GDP	774.519	Tax Revenue/GDP	1.849	CPS/GDP	1.038	INT_PAY/EXPENSE	0.171**
33	Savings/Expenditures	761.388	Cyclically Adjusted Balance /GDP	1.847	Reserves	0.938	GINI COEFF	0.166*
34	Bank Leverage	756.183	Revenue/GDP	1.835	Banking Crises	0.928	EX-DEBT/GDP	0.153**
35	EX-DEBT-PRIVATE/GDP	756.152	REER	1.829	H.EXP (Public)/GOV.EXP	0.927	Revenue/GDP	-0.152**
36	CPS/GDP	738.579	CA/GDP	1.801	NET_DEBT/GDP	0.922	H.EXP (Public)/GOV.EXP	-0.140*
37	GINI COEFF	712.864	Household Debt/GDP	1.791	CAPITAL/ASSETS	0.849	Age Dependency	0.105
38	Reserves	707.545	Credit Rating	1.759	Trade/GDP	0.824	Tax Revenue/GDP	-0.103
39	H.EXP (Public)/GOV.EXP	700.329	Fertility Rate	1.755	GOV.EXP/GDP	0.811	FDI/GDP	-0.101
40	Enrollment Secondary	683.320	GOV.EXP/GDP	1.745	M2/GDP	0.809	CPS/GDP	0.090
41	Primary Balance/GDP	682.901	Rule of Law	1.735	Savings/Expenditures	0.793	H. Expenditure (Total)/GDP	0.087
42	Enrollment Primary	667.923	X/GDP	1.730	Enrollment Tertiary	0.789	Reserves	-0.071
43	EX-DEBT/GDP	647.172	PSAVTT	1.691	Enrollment Secondary	0.784	Enrollment Secondary	0.061
44	GDP growth	642.788	GOV.EFFECT	1.672	Revenue/GDP	0.760	CAPITAL/ASSET	-0.059
45	CAPITAL/ASSETS	638.174	EX-DEBT/X	1.551	REER	0.612	WAGE	-0.058
46	FSI	615.079	FSI	1.541	X/GDP	0.540	Fertility Rate	-0.058
47	TCRR	611.866	INT_PAY/REVENUE	1.497	M/GDP	0.496	EX-DEBT-PRIVATE/GDP	0.034
48	Inflation	608.657	Savings/Expenditures	1.488	EX-DEBT/X	0.458	REER	0.024
49	Household Debt/GDP	567.960	M/GDP	1.477	Democracy	0.301	Democracy	-0.026
50	REER	564.612	Democracy	1.473	EX-DEBT/GDP	0.216	Enrollment Tertiary	-0.020
51	OFDI/GDP	531.554	WAGE	1.341	OFDI/GDP	0.041	Inflation	0.012
52	FDI/GDP	484.981	EX-DEBT-PRIVATE/GDP	1.193	FDI/GDP	0.036		

**Table 2.10.** List of Significant Variables Ranked Based on SRC (Crisis and Non-Crisis Periods)—Spearman’s Rank Correlation and Overall Indexes) in a SOM

Rank	SRC (Crisis)	Values	SRC (No crisis)	Values	Overall Index (1)	Values	Overall Index (2)	Values
1	GDP growth	-0.752***	Primary Balance/GDP	-0.543***	NPL/TGL	14.112	NPL/TGL	5.992
2	Banking Crises	0.547***	GDP growth	-0.510***	Primary Balance/GDP	12.135	Primary Balance/GDP	4.780
3	Household Debt/GDP	0.516***	Cyclically Adjusted Balance /GDP	-0.315**	Cash Balance/GDP	11.617	PSRR	4.769
4	EXDEBT/GDP	0.512***	Cash Balance/GDP	-0.284***	GDP growth	11.148	Corruption	4.257
5	EXDEBT/X	0.490***	Bank Leverage	0.263***	Unemployment	11.059	Cash Balance/GDP	3.969
6	Primary Balance/GDP	-0.476***	Trade/GDP	-0.259***	PSRR	10.725	Unemployment	3.902
7	GOV.EXP/GDP	0.471***	WAGE	0.251***	Rule of Law	10.508	Voice and Accountability	3.472
8	Bank Leverage	0.459***	Banking Crises	0.251***	GOV.EFFECT	10.221	Regulatory Quality	3.357
9	EXDEBTPRIVATE/GDP	0.401***	EXDEBT/X	0.239***	Corruption	10.185	Rule of Law	2.978
10	M2/GDP	0.393***	GOV.EXP/GDP	0.238***	Cyclically Adjusted Balance /GDP	10.128	GDP growth	2.645
11	Cash Balance/GDP	-0.333***	GINI COEFF	0.215**	Voice and Accountability	10.029	GOV.EFFECT	2.548
12	NPL/TGL	0.320***	Savings/Expenditures	-0.194**	Regulatory Quality	9.609	EX-DEBT-GOV/GDP	2.453
13	Savings/Expenditures	-0.314***	CA/GDP	-0.192**	CA/GDP	9.302	NET_DEBT/GDP	2.420
14	Enrollment Secondary	0.305**	NPL/TGL	0.192**	EX-DEBT-GOV/GDP	9.234	Cyclically Adjusted Balance /GDP	2.094
15	X/GDP	0.302**	EXDEBTGOV/GDP	0.172*	NET_DEBT/GDP	8.860	INT_PAY/EXPENSE	1.880
16	Cyclically Adjusted Balance /GDP	-0.264**	CAPITAL/ASSETS	-0.161*	Bank Leverage	8.828	CA/GDP	1.855
17	GINI COEFF	-0.262**	FSI	1	INT_PAY/REVENUE	8.728	Bank Leverage	1.174
18	Unemployment	0.260**	Democracy	-0.156	Banking Crises	8.665	Banking Crises	1.038
19	Credit Rating	-0.240**	X/GDP	-0.145	PSAVTT	8.515	Trade/GDP	0.985
20	EXDEBTGOV/GDP	0.239**	OFDI/GDP	-0.145	INT_PAY/EXPENSE	8.236	PSAVTT	0.811
21	Fertility Rate	0.226*	EXDEBT/GDP	0.139	Credit Rating	8.178	INT_PAY/REVENUE	0.526
22	CAPITAL/ASSETS	-0.220*	M2/GDP	0.117	Trade/GDP	8.012	M2/GDP	0.358
23	M/GDP	0.211*	TCRR	-0.100	TCRR	7.578	Credit Rating	-0.182
24	INT_PAY/EXPENSE	-0.210*	Tax Revenue/GDP	-0.099	M2/GDP	7.492	Age Dependency	-0.517
25	FSI	1	H. Expenditure (Total)/GDP	0.097	Household Debt/GDP	7.352	GINI COEFF	-0.551
26	Inflation	-0.188	M/GDP	-0.094	EX-DEBT/X	7.161	TCRR	-0.606
27	Trade/GDP	0.173	Enrollment Primary	-0.093	Savings/Expenditures	7.065	Tax Revenue/GDP	-1.037
28	WAGE	0.171	PSAVTT	-0.085	Enrollment Primary	7.025	CPS/GDP	-1.041
29	OFDI/GDP	-0.168	Enrollment Tertiary	0.085	GOV.EXP/GDP	6.854	Enrollment Tertiary	-1.087
30	H.EXP (Public)/GOV.EXP	-0.162	Rule of Law	-0.068	Age Dependency	6.852	Enrollment Primary	-1.182
31	H. Expenditure (Total)/GDP	0.157	Unemployment	0.065	GINI COEFF	6.824	Revenue/GDP	-1.206
32	Reserves	-0.152	Reserves	0.062	Tax Revenue/GDP	6.585	GOV.EXP/GDP	-1.332
33	Tax Revenue/GDP	0.142	NET_DEBT/GDP	0.062	Revenue/GDP	6.427	Household Debt/GDP	-1.367
34	REER	0.140	INT_PAY/REVENUE	0.057	Fertility Rate	6.327	Reserves	-1.433
35	CPS/GDP	0.135	FDI/GDP	-0.057	X/GDP	6.301	H. Expenditure (Total)/GDP	-1.441
36	NET_DEBT/GDP	0.119	Voice and Accountability	-0.056	WAGE	6.297	Fertility Rate	-1.506
37	Enrollment Primary	0.117	REER	0.053	H. Expenditure (Total)/GDP	6.274	X/GDP	-1.676
38	Regulatory Quality	-0.109	Age Dependency	0.052	CPS/GDP	6.170	EX-DEBT/X	-1.694
39	Enrollment Tertiary	0.084	Household Debt/GDP	-0.051	H.EXP (Public)/GOV.EXP	6.159	H.EXP (Public)/GOV.EXP	-1.734
40	Rule of Law	0.078	GOV.EFFECT	-0.049	EX-DEBT-PRIVATE/GDP	5.787	CAPITAL/ASSET	-1.762
41	Voice and Accountability	-0.07	Enrollment Secondary	0.048	Reserves	5.780	Savings/Expenditures	-2.043
42	FDI/GDP	0.052	EXDEBTPRIVATE/GDP	0.048	M/GDP	5.721	Enrollment Secondary	-2.128
43	CA/GDP	0.049	H.EXP (Public)/GOV.EXP	0.041	Inflation	5.701	Inflation	-2.279
44	INT_PAY/REVENUE	0.032	CPS/GDP	-0.040	Enrollment Tertiary	5.568	EX-DEBT/GDP	-2.285
45	TCRR	-0.031	PSRR	-0.036	OFDI/GDP	5.473	WAGE	-2.418
46	Revenue/GDP	-0.027	Inflation	0.034	CAPITAL/ASSET	5.431	OFDI/GDP	-2.931
47	Age Dependency	0.021	Regulatory Quality	0.033	Enrollment Secondary	5.312	M/GDP	-2.937
48	Corruption	0.013	Fertility Rate	-0.027	EX-DEBT/GDP	5.222	EX-DEBT-PRIVATE/GDP	-3.759
49	GOV.EFFECT	-0.012	Revenue/GDP	0.024	FSI	4.927	FSI	-3.906
50	PSRR	0.005	Corruption	-0.016	REER	4.232	REER	-3.908
51	PSAVTT	0.005	INT_PAY/EXPENSE	-0.012	Democracy	4.046	FDI/GDP	-3.950
52	Democracy	0.004	Credit Rating	0.010	FDI/GDP	4.017	Democracy	-4.365

Through the SOM analysis, one can also observe the transition of each country from noncrisis to crisis over time, how long the country stayed in crisis zone and when it exited from the crisis. Austria’s movements over time are shown in Figure 2.10. Note that left side of the Figure 2.10 shows the period before the global financial crisis in 2007, while the right

side shows the period after the global financial crisis. From here, we observe that although the fiscal stress augmented in the aftermath of the global financial crisis, Austria did not enter the crisis zone during the period of 2007-2015. In other words, Austria survived both the global crisis and the European debt crisis with little damage.

Figure 2.10. Self-Organizing Map results for Austria from 2003-2015.

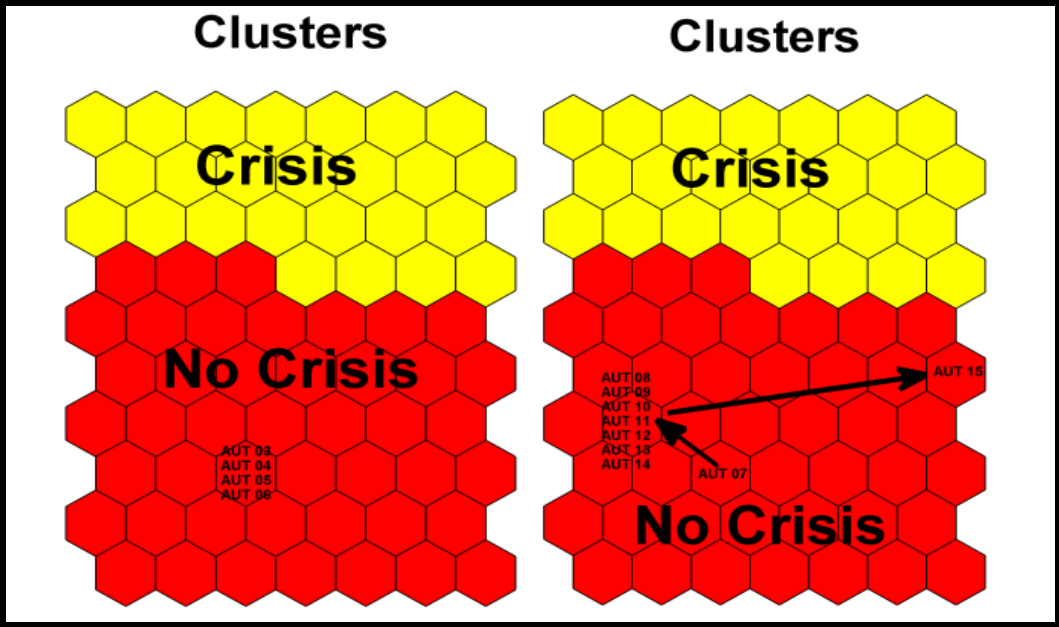
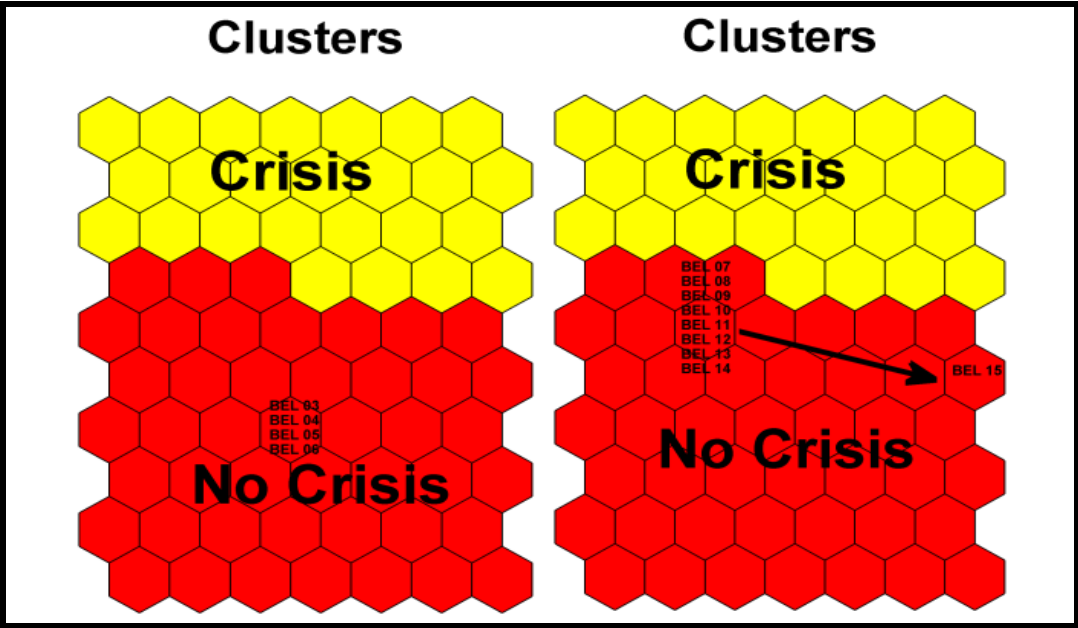
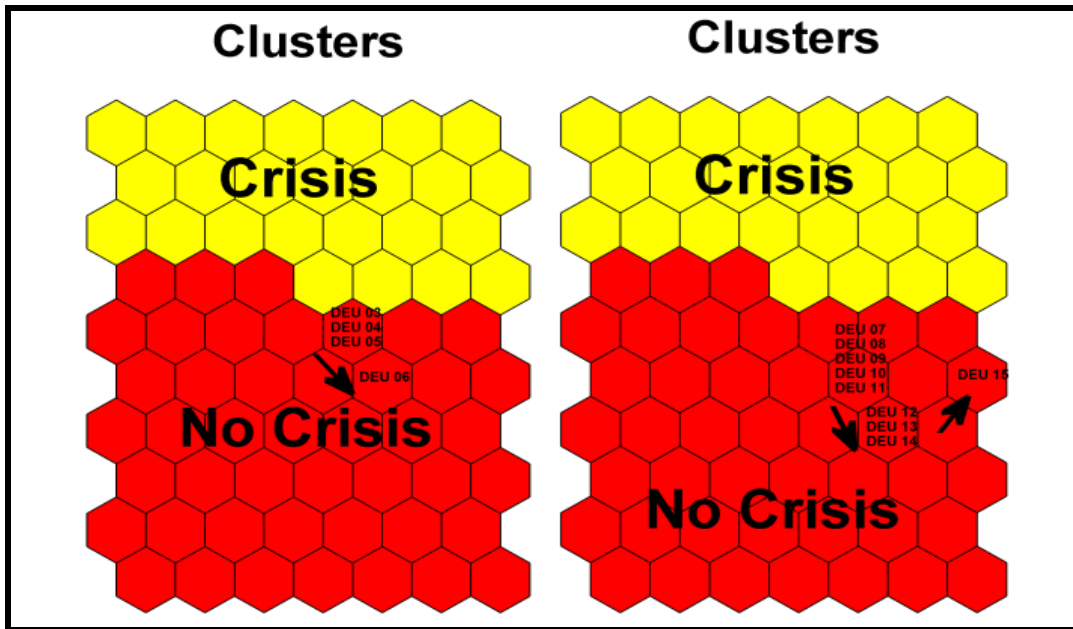


Figure 2.11. Self-Organizing Map results for Belgium from 2003-2015.





**Figure 2.12.** Self-Organizing Map results for Germany from 2003-2015.



According to Figures 2.11 and 2.12, one can affirm that the fiscal stress seriously increased from 2007 to 2009 both in Belgium and Germany. However, neither Belgium nor Germany suffer a debt crisis. After 2009 the fiscal stress significantly lowered in both countries. On the other hand, Denmark seems to be far away from the crisis zone even during the period of 2007-2009 (see Figure 2.13).

**Figure 2.13.** Self-Organizing Map results for Denmark from 2003-2015.

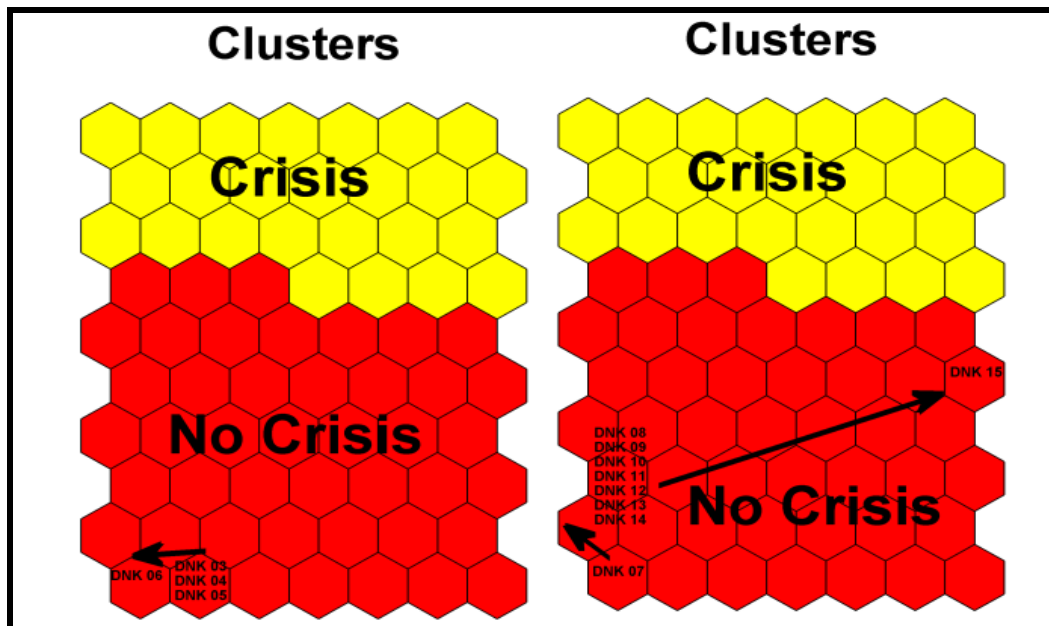
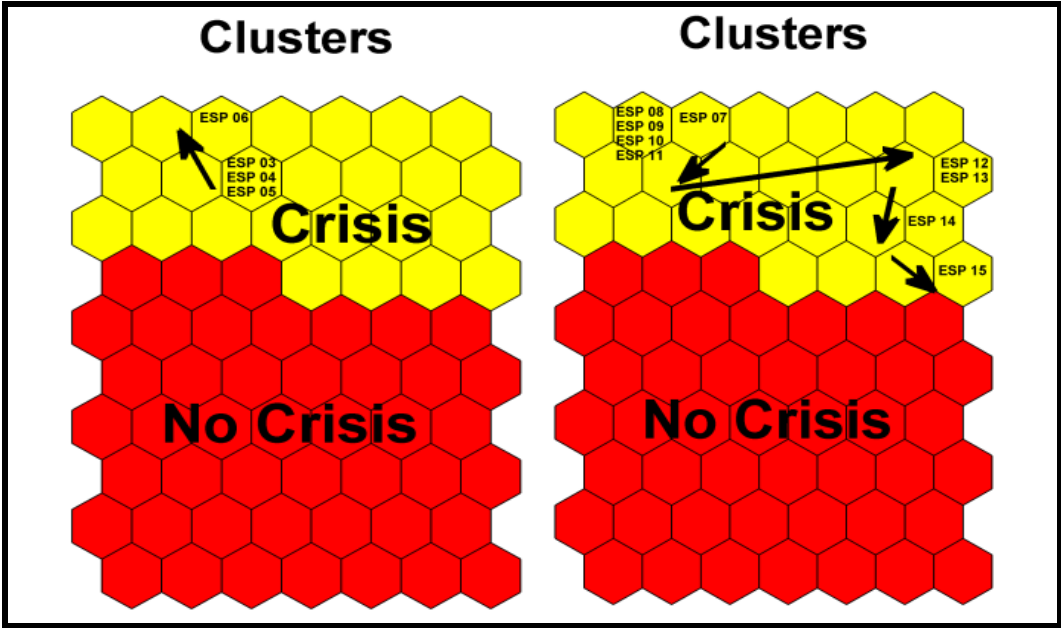


Figure 2.14 presents Spain’s movements from 2003 to 2015. One may clearly observe that Spain was already in crisis zone well before the outbreak of the global financial crisis in 2007. This shows the fact that being an EU and Eurozone member country helped Spain not suffer a debt crisis before 2007. One may also argue that if the global financial crisis did not occur, Spain would maybe have never had a financial and debt crisis. This observation leads to an important consequence: Eurozone is not an optimum currency area since Spain does not have a similar macroeconomic structure. Besides, the below Figure shows that although Spain achieved a relative recovery in 2015, it remains in the crisis zone.

**Figure 2.14.** Self-Organizing Map results for Spain from 2003-2015.



Finland is the next country to analyze. According to the SOM results presented in Figure 2.15, Finland remained far from the crisis zone until 2015 where the fiscal stress seems to have seriously risen.

France is an interesting case (see Figure 2.16). As one of the three leader countries in the EU along with Germany and United Kingdom, France seems to be seriously affected by the global financial crisis. It enters the crisis zone in 2008 and rapidly exits in 2009, but it remains very close to the crisis zone from 2009 to 2015.

Figure 2.15. Self-Organizing Map results for Finland from 2003-2015.

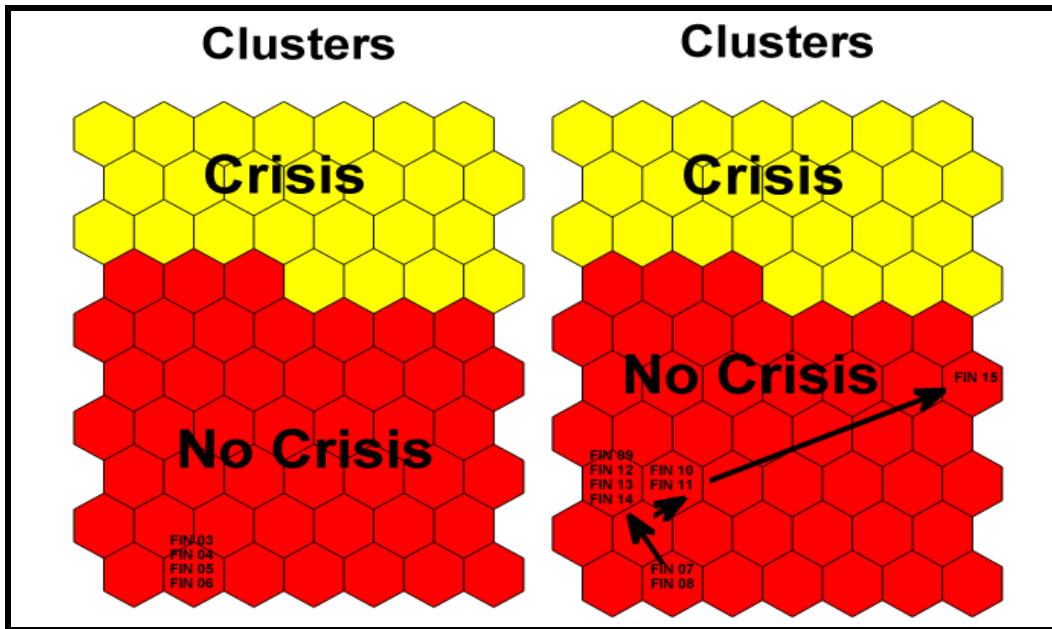


Figure 2.16. Self-Organizing Map results for France from 2003-2015.

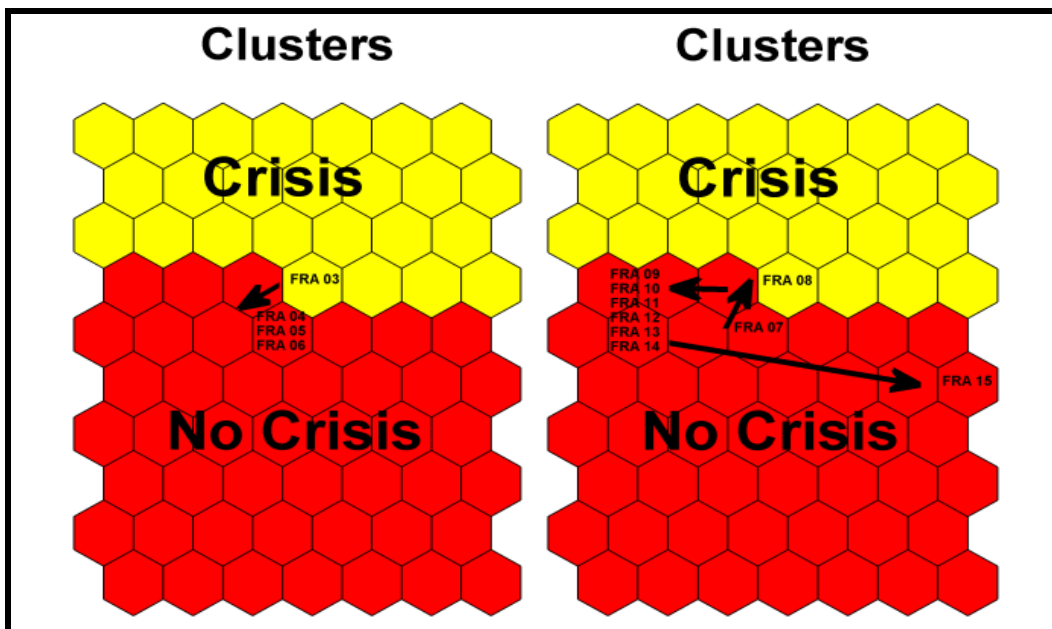
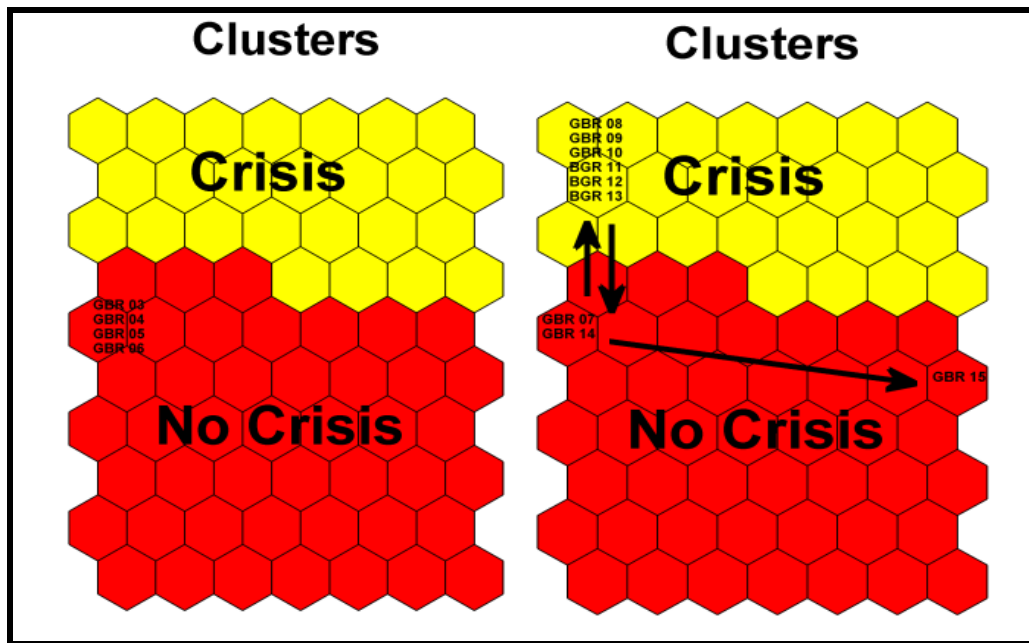
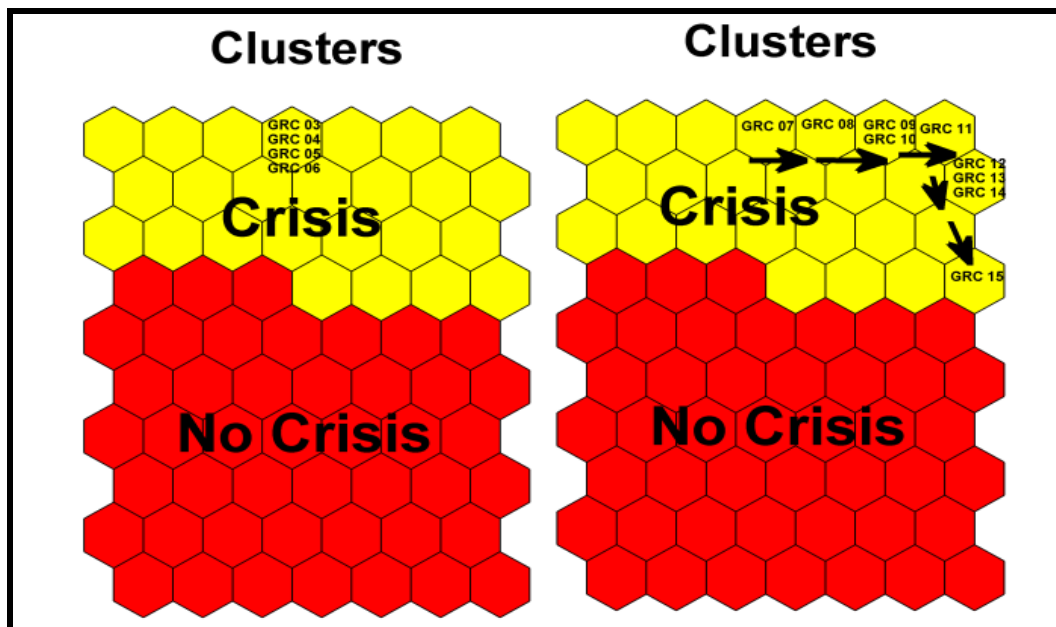


Figure 2.17 indicates that the United Kingdom (UK) is one of the most affected countries by the global financial crisis. Because the UK enters the crisis zone in 2008 and remains within the crisis zone until 2014. This clearly shows the difficulties that the UK economy encountered during this period which may partly explain the Brexit decision.

