Symmetry and Convergence in Monetary Unions*

Nauro F. Campos
*Brunel University London
and ETH-Zurich*
nauro.campos@brunel.ac.uk

Corrado Macchiarelli
*Brunel University London
and London School of Economics*
corrado.macchiarelli@brunel.ac.uk

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Abstract: The study of asymmetries in currency unions often relies on binary classifications based on demand, not supply, shocks. We propose a new approach in which we model supply considerations as over-identifying restrictions. It yields a new theory-based continuous measure of asymmetries capturing the probability of a country being classified as "peripheral." We then use the Phillips-Sul convergence framework to evaluate the dynamics of this new indicator. We identify, yearly between 1990-2015, core, mixed and periphery groups among European economies. Regarding possible determinants, our panel estimates suggest that euro membership and product market regulation tend to make countries significantly less peripheral.

Keywords: Symmetry; Convergence; Euro; EMU; European Union; Core-Periphery; SVAR
JEL codes: E3; F4

1. Introduction

The protracted economic crisis in the Eurozone has fuelled demands for a deeper understanding of the dynamics of core and periphery groups of countries in the European Union, in general, and in its Economic and Monetary Union (EMU), in particular. There is now widespread consensus on the shortcomings of the EMU with even the European Commission openly recognising them and proposing as solution the building up of a Genuine EMU (Begg 2015). Such extensive agreement on the need for solutions co-exists with deep disagreement on causes. One view is that design flaws deepened imbalances (De Grauwe 2016) while another is that policy mistakes hindered convergence (Sandbu 2015). One solution that has been proposed is a flexible euro (Stiglitz, 2016): a two-tier model of a Northern and a Southern Euro where the latter is softer. One tautological way to explain this is that the Southern euro countries would not be part of the core.

This paper has three main objectives, namely to (a) propose a new framework that that can support placing countries along a core-periphery continuum (beyond the much more common binary treatment as either core or periphery), (b) to construct a continuous dynamic theory-based measure (the first, to the best of our knowledge) illustrating the use of this framework for a set of European countries using yearly data from 1960 to 2015, and (c) provide a first preliminary assessment, based on endogenous Optimal Currency Area (hereafter OCA) theory, of the main potential explanatory factors of the dynamics of this measure over time and across countries.

The natural point of departure is the seminal paper by Bayoumi and Eichengreen (1993). This is one of the first papers to identify a core-periphery pattern in the run-up to the European Monetary Union (EMU). Motivated by OCA theory and using a modified Blanchard-Quah

decomposition within the Aggregate Supply-Aggregate Demand (AS-AD) framework, they estimate the degree of demand and supply shocks synchronization for 1963-1989 data. Bayoumi and Eichengreen show that there is a core where shocks are highly correlated (Germany, France, Belgium, Netherlands and Denmark) and a periphery where this correlation is significantly lower (Greece, Ireland, Italy, Portugal, Spain and UK). They forewarn that if persistent, this core-periphery pattern would be detrimental to the EMU project.

We follow the large literature started by Bayoumin and Eichnegreen (1993) in that our exercise is also couched in the canonical AS-AD model. The model implies that positive demand shocks raise prices in both the short- and long-run with no output effects in the long-run, while positive supply shocks lower prices and increase output permanently. De Haan et al. (2008) and Santos and Tenreyro (2010) review this vast literature: It tends not to impose output related restrictions for tractability reasons as this choice leaves their models exactly identified. The novelty of our approach is to explicitly model these output considerations as over-identifying restrictions. We impose this over-identifying restriction in a structural VAR framework so that the predicted effects of supply shocks on output are accounted for.