**Figure 2.17.** Self-Organizing Map results for the United Kingdom from 2003-2015.



**Figure 2.18.** Self-Organizing Map results for Greece from 2003-2015.



Figures 2.18 and 2.19 present the situation of the Greek and Italian economies before and after the outbreak of the global financial crisis. Greece and Italy, like Spain, seem to have already been in crisis zone well before 2007 and they were still in crisis zone in 2015. This suggests that Greece and Italy should not have been Eurozone member countries as they do not meet the necessary conditions.

Figure 2.19. Self-Organizing Map results for Italy from 2003-2015.

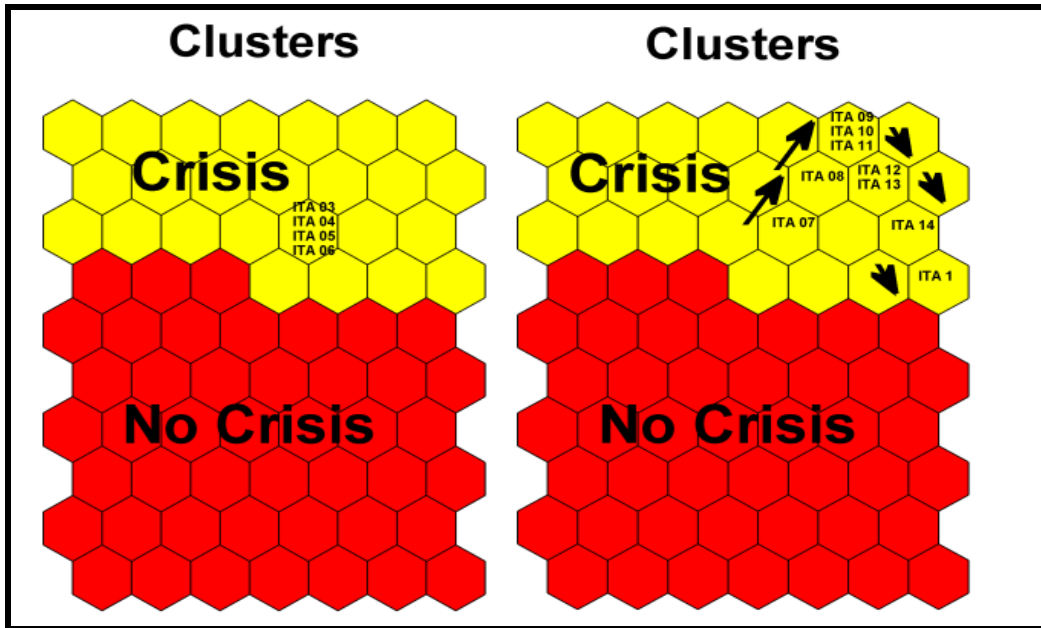
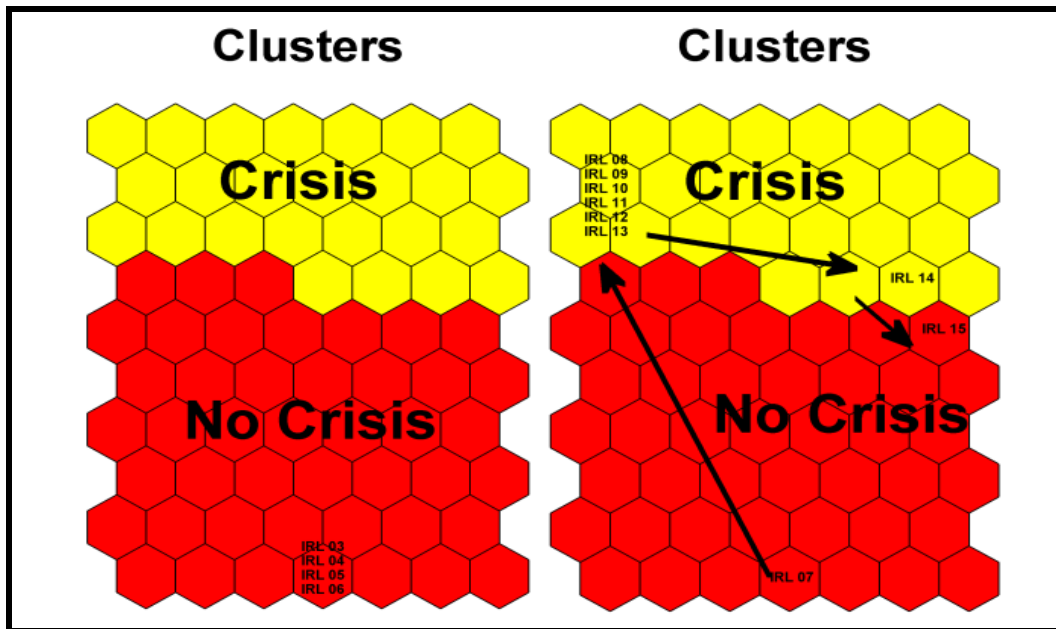


Figure 2.20. Self-Organizing Map results for Ireland from 2003-2015.



Ireland is very interesting case study as observed in Figure 2.20: Ireland was far away from the crisis zone in the pre-global crisis period, but the outbreak of the global crisis seriously affected the Irish economy. More importantly, despite several economic policies

implemented in the aftermath of the crisis, the Irish economy could leave the crisis zone only in 2014.

Figure 2.21. Self-Organizing Map results for Luxembourg from 2003-2015.

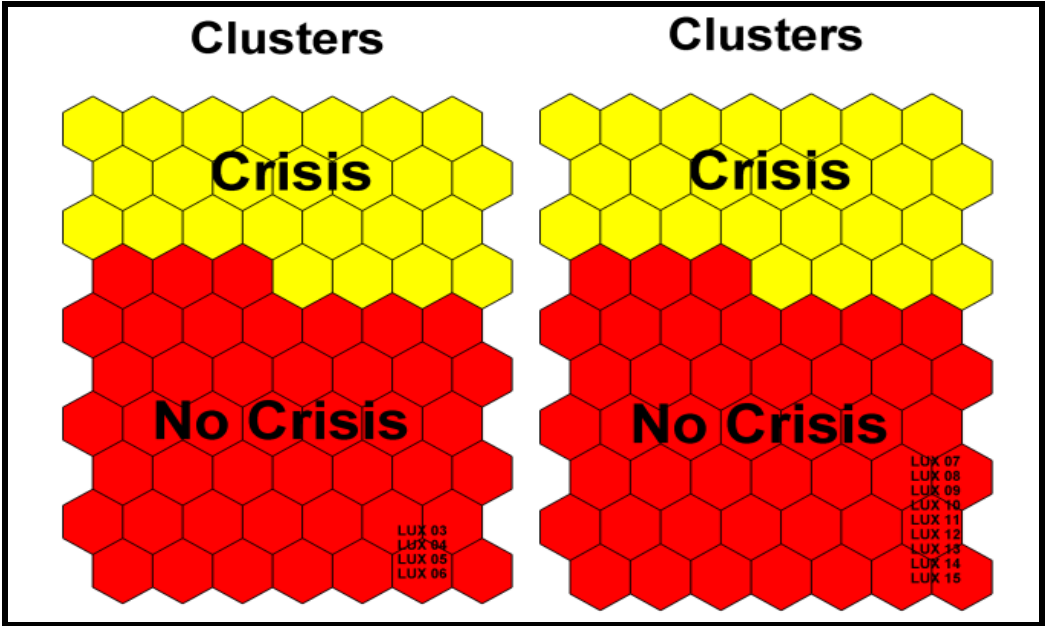
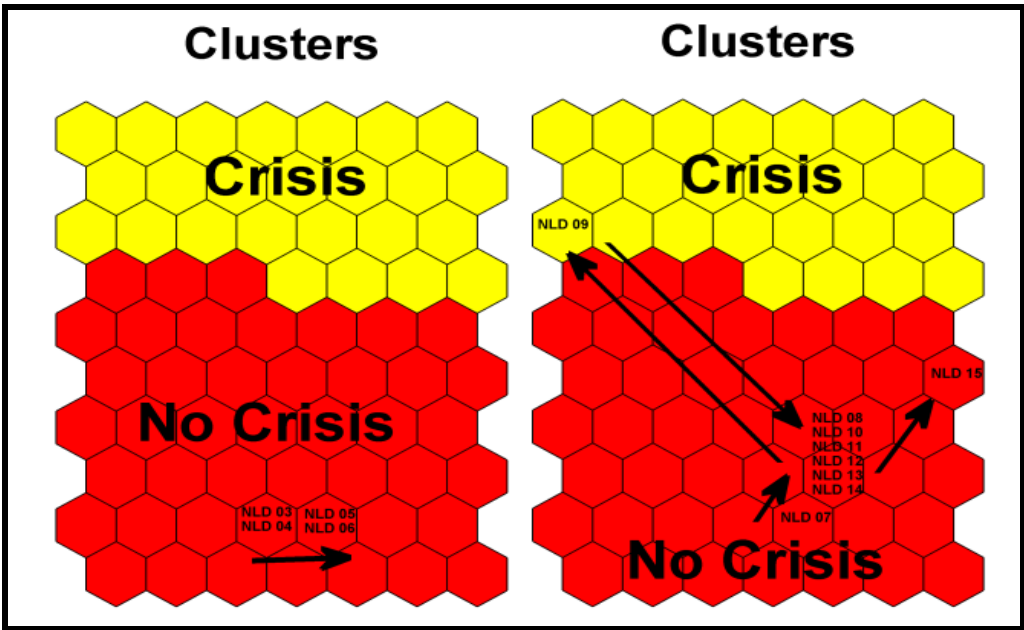


Figure 2.22. Self-Organizing Map results for the Netherlands from 2003-2015.



Figures 2.21, 2.22, and 2.23 show how the economies of Luxembourg, the Netherlands and Sweden behaved during the period of global financial crisis and European

debt crisis. Although Luxembourg and Sweden did not suffer any crisis from 2007 to 2015, the Netherlands entered the crisis zone in 2009. However, like France, the Netherlands exited the crisis zone the following year. Besides, one may also observe that the fiscal stress seriously increases in 2015 in the Netherlands and Sweden.

Figure 2.23. Self-Organizing Map results for Sweden from 2003-2015.

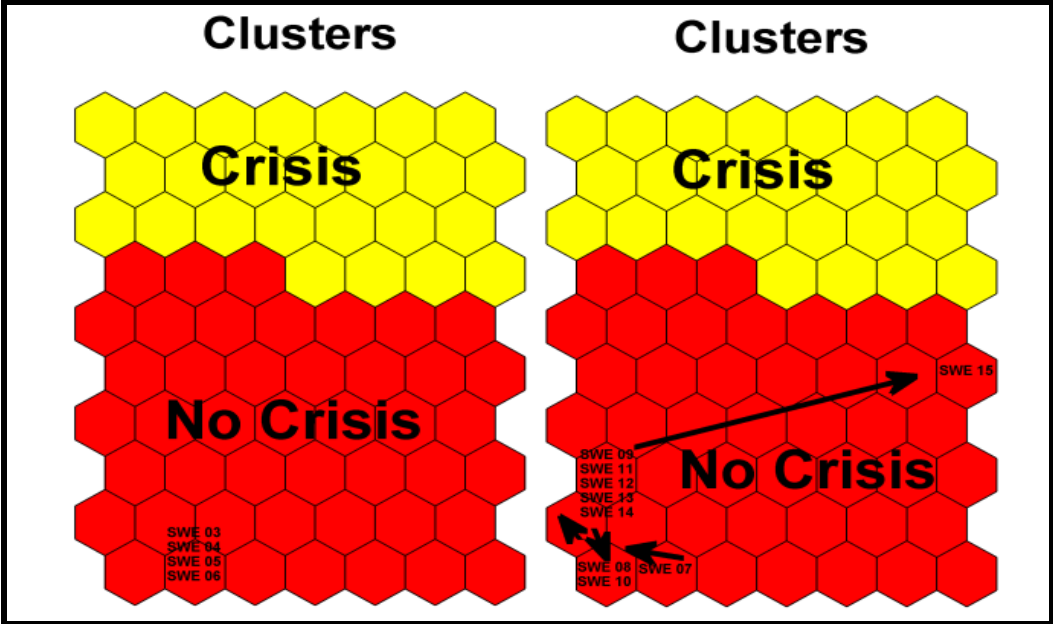


Figure 2.24. Self-Organizing Map results for Portugal from 2003-2015.

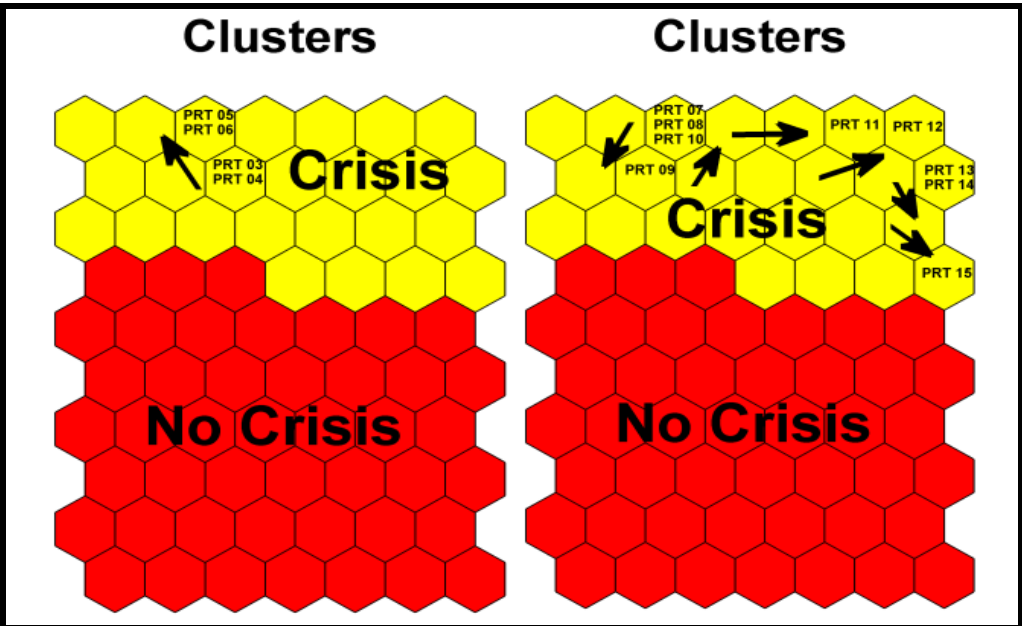


Figure 2.24 indicates that Portuguese economy was already in crisis zone before the outbreak of the global financial crisis, like Greece, Italy, and Spain. Hence, Portugal is another country whose membership to the Eurozone should be questioned.

In order to show in detail, the extent to which the EU-15 countries have been affected by the crisis, we present the behavior of their economies on the maps from 2007 to 2015 (see Figures 2.25, 2.26, 2.27, 2.28, 2.29, 2.30, 2.31, 2.32, and 2.33). In other words, we sum up the above Figures and show the transition of EU-15 countries from noncrisis to crisis state over time. Different maps (or Figures) show that, when Europe was hit by the global financial crisis in 2007, Greece, Italy, Spain, and Portugal had already been in the crisis zone, while others Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Sweden, and the United Kingdom were not. In 2008, the global financial crisis starts to negatively affect the EU and, in particular Eurozone countries. Ireland, France, and the UK, in addition to Greece, Italy, Spain, and Portugal, enter the crisis zone in 2008. In 2009, France moves out of the crisis zone, but it's the Netherlands that enters the crisis zone. In 2010, the Netherlands exits the crisis zone where Greece, Italy, Spain, Portugal, Ireland and the UK remain. By 2014 and 2015, the UK and Ireland exit the crisis zone, respectively.

This clearly shows Greece, Italy, Spain, Portugal, Ireland and the UK to be the most affected European countries from the crisis. The countries heavily affected by the crisis are generally located in Southern Europe, whereas the countries that resisted the crisis better are located in Northern Europe. Interestingly, the southern countries' governance indicators are worse than the northern ones', which seems to have a big influence on the severity of the crisis. On the other hand, this result also indicates that the Southern European countries do not meet the economic or institutional requirements to be a member of the EU and/or the Eurozone and they have enjoyed low borrowing costs as they benefited from the prestige of the Northern European ones. Besides, it seems that they have failed to deploy these financial resources efficiently due to poor governance and therefore have lost fiscal discipline which caused their debts to increase constantly. The importance of governance indicators is evident in countries like the UK and France which have suffered severe deterioration in their macroeconomic balances during the crisis, but they managed to recover contrary to Greece, Italy, Spain, and Portugal.



Figure 2.25. Mapping all countries in 2007.

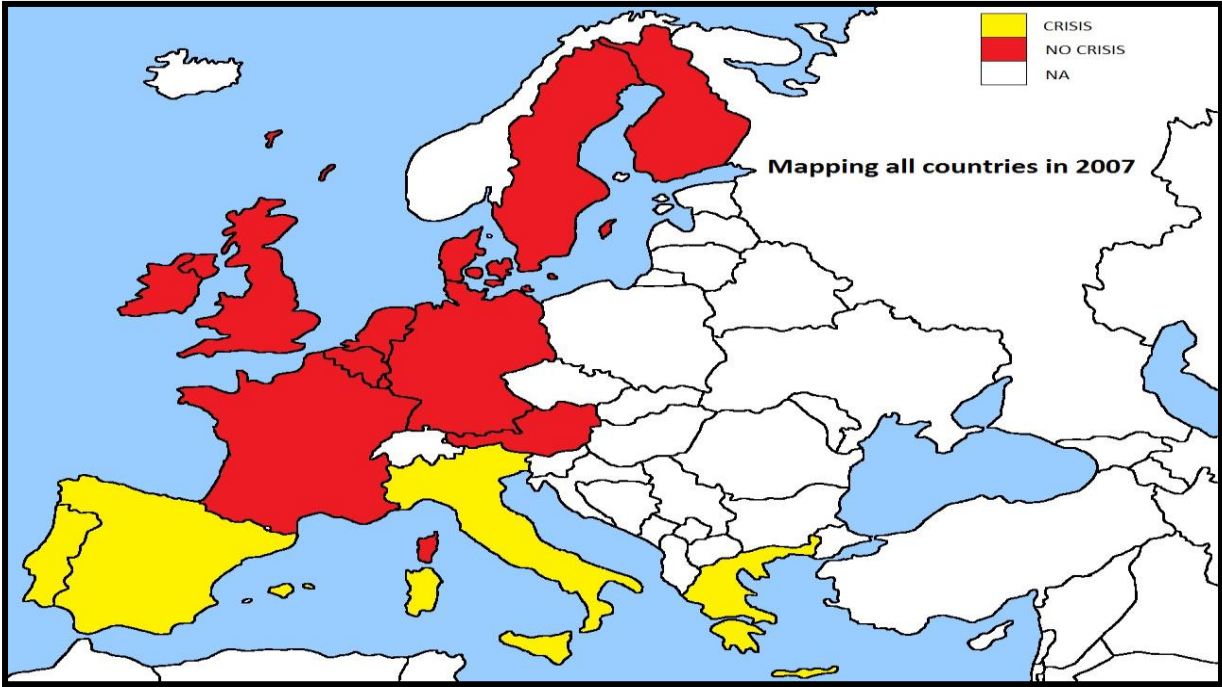


Figure 2.26. Mapping all countries in 2008.

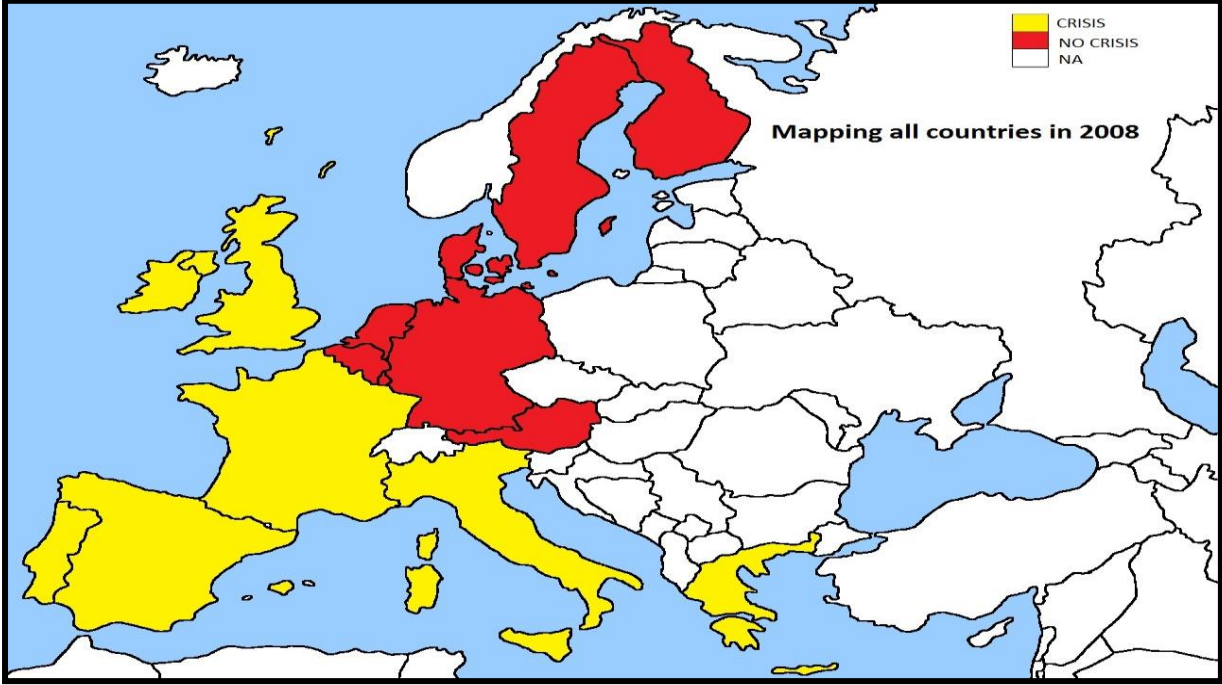




Figure 2.29. Mapping all countries in 2011.

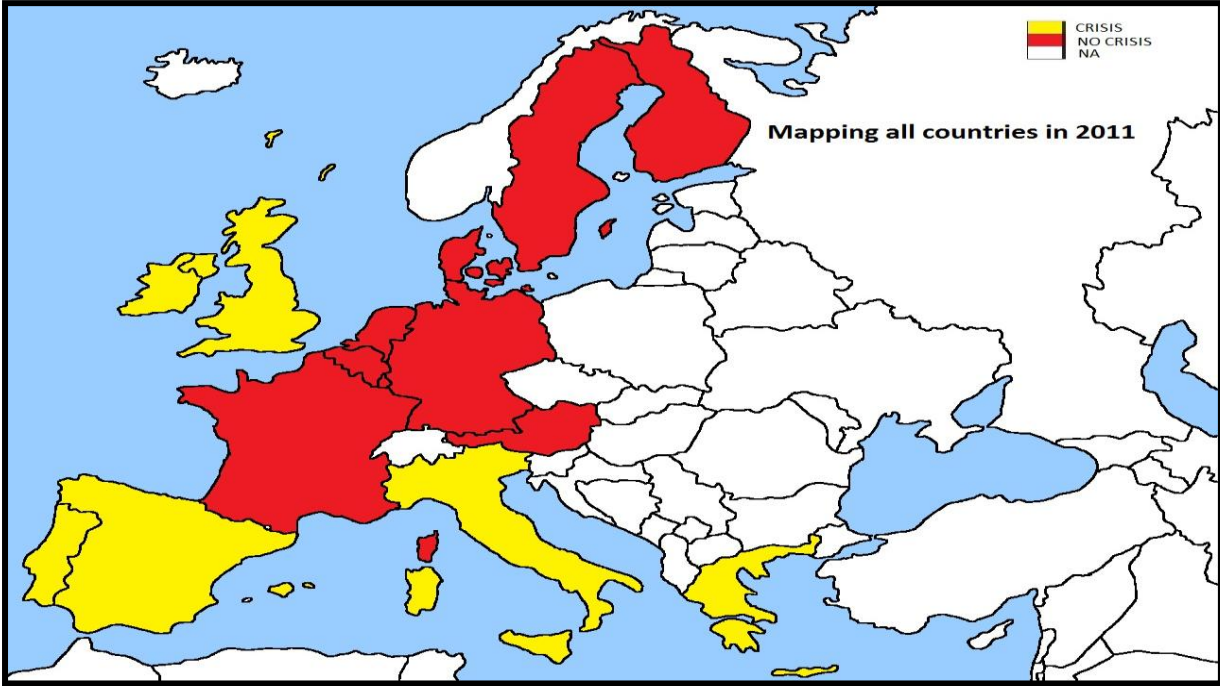
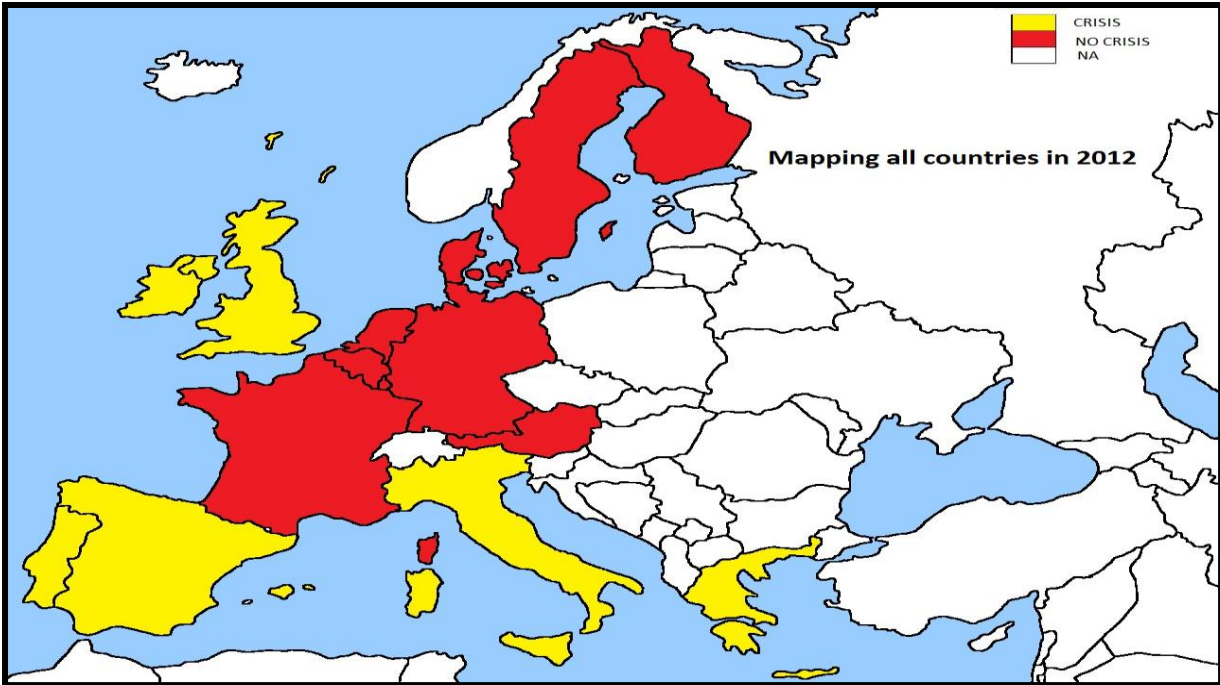
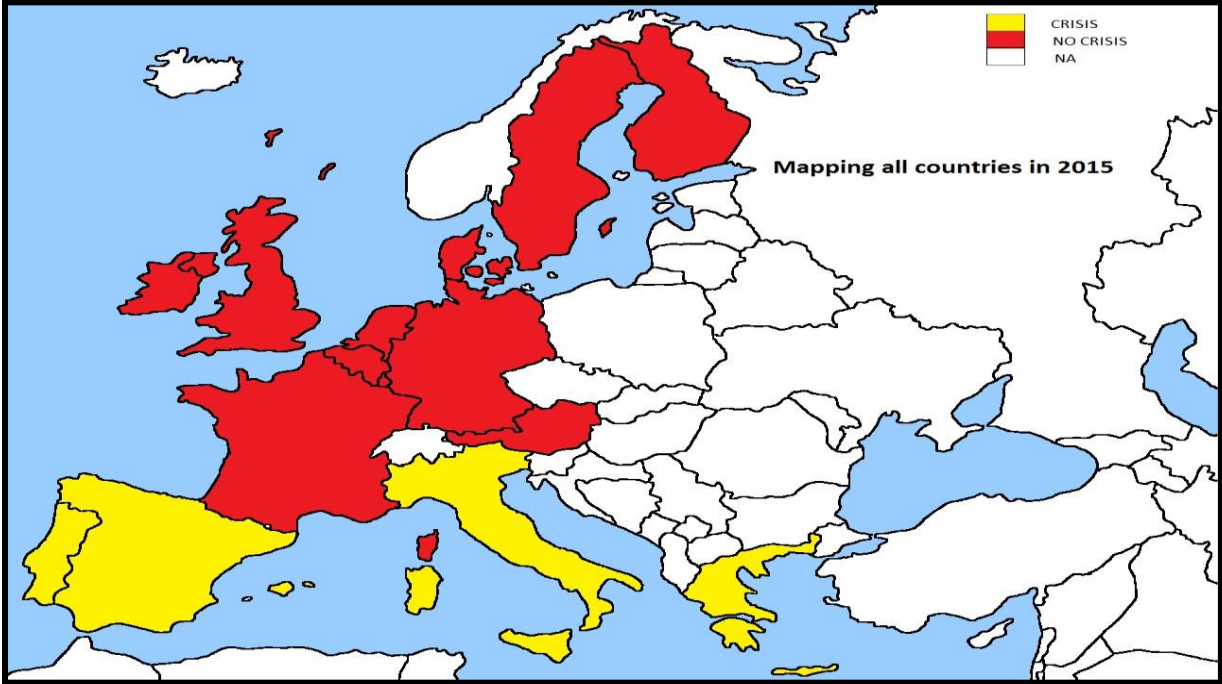


Figure 2.30. Mapping all countries in 2012.





**Figure 2.33.** Mapping all countries in 2015.



The forecast performance results from the SOM estimates are presented in Table 2.11. The SOM model could correctly predict 79.31% of crisis periods and 74% of the noncrisis episodes in the EU-15 from 2003 to 2015. Besides, the model could forecast 100% of crisis episodes in PIIGS countries.

**Table 2.11.** Forecast Performance of SOM

Criteria	Model (EU-15)	Model (Greece, Ireland, Italy, Portugal, Spain)
% and number of correctly predicted non-crises	79.31% (115/145)	18.18% (6/33)
% and number of correctly predicted crises	74.00% (37/50)	100% (32/32)

**Table 2.12.** Logit Estimation Results

Dependent variable: FSI										
Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
NPL/TGL	0.150*** (0.038)	0.063** (0.028)	0.167*** (0.052)	0.164*** (0.052)	0.131*** (0.036)	0.108*** (0.033)	0.096*** (0.031)	0.168*** (0.050)	0.093*** (0.030)	0.175*** (0.042)
Primary Balance/GDP	-0.280*** (0.071)	-0.251*** (0.1348)	-0.153* (0.081)	-0.277*** (0.073)	-0.265*** (0.069)	-0.266*** (0.069)	-0.285*** (0.071)	-0.162** (0.083)	-0.259*** (0.070)	-0.249** (0.103)
PSRR	-0.375*** (0.052)									
Corruption		-1.094*** (0.153)								
Cash Balance/GDP			-0.173** (0.076)							
Unemployment				0.024*** (0.004)						
Voice and Accountability					-1.537*** (0.211)					
Regulatory Quality						-1.361*** (0.187)				
Rule of Law							-1.296*** (0.178)			
GDP growth								-0.612*** (0.123)		
GOV.EFFECT									-1.260*** (0.174)	
Cyclically Adjusted Balance /GDP										-0.165*** (0.039)
CONSTANT	1.323 (2.335)	-1.541** (0.697)	-2.605*** (0.374)	-2.390*** (0.428)	-0.047 (1.613)	-1.240 (0.999)	-0.913 (0.814)	-1.713*** (0.366)	-0.985 (0.829)	-2.333*** (0.351)
Observations	195	195	195	195	195	195	195	195	195	195
Pseudo R <sup>2</sup>	0.27	0.26	0.30	0.26	0.27	0.26	0.27	0.45	0.27	0.26
LR Stat	59.4***	58.4***	63.7***	57.4***	59.0***	58.2***	60.0***	99.7***	59.6***	57.4***
Akaike Info	0.91	0.91	0.89	0.92	0.91	0.91	0.90	0.69	0.91	0.92

**Note:** \*\*\*, \*\* and \* represent statistical significance at the 1%, 5% and 10% level, respectively. The values in parentheses are standard deviations.

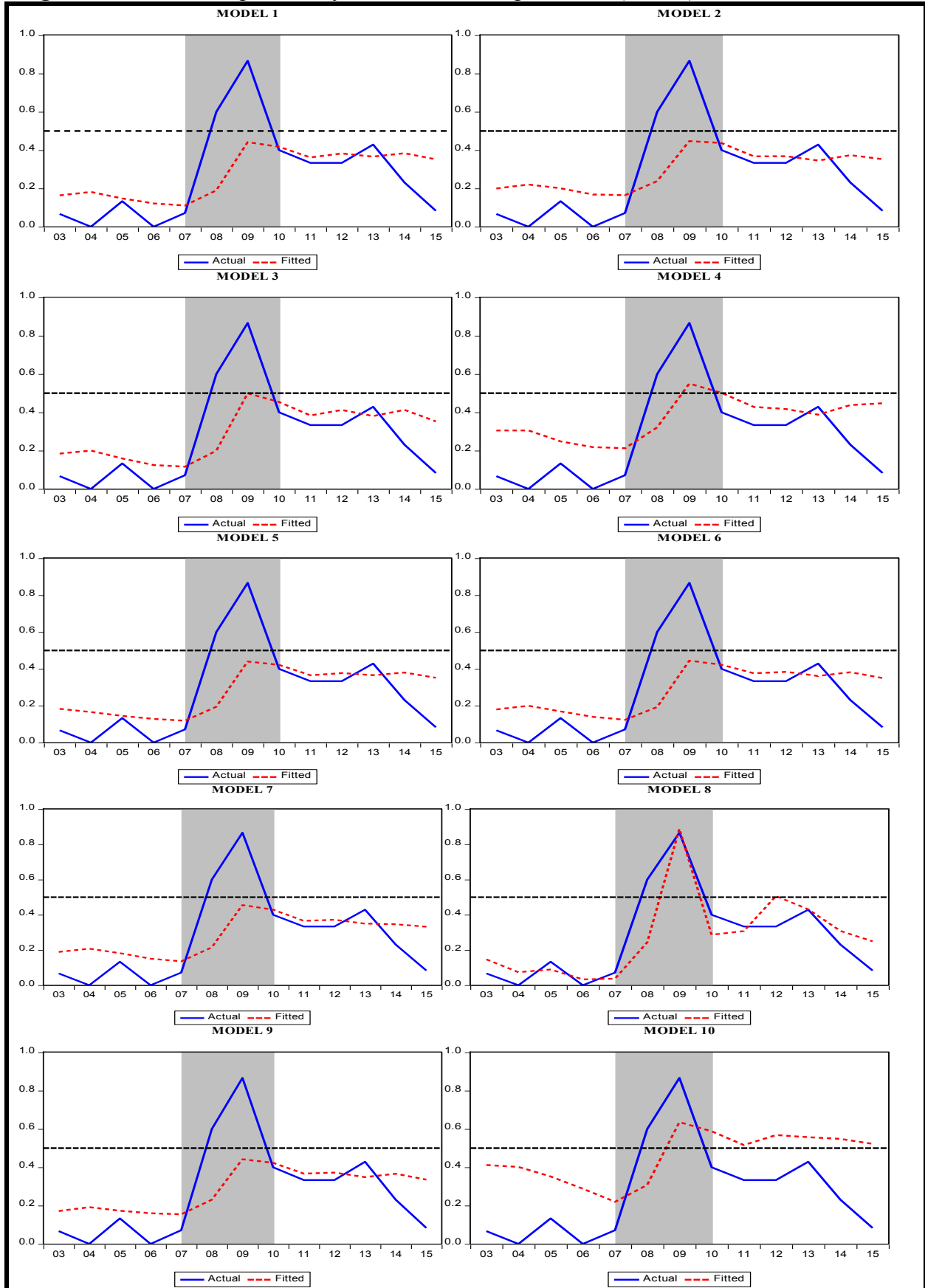
After having obtained the most significant variables that explain the debt crises from the SOM analysis, we use logit estimates where our dependent variable is the fiscal stress index reduced to a binary form. As previously stated, the dependent variable here takes the value 1 during periods of debt crisis and 0 for noncrisis periods. Logit estimation results are based on the leading indicators with the highest significance levels are presented in Table 2.12

Table 2.12 presents the results of ten different estimations. Because of multicollinearity problem, we estimated each indicator separately. One may observe in Table that all explanatory variables used in the model are significant at 1% or 5% a statistical significance level. According to the econometric results, increases in budget balance, PSRR, corruption, cash balance, voice and accountability, regulatory quality, GDP growth, rule of law, government effectiveness, and cyclically adjusted balance are associated with lower probabilities of crisis while increases in NPL / TL and unemployment increase the likelihood of crisis.

Figure 2.34 presents the actual and fitted values of the models estimated for the EU-15, except for Spain, Italy, Greece, Portugal, and Ireland. One may observe that the crisis in Europe can be said to have started in 2007 and has ended in 2010. On the other hand, Figure 2.35 indicates that the crisis in Spain, Italy, Greece, Portugal, and Ireland started in 2007 but ended only in 2014.

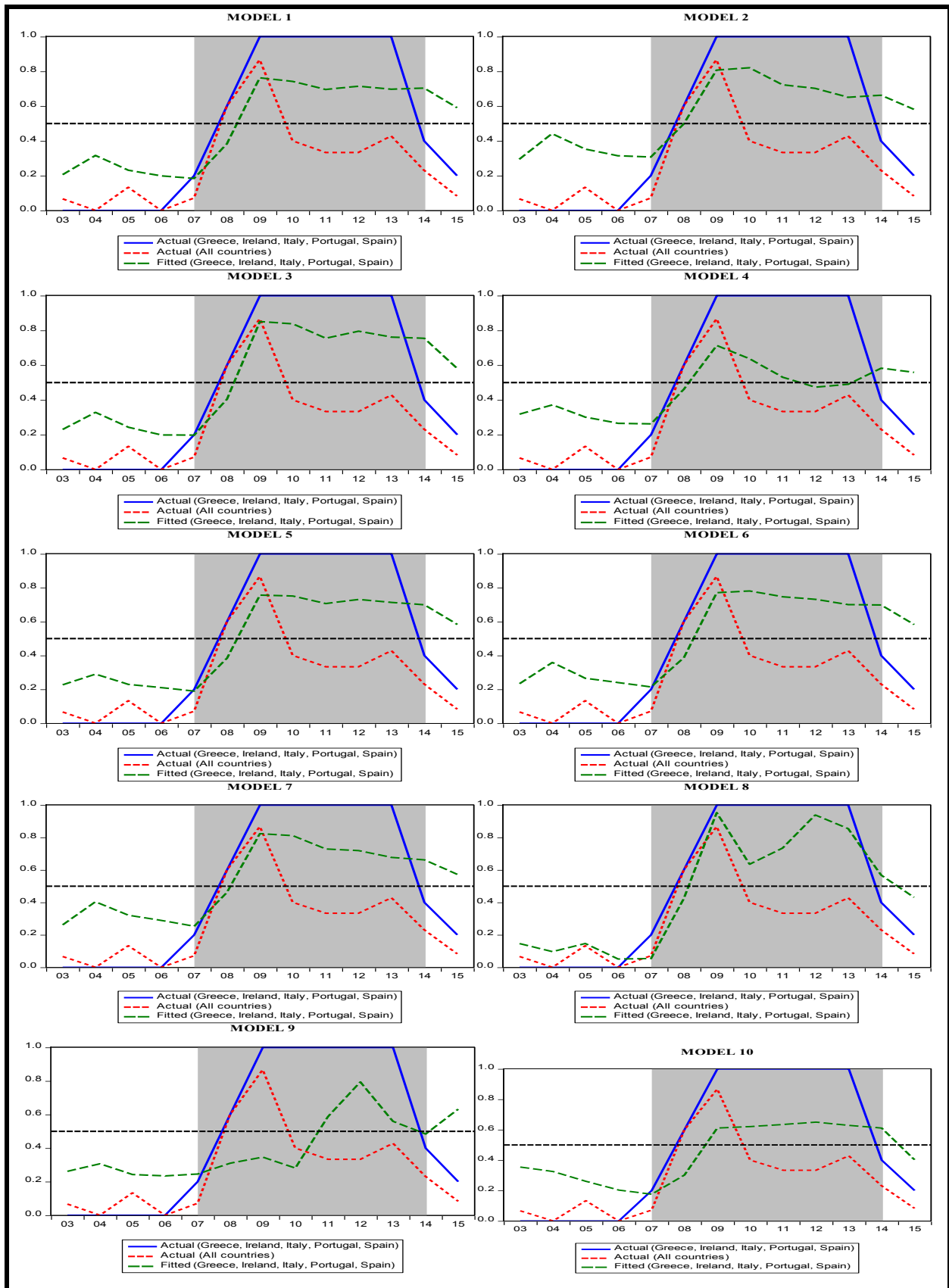
Table 2.13 presents the forecast performance matrices for the logit model. Accordingly, the success of the 10 models for predicting crises varies between 50% and 90% for different cut-off values. In addition, if we include the models' success at predicting noncrisis periods, it varies from 14% to 99%.

**Figure 2.34.** Predicted probability of crises in the logit models (EU-15).





**Figure 2.35.** Predicted probability of crises in the logit models (Greece, Ireland, Italy, Portugal and Spain).



**Table 2.13.** Forecast Performance of Logit Models

<b>Cut-off level</b>	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
<b>C = 0.5</b>										
% and number of correctly predicted non-crises	95.10% (136/143)	93.71% (134/143)	95.10% (136/143)	83.22% (119/143)	95.10% (136/143)	95.10% (136/143)	95.10% (136/143)	97.20% (139/143)	93.71% (134/143)	66.43% (95/143)
% and number of correctly predicted crises	50% (26/52)	55.77% (29/52)	57.69% (30/52)	51.92% (27/52)	50% (26/52)	55.77% (29/52)	55.77% (29/52)	67.31% (35/52)	55.77% (29/52)	53.85% (28/52)
<b>C = 0.25</b>										
% and number of correctly predicted non-crises	76.22% (109/143)	74.83% (107/143)	85.52% (118/143)	40.56% (58/143)	75.52% (108/143)	72.03% (103/143)	76.22% (109/143)	85.31% (122/143)	75.52% (108/143)	21.68% (31/143)
% and number of correctly predicted crises	69.23% (36/52)	73.08% (38/52)	75% (39/52)	76.92% (40/52)	69.23% (36/52)	69.23% (36/52)	73.08% (38/52)	78.85% (41/52)	73.08% (38/52)	88.46% (46/52)
<b>C = 0.2</b>										
% and number of correctly predicted non-crises	68.53% (98/143)	66.43% (95/143)	72.72% (104/143)	34.27% (49/143)	67.83% (97/143)	69.93% (100/143)	65.73% (94/143)	78.32% (112/143)	69.93% (100/143)	13.94% (20/143)
% and number of correctly predicted crises	76.92% (40/52)	75% (39/52)	76.92% (40/52)	88.46% (46/52)	75% (39/52)	73.08% (38/52)	75% (39/52)	78.85% (41/52)	76.92% (40/52)	90.38% (47/52)

We have used the panel Markov as the third analysis method. In this model, the dependent variable (the fiscal stress index) is in the continuous form. Like the logit model, 10 different models are estimated to avoid multicollinearity. Broadly speaking, the results obtained from the Markov approach are similar the results obtained from the logit model. According to Markov estimations, while NPL / TL, corruption, cash balance / GDP, voice and accountability, regulatory quality, rule of law, government effectiveness, and cyclically adjusted balance / GDP are statistically significant in only Regime 1, primary balance / GDP, PSRR, unemployment, and GDP growth are statistically significant in Regimes 1 and 2. If we interpret the results collectively, the ratios of NPL / TL and unemployment increase the likelihood of crisis, while increases in budget balance, PSRR, corruption, cash balance, voice and accountability, regulatory quality, GDP, and rule of law reduce the likelihood of crisis.

As in the logit model, the Markov model estimates also include the forecast performance of each model and the diagnostic test results. According to the results, no problems are found such as normality or autocorrelation in the estimated models. In addition, the linearity test shows that using the Markov regime switching model is more appropriate than the linear models. The Davies test also indicates the number of regimes chosen to be appropriate for the predicted models. As in the case of Abiad (2007), Alvarez-Plata and Schrooten (2006), and Lopes and Nunes (2012), who used the Markov model for crises, our study also assumes two different regime periods. The period with lower mean and volatility indicates the tranquil or noncrisis regime, while the second regime with higher mean and volatility is said to be crisis. Crisis probabilities obtained from the Markov Regime Switching Model are presented separately for the EU-15 and PIIGS (Spain, Italy, Greece, Portugal, and Ireland). Unlike the logit model, Markov model forecasts show that the crisis started in late 2007 and lasted until 2013, both in PIIGS and other 11 countries.

The forecast performance results obtained from the Panel Markov model are given in Table 2.15. According to the results, the models are able to predict, at 0.5 threshold level, all crisis episodes occurred in the EU-15 in the period of 2003-2015 and nearly 80% of noncrisis periods.

**Table 2.14.** Markov Estimation Results

Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
NPL/TGL (Regime 1)	0.0852*** (4.6928)	0.0860*** (4.6168)	0.0840*** (5.6005)	0.0691** (2.5123)	0.0799*** (4.3170)	0.0824*** (4.4995)	0.0740 *** (4.4310)	0.0429*** (2.9431)	0.0850*** (4.6662)	0.0840*** (5.6520)
NPL/TGL (Regime 2)	0.0020 (0.0193)	0.0081 (0.0748)	0.0223 (0.2283)	0.0170 (0.1403)	0.0064 (0.0550)	0.0120 (0.1178)	0.0057 (0.0551)	0.0364 (0.3093)	0.0005 (0.0049)	0.0398 (0.4684)
Primary Balance/GDP (Regime 1)	-0.3012*** (-4.2105)	-0.0316*** (-9.8841)	-0.2882*** (-7.0861)	-0.3030*** (-10.6341)	-0.2977*** (-9.6040)	-0.2997*** (-10.0140)	-0.2967*** (-9.7860)	-0.2192*** (-11.2549)	-0.3010*** (-9.6911)	-0.3076*** (-7.4115)
Primary Balance/GDP (Regime 2)	-0.2277** (-2.0433)	-0.2347** (-2.0862)	-0.2100* (-1.7335)	-0.2210* (-1.9493)	-0.2290** (-2.0338)	-0.2362** (-2.0885)	-0.2399** (-2.0749)	-0.1864 (-0.9240)	-0.2273** (-2.0389)	-0.1602 (-1.0865)
PSRR (Regime 1)	-0.5258** (-2.3573)									
PSRR (Regime 2)	-1.6070* (-1.6448)									
Corruption (Regime 1)		-0.5181*** (-2.8380)								
Corruption (Regime 2)		-0.8653 (-0.9782)								
Cash Balance/GDP (Regime 1)			-0.1913*** (-6.4542)							
Cash Balance/GDP (Regime 2)			-0.0698 (-0.75690)							
Unemployment (Regime 1)				0.0893** (2.1616)						
Unemployment (Regime 2)				0.1897* (1.8022)						
Voice and Accountability (Regime 1)					-1.8370*** (-3.6224)					
Voice and Accountability (Regime 2)					-3.2583 (-1.2709)					
Regulatory Quality (Regime 1)						-1.0375*** (-2.8681)				
Regulatory Quality (Regime 2)						-1.5038 (-0.9755)				
Rule of Law (Regime 1)							-0.8168*** (-3.0846)			
Rule of Law (Regime 2)							-1.3201 (-0.9453)			
GDP growth (Regime 1)								-0.4262*** (-11.7979)		
GDP growth (Regime 2)								-0.5844*** (-3.4714)		
GOV.EFFECT (Regime 1)									-0.6890** (-2.4132)	
GOV.EFFECT (Regime 2)									-1.9062 (-1.5911)	
Cyclically Adjusted Balance /GDP (Regime 1)										-0.2166*** (-6.4593)
Cyclically Adjusted Balance /GDP (Regime 2)										-0.2517 (-1.5493)
CONSTANT (Regime 1)	3.0353** (2.3498)	0.7753** (2.4738)	-0.6157*** (-4.8374)	-0.7358** (-2.2208)	2.4941*** (3.5863)	1.4636*** (2.7435)	1.2027*** (2.8605)	0.7648*** (7.2357)	1.0208** (2.2128)	-0.5427*** (-4.6762)
CONSTANT (Regime 2)	11.6515** (2.1514)	3.9409*** (2.9538)	2.3620** (2.5289)	0.7188 (0.5726)	6.9388** (2.1365)	4.9064** (2.3032)	4.6355** (2.3107)	2.4270*** (4.1550)	5.2348*** (3.0322)	1.7041** (2.0224)

**Note:** \*\*\*, \*\* and \* represent statistical significance at the 1%, 5% and 10% levels, respectively. The values in parentheses are *t*-values.

**Table 2.15.** Forecast Performance of PMRSM (EU-15)

<b>Cut-off level</b>	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
<b>C=0.5</b>										
% and number of correctly predicted non-crises	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% and number of correctly predicted crises	100%	100%	100%	100%	100%	100%	100%	0%	100%	100%
<b>C=0.25</b>										
% and number of correctly predicted non-crises	72.72%	54.54%	63.63%	63.63%	63.63%	63.63%	63.63%	90.90%	63.63%	72.72%
% and number of correctly predicted crises	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
<b>C=0.2</b>										
% and number of correctly predicted non-crises	54.54%	45.45%	45.45%	27.27%	45.45%	45.45%	36.36%	81.81%	45.45%	54.54%
% and number of correctly predicted crises	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

**Table 2.16.** Forecast Performance of PMRSM (Greece, Ireland, Italy, Portugal, and Spain)

<b>Cut-off level</b>	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
<b>C=0.5</b>										
% and number of correctly predicted non-crises	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% and number of correctly predicted crises	66.66%	66.66%	83.33%	66.66%	83.33%	83.33%	50.00%	33.33%	83.33%	83.33%
<b>C=0.25</b>										
% and number of correctly predicted non-crises	42.86%	28.57%	28.57%	28.57%	28.57%	28.57%	28.57%	85.71%	28.57%	28.57%
% and number of correctly predicted crises	100%	100%	100%	100%	100%	100%	100%	83.33%	100%	100%
<b>C=0.2</b>										
% and number of correctly predicted non-crises	42.86%	28.57%	28.57%	28.57%	28.57%	28.57%	28.57%	57.14%	28.57%	28.57%
% and number of correctly predicted crises	100%	100%	100%	100%	100%	100%	100%	83.33%	100%	100%

**Table 2.17.** Test Statistics for the Markov Regime Switching Models

MODELS	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Sigma 0	-0.3609	-0.3618	-0.3417	-0.3967	-0.3563	-0.3652	-0.3619	-0.3880	-0.3605	-0.3658
Sigma 1	1.4222	1.4276	1.6380	1.4162	1.4281	1.4235	1.4327	1.5241	1.4219	1.4227
P <sub>00</sub>	0.7944	0.7942	0.8001	0.7859	0.7953	0.7937	0.7959	0.8327	0.7944	0.7940
P <sub>11</sub>	0.4819	0.4800	0.4790	0.4826	0.4746	0.4800	0.4705	0.3092	0.4816	0.4843
Log-Likelihood	-365.36	-365.51	-365.54	-364.98	-365.04	-365.17	-363.92	-327.11	-365.35	-365.50
Linearity Test $\chi^2$	168.13***	168.60***	168.32***	168.17***	168.84***	168.79***	170.34***	204.02***	168.15***	168.59***
Serial correlation $\chi^2$	19.66 [0.10]	21.30 [0.07]	19.45 [0.11]	21.41 [0.07]	21.26 [0.07]	20.68 [0.08]	24.23 [0.03]	9.46 [0.73]	19.33 [0.11]	19.63 [0.10]
Normality $\chi^2$	4.27 [0.12]	4.51 [0.10]	5.47 [0.06]	7.16 [0.03]	3.89[0.14]	4.97 [0.08]	3.88 [0.14]	3.24 [0.20]	4.33 [0.11]	5.03 [0.08]
Davies p-value	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

**Note:** \*\*\*, \*\*, and \* represent statistical significance at the 1%, 5% and 10% levels, respectively. The values in brackets are  $p$ -values.

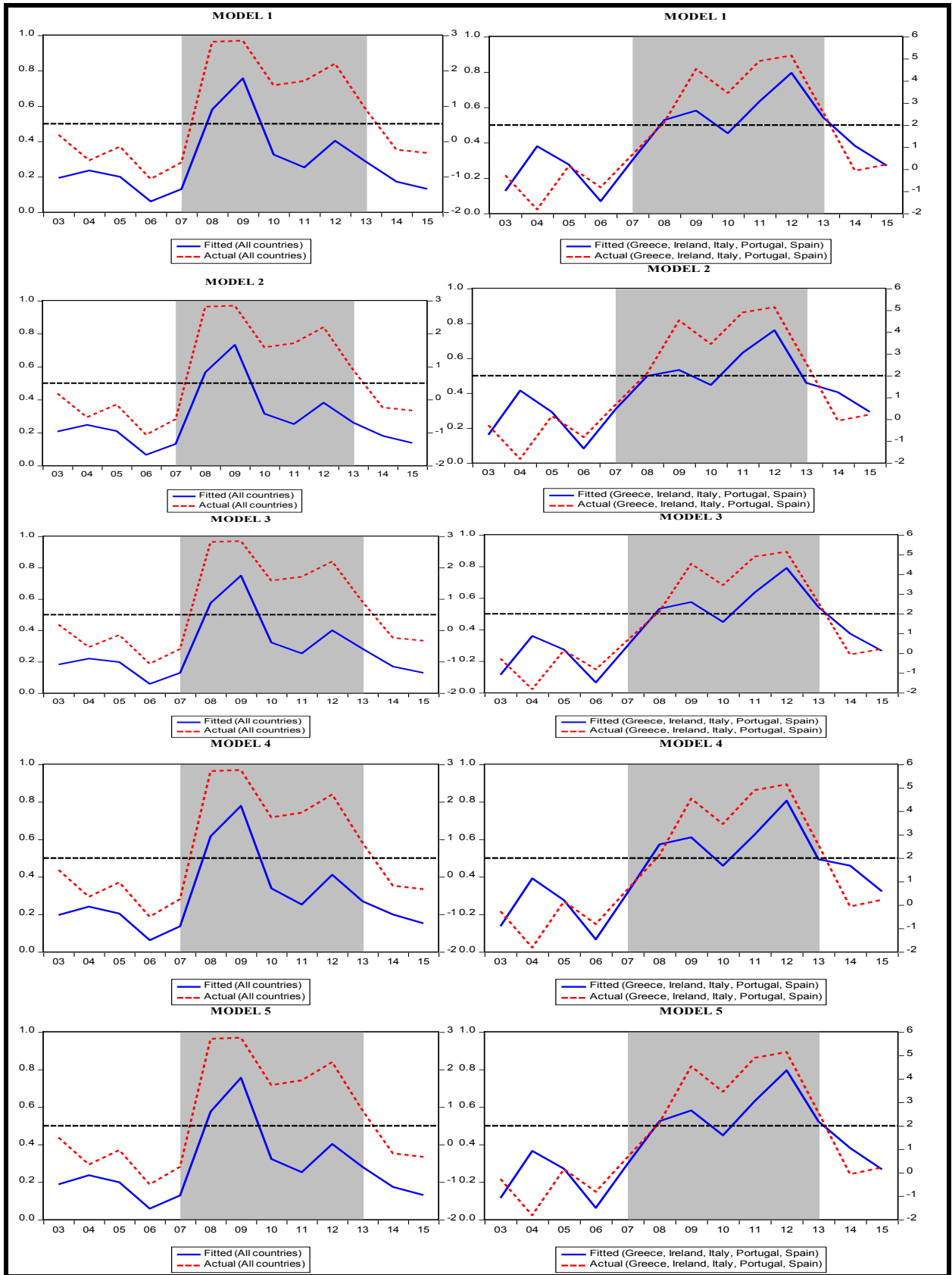


Figure 2.36. Predicted probability of crisis in the Markov Regime Switching Models (1-5).