There are three main findings regarding symmetry, convergence and correlates of symmetry. Firstly, modelling supply considerations as over-identifying restrictions produces a new theory-based continuous measure. Our measure is the percentage of times this fuller, or more structural, AS-AD model is rejected. The more frequently this full set of restrictions is rejected, the more peripheral a country is said to be. The lower is this frequency, that is, the less often the full AS-AD model is rejected for a given country in a given year, the higher is the probability of a country being classified as core. This is implemented by bootstrapping the original VAR residuals and counting the number of rejections at each bootstrap replication:

country-years for which the AS-AD model is rejected more (less) than half of the time are classified as periphery (core). For convenience, we call our index *NORD* (as it reflects the "number of rejections dynamics.")

Secondly, we study convergence using the Phillips and Sul (2007) framework. Here, we are able to identify a new set of core countries (Austria, Belgium, France, Germany, Italy and Netherlands), an intermediary set (Denmark, Greece, Spain, Sweden and the UK), and a periphery (Finland, Ireland, Norway, Portugal and Switzerland). Notice that *NORD* decreases for the core countries (broadly confirming the endogenous OCA predictions), remains high and constant for a deep-rooted periphery (worrisomely corroborating Bayoumi and Eichengreen's early warnings), and varies substantially for a mixed set of countries. As for the latter, Spain moves towards the core over time. Greece and, somewhat surprisingly, Sweden become "more peripheric" over time. Denmark's is practically static while the UK seems to charge in and out of the core.

The third main finding refers to our attempt to uncover factors that can help explain the variation of this new measure across countries and over time. We believe these correlates indicate whether or not our measure is doing a good job at capturing core, periphery, and their dynamics; the latter being an issue that has received scant attention in previous research. Using a specification based on endogenous OCA theory, panel estimates suggest that euro membership and stricter product market regulations make countries more or less core, respectively. Further, we find that trade openness and, to a lesser extent, foreign direct investment, help to "import competition" and in so doing substitute for regulations: imports (but not so much exports) increase the probability of a country being classified as core. The findings are robust to numerous changes in specification, measurement, estimators (e.g., OLS or probit) and split

samples (e.g., post-crisis period).

The paper is organised as follows. Section 2 sets up the conceptual framework. Section 3 discusses implementation and estimation issues. Section 4 introduces our new measure. Section 5 presents econometric results evaluating the robustness of this new measure. Section 6 concludes.

2. Core and Periphery in Optimum Currency Areas

In this section, we discuss why to understand the importance and urgency of core and periphery dynamics in the European Union, in general, and in the EMU, in particular, one should go beyond the standard business cycles synchronisation framework and towards a more encompassing notion. Based on optimal currency area (OCA) theory considerations, we discuss other approaches to identify core-periphery sets so as to properly contextualise our effort.

The main research question driving the OCA scholarship regards the costs and benefits of sharing a currency (Alesina and Barro, 2002). The main cost is the loss of monetary policy autonomy. Benefits are mostly in terms of reduction of transaction costs and exchange rate uncertainty, and of increasing price transparency, trade and competition.[1]

One way of framing the issue of optimum currency areas (OCA) is by De Grauwe and Mongelli (2005). They study interactions between symmetry, flexibility and openness. Particularly, they show there exists a minimum combination of these that countries must reach for a monetary union to generate positive net benefits (see also (Farhi and Werning, 2015). De Grauwe and Mongelli (2005) place the Eurozone (EU) within (to the outside) of the OCA-line suggesting those countries are (not yet) sufficiently integrated to generate efficiency gains that can compensate for the macroeconomic costs of the union. They also note the degree of openness

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[1] The literature is surveyed in De Haan et al. (2008), Silva and Tenreyro (2010) and Glick and Rose (2016).

and symmetry may change over time. Before the EMU, there was an intense debate about the extent to which a monetary union affects symmetry (Krugman, 1993). De Grauwe and Mongelli (2005) view is that in the EU specialisation will bring about less symmetry and thus countries move downwards along the OCA plane.