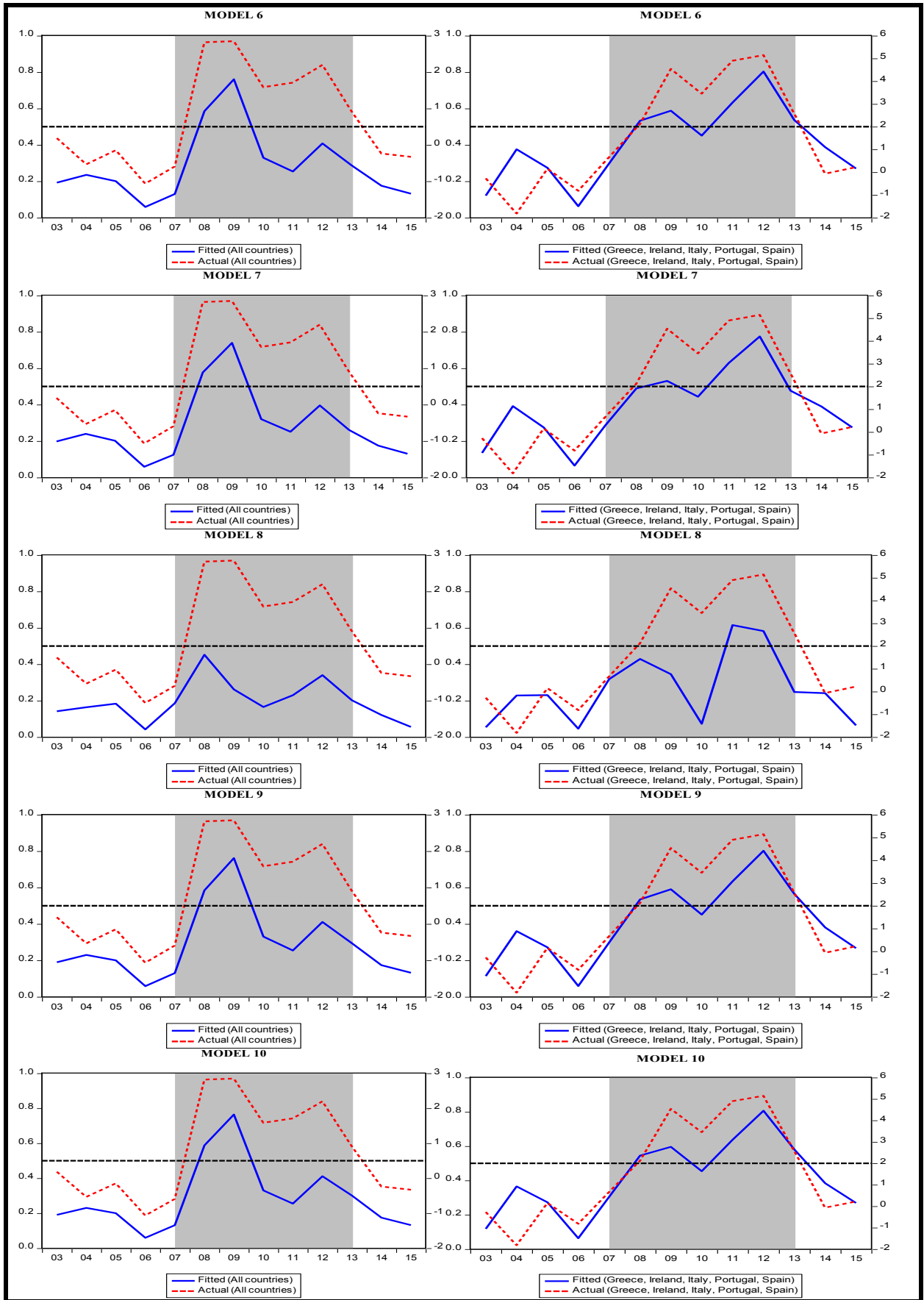


Figure 2.37. Predicted probability of crisis in the Markov Regime Switching Models (6-10).

## 2.6. Conclusion

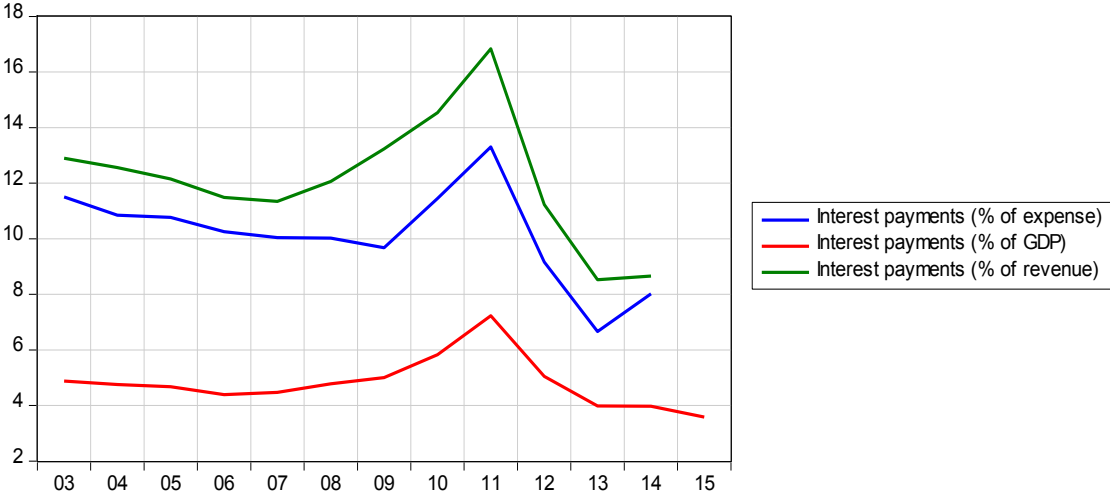
As the results obtained from the SOM, Logit, and Markov models are very similar, we propose an overall interpretation in this subsection. All three models indicated that NPL / TL, Primary Balance / GDP, PSRR, Corruption, Cash Balance / GDP, Unemployment, Voice and Accountability, Regulatory Quality, Rule of Law, GDP growth, Government Effectiveness, and Cyclically Adjusted Balance / GDP are all correctly signed and significant in explaining the occurrence of the debt crisis in the EU-15. Hence, one may affirm that increases in NPL / TL and unemployment are likely to increase the likelihood of a crisis, while increases in the Primary Balance / GDP, PSRR, Corruption, Cash Balance / GDP, Unemployment, Voice and Accountability, Regulatory Quality, Rule of Law, GDP growth, Government Effectiveness, and Cyclically Adjusted Balance / GDP reduce the probability of a crisis. The similarity of the results obtained in all three models is an important indicator of consistency for our investigation.

The fact that these variables have played a significant role in the emergence of the debt crisis suggests that changes in these variables are due to specific systematic movements. Accordingly, we see that the growth rates of countries in the crisis zone had fallen before the outbreak of the crisis. Having low growth rates poses two major threats for these countries. First, significant reductions in tax revenues draw attention due to these countries' decreasing total income. Tax income reductions increase the difficulties encountered for paying current public debts, which leads to a degradation in the overall fiscal situation. The second problem is the dramatic increase in unemployment due to the economic contraction. The rise in unemployment benefits and the presence of social safety nets exert an additional pressure on public finance.

Along with the decrease in these countries' incomes, they have had to face a sharp contraction of both their imports (resulting from income reduction) and exports (due to the contraction of world trade and, in particular, intra-European trade). Economic contraction is accompanied by a significant rise in the ratio of banks' non-performing loans to total loans during the crisis period. As banks' financial health dramatically deteriorated, new pressure on public finance appeared. Indeed, investors expected government interventions to save the too-big-to-fail banks. SOM results indicate that the banking crisis index reached to high levels during the debt crisis period. This supports the claim that banking sector problems are an important determinant of the European debt crisis. In the case of a debt crisis, governments have to pay high interest rates because they cannot pay their principal or interest on time.

However, this rise in risk premiums induces a vicious cycle by exacerbating tensions on public finances. This is precisely the situation that Greece experienced during the European debt crisis. Figure 2.38 shows the share of Greece’s interest payments in terms of expenses, revenue, and GDP. According to the Figure, Greece’s share of interest payments started to increase especially after reaching its highest value in 2011 through three indicators. This clearly indicates that Greece had financed its public spending through large-scale borrowing after entering the Eurozone; in turn, this increased the country’s interest payments along with its debt burden on the budget. As seen, this situation turned into a debt crisis for Greece.

**Figure 2.38.** Indicators for Greece’s interest payments.

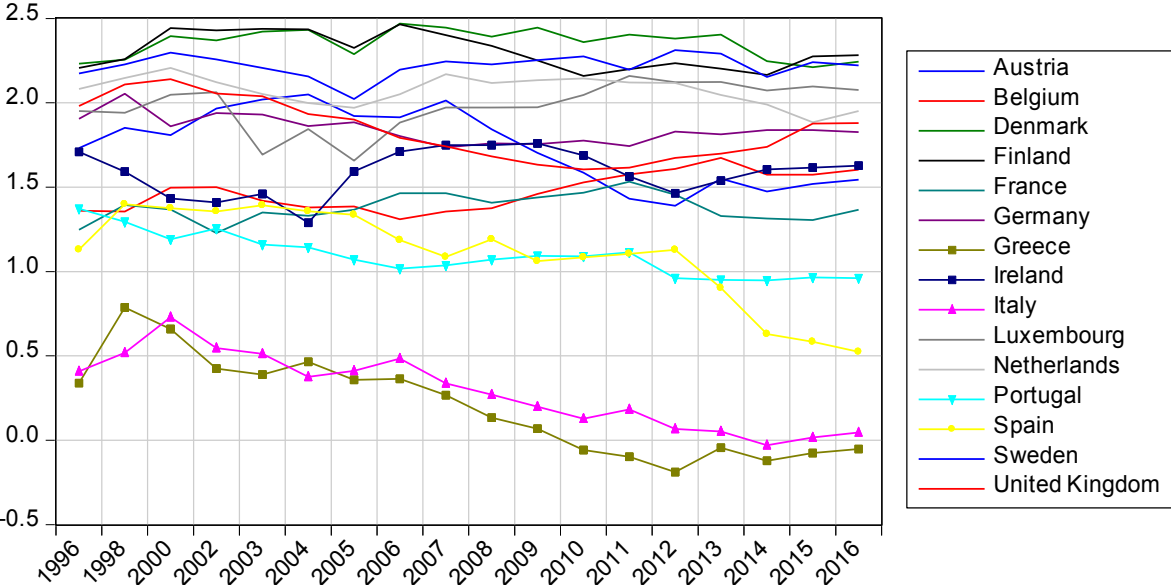


This also applies to other EU member states in which interest payments reached very serious levels. This conclusion supports the SOM-analysis results, according to which interest payments increased substantially in crisis countries. Another noteworthy result from the estimations is that despite the similar deteriorations in macroeconomic variables that Portugal, Ireland, Italy, Greece, and Spain had experienced, some other European countries had overcome the crisis in a shorter period. A closer inspection suggests governance indicators to play an important role.

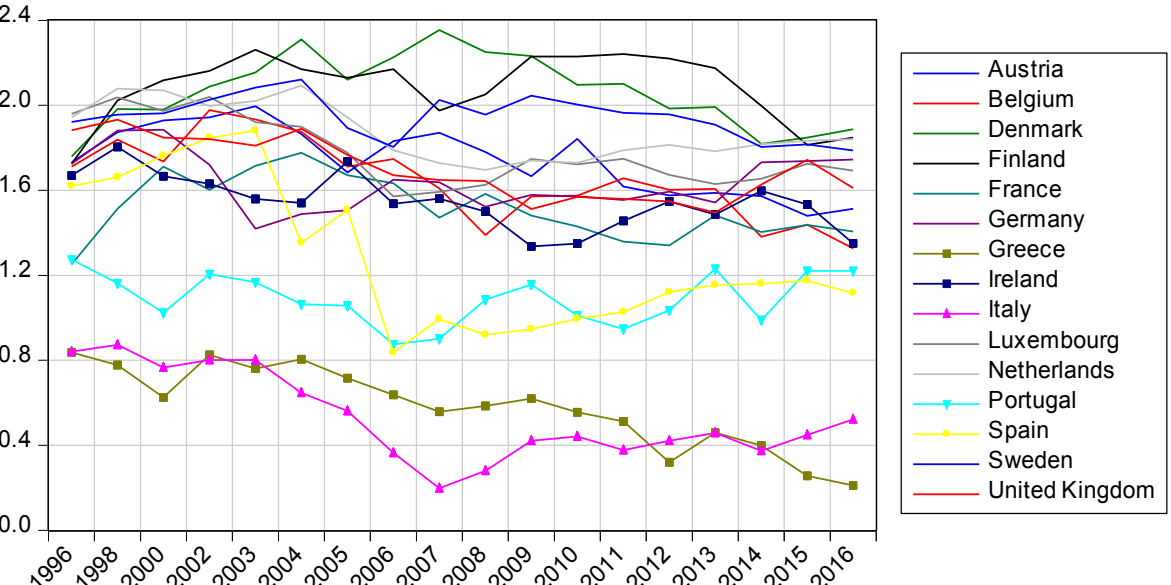
The following graphs show the variables of Control of Corruption, Government Effectiveness, Political Stability and Absence of Violence / Terrorism, Regulatory Quality, Rule of Law, and Voice and Accountability for the EU-15 countries. One can argue through these Figures that Spain, Italy, Greece and Portugal have the lowest governance values before and after the establishment of the European monetary union. This has also played an important role in these countries as they could not quickly recover from the crisis. Among the

PIIGS, Ireland has relatively better governance indicators (closer to the average values in the Eurozone) that may explain why Ireland could exit the crisis zone while other four countries are still in crisis zone. In addition, this may also explain why France, the Netherlands, and the UK, despite deterioration in their core macroeconomic indicators, could quickly recover from the crisis, by assuring the fiscal discipline. This implies that the existing crisis further deepened with the mismanagement of public resources during the crisis. Consequently, the soundness of governance indicators is said to have also had an impact on crisis duration.

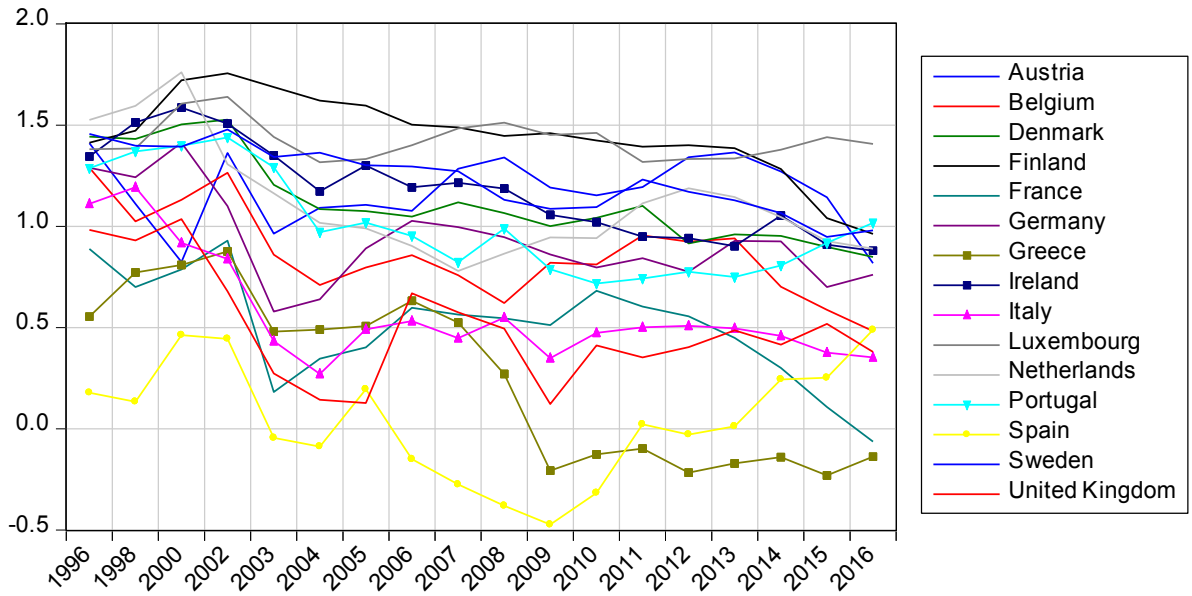
**Figure 2.39.** Control of corruption.



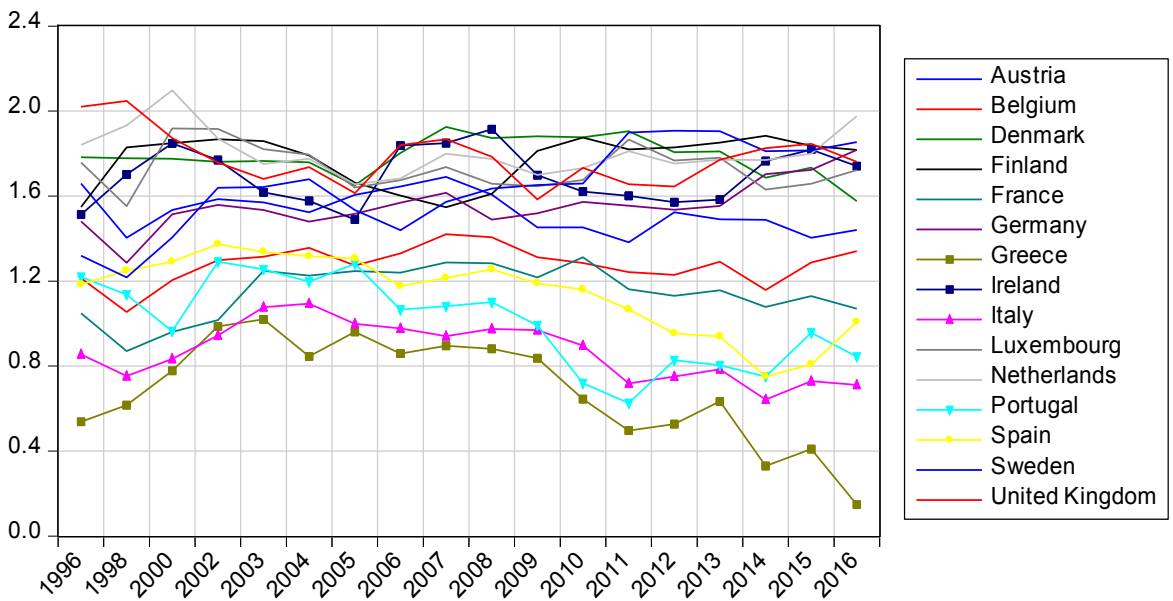
**Figure 2.40.** Government effectiveness.



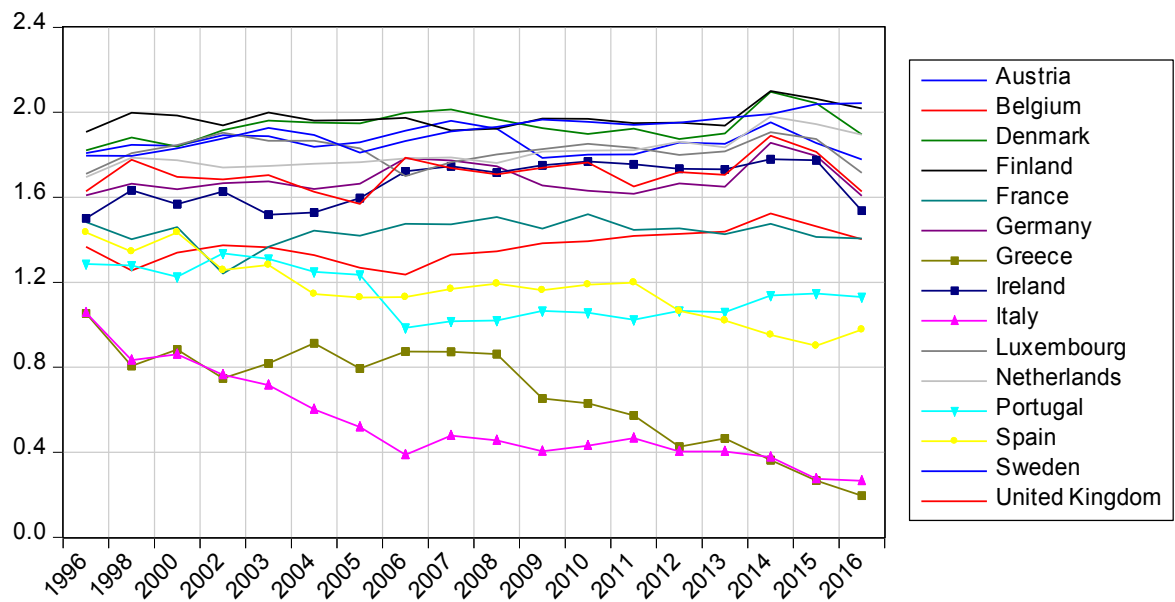
**Figure 2.41.** Political stability and absence of violence/terrorism.



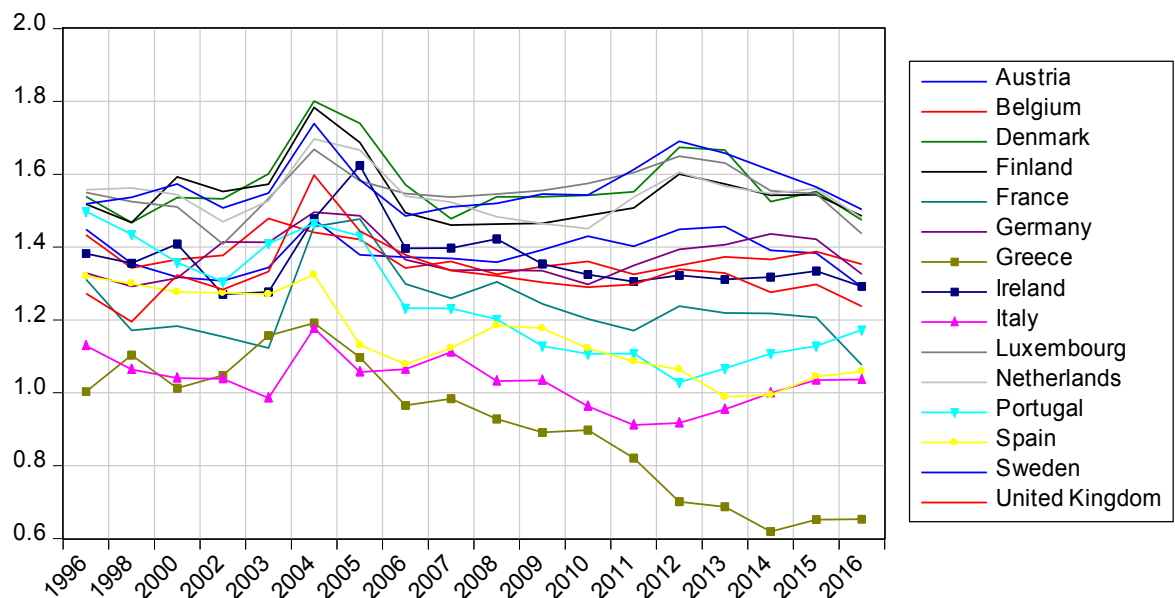
**Figure 2.42. Regulatory Quality**



**Figure 2.43. Rule of law.**



**Figure 2.44. Voice and accountability.**



Besides, the fact that each country has different fiscal policies despite the common monetary policy is important to recall. In this case, the countries that benefitted from Europe's prestige have lost their financial discipline over time, causing them to implement expansionary fiscal policies for populist objectives. This played an important role in reaching excessive debt stocks.

Another important issue that needs to be considered is whether the Eurozone is an optimal money area. As well known, Mundell (1961), McKinnon (1963), and Kenen (1969)

pioneered the study of optimal money area theory. Basically, in addition to the geographical closeness of the countries that make up this area, economic similarity is crucial for the success of an optimum money area. Initially, this similarity for the EU members was provided by the Maastricht Criteria (1992) for economic and monetary union, and the Copenhagen Criteria (1993) for full membership. As the objective of the Maastricht Criteria is to bring member countries closer to each other economically, they are called convergence criteria. Accordingly, there are five important convergence criteria.<sup>3</sup> The first one is the price stability which is evaluated by considering the consumer prices. According to this criterion, countries' annual inflation rate should not exceed the average of the three best performing countries by 1.5 percentage points. The second convergence criterion is sound public finance. This criterion is evaluated by considering Government Deficit / GDP ratio. The ratio should not exceed 3% for countries. The third one is sustainable public finance that considers the ratio of Government Debt / GDP. Accordingly, countries should not exceed 60% of the Government Debt / GDP ratio. The fourth one is the durability of convergence, measured by taking into account the long-term interest rate. According to this, the long-term interest rate of countries should not exceed the three best performing countries by more than 2 percentage points. The final criterion is exchange rate stability. This criterion is measured through deviations from the central rate. This criterion is evaluated according to whether the money of the country has devalued within the last two years.

When we examine the movements of the EU-15 countries over time in terms of macro, financial, and governance indicators, there is no homogenous structure within the EU-15 in the framework of the Maastricht criteria. This situation can be followed easily from the Figures obtained from the SOM analysis which show the movements of these countries over time: Portugal, Italy, Ireland, Greece, and Spain show quite different economic indicators from the other countries not only in periods of financial and debt crises but also in the pre-crisis period of 2002-2006. Compared to other countries, Greece, Spain, Portugal, and Italy seem to be in crisis well before the occurrence of the global financial crisis. This may have created negative pressure on the EU and Eurozone. An interesting feature of these countries is that, except for Ireland, they are located in Southern Europe. What is interesting here is that although Ireland is a northern country, it has been severely affected by the crisis just like the other southern countries. Zestos (2015) described Ireland economically as a southern country

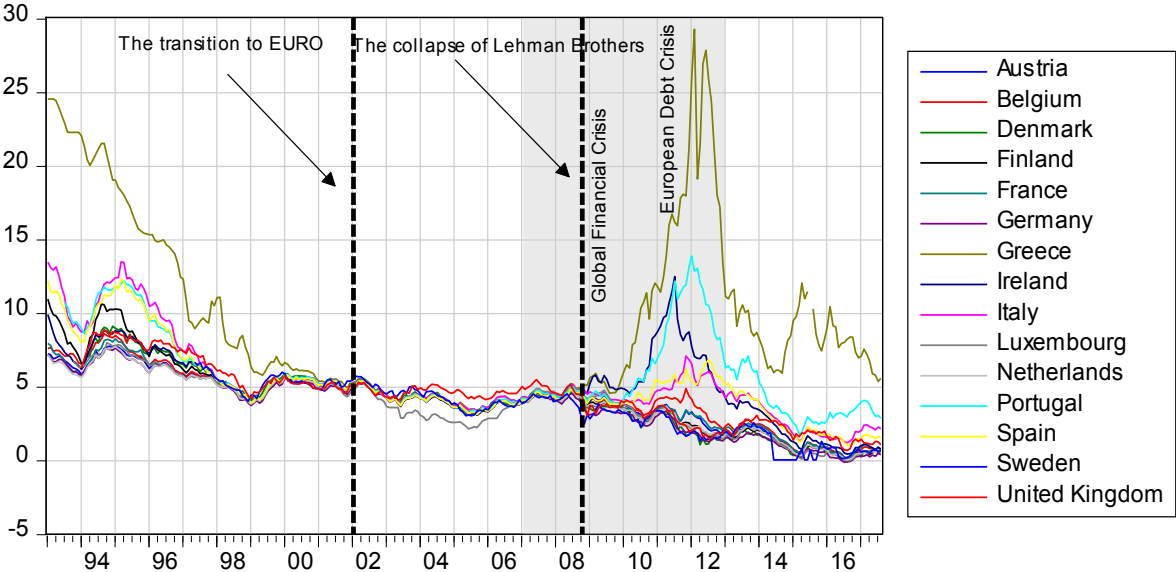
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<sup>3</sup> For more information on these criteria, see European Commission (2018). [https://ec.europa.eu/info/business-economy-euro/euro-area/enlargement-euro-area/convergence-criteria-joining\\_en](https://ec.europa.eu/info/business-economy-euro/euro-area/enlargement-euro-area/convergence-criteria-joining_en).

despite its location in Northern Europe. Perhaps Ireland can be considered as a transition country between the two regions as it seriously suffered the crisis just like Spain, Portugal, Greece, and Italy; however, it has managed to recover from the crisis contrary to other four countries. Our results indicate that European countries appear to be gathered under two different groups: southern and northern countries.

From a literary perspective, the success of a monetary union is based on four basic elements (Frankel & Rose, 1998): a) the extent of trade, b) the similarity of the shocks and cycles, c) the degree of labor mobility, and d) the system of risk-sharing, usually through fiscal transfers. In accordance with these criteria and based on results of this study, the Eurozone obviously does not precisely fulfill these conditions. As emphasized above, the fact that the Eurozone has a bilateral structure means that economic similarity cannot be achieved among these countries. Moreover, the fact that the degree of impact from external shocks was higher in Portugal, Italy, Ireland, Greece, and Spain implies that the EMU is in violation of another requirement for success. This can easily be seen when considering the crisis probabilities after the Markov estimates. Figures 2.34 to 2.37 show that the northern countries easily overcame the financial crisis while the southern countries were affected more severely by it. Considering these conditions, the EU-15 countries do not have the minimum requirements for a monetary union. This can also be seen in the countries' 10-yr. government bond rates before and after the monetary union, as shown in Figure 2.45.

**Figure 2.45.** 10-year government bond rates for EU-15.



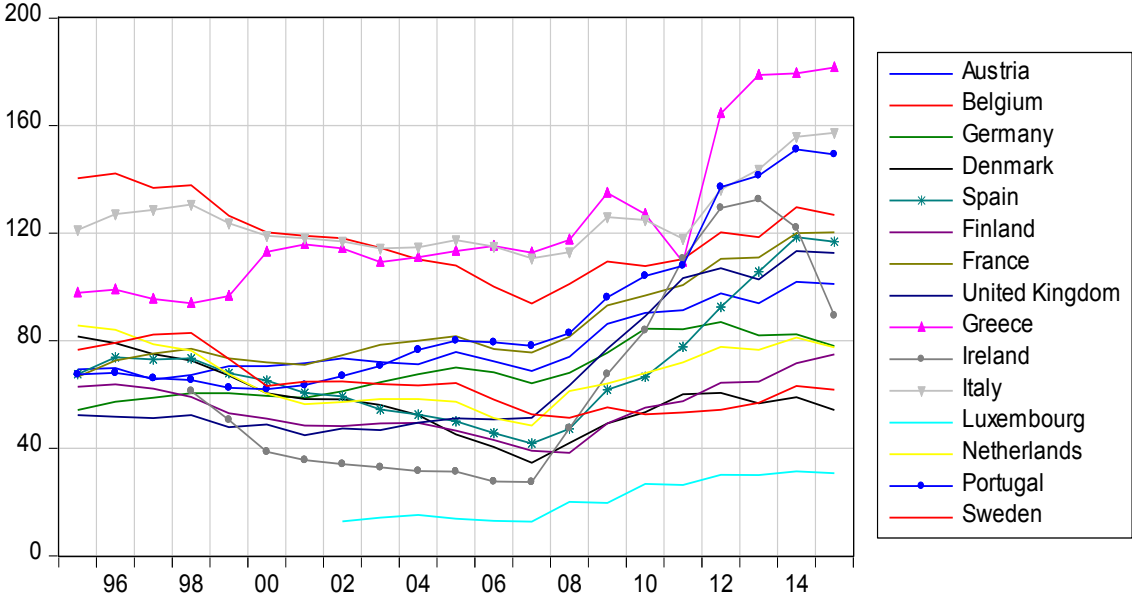
Accordingly, Greece, Spain, Ireland, Portugal, and Italy could only borrow with high interest rates before the monetary union, while after entering the union, they have been able to borrow with low interest rates like the other countries thanks to the prestige of the Eurozone.



However, these countries can be seen to have reached pre-monetary union borrowing interest rates after the financial crisis starting in 2007 and afterwards spreading to Europe.

The fact that these countries could borrow cheaply led to serious increases in public debt. The effects of the expanding fiscal policies in these countries can also be seen from their increase in public debt (see Figure 2.46).

**Figure 2.46.** Government debt as % of GDP for EU-15.



After becoming a member of the EMU, the share of the public debt stock in GDP has been constantly growing in parallel with the decline in interest rates for Portugal, Italy, Ireland, Greece, and Spain. This shows that these countries were able to borrow cheaply and, consequently, increase their spending. However, the expenditures are made not in order to increase the income of the country in the long term but rather in the housing sector for short-term profit. De Jong et al. (2017) emphasized that an increase in public spending will have long-term positive effects on the potential output of the economy and public finance, depending largely on the efficiency of the investment and the productivity of public capital. If this ratio is low, an increase in public investment results in greater deterioration of the debt ratio and less permanent output. However, public investments are not being used effectively when observing the recent developments in Portugal, Ireland, Italy, Greece, and Spain.

In addition, EU-15 countries can be said to have similar levels over time in areas such as education and health spending. This is evidenced by the fact that these indicators have a very similar appearance in the SOM results. While convergence has been successful for some of the major social and developmental indicators of Europe, the funding methods for improvements in these indicators are quite different: the northern countries less affected by the crisis finance this social spending by income generated with increases in production, while

the southern countries mostly finance it by borrowing which is mostly acquired through European prestige-based cheap borrowing facility. More importantly, this funding was not used for long-term sustainable growth that would guarantee to pay public debts in the future. Instead, they used this funding opportunity to produce more low value-added goods.

On the other hand, model test results do not indicate any diagnostic problem and the linearity test results suggest that using nonlinear models such as the Markov and logit is appropriate to predict debt crisis. When we assess the forecast performance of different models, one should note that comparing the results obtained through the SOM with the logit and Markov forecasts can be misleading for two reasons. The first is that SOM uses 51 different leading indicators while the logit and Markov model employ only 12. The second is that different thresholds cannot be used in the SOM approach. The forecast performance results from SOM show the model can predict crisis periods for the EU-15 more successfully than the noncrisis periods. The forecast performance of the logit and Markov models differs according to the selected threshold value. But, Markov estimates predict crisis periods more successfully than logit, while logit estimates predict noncrisis periods more successfully than the Markov estimates. Markov models could predict approximately 100% of the crisis periods correctly, while the logit model predicted 100% of the noncrisis periods. Selecting a lower threshold for both models improves the number of correctly predicted crisis periods but also causes non-crisis periods to be perceived as crises (Type II errors). Markov estimates can be said to have more Type II errors. In contrast, choosing a higher threshold value reduces the number of false alarms but at the expense of increasing the number of missed crises (Type I errors), particularly in logit models. This may be due to the technical features of these models; in logit models the crisis index takes the binary form (1 or 0), and the method attempts to forecast these crisis (1) and non-crisis (0) episodes, while the Markov method uses the dependent variable in a continuous form that measures increases in crisis probability.

When analyzing the crisis probabilities measured by the logit and Markov models, we observe that the models signal a crisis for Portugal, Italy, Ireland, Greece, and Spain over the period of 2008-2013 and an increasing fiscal pressure in other countries in 2008 and 2009. This is consistent with the reality since the financial crisis started to spread to Europe following the failure of Lehman Brothers in September 2008. Here one should note that the PIIGS were much worse affected by the crisis as their debt stock was already quite high and the possibility of borrowing even at higher rates stopped after the crisis. Even though policy measures (expansionary monetary and fiscal policies) achieved a relative success in restoring

confidence in the financial sector and in reducing the effects of the crisis on the real sector, the nationalization of private debt naturally led public debts to rise to very high levels. As credit rating agencies (Standard & Poor's, Moody's and Fitch) lowered the country rates and the debate on who will bear the cost of the crisis was not clarified, the Europe went through the most severe crisis of its recent history.

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## Chapter 3

# Revisiting Fiscal Convergence in the European Union with Combined Unit Root Tests

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### 3.1. Introduction

The main objective of this chapter is to analyze whether the PIIGS, the most affected crisis countries in the EU, and the new member states to the EU fiscally converge with the EU-10 and EU-15 countries, respectively. Here, the EU-10 countries are Austria, Belgium, Denmark, Finland, France, Germany, Luxembourg, Netherlands, Sweden, the United Kingdom. The EU-15 is obtained by adding Portugal, Ireland, Italy, Greece, and Spain to the EU-10 countries. The new member countries are Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia. The main reason for comparing the PIIGS with the EU-10 is to determine whether these countries' fiscal factors differ since they are most affected crisis countries in the EU. In addition, the new member states are compared with the EU-15 countries to determine these countries' fiscal similarities or differences and to get an idea about the future of the EU. Here, following De Bandt and Mongelli (2000), Blot and Serranito (2006), Kočenda et al. (2008) and Bertarelli et al. (2014) we check the fiscal convergence by considering two fiscal criteria underlined in the Treaty of Maastricht.<sup>4</sup> The first one is that the ratio of public debt stock to GDP should not exceed 60% while the second one is that the budget deficit should not exceed 3% of the GDP. The Maastricht criteria (also known as the euro convergence criteria) are the criteria which EU member states are required to meet to enter the third stage of the Economic and Monetary Union (EMU) and adopt the euro as their currency. Here, some countries included in the analysis are not members of the EMU, hence this may provide us with information about the possibility of their future membership to the EMU.

In this study, we test the fiscal convergence among the EU member countries over the period from 1995Q1 to 2017Q2. To do so, the study employs two dependent variables based on Maastricht Criteria, i.e. public debt over GDP and budget deficit over GDP, and uses

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<sup>4</sup> The studies of Esteve et al. (2000), Sosvilla Rivero et al. (2001), Zodrow (2003), Delgado (2006), Kemmerling (2010), Delgado and Presno (2010, 2011), Vintilă et al. (2014) and Ioana-Laura (2015) consider the definition of convergence in terms of taxation.

traditional unit root tests (ADF, Dickey and Fuller, 1979), nontraditional one (Zivot and Andrews, 1992)- and two-structural breaks (Lee and Strazicich, 2003) along with nonlinear unit root tests (KSS). The results indicate that Portugal, Ireland, Italy, Greece, and Spain (PIIGS) diverge from other EU-15 countries in terms of public debt-to-GDP ratio. In addition, results also show that all PIIGS countries except for Greece converge to EU-10 in terms of budget deficit-to-GDP ratio. This result is interesting since the accumulation of public debt is not mainly related to budget deficits but other structural factors like trade and/or current deficits.

The remainder of the chapter is organized as follows. Section 3.2 presents the data and methodology. Section 3.3 presents and evaluates the estimation results. Section 3.4 concludes.

### **3.2. Data and Methodology**

The study uses the period from the 1995Q1 to 2017Q2 as the analysis period. As underlined by Kočenda et al. (2008), the main reason for choosing this period is that countries that have joined the EU in 2004 made their official membership applications to the EU in 1995. The data used in the study is gathered from the IMF and OECD databases. As the time series techniques used in this study do not allow missing observations, we fulfilled the missing observations by using the cubic spline method.

In the literature, convergence analysis is realized using both different measurement methods and data types. When we check the previous studies, we observe that the convergence has often been used to test cross-country income convergence. However, studies conducted in the last 10 years have tested also convergence in different areas of economics. Energy (Mulder & de Groot, 2012; Burnett & Madariaga, 2017), health (Wang, 2009; Lau et al., 2014), military spending (Lau et al., 2016; Arvanitidis et al., 2014), income inequality (Lessmann & Seidel, 2017; Apergis et al., 2018), transportation (Beyzatlar & Yetkiner, 2017), financial development, (Kılınc et al., 2017), and housing costs (Kim & Rous, 2012) are some examples. In the literature, absolute or conditional convergence, sigma-convergence, and stochastic convergence are measured through different methods. Additionally, the econometric techniques used in convergence analysis studies differ from each other. Accordingly, studies on convergence use cross sections, time series, and panel datasets. For example, studies using cross-sectional data include Baumol (1986), Dowrick and Nguyen (1989), Barro (1991), and Barro and Sala-i-Martin (1992); time-series studies include Bernard

and Durlauf (1995), Oxley and Greasley (1995), Carlino and Mills (1996), Greasley and Oxley (1997), Oxley and Greasley (1999), Li and Pappel (1999), Datta (2003), Bentzen (2005), Chong et al. (2008), and Ayala et al. (2013); and, studies using panel data technique include Islam (1995), Weeks and Yudong Yao (2003), Westerlund and Basher (2008), and Hao et al. (2015). In this study, we opt for time-series techniques by using unit root tests.

Unit root tests were first used in convergence analysis with the augmented Dickey-Fuller (ADF) test to test the stochastic convergence among countries. In convergence analysis, the model with constants and trends is used as a suitable model for the ADF test. In the unit root tests, the null hypothesis is that the series is not stationary; the alternative hypothesis is that the series is stationary, or that it does not contain unit roots. According to the ADF test results, stating that the series is stationary indicates stochastic convergence between countries, but the regression model below should be estimated to determine the presence of  $\beta$  convergence (Ayala et al. 2013):

$$y_t = \mu + \beta t + u_t \quad (3.1)$$

For analyzing  $\beta$  convergence, the following different situations may occur.

- a) C ( $\beta$  convergence): There is  $\beta$  convergence if  $\mu$  and  $\beta$  have opposite signs and are statistically significant ( $\mu \neq 0$  and  $\beta \neq 0$ ).
- b) D (divergence form different levels): If  $\mu$  and  $\beta$  have the same polarity and are statistically significant, divergence exists from different levels ( $\mu \neq 0$  and  $\beta \neq 0$ ).
- c) c (constant at different levels): If  $\mu$  is statistically significant while  $\beta$  is not, the constant is found to stay at different levels ( $\mu \neq 0$  and  $\beta=0$ ).
- d) d (divergence from same level): If  $\mu$  is not statistically significant while  $\beta$  is, there is divergence from the same level ( $\mu = 0$  and  $\beta \neq 0$ ).
- e) E (remains at the same level): If neither  $\mu$  nor  $\beta$  are statistically significant, they remain at the same level ( $\mu = 0$  and  $\beta = 0$ ).

$\beta$  convergence is tested according to the polarity and statistical significance of  $\mu$  and  $\beta$ .

The presence of structural breaks in a time series can significantly affect the stability of results achieved through conventional unit root tests (Dickey & Fuller, 1979; Phillips & Perron, 1988; Kwiatkowski et al., 1992). Hence, new unit root tests that take into consideration structural break(s) have been developed in the literature. For instance, Perron (1989) and Zivot and Andrews (1992) have considered single breaks in the series. The main difference between Perron's (1989) and Zivot and Andrews's (1992) structural break unit root tests is that Perron's (1989) breakdown period is exogenous to the model while Zivot and

Andrews's (1992) one is endogenously included in the model. As this study tests for the existence of fiscal convergence among EU member countries, Zivot and Andrews's (1992) structural break unit root test is applied due to the decision of endogenous over single break unit root tests. Analyzing convergence via unit root tests with a structural break, the null hypothesis is that the series is not stationary, as in traditional unit root tests; therefore, no convergence exists between countries, and the alternative hypothesis is that the series is stationary with a structural break, namely, convergence between countries. If the null hypothesis is rejected in the analysis, then the following equation must be estimated to test  $\beta$  convergence among countries.

$$y_t = \mu_1 DU_{1t} + \mu_2 DU_{2t} + \beta_1 TIME_{1t} + \beta_2 TIME_{2t} + u_t \quad (3.2)$$

where  $DU_{1t} = 1$  if  $t \leq T_B$ , otherwise  $DU_{1t} = 0$ ;  $DU_{2t} = 1$  if  $t > T_B$ , otherwise  $DU_{2t} = 0$ ;  $TIME_{1t} = t$  if  $t \leq T_B$ , otherwise  $TIME_{1t} = 0$ ;  $TIME_{2t} = t - T_B$  if  $t > T_B$ , otherwise  $TIME_{2t} = 0$ . Interpreting the coefficients here is done in the same way as the previously predicted equations.

In the presence of more than one structural break, both the traditional unit root tests and the single-break unit root tests (i.e. Perron, 1989; Zivot & Andrews, 1992) can give biased results. For this reason, deciding whether convergence or divergence exists between countries would be incorrect. To solve this problem, unit root tests that take into account more than one structural break have been used in the convergence literature. In the time series literature, two unit root tests (i.e., Lumsdaine & Papell, 1997; Lee & Strazicich, 2003) have been used to test convergence between countries. In this study, Lee and Strazicich's (2003) two-break unit root test is used to test for fiscal convergence between EU countries. As in the case of unit root tests with one structural break, the null hypothesis here emphasizes the series to not be stationary and thus no convergence to exist between countries, while the alternative hypothesis is that the series is stationary with structural breaks. In order to test  $\beta$  convergence between countries, the following equation must be estimated:

$$y_t = \mu_1 DU_{1t} + \mu_2 DU_{2t} + \mu_3 DU_{3t} + \beta_1 TIME_{1t} + \beta_2 TIME_{2t} + \beta_3 TIME_{3t} + u_t \quad (3.3)$$

where  $DU_{1t} = 1$  if  $t \leq T_B$ , otherwise  $DU_{1t} = 0$ ;  $DU_{2t} = 1$  if  $T_{1B} < t \leq T_{2B}$ , otherwise  $DU_{2t} = 0$ ;  $TIME_{1t} = t$  if  $t \leq T_{1B}$ , otherwise  $TIME_{1t} = 0$ ;  $TIME_{2t} = t - T_{1B}$  if  $T_{1B} < t \leq T_{2B}$ , otherwise  $TIME_{2t} = 0$ ; and  $TIME_{3t} = t - T_{2B}$  if  $t > T_{2B}$ , otherwise  $TIME_{3t} = 0$ . Here, the interpretation of the coefficients is done in the same way as the previously predicted equations.

Finally, the nonlinear nature of some series causes the linear unit root test results to become misleading. In order not to encounter such a situation, firstly the appropriate unit root test should be selected and applied after the linearity of the series. Early studies on nonlinear

convergence have mainly employed the nonlinear unit root test developed by Kapetanios et al. (2003). Kapetanios et al. used the smooth transition autoregressive (STAR) process to incorporate the ADF unit-root test into non-linearity. This process is expressed in the equation below.

$$\Delta x_t = \mu + \sum_{j=1}^p \rho_j \Delta x_{t-j} + \delta y_{t-1}^3 + v_t \quad (3.4)$$

Although this test is an important tool for convergence analysis, it does not distinguish between convergence and long-term catch-up (Chong et al., 2008). Chong et al. combined the nonlinear unit root test from Kapetanios et al.'s (2003) and Oxley and Greasley's (1995) time series convergence analysis tests by adding an additive intercept and trend component to the KSS model. In this case, the new estimation equation is defined as:

$$\Delta y_t = \mu + \sum_{j=1}^p \rho_j \Delta y_{t-j} + \delta y_{t-1}^3 + \phi G(\text{trend}) + \xi_t \quad (3.5)$$

where the  $y_t$  series indicates the original state of the series as different from the de-meaned and de-trended  $x_t$  series;  $G(\text{trend})$  is the linear and nonlinear trend. In this study, as in Chong et al. (2008), the square trend has been used for the nonlinear trend. To interpret this equation in economic terms as in Oxley and Greasley (1995), the absence of a nonlinear unit root ( $\delta < 0$ ) implies either that the nonlinearity is catching up given the presence of a deterministic trend ( $\phi \neq 0$ ) or that the nonlinearity is converging in the long term if the deterministic trend is absent ( $\phi = 0$ ). If there is a nonlinear unit root in the series, the conclusion is divergence.

To examine a potential convergence process in public debt and budget deficit, we start with an endogenous system design that considers the government's existence. As in an endogenous growth model, all endogenous factors should grow at the same rate; any convergence process in the rate of economic growth will reflect the dynamics of the other endogenous indicators which are two specific government indicators in this study. The government's existence in this model is based on the essentials of Barro and Sala-i Martin (1995).

### Household Utility Function:

$$U = \int_0^{\infty} \left( \frac{c^{1-\theta}}{1-\theta} \right) e^{-\rho t} dt \quad (3.6)$$



where  $c$  stands for consumption,  $\theta$  is the elasticity of substitution, and  $\rho$  is the subjective discount rate.

**Government:**

$$G + V = \tau_w wL + \tau_a r(\text{asset}) + \tau_c C + \tau_F (\text{Firm earning}) \quad (3.7)$$

where  $G$  is the government expenditures,  $V$  represents the transfer expenditures,  $w$  signifies wage,  $L$  indicates labor,  $C$  denotes consumption, and  $\tau$  refers to taxes levied for  $\tau \in (0,1)$ . The dot matrix gives the derivative with respect to time.

**Household Budget Constraint:**

$$\dot{a} = (1 - \tau_w)w + (1 - \tau_a)ra - (1 - \tau_c)C - na + v \quad (3.8)$$

where  $n$  means population growth,  $a$  demonstrates assets per capita, and  $v$  explains transfer expenditures per capita.

**Consumption Growth Rate:**

$$\frac{\dot{c}}{c} = \frac{1}{\theta} [(1 - \tau_a)r - \rho] \quad (3.9)$$

Household determines the decision to consume, whether it increases or decreases, according to the after-tax return of assets.

**Firm Production:**

$$Y = F(K, L) \quad (3.10)$$

$$\text{After-Tax Profit} = (1 - \tau_F)[F(K, \hat{L}) - wL - \delta K] - rK \quad (3.11)$$

In order to maximize profit, one needs to take the derivative of the function with respect to  $K$ , setting the derivative equal to zero. First, if the expression is written explicitly as:

$$\pi = (1 - \tau_F)F(K, \hat{L}) - (1 - \tau_F)wL - (1 - \tau_F)\delta K - rK \quad (3.12)$$

$$(1 - \tau_F)f'(\hat{k}) - (1 - \tau_F)\delta - r = 0 \rightarrow f'(\hat{k}) = \frac{r}{(1 - \tau_F)} + \delta$$

Then the capital accumulation function is derived as follows:

$$\begin{aligned}\hat{k} &= f(\hat{k}) - \hat{c} - (x+n+\delta)\hat{k} - \hat{g} \\ \text{where } \hat{c} &= \frac{c}{\hat{L}} = ce^{-xt} \text{ and } \hat{g} = \frac{G}{\hat{L}}\end{aligned}\quad (3.13)$$

where  $x$  shows the rate of increase in technology.

**Marginal Efficiency of Labor:**

$$w = e^{xt} [f(\hat{k}) - \hat{k} f'(\hat{k})] \quad (3.14)$$

$$\frac{\dot{\hat{c}}}{\hat{c}} = \frac{\dot{c}}{c} - x \text{ the consumption increase rate is constructed as effective consumption. In this}$$

case, after adding  $\frac{\dot{c}}{c}$  if it is written in its extended form:

$$\frac{\dot{\hat{c}}}{\hat{c}} = \frac{1}{\theta} [(1-\tau_a)(1-\tau_F)[f'(\hat{k}) - \delta] - \rho - \theta x] \quad (3.15)$$

where the capital is exposed to two different taxes.

**Steady State:**

$$\begin{aligned}f(\hat{k}) &= \hat{c} + (x+n+\delta)\hat{k} - \hat{g} \\ \frac{\partial f(\hat{k})}{\partial \hat{k}} &= x+n+\delta \rightarrow f'(\hat{k}) - \delta = x+n\end{aligned}\quad (3.16)$$

If we bring this together with the structure in  $\frac{\dot{\hat{c}}}{\hat{c}}$  we get the Transversality Condition:

$$\lim_{t \rightarrow \infty} \left\{ \hat{k} \cdot \exp\left(-\int_0^t [(1-\tau_a)(1-\tau_F) \cdot (f'(\hat{k}) - \delta) - x - n] du\right) \right\} = 0 \quad (3.17)$$

In short, to increase the net product of capital in Steady State, the condition of  $f'(\hat{k}^*) - f > \frac{(x+n)}{(1-\tau_a)(1-\tau_F)}$  should be provided.

Greiner (2007):

$$\dot{B} = Br - S \quad (3.18)$$

where  $B$  describes public debt,  $r$  states real interest rate, and  $S$  stands for government surplus.

$$\begin{aligned}S &= T - Ip \\ Ip &= G + V\end{aligned}\quad (3.19)$$

Greiner (2007) assumes the ratio of public surplus to GDP to be the linear difference of Debt / GDP and to be constant:

$$\frac{T - Ip}{Y} = \phi + \beta \frac{B}{Y} \quad (3.20)$$

where  $\phi$  and  $\beta$  are constant,  $\phi$  reflects how  $S$  reacts in reality to the increase in  $Y$ .

$$T - Ip = \phi Y + \beta B \quad S = \phi Y + \beta B \quad (3.21)$$

then it can be written as

$$\dot{B} = Br - (T - Ip) = Br - \phi Y - \beta B \quad (3.22)$$

and becomes

$$\dot{B} = B(r - \beta) - \phi Y \quad (3.23)$$

The equations up to now include capital, consumption, public expenditures and, accordingly, a structure in which public debt is endogenous. Let us assume that  $\tau \rightarrow \tau_w, \tau_F, \tau_w, \tau_c$ , is the weighted average where  $\tau$  represents the general tax rate.  $T - Ip = \phi Y + \beta B$  has been assumed above. Let's leave  $Ip$  alone. In this case, if  $Y = T / \tau$  then  $\phi Y = \phi(T / \tau)$  and the equation can be written as:

$$Ip = T - \phi Y - \beta B \Rightarrow T = \tau Y$$

If  $Ip = T(1 - (\phi / \tau) - \beta B)$  and  $Ip = I - (\phi / \tau)$  then it becomes  $Ip = T(Ip - \beta B)$ .

Every public expenditure made can be considered as an accumulated public expenditure. Suppose that the public expenditure accumulation function is not subject to detrition:

$$\dot{Ip} = ipT - \beta B \quad (3.24)$$

then  $Ip$  becomes

$$ip = 1 - \frac{\phi}{\tau} \quad \text{and} \quad \dot{B} = Br - B\beta - \phi Y \quad (3.25)$$

Then the public debt accumulation function can be written as follows:

$$\dot{B} = (r - \beta)B + T(ip - 1) \quad (3.26)$$

The positive difference between the real interest rate and the  $\beta$  parameter showing the public surplus of public debt is observed to increase the accumulation of public debt and tax revenues to decrease this accumulation as the parenthesis  $(Ip - 1)$  is negative. In short, the

simple system here is a structure where  $Y, K, Ip$  (i.e.  $G$  and  $V$ ),  $C$  and  $B$  are internal. In the balanced growth path, all grow at the same rate:

$$\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{G}}{G} = \frac{\dot{V}}{V} = \frac{\dot{C}}{C} = \frac{\dot{B}}{B} = \mu \quad (3.27)$$

where  $\mu$  indicates the growth rate in the balanced growth path. So, a growth (or convergence process) to be defined for one of these will actually reflect the growth (or convergence) of all. The convergence process of GDP per capita can be defined as:

$$\frac{d \ln \hat{y}(t)}{dt} = \lambda(\ln(\hat{y}^*) - \ln \hat{y}(t)) \quad (3.28)$$

where  $\hat{y}^*$  may represent the level of the stationary state GDP per capita (or any time after any time  $t$ ). The process of convergence between any period  $t_1 - t_2$  is as follows:

$$\ln \hat{y}(t_2) - \ln \hat{y}(t_1) = (1 - e^{-\lambda \gamma}) \ln \hat{y}^* - (1 - e^{-\lambda \gamma}) \ln \hat{y}(t_1) \quad (3.29)$$

The process that applies to GDP per capita is also valid for  $B$  (public debt) and public budget deficit (let's say  $DF$ ). Here  $DF$  actually refers to a negative  $S$ .

Let's write  $\frac{\dot{DF}}{DF} = \dot{S}/S = \mu$ . This is due to the fact that  $S = T - Ip$ , and  $(T - Ip) / Y = \phi + \beta(B / Y)$  has been previously defined (see Eq. 3.20).

### 3.3. Empirical Results

The results of the analysis on whether fiscal convergence exists among the EU countries are presented in Table 3.1. According to the ADF unit root test results for the general government debt-to-GDP ratio, no fiscal convergence is found among the EU countries since the series are not stationary. One may then argue that the shocks related to the fiscal differences among EU countries can be said to be permanent. This confirms the validity of divergence between the EU-10 and PIIGS (in total, the EU-15), and the new member states. However, in the case of one or more structural breaks, the resulting ADF unit root test results may be misleading. For this reason and in order to make a clearer decision about whether convergence or catch-up exists between countries, the Zivot-Andrews structural break unit root test results are included. According to the results presented in Table 3.1, no fiscal convergence is found between the EU-10 and the PIIGS, and new member countries. The test

results indicate the fiscal differences between countries to not disappear with models that consider a single structural break; the shocks related to fiscal differences between countries are permanent.

In the next stage of analysis, the results of Lee and Strazicich's (2003) unit root test with two breaks are taken into consideration in light of the possibility of more than one structural break in the series. The results presented in Table 3.1 indicate that Greece, Latvia, Portugal, and Croatia are stationary with structural breaks. For the other countries included in the analysis, financial differences are not stationary, as in the other unit root tests. Hence, these countries do not show convergence and the shocks related to fiscal differences are permanent. Greece, Latvia, Portugal, Slovenia, and Croatia are stationary with structural breaks; Greece and Portugal show stochastic convergence with the EU-10, and Latvia and Croatia with the EU-15, but in order to state this information as certain, Equation 3.3 should be estimated and the results should be interpreted accordingly. In other words, for the countries that we find stochastic convergence,  $\beta$  convergence should be tested. Table 3.2 shows the estimation results for Greece, Latvia, Portugal, Slovenia, and Croatia. According to the results, the structural break periods for Greece are in 2007Q1 and 2011Q4. Hence, Greece seems to have fiscally diverged from the EU10 countries before the occurrence of the global financial crisis. Besides, Greece shows weak convergence between 2007Q1 and 2011Q4, and weak divergence after 2011Q4. According to these results, Greece is generally seen to fiscally diverge from the EU-10 countries during the analysis period. For Latvia, 2007Q2 and 2013Q4 have been determined as structural breaks. Latvia shows  $\beta$  convergence before 2007Q2, weak convergence between 2007Q2 and 2013Q4, and  $\beta$  convergence after 2013Q4. According to these results, Latvia can generally be concluded to have fiscally converged with the EU-15 countries during the analysis period. When we examine the results for Portugal, the break periods are 2000Q3 and 2010Q4. In the pre-2000Q3 period, Portugal showed weak convergence with the EU-10 countries,  $\beta$  convergence between 2000Q3 and 2010Q4, and weak divergence after 2010Q4. For Slovenia,  $\beta$  convergence to EU-15 countries has been determined in the pre-1999Q4 period, weak convergence between 1999Q4 and 2011Q3, and  $\beta$  convergence to EU-15 countries post 2011Q3. According to these results, Slovenia can be said to generally converge with EU-15 countries fiscally during the analysis period.