There are at least two noteworthy recent developments in OCA theory. The original OCA formulation stressed labour mobility, product diversification and trade openness as key criteria and explored the possible endogeneity of currency unions (Frankel and Rose, 1998). Recent work called attention to the additional role of credibility shocks. If there are varying degrees of policy commitment (furthering time inconsistency problems), countries with dissimilar credibility shocks should find convenient to join a currency union (Chari *et al*. 2015).

A second recent and important strand highlights that, although OCA criteria are often thought of as independent, they should instead be considered jointly, e.g., by focusing on the interactions between openness and mobility (Farhi and Werning, 2015).

The optimality of a currency area is a function of the relative power (and of the relative "distance") between its members. If these differentials are large, it is common to speak of a core and a periphery. It is expected that core countries would be those more closely meeting the OCA criteria. Given its importance for OCA, it is not surprising there have been various attempts of classifying countries into core and periphery sets. A basic way of distinguishing these methods is whether or not core-periphery status is imposed *a priori*.

A statistical technique often used here is cluster analysis. This method helps to determine the overall number and the composition of different grouping (or clusters) given that the elements (countries or regions) which are assigned to a given cluster are more similar to each other than to those in other clusters according to pre-defined criteria. Cluster analysis is a broad

statistical methodology that involves various ways of estimating these groups and the distance among them. These can be thought of as different algorithms differing in their criteria and efficiency in determining the composition of each cluster.

Artis and Zhang (2001) investigate actual and prospective membership of the EMU by applying clustering techniques to a set of variables suggested by the theory of Optimal Currency Areas. The OCA criteria they employ are the extent of synchronisation in business cycles (symmetry in output shocks), volatility in the real exchange rate, synchronisation in the real interest rate cycle, openness to trade, inflation convergence, and labour market flexibility. Their analysis reveals that the member countries may be divided into three groups: those belonging to the core (Germany, France, Austria, Belgium and the Netherlands), those part of a Northern periphery (Denmark, Ireland, the UK, Switzerland, Sweden, Norway and Finland) and those belonging to a Southern periphery (Spain, Italy, Portugal and Greece). Their method delivers a rather intuitive classification of countries and, more usefully, allows researchers to see how these classifications change for each of the OCA criteria and multiple combinations of them.

There are other, more theory-based, approaches. Bayoumi and Eichengreen (1993) is a seminal piece in this regard. They put forward an approach stressing business cycle synchronisation embedded in a standard Aggregate Demand and Aggregate Supply framework. Using 1960 to 1989 data, they classify countries into core and periphery groups and famously warm that the gap between these groups put in risk the very planning of the Single Currency. We discuss these results below in greater detail, but it is important to bring to the fore a related paper by these authors that produce an objective index to classify countries into core and non-core.

Bayoumi and Eichengreen (1997) construct an "optimum-currency-area index for European countries." The crucial element of their approach is to identify the determinants of

nominal exchange rate variability which they argue reflect OCA characteristics and support predictions of which countries pertain to each set. This is justified conceptually and empirically. Conceptually, they argue that OCA focuses on criteria that ultimately make exchange rates more stable and monetary unification less costly. In their model, bilateral exchange rate variability is a function of GDP, trade, economic structure dissimilarity, and a measure of output synchronisation. Using 1973 to 1992 data, they find these carry expected signs and are statistically significance so they use them to forecast variability in 1987, 1991 and 1995.

Their econometric analysis allows them to identify three groups: in the first "rapidly converging" group are Germany, Austria, Belgium, the Netherlands, Ireland and Switzerland. The second group is one that has experienced little convergence and contains United Kingdom, Denmark, Finland, Norway and France. The third group is a set of countries that are "gradually converging" to the EMU and includes Sweden, Italy, Greece, Portugal and Spain. The two most consequential results from this analysis, with the benefit of hindsight, are that (1) France is positioned in the set that diverges from the Maastricht criteria but (2) that overall "economic integration has thus increased countries' readiness for monetary integration" (Bayoumi and Eichengreen 1997, p. 769).