**Table 3.1.** Unit Root Tests for Debt/GDP Convergence

	ADF		ZA			LS						
	$\tau$	k		k	Break Dates		D	DT	Break Dates	$\lambda_1$	$\lambda_2$	k
Czech Republic	-0.492 [-3.460]	0	-3.911 [-5.080]	0	2003Q1	-4.752	-2.039 1.650	3.076 -5.088	2000Q4 2009Q1	0.264	0.637	10
Estonia	-1.091 [-3.460]	0	-2.569 [-5.080]	0	2008Q4	-5.401*	2.334 2.354	1.174 -6.237	2000Q3 2008Q2	0.253	0.593	11
Greece	-2.739 [-3.460]	0	-4.604 [-5.080]	0	2010Q3	-5.757**	-0.661 -16.194	-0.822 3.556	2007Q1 2011Q4	0.538	0.747	9
Ireland	-1.621 [-3.461]	2	-3.402 [-5.080]	2	2010Q1	-5.311	0.099 -1.144	0.033 2.420	2006Q1 2011Q1	0.495	0.714	10
Italy	-1.054 [-3.462]	4	-3.581 [-5.080]	4	2010Q1	-4.371	0.372 -0.628	-3.031 4.435	1999Q3 2012Q3	0.209	0.769	8
Latvia	-3.341 [-3.461]	2	-4.466 [-5.080]	2	2012Q1	-7.214***	-1.482 1.021	5.878 -4.222	2007Q2 2013Q4	0.549	0.835	11
Poland	-1.345 [-3.461]	1	-3.031 [-5.080]	1	2001Q2	-5.087	-2.534 0.596	2.648 -3.179	2004Q3 2010Q4	0.429	0.703	11
Portugal	-2.758 [-3.462]	4	-4.527 [-5.080]	4	2010Q4	-5.990**	2.393 -2.679	-1.615 5.672	2000Q3 2010Q4	0.253	0.703	10
Slovak Republic	-2.257 [-3.461]	1	-2.797 [-5.080]	1	2001Q1	-5.375*	1.667 -1.649	-4.300 -2.751	2003Q3 2007Q3	0.220	0.736	10
Slovenia	-1.908 [-3.462]	1	-3.921 [-5.080]	1	2008Q4	-5.701**	0.459 -2.189	0.644 8.082	1999Q4 2011Q3	0.455	0.795	10
Spain	-1.967 [-3.462]	4	-3.150 [-5.080]	4	2005Q1	-5.133	0.156 -1.224	-2.690 3.616	2004Q4 2012Q2	0.407	0.835	8
Bulgaria	-0.443 [-3.460]	0	-2.715 [-5.080]	0	2011Q1	-5.006	0.727 -1.002	-4.038 6.590	2004Q1 2013Q4	0.242	0.626	5
Cyprus	-1.296 [-3.460]	0	-3.198 [-3.198]	0	2008Q2	-5.101	-1.533 5.239	2.590 -3.526	2000Q2 2009Q1	0.231	0.747	9
Lithuania	-2.434 [-3.460]	0	-4.218 [-5.080]	0	1998Q3	-5.154	0.470 4.578	-0.267 -4.370	2000Q1 2011Q4	0.396	0.659	9
Malta	-2.041 [-3.460]	0	-3.879 [-5.080]	0	2000Q4	-4.065	-1.678 -0.439	-3.104 -3.871	2003Q4 2009Q4	0.308	0.747	4
Romania	-2.627 [-3.460]	0	-3.618 [-5.080]	0	2003Q1	-5.127	-2.404 4.765	-3.002 -3.293	2001Q4 2011Q4	0.308	0.747	8
Croatia	-2.391 [-3.462]	1	-3.465 [-5.080]	1	2008Q4	-6.964***	1.004 -2.790	-9.632 9.993	2002Q4 2011Q4	0.364	0.773	11
Hungary	-1.683 [-3.460]	0	-3.429 [-5.080]	9	2005Q1	-4.333	-2.816 0.143	-6.535 -0.688	1999Q3 2009Q1	0.208	0.626	6

**Note:** The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively. ADF: Augmented Dickey-Fuller test, ZA: Zivot-Andrews (1992), LS: Lee and Strazicich (2003).

**Table 3.2.**  $\beta$  Convergence Estimation Results for model with two structural breaks for Debt to GDP ratio

Country	$\mu_1$	$\beta_1$	Decision	$T_{b1}$	$\mu_2$	$\beta_2$	Decision	$T_{b2}$	$\mu_3$	$\beta_3$	Decision
Greece	25.378*** (1.341)	0.598*** (0.049)	D	2007Q1	-84.746 (12.909)	2.597*** (0.224)	c	2011Q4	7.487 (19.120)	1.154*** (0.243)	d
Latvia	-53.805*** (0.530)	0.197*** (0.019)	C	2007Q2	16.219 (13.070)	-0.823*** (0.209)	c	2013Q4	-258.313*** (40.066)	2.645*** (0.478)	C
Portugal	-4.287*** (0.280)	-0.016 (0.015)	c	2000Q3	-40.126*** (2.630)	1.306*** (0.044)	C	2010Q4	14.494 (11.450)	0.643*** (0.149)	d
Slovenia	-50.708*** (0.371)	0.591*** (0.035)	C	1999Q4	-33.943*** (0.796)	-0.017 (0.018)	c	2011Q3	-107.001*** (11.834)	1.161*** (0.153)	C
Croatia	-40.024*** (0.681)	1.0111*** (0.039)	C	2002Q4	-1.339 (1.140)	-0.523*** (0.023)	c	2011Q4	-78.439*** (16.229)	0.866*** (0.209)	C

**Note:** The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively. *C* indicates  $\beta$  convergence, *c* indicates  $\beta$  convergence with only one estimate statistically significant, *D* indicates divergence, *d* indicates divergence with only one estimate statistically significant and *E* indicates equilibrium growth. The values in parentheses are standard errors.

For Croatia, 2002Q4 and 2011Q4 are found to be the structural break periods. Croatia has  $\beta$  convergence to EU-15 countries before 2002Q4, poor convergence between 2002Q4 and 2011Q4, and  $\beta$  convergence after 2011Q4. Finally, the non-linear unit root tests will be analyzed through the KSS unit root test for the countries. Determining whether a series is linear or nonlinear is important in time series. For nonlinear data, testing the stationarity of the data with linear unit root tests will significantly reduce the power of the tests and lead to false results. For this reason, results from the KSS unit root tests are given to determine the stationarity of variables and thus make a clearer decision on whether convergence exists among the countries of study. Before deciding whether the series are linear or nonlinear, Harvey and Leybourne's (2007) and Harvey et al.'s (2008) linearity test are presented in Table 3.3.

**Table 3.3.** Harvey and Leybourne (2007) and Harvey et al. (2008) linearity tests for Debt to GDP ratio.

Country	$W_{10\%}^*$	$W_{5\%}^*$	$W_{1\%}^*$	$W_{\lambda}$
Czech Republic	2.02	2.03	2.05	1.76
Estonia	7.27	7.29	7.33	5.96
Greece	7.44	7.55	7.74	6.67*
Ireland	31.65***	31.87***	32.25***	19.53***
Italy	0.85	0.86	0.86	0.89
Latvia	2.01	2.02	2.03	1.02
Poland	3.96	3.99	4.04	4.36
Portugal	4.14	4.15	4.18	0.86
Slovak Republic	2.91	2.94	2.99	2.38
Slovenia	2.43	2.43	2.44	2.86
Spain	7.62	7.68	7.80*	2.57
Bulgaria	1.70	1.70	1.71	1.54
Cyprus	9.91**	9.95**	10.01**	7.70**
Lithuania	4.57	4.59	4.62	3.09
Malta	2.12	2.14	2.19	1.86
Romania	2.18	2.19	2.21	1.75
Croatia	2.25	2.26	2.27	2.13
Hungary	1.00	1.01	1.02	1.09

**Notes:** The critical values for  $W_{\lambda}$  are 9.21 (1%), 5.99 (5%) and 4.60 (10%). The critical values for  $W^*$  are 13.27 (1%), 9.48 (5%) and 7.77 (10%). The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively.

Table 3.3 shows the linearity test statistics results of  $W^*$  for Harvey and Leybourne (2007) and  $W_{\lambda}$  for Harvey et al. (2008). For both linearity tests, exceeding critical values indicates rejecting the null hypothesis of the series' linearity and accepting the alternative hypothesis of the series' nonlinearity. According to these results, both  $W^*$  and  $W_{\lambda}$  test statistics exceed 1% for Ireland and 5% for Cyprus. As the Ireland and Cyprus series are



nonlinear in this case, conducting the nonlinear unit root tests to check the stationary nature of the series would be more appropriate. Table 3.4 and 3.5 show the nonlinear KSS unit root test results for all countries used in the study. The models in Table 3.4 are models with linear trends. Here, the results of the KSS unit root test have not been interpreted, as the series apart from Ireland and Cyprus are considered to be linear. The Ireland and Cyprus series are concluded not to be stationary due to not exceeding the critical values, hence they do not converge with the EU-10.

In addition to these analyses, Sigma convergence has been tested for all countries. The presence of Sigma convergence is generally interpreted using the coefficient of variation (*CV*). In addition, some studies have shown that sigma convergence is measured using variation or standard deviation. The coefficient of variation is calculated using the formula where  $CV = \text{standard deviation} / \text{mean}$ . In order to test the existence of convergence more easily, the trend coefficient has also been added to the *CV* (Vojinovic et al. 2009). In this study, Sigma convergence has been tested using standard deviation. In the convergence literature, the absence of convergence  $\beta$  indicates that no Sigma convergence. Hence, the previously analyzed countries not showing  $\beta$  convergence according to the linear/nonlinear unit root tests are assumed to not show Sigma convergence in terms of the debt-to-GDP ratio. Accordingly, countries other than Latvia, Greece, Portugal, Slovenia, and Croatia are accepted to not show Sigma convergence due to the lack of  $\beta$  convergence. The results of the Sigma convergence are given in Figures 3.1, 3.2, and 3.3.

Results for Sigma convergence show that Greece generally diverges fiscally from the EU-10 countries. This also supports previous unit root analyses. Latvia is the second country whose Sigma convergence has been checked. Latvia is observed to converge with the EU-15 countries fiscally during the analysis period. This situation supports the results from the two-break unit root test. Portugal is another country whose Sigma convergence has been tested. The results obtained for Portugal show limited convergence with the EU-10 countries by 2010; after this period, there is divergence. This is consistent with the results from the two-break unit root tests. Slovenia shows  $\beta$  convergence with the EU-15 countries fiscally, except for weak convergence between 1999-2011. This is also confirmed by the unit root test results. Croatia's Sigma convergence results show convergence with the EU-15 countries. This also supports the unit root tests with two breaks. Accordingly, in addition to the weak convergence between 2002 and 2011, Croatia shows  $\beta$  convergence fiscally with the EU-15 countries.

**Table 3.4.** KSS test with constant and linear trend (Debt/GDP convergence)

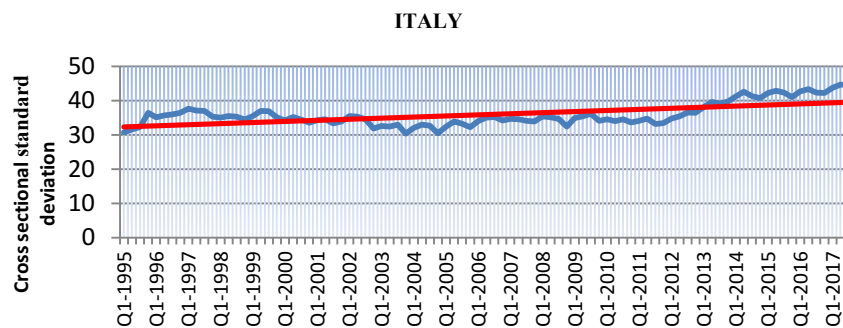
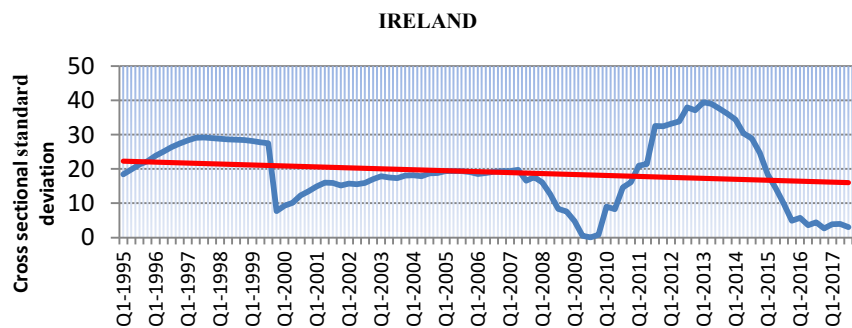
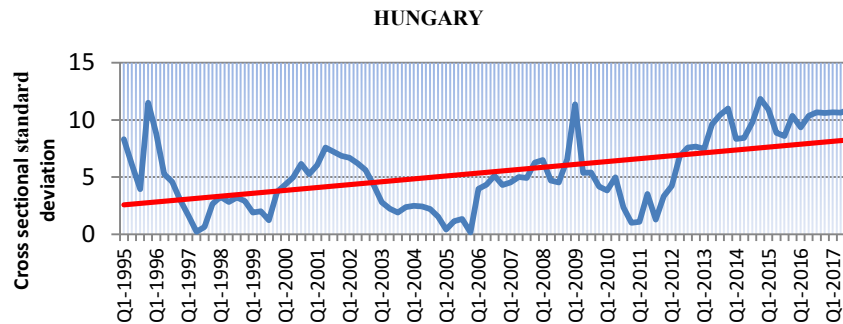
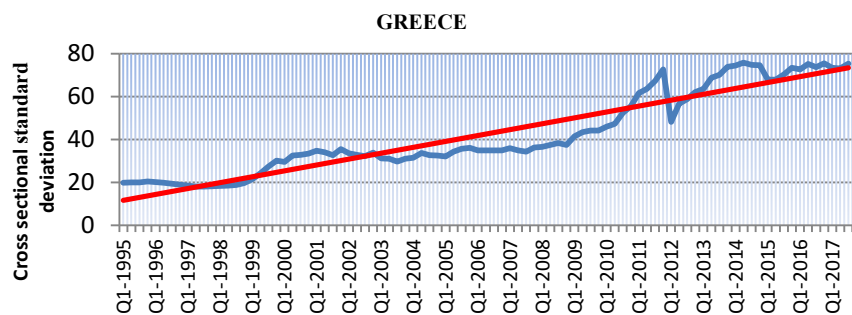
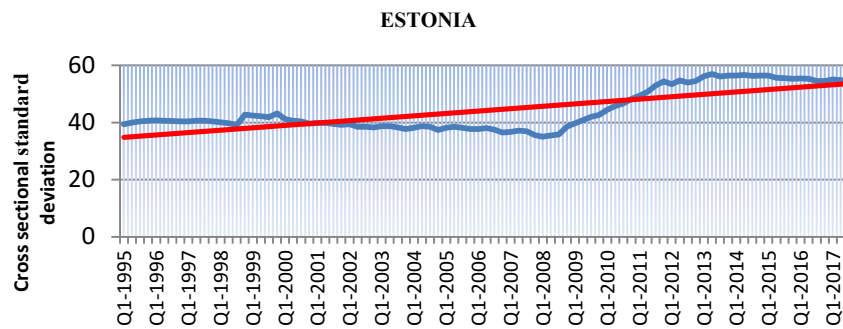
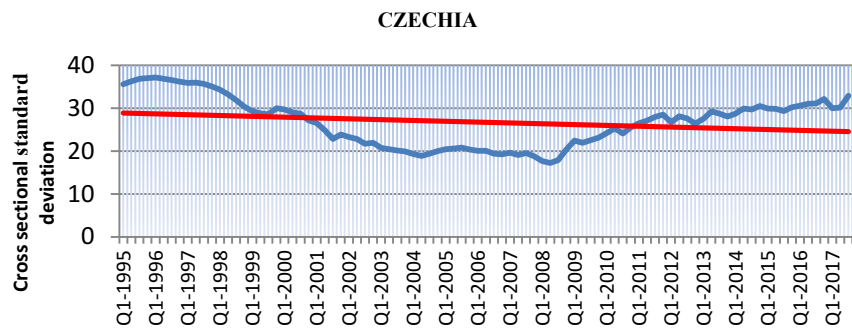
Country	Lag	$\delta$		$\phi$		Results
		Estimator	t statistic	Estimator	t statistic	
Czech Republic	0	$-0.555 \times 10^{-5}$	-1.772	$-0.679 \times 10^{-2}$	-1.826	-
Estonia	0	$-0.181 \times 10^{-5}$	-1.129	-0.015	-1.481	-
Greece	0	$-0.557 \times 10^{-5}$	-1.683	0.067	2.436	-
Ireland	0	$-0.123 \times 10^{-4}$	-1.215	0.010	0.635	Divergence
Italy	0	$-0.229 \times 10^{-5}$	-0.732	0.010	1.301	-
Latvia	1	$-0.212 \times 10^{-5}$	-1.114	0.002	0.202	-
Poland	1	$-0.219 \times 10^{-4}$	-1.880	-0.005	-1.491	-
Portugal	0	$-0.720 \times 10^{-5}$	-2.622	0.033	3.568**	-
Slovak Republic	1	$-0.464 \times 10^{-4}$	-2.522	-0.020	-2.441	-
Slovenia	4	$-0.254 \times 10^{-5}$	-1.860	0.002	0.802	-
Spain	1	$-0.222 \times 10^{-4}$	-1.263	0.014	0.036	-
Bulgaria	1	$-0.835 \times 10^{-5}$	-2.890	-0.032	-3.341**	-
Cyprus	3	$-0.135 \times 10^{-3}$	-2.549	0.003	0.476	Divergence
Lithuania	0	$-0.723 \times 10^{-5}$	-3.074*	-0.014	-2.467	-
Malta	1	$-0.381 \times 10^{-4}$	-2.878	-0.013	-3.154**	-
Romania	0	$-0.817 \times 10^{-5}$	-3.202**	-0.019	-3.170**	-
Croatia	4	$-0.984 \times 10^{-5}$	-2.283	-0.001	-0.475	-
Hungary	0	-0.001	-3.483**	-0.015	-2.485	-

**Note:** The critical values of the t statistics for  $\delta$  are -3.05 (%10), -3.35 (%5) and -3.96 (%1). The critical values of the t statistics (left tail) for  $\phi$  are -2.57 (%10), -2.94 (%5) and -3.68 (%1). The critical values of the t statistics (right tail) for  $\phi$  are 2.59 (%10), 2.93 (%5) and 3.65 (%1). All critical values are obtained from Table 1a and Table 1b of Chong et al. (2008). The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively.

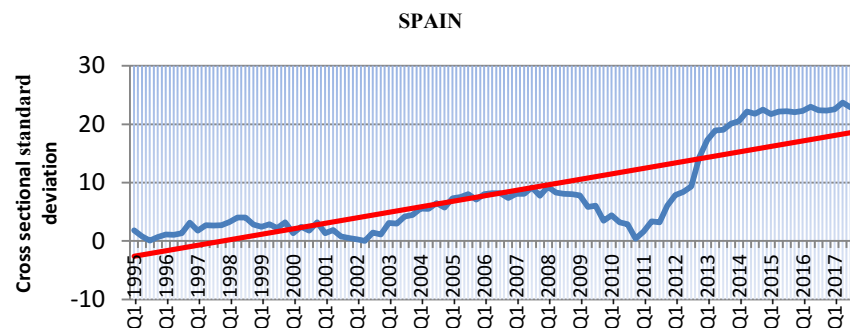
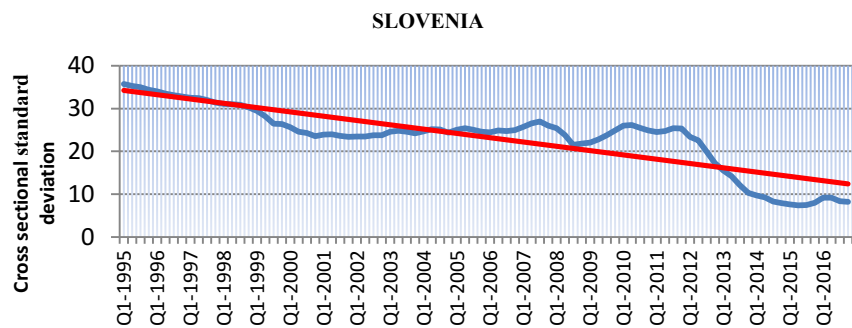
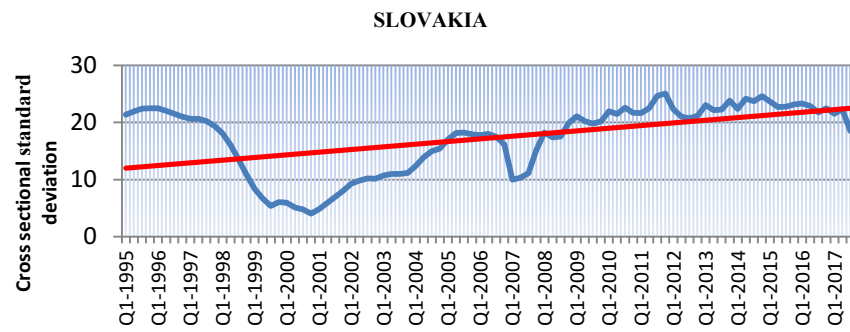
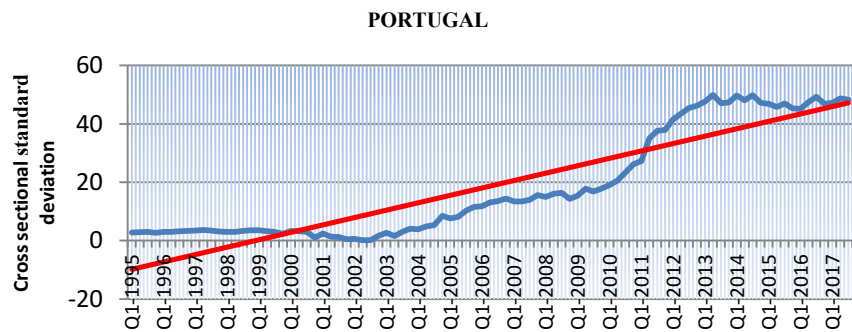
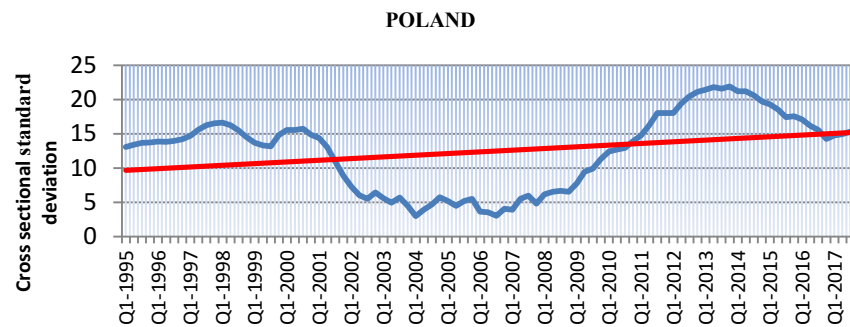
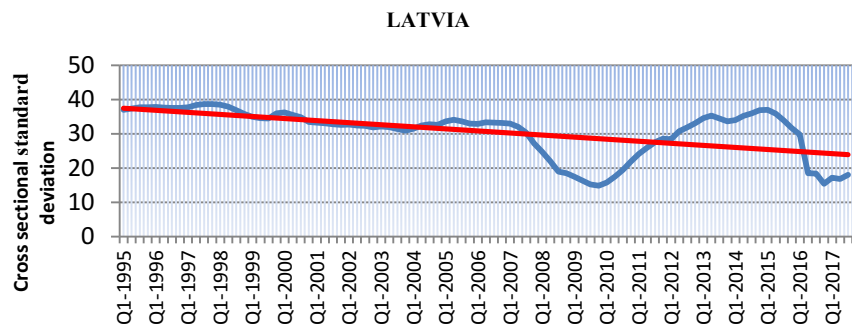
**Table 3.5.** KSS test with constant and nonlinear trend (Debt/GDP convergence)

Country	Lag	$\delta$		$\phi$		Results
		Estimator	t statistic	Estimator	t statistic	
Czech Republic	0	$-0.558 \times 10^{-5}$	-1.893	$-0.108 \times 10^{-3}$	-2.254	-
Estonia	0	$-0.772 \times 10^{-6}$	-0.698	$-0.135 \times 10^{-3}$	-1.231	-
Greece	0	$-0.123 \times 10^{-4}$	-1.915	0.002	2.275	-
Ireland	0	$-0.111 \times 10^{-4}$	-1.030	$0.745 \times 10^{-4}$	0.306	Divergence
Italy	0	$-0.167 \times 10^{-5}$	-0.792	$0.131 \times 10^{-3}$	1.757	-
Latvia	1	$-0.190 \times 10^{-5}$	-1.349	$0.435 \times 10^{-4}$	1.796	-
Poland	1	$-0.225 \times 10^{-4}$	-1.382	$-0.688 \times 10^{-4}$	-1.382	-
Portugal	0	$-0.130 \times 10^{-4}$	-2.899	0.001	3.450**	-
Slovak Republic	1	$-0.438 \times 10^{-4}$	-2.332	$-0.269 \times 10^{-3}$	3.451**	-
Slovenia	4	$-0.281 \times 10^{-5}$	-2.007	$0.357 \times 10^{-4}$	1.004	-
Spain	0	$-0.595 \times 10^{-4}$	-2.540	$0.337 \times 10^{-3}$	3.181**	-
Bulgaria	1	$-0.928 \times 10^{-5}$	-2.570	-0.001	-2.614	-
Cyprus	3	$-0.136 \times 10^{-3}$	-2.398	$0.721 \times 10^{-4}$	0.737	Divergence
Lithuania	0	$-0.545 \times 10^{-5}$	-3.100*	$-0.140 \times 10^{-3}$	-1.960	-
Malta	1	$-0.616 \times 10^{-4}$	-3.887**	$-0.279 \times 10^{-3}$	-4.865***	-
Romania	0	$-0.330 \times 10^{-5}$	-1.715	$-0.116 \times 10^{-3}$	-1.781	-
Croatia	8	$-0.115 \times 10^{-4}$	-2.329	$-0.171 \times 10^{-4}$	-0.588	-
Hungary	0	-0.001	-3.483**	-0.015	-2.485	-

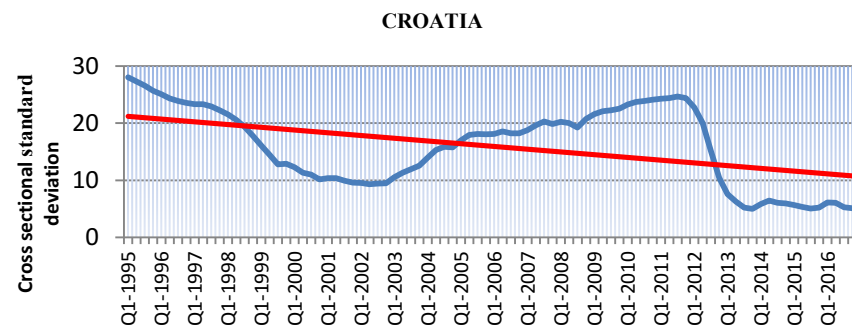
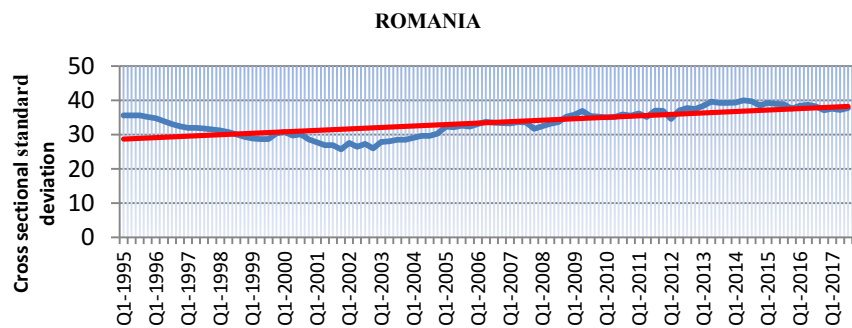
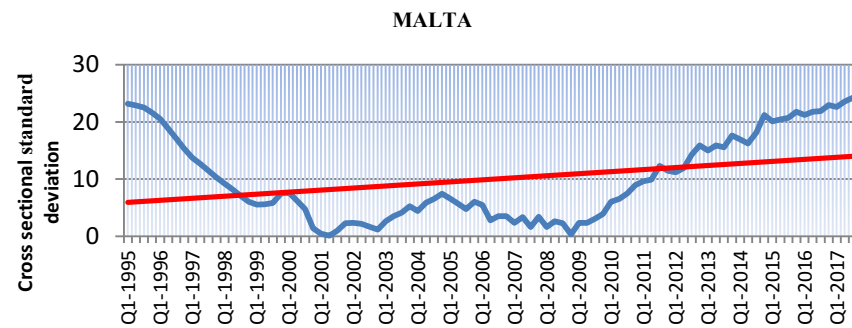
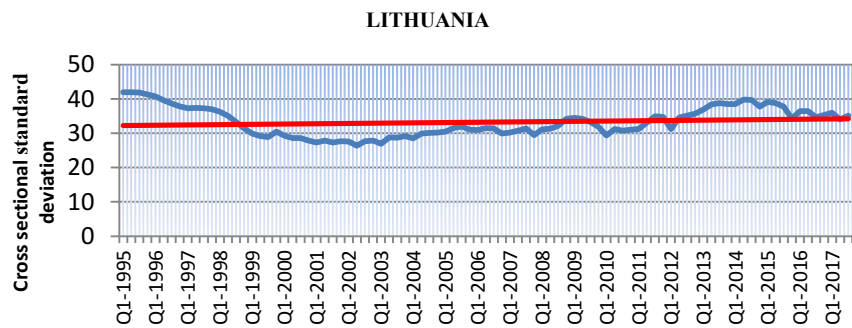
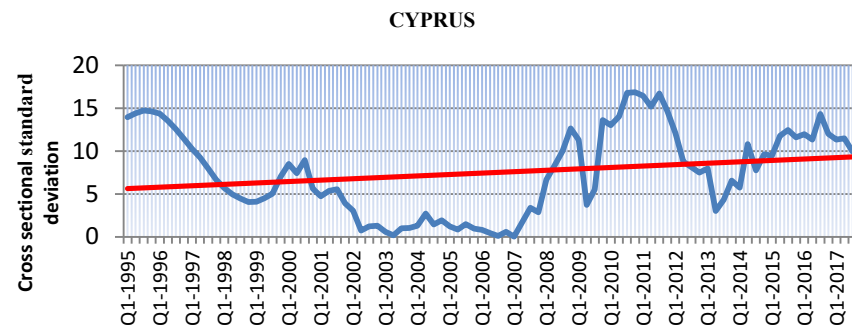
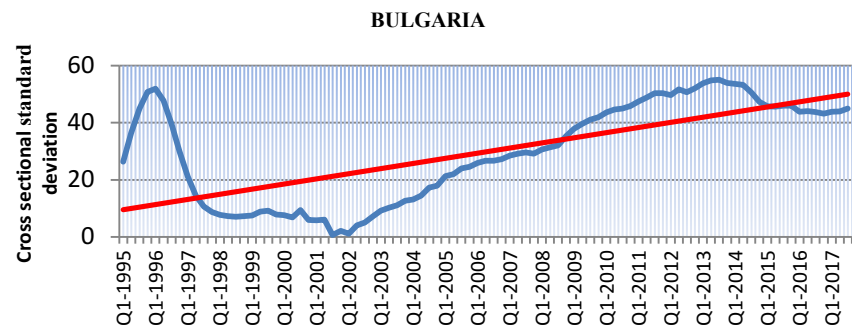
**Note:** The critical values of the t statistics for  $\delta$  are -3.07 (%10), -3.40 (%5) and -4.02 (%1). The critical values of the t statistics (left tail) for  $\phi$  are -2.65 (%10), -2.98 (%5) and -3.74 (%1). The critical values of the t statistics (right tail) for  $\phi$  are 2.63 (%10), 2.97 (%5) and 3.70 (%1). All critical values are obtained from Table 1a and Table 1b of Chong et al. (2008). The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively.



**Figure 3.1.** Sigma Convergence for Debt to GDP ratio



**Figure 3.2. Sigma Convergence for Debt to GDP ratio (Continued)**



**Figure 3.3.** Sigma Convergence for Debt to GDP ratio (Continued)

According to the above results, new EU members and Portugal, Italy, Ireland, Greece, and Spain do not converge with EU-10 countries in terms of the debt-to-GDP ratio. Now, we test fiscal convergence with budget deficit-to-GDP ratio. Table 3.6 shows the unit root test results for testing budget deficit-to-GDP ratio convergences. According to the ADF unit root test results, the series of all countries except Ireland, Latvia, Spain, and Hungary are stationary. Therefore, all countries except Ireland, Latvia, Spain, and Hungary converge with the target country groups. When we check the Zivot-Andrews single-break unit root test results countries except for Ireland, Latvia, Poland, Spain, Lithuania, Croatia, and Hungary show stochastic convergence in terms of the budget deficit-to-GDP ratio with target country groups. However, to test whether these countries show  $\beta$  convergence, the equation 3.2 must be estimated. The estimation results for testing  $\beta$  convergence are presented in Table 3.7. According to the results, 2004Q1 is a structural break period for the Czech Republic. The Czech Republic is seen to show weak divergence from the EU-15 countries before 2004Q1 and  $\beta$  convergence with the EU-15 countries in terms of the budget deficit-to-GDP ratio after 2004Q1. For Estonia, 2010Q3 is found as a structural break period. Estonia has fiscally weak convergence with the EU-15 countries before 2010Q3 while showing  $\beta$  convergence with the EU-15 countries after 2010Q3. The structural break period for Greece is in 2013Q4. Hence, one may argue that Greece converges with the EU-10 countries in the pre-2013Q4 period.

For Italy, 2008Q2 is found to be a structural break period. Italy has low convergence with the EU-10 countries in the period before 2008Q2 in terms of the budget deficit-to-GDP ratio and to have remains at the same level in the following periods. The period of 2011Q3 is the structural break period for Portugal. This means that Portugal has  $\beta$  convergence with the EU-10 before the 2011Q3 period and to have remained at the same level in the following period. The structural break period for the Slovak Republic occurs in 2003Q1. The Slovak Republic shows fiscal  $\beta$  convergence with the EU-15 countries before and after 2003Q1. For Slovenia, 2013Q4 was determined as the structural break period. Slovenia is concluded to have remained at the same level in the period following its weak convergence with the EU-15 countries in the pre-2013Q4 period. The structural break period for Bulgaria is 2014Q2. Bulgaria shows weak convergence with the EU-15 countries before and after its structural break period. The structural break period for Cyprus is 2013Q4. Cyprus shows weak convergence with the EU-15 countries before and after its structural break date.

**Table 3.6.** Unit Root Tests for Budget Deficit Convergence

	ADF		ZA			LS						
	$\tau$	k		k	Break Dates		D	DT	Break Dates	$\lambda_1$	$\lambda_2$	k
Czech Republic	-6.317** [-3.461]	0	-9.032** [-5.080]	0	2004Q1	-8.781***	-0.573 1.934	-3.622 -6.256	2001Q4 2012Q1	0.311	0.767	0
Estonia	-4.819** [-3.463]	4	-5.681** [-5.080]	4	2010Q3	-7.678***	2.454 1.734	-4.356 2.704	2002Q4 2009Q2	0.356	0.644	6
Greece	-6.839** [-3.461]	0	-10.665** [-5.080]	0	2013Q4	-9.674***	1.816 1.008	-3.891 3.191	2005Q4 2013Q3	0.489	0.833	0
Ireland	-1.424 [-3.462]	2	-3.806 [-5.080]	2	2008Q2	-6.457***	-1.287 -8.990	-1.084 5.844	2007Q4 2009Q4	0.578	0.667	10
Italy	-4.838** [-3.461]	1	-6.803** [-5.080]	1	2009Q2	-9.848***	1.503 -0.430	0.356 4.102	2007Q2 2009Q3	0.556	0.656	0
Latvia	-2.968 [-3.464]	5	-3.762 [-5.080]	5	1999Q3	-6.658***	-1.967 2.176	4.573 -3.875	2003Q1 2006Q4	0.367	0.533	9
Poland	-3.505** [-3.462]	3	-4.038 [-5.080]	3	2009Q2	-7.907***	-7.485 2.412	7.147 -6.956	1999Q4 2008Q4	0.222	0.622	6
Portugal	-9.462** [-3.461]	0	-11.754** [-5.080]	0	2011Q3	-10.864***	-0.843 -1.662	1.682 1.819	2009Q3 2013Q4	0.656	0.844	0
Slovak Republic	-4.565** [-3.461]	0	-6.209** [-5.080]	0	2003Q1	-6.684***	-5.090 0.712	6.048 -4.685	2002Q3 2007Q3	0.344	0.567	10
Slovenia	-8.526** [-3.461]	0	-11.053** [-5.080]	0	2013Q4	-15.377***	0.593 -21.590	-3.625 15.995	2000Q3 2013Q3	0.256	0.833	11
Spain	-1.751 [-3.463]	4	-4.799 [-5.080]	4	2008Q1	-6.355***	-1.375 -7.078	-2.400 6.460	2007Q3 2012Q3	0.567	0.789	11
Bulgaria	-3.604** [-3.462]	3	-5.429** [-5.080]	3	2014Q2	-9.384***	-1.216 -1.609	4.321 3.287	2012Q2 2015Q2	0.778	0.911	2
Cyprus	-8.200** [-3.461]	0	-8.872** [-5.080]	0	2013Q4	-9.833***	-2.442 -12.310	8.407 10.101	2007Q1 2013Q4	0.544	0.844	10
Lithuania	-3.906** [-3.461]	1	-4.770 [-5.080]	1	2007Q4	-8.620***	4.183 -0.231	-4.853 6.370	2006Q1 2010Q1	0.500	0.678	0
Malta	-4.341** [-3.461]	1	-5.498** [-5.080]	1	2009Q1	-5.514*	-5.497 2.033	5.075 -4.614	2003Q3 2013Q1	0.389	0.833	9
Romania	-9.724** [-3.461]	0	-10.678** [-5.080]	0	2006Q4	-4.676	-2.479 -3.551	3.824 3.253	2003Q2 2011Q3	0.035	0.744	11
Croatia	-3.616** [-3.462]	3	-3.846 [-5.080]	3	2002Q1	-8.770***	0.784 -0.412	3.460 -1.370	2007Q2 2013Q3	0.556	0.833	1
Hungary	-2.171 [-3.462]	3	-3.645 [-5.080]	3	2008Q1	-9.303***	-6.509 -1.131	7.565 -5.705	2005Q4 2011Q1	0.489	0.722	0

**Note:** The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively. ADF: Augmented Dickey-Fuller test, ZA: Zivot-Andrews (1992), LS: Lee and Strazicich (2003).



**Table 3.7.**  $\beta$  Convergence Estimation Results for model with one structural break for Budget Deficit to GDP ratio

Country	$\mu_1$	$\beta_1$	Decision	$T_{b1}$	$\mu_2$	$\beta_2$	Decision
Czech Republic	-0.822 (0.806)	-0.125*** (0.040)	d	2004Q1	-4.184*** (1.008)	0.078*** (0.016)	C
Estonia	2.825** (1.064)	-0.005 (0.030)	c	2010Q3	24.949*** (3.001)	-0.243*** (0.039)	C
Greece	-3.207*** (0.829)	-0.090*** (0.019)	C	2013Q4	-31.002 (17.577)	0.361 (0.213)	E
Italy	-1.809*** (0.437)	-0.027* (0.014)	c	2008Q2	0.163 (1.107)	-0.016 (0.015)	E
Portugal	-1.422** (0.617)	-0.075*** (0.016)	C	2011Q3	-13.140 (7.771)	0.130 (0.099)	E
Slovak Republic	-3.073*** (1.048)	-0.179*** (0.058)	C	2003Q1	-2.398*** (0.751)	0.028** (0.012)	C
Slovenia	-0.973** (0.477)	0.008 (0.011)	c	2013Q4	-17.336* (8.742)	0.198* (0.105)	E
Bulgaria	1.166 (0.876)	0.029 (0.020)	E	2014Q2	-27.106 (27.301)	0.324 (0.327)	E
Cyprus	-1.363* (0.770)	0.022 (0.018)	E	2013Q4	-67.817 (49.318)	0.813 (0.597)	E
Malta	-9.968*** (0.878)	0.159*** (0.028)	C	2009Q1	6.056* (3.054)	-0.054 (0.041)	E
Romania	-3.920*** (1.269)	0.107** (0.047)	C	2006Q4	-5.709** (2.355)	0.074** (0.034)	C

**Note:** The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively. C indicates  $\beta$  convergence, c indicates  $\beta$  convergence with only one estimate statistically significant, D indicates divergence, d indicates divergence with only one estimate statistically significant and E indicates equilibrium growth. The values in parentheses are standard errors.

The structural break period for Malta is 2009Q1. Before the structural break period, Malta shows convergence with the EU-15 countries and remains at the same level in the following period. Finally, the structural break period for Romania is in 2006Q4. Romania shows  $\beta$  convergence to the EU-15 countries fiscally before and after its structural break period.

After the Zivot-Andrews single break unit root test results, Lee and Strazicich's (2003) two-break unit root test results are included. In accordance with Lee and Strazicich, the results of the two-break unit root test conclude countries other than Malta and Romania to be stationary with structural breaks. As stated earlier, this indicates stochastic convergence but does not provide information on  $\beta$  convergence. Therefore, the equation 3.3 should be estimated. The results of estimating whether the countries apart from Malta and Romania show  $\beta$  convergence with the target countries are given in Table 3.8. According to these results, the structural break periods for the Czech Republic are 2001Q4 and 2011Q2. This means that the Czech Republic had the same level of fiscal standing as the EU-15 countries before 2001Q4,  $\beta$  convergence between 2001Q4 and 2011Q2, and the same levels after 2011Q2. Estonia's structural break periods are 2002Q4 and 2009Q2. Accordingly, Estonia remains at the same level in the pre-2002Q4 period as the EU-15 countries, while  $\beta$  convergence appears in the subsequent periods. For Greece, structural break periods are in 2005Q4 and 2013Q3, thus Greece diverges from the EU-10 countries in the pre-2005Q4 period. Results indicate that Ireland's structural breaks are 2007Q4 and 2009Q4, and Ireland shows  $\beta$  convergence with the EU-10 countries before the 2007Q4 period. For Italy, the structural breaks are in 2007Q2 and 2009Q3. Italy is fiscally divergent from the EU-10 countries prior to 2007Q2, staying at the same level between 2007Q2 and 2009Q3, and achieving  $\beta$  convergence after 2009Q3. Latvia's structural breaks are in 2003Q1 and 2006Q4. Latvia seems to have  $\beta$  convergence with the EU-15 countries in terms of budget deficit-to-GDP ratio after 2006Q4. Poland's structural break periods are 1999Q4 and 2008Q4. This means that it has  $\beta$  convergence between 1999Q4 and 2008Q4. The structural break periods obtained for Portugal are in 2009Q3 and 2013Q4. Accordingly, Portugal diverges fiscally from the EU-10 countries prior to 2009Q3. The breakdown periods for the Slovak Republic are in 2002Q3 and 2007Q3 and it fiscally diverges from the EU-15 countries before 2002Q3. The structural breaks for Slovenia are 2000Q3 and 2013Q3 and it has weak  $\beta$  convergence between 2000Q3 and 2013Q3.

**Table 3.8.**  $\beta$  Convergence Estimation Results for model with two structural breaks for Budget Deficit to GDP ratio

Country	$\mu_1$	$\beta_1$	Decision	$T_{b1}$	$\mu_2$	$\beta_2$	Decision	$T_{b2}$	$\mu_3$	$\beta_3$	Decision
Czech Republic	-1.142 (0.900)	-0.085 (0.059)	E	2001Q4	-10.428*** (1.497)	0.202*** (0.032)	C	2011Q2	-0.819 (3.167)	0.032 (0.041)	E
Estonia	3.219* (1.626)	-0.044 (0.093)	E	2002Q4	14.173*** (3.452)	-0.268*** (0.077)	C	2009Q2	22.796*** (3.469)	-0.254*** (0.047)	C
Greece	-3.093*** (0.817)	-0.096*** (0.033)	D	2005Q4	-2.263 (5.818)	-0.103 (0.098)	E	2013Q3	-26.269 (15.363)	0.305 (0.187)	E
Ireland	3.281*** (0.589)	-0.056*** (0.020)	C	2007Q4	42.436 (38.649)	-0.930 (0.702)	E	2009Q4	-69.410*** (11.461)	0.843*** (0.153)	C
Italy	-1.712*** (0.452)	-0.033** (0.016)	D	2007Q2	-12.792 (12.205)	0.188 (0.228)	E	2009Q3	2.658** (1.188)	-0.047*** (0.016)	C
Latvia	3.085** (1.284)	-0.190** (0.071)	C	2003Q1	-0.719 (5.515)	0.047 (0.139)	E	2006Q4	-6.707*** (2.270)	0.104*** (0.033)	C
Poland	-0.115 (0.801)	-0.155* (0.076)	E	1999Q4	-5.456*** (0.95)	0.066** (0.025)	C	2008Q4	1.455 (2.222)	-0.024 (0.030)	E
Portugal	-1.513** (0.609)	-0.071*** (0.018)	D	2009Q3	-25.142* (12.090)	0.306 (0.181)	E	2013Q4	-36.059* (17.696)	0.402* (0.214)	E
Slovak Republic	-2.284** (1.105)	-0.198*** (0.065)	D	2002Q3	1.906 (4.097)	-0.094 (0.101)	E	2007Q3	-1.064 (1.165)	0.011 (0.016)	E
Slovenia	-0.458 (0.870)	-0.015 (0.017)	E	2000Q3	-2.082** (0.965)	0.031 (0.019)	c	2013Q3	-66.959* (36.119)	0.783* (0.442)	E
Spain	0.180 (0.708)	0.013 (0.025)	E	2007Q3	5.533 (5.196)	-0.186** (0.086)	c	2012Q3	-21.987** (8.185)	0.219** (0.102)	C
Bulgaria	1.249 (0.961)	0.025 (0.024)	E	2012Q2	54.852 (30.198)	-0.714 (0.402)	E	2015Q2	14.657 (24.938)	-0.160 (0.292)	E
Cyprus	-0.096 (0.944)	-0.056 (0.035)	E	2007Q1	12.744*** (4.060)	-0.191*** (0.066)	C	2013Q4	-67.817 (49.318)	0.813 (0.597)	E
Lithuania	-7.005***	0.066	c	2006Q1	104.483***	-2.218***	C	2010Q1	-11.916	0.169	E

	(2.157)	(0.086)			(23.810)	(0.456)			(7.559)	(0.100)	
Croatia	-2.139** (0.975)	0.002 (0.035)	c	2007Q2	0.701 (3.454)	-0.026 (0.056)	E	2013Q3	-29.324*** (6.787)	0.346*** (0.083)	C
Hungary	-2.194*** (0.734)	-0.099*** (0.030)	D	2005Q4	-43.443*** (5.025)	0.769*** (0.093)	C	2011Q1	2.100 (4.805)	-0.021 (0.062)	E

**Note:** The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively. *C* indicates  $\beta$  convergence, *c* indicates  $\beta$  convergence with only one estimate statistically significant, *D* indicates divergence, *d* indicates divergence with only one estimate statistically significant and *E* indicates equilibrium growth. The values in parentheses are standard errors.

Spain's structural breaks are 2007Q3 and 2012Q3 and it has weak  $\beta$  convergence between 2007Q3 and 2012Q3 and  $\beta$  convergence after 2012Q3. The structural breaks for Bulgaria are 2012Q2 and 2015Q2 and Bulgaria remains at the same level as the EU-15 countries during the analysis period. As for the last country, Cyprus has 2007Q1 and 2013Q4 for its structural breaks. Cyprus has  $\beta$  convergence between 2007Q1 and 2013Q4, and remains at the same level in post-2013Q4.

In the next stage of the study, linearity tests have been performed to determine whether the series are linear or nonlinear within the variable of budget deficit-to-GDP ratio. This aims to prevent erroneous stationary results due to misidentifying the series type. In Table 3.9 are presented Harley and Leybourne's (2007)  $W^*$  and Harvey et al.'s (2008)  $W_\lambda$  linearity test statistics.

**Table 3.9.** Harvey and Leybourne (2007) and Harvey et al. (2008) linearity tests for Budget Deficit to GDP ratio.

Country	$W_{10\%}^*$	$W_{5\%}^*$	$W_{1\%}^*$	$W_\lambda$
Czech Republic	1.56	1.57	1.59	0.68
Estonia	3.44	3.73	4.29	0.89
Greece	3.79	4.21	5.09	3.46
Ireland	10.19**	10.30**	10.49**	5.92*
Italy	0.69	0.79	0.99	3.34
Latvia	17.43***	17.52***	17.67***	7.70**
Poland	3.60	3.63	3.69	1.08
Portugal	19.60***	20.00***	20.74***	2.28
Slovak Republic	2.83	2.85	2.88	1.70
Slovenia	2.19	2.23	2.30	0.98
Spain	10.50**	10.57**	10.70**	8.56**
Bulgaria	17.47***	17.53***	17.66***	6.70*
Cyprus	1.49	1.50	1.53	0.81
Lithuania	21.82***	21.95***	22.19***	4.09
Malta	7.49	7.60	7.81	3.03
Romania	8.96*	9.14*	9.47*	8.75**
Croatia	5.18	5.21	5.27	1.08
Hungary	11.00**	11.08**	11.23**	9.52***

**Notes:** The critical values for  $W_\lambda$  are 9.21 (1%), 5.99 (5%) and 4.60 (10%). The critical values for  $W^*$  are 13.27 (1%), 9.48 (5%) and 7.77 (10%). The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively.

According to the results, at least one of either the  $W^*$  and  $W_\lambda$  test statistics for Ireland, Latvia, Portugal, Spain, Bulgaria, Lithuania, Romania, and Hungary exceed the critical value at 5%. Accordingly, the series obtained for these countries are nonlinear in form and thus using nonlinear unit root tests is more appropriate than linear unit root tests for determining whether these countries converge with the target country groups. Table 3.10 shows the

nonlinear KSS unit root test results obtained for the model with constant and linear trends. According to the KSS unit root test results, Latvia, Bulgaria, Romania, and Hungary show convergence with the EU-15 countries. In addition, Lithuania is has fiscally diverged from the EU-15 countries. Ireland has been converging with the EU-10 countries while Portugal and Spain have been catching-up. Table 3.11 shows the nonlinear KSS unit root test results obtained for the constant and nonlinear trend models. Similar results are obtained with the linear trend model. This situation shows that results are quite consistent. In contrast to the linear trend model, Portugal shows convergence with the EU-10 countries. The point to note here is how countries are determined to be diverging from, converging with, or catching up to the target countries. Accordingly, if both  $\delta$  and  $\phi$  are statistically significant, the country is catching up to the target country group, if only  $\delta$  is significant we conclude that the country is converging, and if neither  $\delta$  nor  $\phi$  are statistically significant the country is diverging from the target country group.

After all these unit root tests and  $\beta$  convergence, we now analyze the Sigma convergence results. As in the debt-to-GDP ratio, Sigma convergence will go untested if no  $\beta$  convergence exists in the budget deficit-to-GDP ratio. The Sigma convergence results for all countries are shown in Figure 3.4, 3.5, and 3.6. The fact that the standard deviation has a decreasing trend indicates that Czech Republic has shown sigma convergence in fiscal terms to EU-15 countries. This also supports both single- and double-break unit root test results. The Sigma convergence results indicate Estonia to be fiscally converging with the EU-15 countries. This situation confirms the  $\beta$  convergence estimates. Sigma convergence analysis for Greece shows the divergence from the EU-10 countries. This is observed from the  $\beta$  convergence analysis showing mostly divergence. The sigma convergence results for Ireland shows that Ireland has fiscally diverged from the EU-10 countries. The results of  $\beta$  convergence show general convergence with the EU-10 countries. Here,  $\beta$  convergence should be noted as insufficient for Sigma convergence. For this reason,  $\beta$  convergence was obtained for Ireland while sigma convergence could not. Italy has Sigma convergence. This corresponds to the conclusion that Italy converges with the EU-10 countries in terms of the budget deficit-to-GDP ratio within the estimates of  $\beta$  convergence. The sigma convergence analysis for Latvia states that Latvia has converged with the EU-15 countries fiscally over time. This is consistent with the nonlinear KSS unit root test results.

**Table 3.10.** KSS test with constant and linear trend (Budget Deficit to GDP Convergence)

Country	Lag	$\delta$		$\phi$		Results
		Estimator	t statistic	Estimator	t statistic	
Czech Republic	0	-0.008	-3.321*	$-0.442 \times 10^{-3}$	-0.174	-
Estonia	0	-0.003	-3.351**	0.008	1.282	-
Greece	0	-0.001	-8.645***	-0.015	-1.844	-
Ireland	0	-0.001	-11.155**	-0.018	-1.386	Convergence
Italy	0	-0.015	-3.596**	-0.005	-2.453	-
Latvia	0	-0.011	-3.914**	0.003	0.925	Convergence
Poland	0	-0.022	-4.836***	-0.006	-2.923*	-
Portugal	0	-0.007	-5.439***	-0.023	-3.202**	Catching-up
Slovak Republic	0	-0.001	-1.849	$-0.201 \times 10^{-3}$	-0.129	-
Slovenia	0	-0.001	-44.990***	-0.010	-0.956	-
Spain	0	-0.007	-4.978***	-0.018	-3.695***	Catching-up
Bulgaria	0	-0.010	-6.684***	$-0.260 \times 10^{-3}$	-0.039	Convergence
Cyprus	0	-0.001	-49.054***	-0.012	-1.215	-
Lithuania	0	-0.001	-3.031	-0.015	-1.529	Divergence
Malta	0	-0.002	-1.970	-0.001	-0.357	-
Romania	1	-0.001	-4.099***	-0.002	-0.578	Convergence
Croatia	0	-0.002	-1.806	$0.162 \times 10^{-3}$	0.065	-
Hungary	0	-0.003	-4.950***	-0.006	-1.375	Convergence

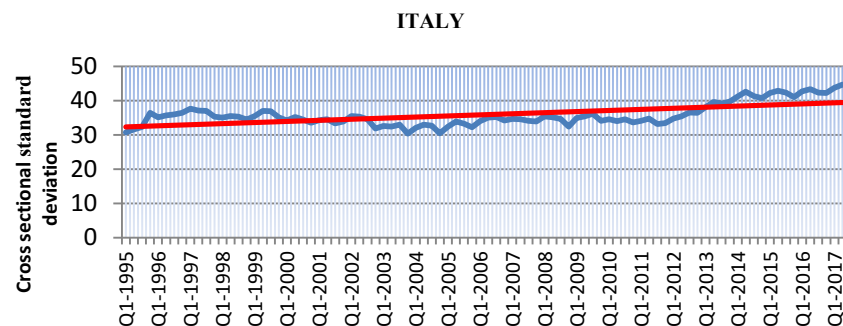
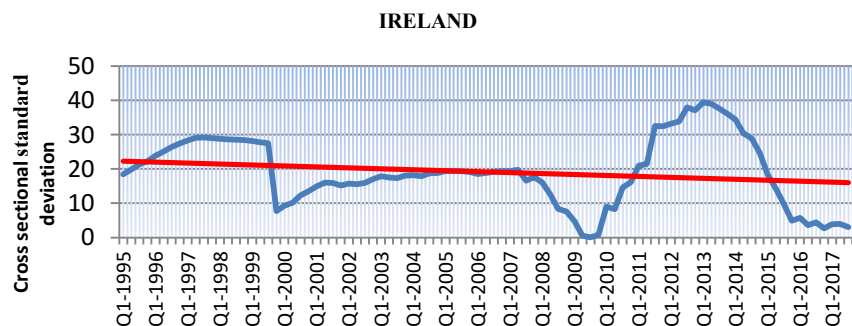
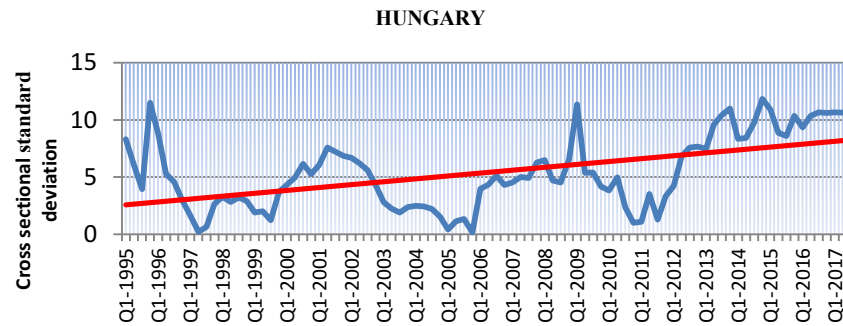
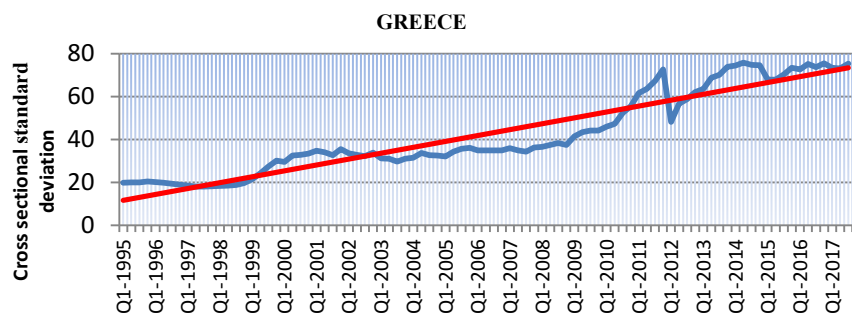
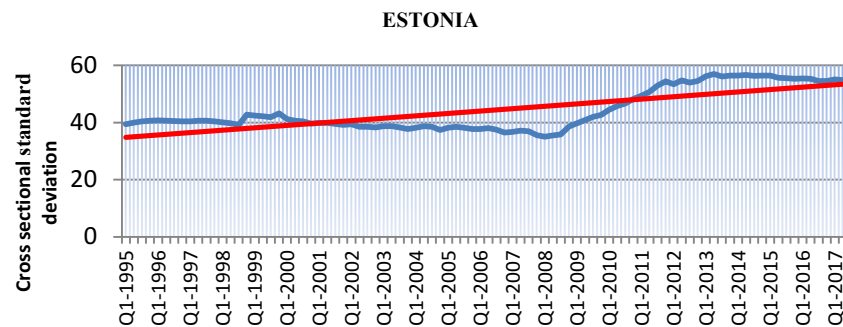
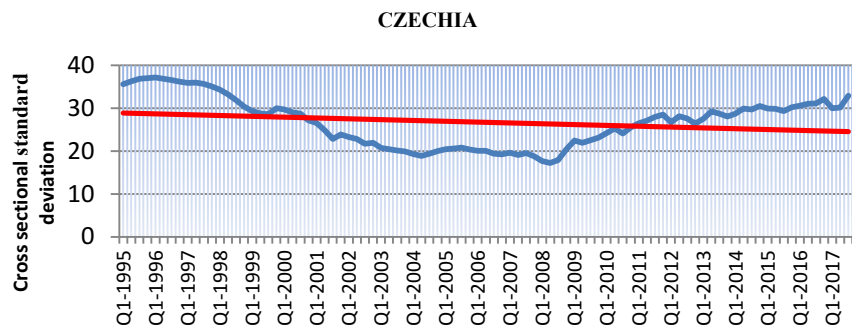
**Note:** The critical values of the t statistics for  $\delta$  are -3.05 (%10), -3.35 (%5) and -3.96 (%1). The critical values of the t statistics (left tail) for  $\phi$  are -2.57 (%10), -2.94 (%5) and -3.68 (%1). The critical values of the t statistics (right tail) for  $\phi$  are 2.59 (%10), 2.93 (%5) and 3.65 (%1). All critical values are obtained from Table 1a and Table 1b of Chong et al. (2008). The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively.