A different estimation framework to analyse the issue of asymmetries in the EMU is Basse (2014) which uses cointegration and structural breaks to try to identify EMU core member countries. The OCA dimension he is most interested in is changes in sovereign credit risk (bond markets) and the sample includes only selected EMU members (Germany, France, Belgium, Austria, Finland, and the Netherlands.) The main finding raises questions about the suitability of France as a core country.

One final noteworthy approach in terms of providing useful insights to understanding core and periphery in the EMU involves studies in which membership is assigned in advance, *a priori*. Arestis and Phelps (2016) perform an "endogeneity analysis" of output synchronization (differentiating output amplitude from concordance) using panel data (covering 1994 to 2013), for all members as well as for different country groups, including core, periphery, central and eastern European countries, northern European countries and the euro-candidate countries. The quantification of trade-related and direct spillover channels associated with monetary integration gives insights into the relative importance of direct and indirect (through trade) synchronisation gains arising from EMU membership. For all members, membership and trade appear to increase both amplitude and coincidence of their business cycles. The individual group analysis shows that core and northern countries have experienced much larger trade spillovers in terms of synchronisation than peripheral and Central and Eastern European countries. They suggest future research on the direct euro membership effects by trying to unpack the role of institutions and changes in the transmission mechanism since the introduction of the single currency.

3. Implementation

The methodology introduced by Bayoumi and Eichengreen (1993) is an extension of the Blanchard and Quah (1989) procedure for decomposing permanent (supply) and temporary (demand) shocks. Consider a system where the true model is represented by an infinite moving average of a (vector) of variables, X_t, and shocks, ϵ_t. Using the lag operator L, a bi-variate VAR featuring real GDP and its deflator can be written as an infinite moving average representation of demand and supply disturbances:

$$X_t = A_0\epsilon_t + A_1\epsilon_{t-1} + A_2\epsilon_{t-2} + A_3\epsilon_{t-3} + \cdots = \sum_{i=0}^{\infty} L^i A_i \epsilon_t \qquad (1)$$

where $X_t = [\Delta y_t, \Delta p_t]$ and the matrices A represent the impulse response functions of the shocks to the elements of X. It follows that

$$\begin{bmatrix} \Delta y_t \\ \Delta p_t \end{bmatrix} = \sum_{i=0}^{\infty} L^i \begin{bmatrix} a_{11i} & a_{12i} \\ a_{21i} & a_{22i} \end{bmatrix} \begin{bmatrix} \epsilon_{dt} \\ \epsilon_{st} \end{bmatrix} \tag{2}$$

where y_t and p_t represent the logarithm of the adjusted output and prices and ϵ_t are $i.i.d.$ disturbances, which identify supply and demand shocks (Ramey, 2016). For the i-th country, a_{11i} represents element a_{11}, in matrix A_i and so on.

This framework implies that supply shocks have permanent effects on output, while demand shocks have temporary effects. Both have permanent (opposite) effects on prices. The cumulative effect of demand shocks on the change in output must be zero:

$$\sum_{i=0}^{\infty} a_{11i} = 0 \tag{3}$$

so it can be estimated using a VAR. Each element can be regressed on lagged values of all the elements of X. Using B to represent these estimated coefficients:

$$X_t = B_1 X_{t-1} + B_2 X_{t-2} + \cdots + B_n X_{t-n} + e_t$$

$$= \left(I - B(L)\right)^{-1} e_t \tag{4}$$

$$= (I + B(L) + B(L)^2 + \cdots) e_t$$

$$= e_t + D_1 e_{t-1} + D_2 e_{t-2} + D_3 e_{t-3}$$

where e_t represents the residuals from the VAR equations. In order to convert (4) into the model in (2) under (3), the residuals from the VAR, e_t, are transformed into demand and supply shocks using the standard relation between the VAR's residuals (e_t) and demand and supply shocks, i.e. $e_t = C\epsilon_t$. For each country, exact identification of the C matrix requires four restrictions. Two are normalizations, which define the variance of the shocks ϵ_{dt} and ϵ_{st}. The third restriction is from assuming that demand and supply shocks are orthogonal to each other. The fourth that demand shocks have only temporary effects on output (equation 3).