**Table 3.11.** KSS test with constant and nonlinear trend (Budget Deficit to GDP Convergence)

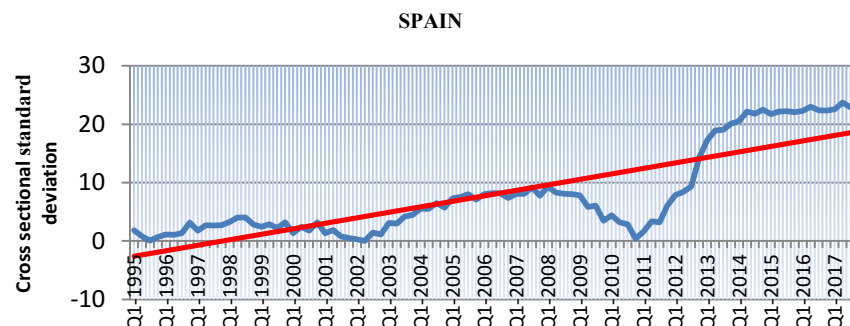
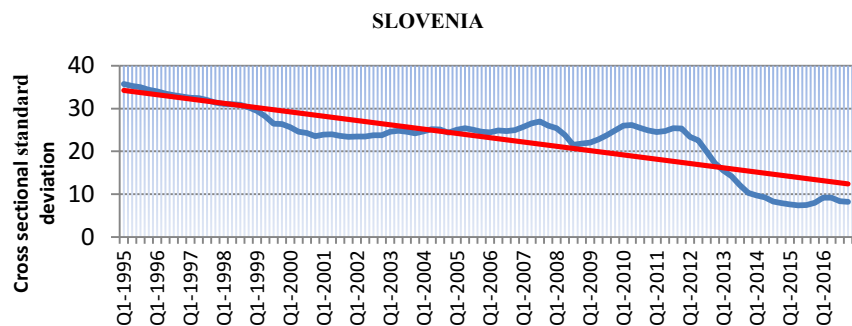
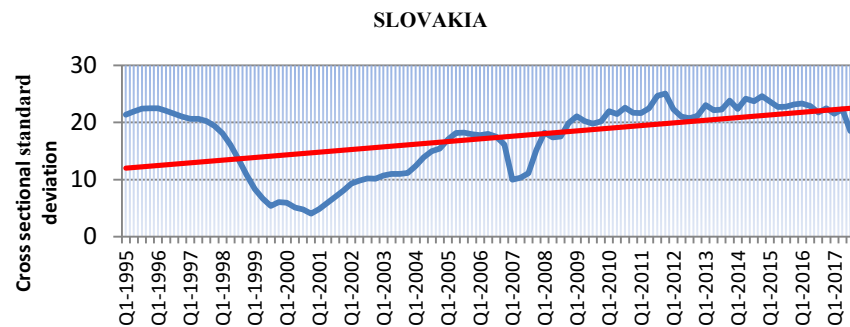
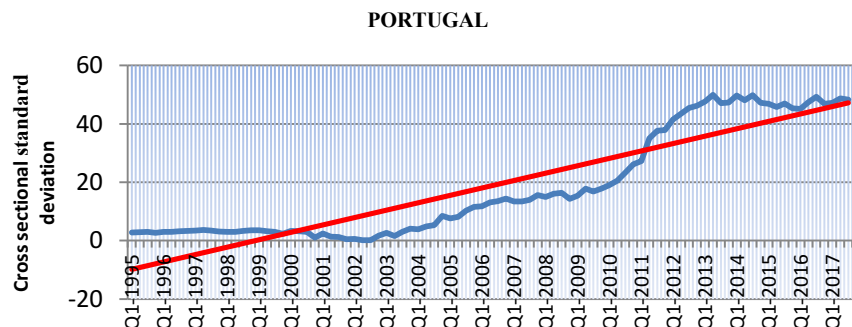
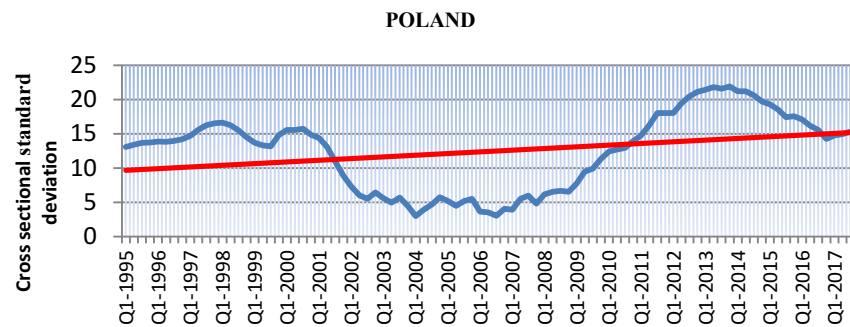
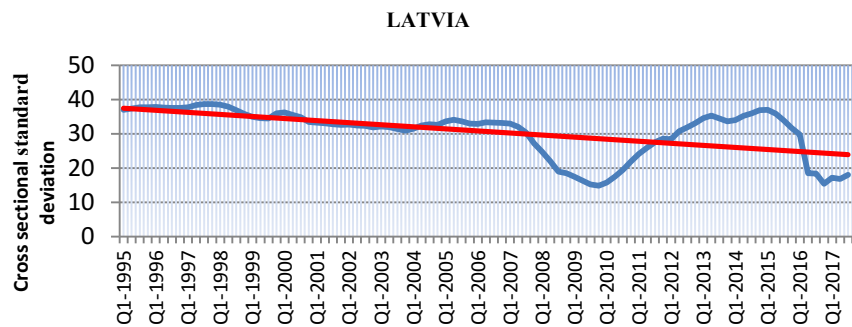
Country	Lag	$\delta$		$\phi$		Results
		Estimator	t statistic	Estimator	t statistic	
Czech Republic	0	-0.008	-3.261*	$0.184 \times 10^{-4}$	0.604	-
Estonia	0	-0.003	-3.357	$0.829 \times 10^{-4}$	1.018	-
Greece	0	-0.001	-9.561***	$-0.181 \times 10^{-3}$	-1.366	-
Ireland	0	-0.001	-10.836***	$-0.221 \times 10^{-3}$	-1.239	Convergence
Italy	0	-0.015	-3.740**	$-0.468 \times 10^{-4}$	-2.227	-
Latvia	0	-0.011	-3.899**	$0.407 \times 10^{-4}$	0.994	Convergence
Poland	0	-0.021	-4.696***	$-0.438 \times 10^{-4}$	-1.929	-
Portugal	0	-0.007	-5.574***	$-0.270 \times 10^{-3}$	-2.413	Convergence
Slovak Republic	0	-0.001	-1.829	$0.379 \times 10^{-5}$	0.211	-
Slovenia	0	-0.001	-37.138***	$-0.160 \times 10^{-3}$	-0.936	-
Spain	0	-0.007	-5.068***	$-0.248 \times 10^{-3}$	-3.049**	Catching-up
Bulgaria	0	-0.010	-6.727***	$-0.335 \times 10^{-3}$	-0.357	Convergence
Cyprus	0	-0.001	-45.325***	$-0.197 \times 10^{-3}$	-1.244	-
Lithuania	0	-0.001	-2.935	$-0.141 \times 10^{-3}$	-1.149	Divergence
Malta	0	-0.002	-1.982	$0.913 \times 10^{-5}$	0.254	-
Romania	1	-0.001	-4.096***	$-0.308 \times 10^{-4}$	-0.738	Convergence
Croatia	0	-0.002	-1.811	$0.901 \times 10^{-4}$	0.266	-
Hungary	0	-0.003	-4.481***	$-0.476 \times 10^{-4}$	-0.855	Convergence

**Note:** The critical values of the t statistics for  $\delta$  are -3.07 (%10), -3.40 (%5) and -4.02 (%1). The critical values of the t statistics (left tail) for  $\phi$  are -2.65 (%10), -2.98 (%5) and -3.74 (%1). The critical values of the t statistics (right tail) for  $\phi$  are 2.63 (%10), 2.97 (%5) and 3.70 (%1). All critical values are obtained from Table 1a and Table 1b of Chong et al. (2008). The superscripts \*\*\*, \*\* and \* denote the significance at 1%, 5% and 10% level, respectively.

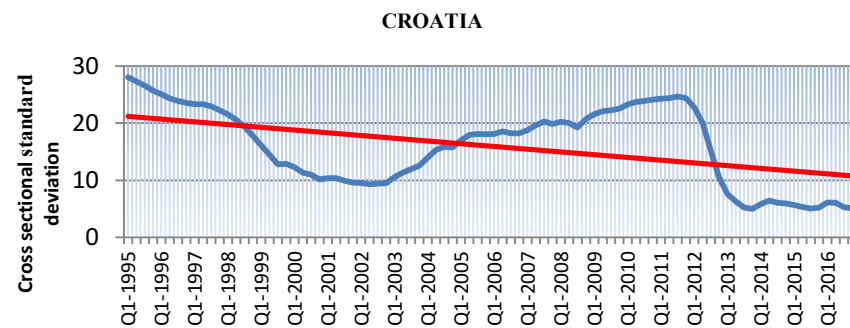
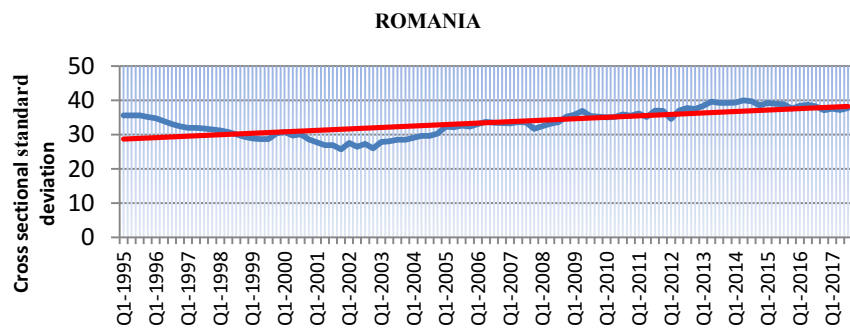
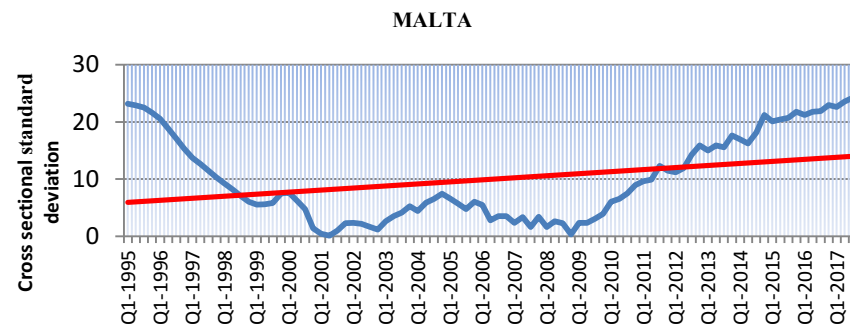
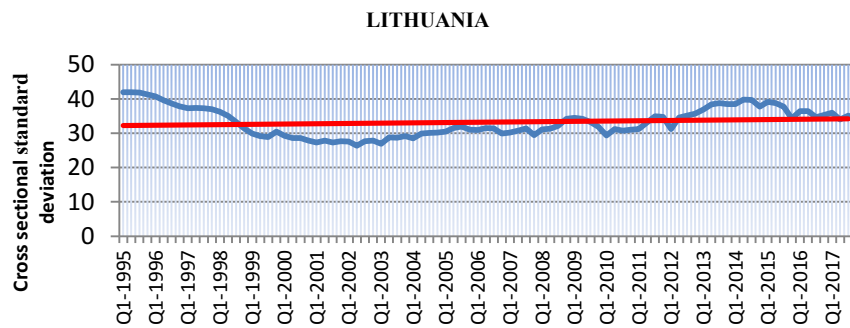
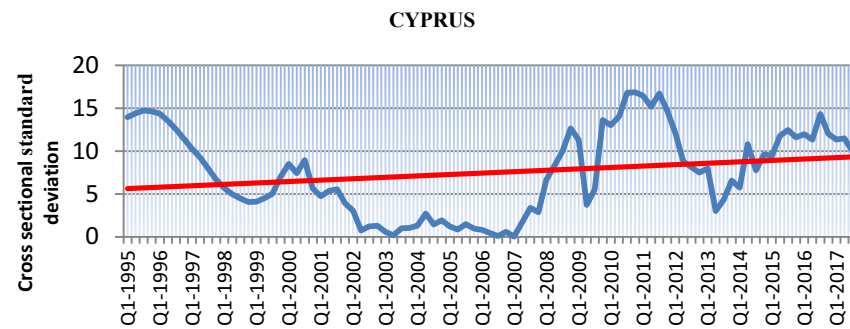
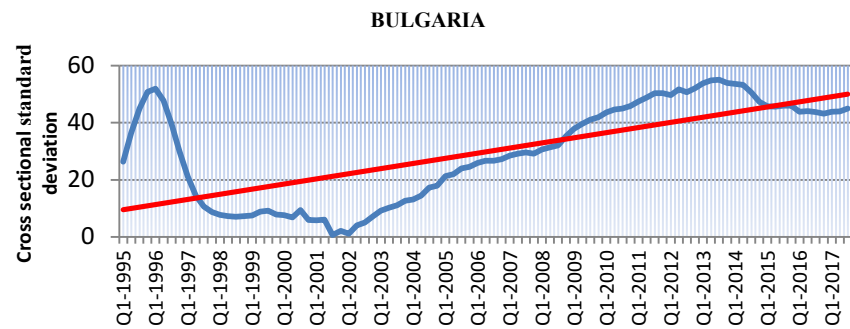




**Figure 3.4.** Sigma Convergence for Budget Deficit to GDP ratio



**Figure 3.5. Sigma Convergence for Budget Deficit to GDP ratio (Continued)**



**Figure 3.6.** Sigma Convergence for Budget Deficit to GDP ratio (Continued)

Poland has Sigma convergence, which means that Poland has fiscally converged over time with the EU-15 countries. This corresponds to the results obtained from the unit root tests. The Sigma convergence results for Portugal indicate Portugal to have diverged from the EU-10 countries, while the non-linear KSS unit root test results show it to be catching up in the linear trend model and converging in the nonlinear trend model. As stated before,  $\beta$  convergence does not mean that sigma convergence will occur. The Sigma convergence results for the Slovak Republic indicate the Slovak Republic has fiscal convergence with the EU-15 countries during the period. The results of Sigma convergence for Slovenia indicate divergence from the EU-15 countries in terms of the budget deficit-to-GDP ratio, whereas the  $\beta$  convergence results mostly show convergence. The Sigma convergence results for Spain indicate Spain to have diverged fiscally from the EU-10 countries, but the KSS unit root test results indicate Spain to be catching up. For Bulgaria, the Sigma convergence results show it has diverged fiscally from the EU-15 countries. However, the  $\beta$  convergence results indicate convergence for Bulgaria. The Sigma convergence results for Lithuania indicate that Lithuania has fiscally converged with the EU-15 countries over time, but the KSS unit root test results indicate the country has diverged. The Sigma convergence for Cyprus indicates the convergence with the EU-15 countries over time. This corresponds to the convergence result obtained from both the single- and double-break unit root tests. The Sigma convergence for Croatia shows convergence with the EU-15. This situation is also confirmed by the results of the double-break unit root tests. The results of Sigma convergence for Hungary indicate that Hungary has converged with the EU-15. Similarly, Sigma convergence for Romania shows both Sigma and  $\beta$  convergence to have occurred and Romania has been fiscally converging with the EU-15 countries. Finally, the results of Sigma convergence for Malta indicate Malta to converge with the EU-15 countries.

### **3.4. Conclusion**

The study aimed to test whether the fiscal differences among countries have played a role in the emergence of the European debt crisis and to determine how fiscally the new EU member states, which are likely to be included in the monetary union, converge with the EU-15 countries. This analyzes whether the weakness of the countries affected by the crisis has been caused by the loss of fiscal discipline as well as the extent to which the new member

states have met the criteria required for becoming a member of the EMU after their membership to the EU. Here, the criteria for fiscal convergence are that public debt stock does not exceed 60% and that budget deficits as a ratio of GDP do not exceed 3%.

We designed an endogenous system in which the public authority exists in order to analyze the potential convergence of public debts and budget deficits. To test the fiscal convergence between countries, we first used the ADF test, then Zivot and Andrews's (1992) and Lee and Strazicich's (2003) unit root tests with structural breaks. The structural break periods obtained from the unit root tests are particularly concentrated in the periods when the European debt crisis occurred. Finally, this study also used the KSS (2003) nonlinear unit root tests, unlike other studies in the literature, to determine the existence of convergence. In addition to testing the existence of  $\beta$  convergence for all countries included in the analysis, Sigma convergence analysis was also estimated. The study found that, although the test results are quite consistent with each other, inconsistencies exist between the Sigma and  $\beta$  convergence results for some countries. According to the results, Portugal, Italy, Ireland, Greece, and Spain show divergence from the EU-10 countries in terms of the debt-to-GDP ratio. Besides, tests using the budget deficit-to-GDP ratio as fiscal convergence criterion show that all countries except for Greece have managed to converge fiscally with the EU-10 countries. The new member countries except for Croatia, Latvia, and Slovenia are said to have converged with the EU-15 countries in terms of the debt-to-GDP ratio. When analyzing the convergence for new member countries in terms of the budget deficit-to-GDP ratio, Croatia, Cyprus, the Czech Republic, Estonia, Latvia, Poland, Romania, Slovakia, and Slovenia have shown fiscal convergence. When interpreting these results, both the PIIGS and new member countries have difficulty to converge with the target country groups in terms of the debt-to-GDP ratio, but more countries provide fiscal convergence in terms of the budget deficit-to-GDP ratio. Accordingly, countries such as Greece, Portugal, Ireland, Italy, Spain, and Cyprus, which have suffered from the crisis, have differentiated and lost their fiscal discipline especially compared with other countries in terms of the public debt-to-GDP ratio. These countries need to take important steps to prevent public debt to increase so they can maintain their presence in the EMU. The results of this study, as in Kocenda et al. (2008), argue that monetary unions do not generally guarantee the fiscal convergence. Additionally, the convergence in terms of public debt of the new member states except for Croatia, Latvia, and Slovenia with the EU-15 and even the EU-10 countries may prevent the negativity of other

countries affected by the debt crisis if they become members of the monetary union in the future. In addition, possible policy mismatches can be prevented by ensuring that the union is homogeneous in terms of its fiscal conditions.

## CONCLUSIONS

The recent European debt crisis led to huge social and economic costs such as loss of production, unemployment, and increasing debt stock. Hence, we first aimed to identify the determinants this crisis. To do so, in the first chapter of this thesis we constructed a fiscal pressure index for the EU-15 countries, since defining the crisis and identifying the crisis periods is crucial to all econometric models that focus on financial crises. The problem, here, is there is no consensus on how to define fiscal pressure in the literature. Thus, we calculated the fiscal pressure index for each of the EU-15 countries by taking into account the studies of Baldacci et al. (2011a, 2011b) and Hernandez de Cos et al. (2014). However, our definition differs from the definition of previous studies since they focus on mainly to default events and their fiscal pressure index takes the value of 1 or 0. However, defining the fiscal pressure as a binary variable brings a constraint to the empirical analysis. This is why we developed a new continuous-time financial pressure index using BYP (Bond Yield Pressure), Government bond spreads (relative to 10-year US Treasury bonds)  $i$ ,  $r-g$  imputed interest rate on general government debt minus real GDP growth rate  $i$ , PSBPR (Public Sector Borrowing Requirement), GGGD (General Government Gross Debt), Net debt to GDP, and the CAPB (Cyclically-Adjusted Primary Balance to GDP). After building the fiscal pressure index for each EU-15 country, we calculated threshold values for the index. When the index exceeds the calculated threshold value, the index signals a crisis episode. However, as there is no consensus on what the optimal threshold should be for an index, we tended to use different measures such as the accuracy measures, sensitivity-specificity figures, and KLR cut-off method methods as in Candelon et al. (2012). The results indicate that all EU-15 countries except for Germany seem to have suffered a debt crisis following the global financial crisis. Moreover, our results show that the debt crisis in Greece, Ireland, Italy, Portugal, Spain, and the UK lasted longer than in other countries. The similarity of our results with the the results of the previous studies can be considered as an important indicator of accuracy and consistency and may orient future researchers to employ continuous fiscal pressure indexes.

The second chapter of the thesis aimed to identify the variables that caused the emergence of the European debt crisis. For this purpose, we first considered a very large set of 51 leading indicators. The set of leading indicators consisted of six groups: public and real sector variables, external balance and capital flow variables, financial sector variables, debt

indicators, social indicators, and governance indicators. In addition to macro and microeconomic variables, we also considered governance indicators, mostly ignored in the existing literature. This is a significant contribution to the literature.

Besides, we also employed three estimation methods: SOM, Logit, and Markov models. The main reason for choosing the SOM as the first estimation method is that it is a nonparametric method that allows one to observe the relationship among multiple variables. In addition, while estimating a large number of variables is impossible with conventional econometric methods, the SOM can incorporate highly correlated variables with each other simultaneously. The SOM also gives us the possibility to rank the leading indicators according to their order of importance in the emergence of the debt crisis. To do so, we used different measures such as the structuring index (RI), cluster description index (CD) and Spearman rank correlation index (SRC). However, as there are discrepancies related to order the importance among different measures, we also constructed two different overall indexes to rank the variables. We then selected the most significant 10 variables to be employed in Logit and Markov estimations.

According to the results obtained from Logit and Markov estimations, the variables NPL / TL, Primary Balance / GDP, PSRR, Corruption, Cash Balance / GDP, Unemployment, Voice and Accountability, Regulatory Quality, Rule of Law, GDP Growth, Government Effectiveness, and Cyclically-Adjusted Balance / GDP are all correctly signed and statistically significant in explaining the debt crisis. Note that the fact that the results obtained from all three estimation methods are quite similar is accepted as an important indicator of consistency. Another interesting point in the estimation results is that despite the similar deterioration in macroeconomic variables, some European countries seem to have exited the crisis very quickly contrary to some countries like Portugal, Italy, Ireland, Spain, or Greece. When comparing these two sets of countries in detail, governance indicators are seen to have played an important role. This situation is observed from the fact that good governance indicators in the SOM, Logit, and Markov results significantly reduced the possibility of debt crisis. Greece, Italy, Spain, Portugal, and Ireland, which were affected by the crisis for a longer and deeper period, all have poor governance indicators. Therefore, the convergence of countries in terms of governance is very important in addition to economic convergence. Moreover, our Logit and Markov models were quite successful in predicting the crisis



episodes over the period of 2003-2015. To be more precise, nearly all crisis and noncrisis periods in the EU-15 were correctly predicted by our models.

The third chapter of the study analyzed the existence of fiscal convergence among EU countries. With the recent debt crisis, the question of a fiscal similarity among the member countries has gained great importance. For this reason, this study tested the existence of fiscal convergence by considering the two basic indicators in the Maastricht criteria. These criteria are the debt-to-GDP and the budget deficit-to-GDP ratios. Accordingly, Portugal, Spain, Ireland, Italy, and Greece, which were severely damaged by the debt crisis in comparison to other countries, were compared with the EU-10 countries, and then the new member states were compared with the EU-15 countries over the period from 1995Q1 to 2017Q2. Considering the analysis techniques, period gaps, and countries included in analyses, some important elements were ignored in analyzing fiscal convergence by the existing literature. Hence, we used a wide range of data and large set of countries, as well as new techniques (the ADF unit root test, Zivot and Andrews's (1992) single-break unit root test, Lee and Strazicich's (2003) double-break unit root test, and nonlinear KSS (2003) non-linear unit root tests) to fulfill the shortages of the early literature.

Results indicate Portugal, Spain, Italy, Ireland, and Greece have not shown convergence with the EU-10 countries in terms of the debt-to-GDP ratio. In addition, except for Greece there exists convergence among EU-15 countries in terms of the budget deficit-to-GDP ratio. The results for the new member states show that there is no convergence in terms of the debt-to-GDP ratio with EU-15 countries, aside from Croatia, Latvia, and Slovenia, while in terms of the budget deficit-to-GDP ratio, Croatia, Cyprus, the Czech Republic, Estonia, Latvia, Poland, Romania, Slovakia, and Slovenia show fiscal convergence. The general result obtained from this is that although most member countries have achieved convergence in terms of the budget deficit-to-GDP ratio, they cannot show the same success in terms of the debt-to-GDP ratio. This situation implies that the most affected countries from the crisis (Greece, Portugal, Ireland, Italy, Spain and Cyprus) had a significant difference of the debt-to-GDP ratio with other member countries. As in Kocenda et al. (2008), we conclude that being a member of the monetary union does not guarantee fiscal convergence. Hence, beside implementing a common monetary policy, the EU needs also to homogenize fiscal policies of its member countries. Otherwise, similar crises will be likely to emerge in the future.

What are the policy implications of our findings? The first one is that constructing the continuous-time fiscal stress index which produces consistent and robust results in identifying fiscal pressure and/or crisis episodes may allow the authorities to take measures to prevent crises. The second one is that governance quality matters both in the outbreak and the length of debt crises. Hence, increasing governance quality could be a significant preventive response to future crises and the EU may exert pressures on member countries to harmonize governance indicators.

On the other hand, our empirical analysis also indicates that EU member states do not converge fiscally, in particular in terms of public debts. As the member states do converge in terms of budget deficits, we think that there may be some structural factors such as trade and current deficits leading to steady increases in public debt stock of some member countries. A closer look at Portugal, Ireland, Italy, Greece and Spain, which were severely affected by the crisis, shows that these countries significantly differ from other member countries in terms of current account deficits. Until the outbreak of the global crisis, these deficits were easily financed by external borrowing at low rates although their debt stock steadily increased. This shows that those countries largely benefited from the ‘prestige’ of the Union. Hence, one may affirm that current account balance may be considered as another convergence criteria for the countries that want to join the EMU. However, one may argue that as some countries like Germany have constantly current current account surpluses, the member countries may find ways to finance each other. However, as clearly seen in the recent debt crisis, countries may be reluctant to pay debts of other member countries. This definitely increases both the duration and the severity of the crisis. Therefore, it is important for the Union to set and announce how, under what conditions, and by whom the financing will be provided in a more clear and faster way.

In addition, the member states of the monetary union have common monetary policy while they do not have a common fiscal policy. The inconsistencies between two policies can lead countries to the crisis. Thus, it is a very important for countries to converge not only financially but also fiscally. Considering this, the debate on whether the European Union is an optimal currency area is still up-to-date as it was in the first day of establishment of the Union. The main conclusion reached here is that the convergence criteria should be revised by taking into account the above-mentioned issues in addition to the existing conditions in order to keep the UE continuing. This rises another question on how to reform the EU, but more importantly the Eurozone: Should the authorities in the EU allow member states which have

increasing debt ratios and worsening macroeconomic balances to leave the Eurozone. By leaving the EMU, the country suffers a sharp deterioration in its economy, a rapid depreciation of its 'new' national currency and an inflation spike. The country will probably announce debt default. Real depreciation will then give the country the competitive power to drive economic growth. However, allowing the exit of a member state may affect the sustainability of the Union, ultimately leading to its collapse.

Further studies can be carried out to include both a wider time period and a larger country set. In this way, more comprehensive results can be achieved for the constructed fiscal stress index and these results can be presented in a comparable way with previous studies. Besides, a very large set of indicators can be used to identify the factors that construct the fiscal stress index; it is thus possible to convert these indicators into the index by methods such as principal component analysis. Convergences between countries can also be tested for the governance quality. This also allows us to conclude to what extent countries are similar in terms of governance.

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