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Figure 1 reproduces the seminal results from Bayoumi and Eichengreen (1993.) Using pre-EMU data to estimate the degree of business cycles synchronization, Bayoumi and Eichengreen convincingly argue that there is a core (Germany, France, Belgium, Netherlands and Denmark) where supply shocks are highly correlated and a periphery (Greece, Ireland, Italy, Portugal, Spain, and the UK) where synchronisation is lower. Importantly, these two groups are clearly visible "to the naked eye," especially from the point of view of supply shocks (Figure 1).

[Figure 1 about here]

The standard AD-AS model implies that demand shocks raise prices in both the short and long run, while supply shocks lower prices and increase demand permanently. In order to fully reflect the structure of the underlying theoretical model, we impose an additional over-identifying restriction in the VAR that supply shocks have permanent effects on output.[2]

We pay particular attention to modelling the effect of permanent (supply) shocks on output, on top of the usual demand-side one. Since the proposed over-identifying restriction is sufficient to generate structural disturbances in line with AD-AS dynamics, any additional long-run restriction may be redundant in this setting.

Theoretically, testing for the "symmetry" of shocks also reflects the idea that the distinction between permanent and temporary shocks matters when it comes to adjustment within a currency union. According to De Grauwe (2016), when shocks are permanent, the slope of the usual existing trade-off between flexibility and symmetry is likely to depend on the nature of the

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[2] In addition to trying to implement the AS-AD model more fully, another important reason we adopt the proposed over-identifying restriction is that inflation differentials are often considered a 'normal feature of currency unions' (see e.g., ECB, 2017), hence we impose no restrictions on the reaction of inflation to demand and supply shocks, respectively.

shocks. Particularly, when permanent shocks dominate this tradeoff is likely to be steeper. Conversely, when temporary shocks dominate, the tradeoff will be flatter. We extend this idea further and suggest that it is not only the nature of the shock that matters but also the direction and extent by which shocks are pushing an economy "out of sync."

We test for symmetry of permanent shocks in our model by imposing $\sum_{i=0}^{\infty} a_{12i} = \gamma$, where $\gamma > 0$. This assumption implies that demand across each country respond qualitatively (sign) and quantitatively (size) in the same way to supply shocks. In terms of the structural VAR:

$$\sum_{i=1}^{\infty} \begin{bmatrix} d_{11i} & d_{12i} \\ d_{21i} & d_{22i} \end{bmatrix} \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} = \begin{bmatrix} 0 & \gamma \\ . & . \end{bmatrix} \tag{5}$$

In order to construct a test for the over-identifying restriction described above, we estimate a SVAR model that is fully consistent with Bayoumi and Eichengreen (1993). Differently from the literature that follows Bayoumi and Eichengreen, we bootstrap the original VAR residuals in a *i.i.d.* fashion and generate K = 10.000 data sets.[3] For each of the k-*th* samples, we proceed with a structural analysis and test for the over-identifying restriction based on a LR-test. We record the number of rejections of the over-identifying restriction test at each bootstrap replication and calculate the number of rejections (*NORD*):

$$NORD_i = 100 \times \frac{\sum_{k=1}^{K} \left\{ NORD=1 \left| -2(L_r - L_u) > \chi^2_{q-\left(\frac{n^2-n}{2}\right)} \right. \right\}_{i,k}}{K} \tag{6}$$

where L_u and L_r are the maximized values of the (Gaussian) log likelihood function of the unrestricted and restricted regressions, respectively. Under H_0, the LR statistic has an asymptotic distribution with degrees of freedom equal to the number of long-run restrictions (q) minus

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[3] One concern is the possible effects from any regime changes between 1960 and 2015. Using a dummy saturation approach, first proposed by Hendry e*t al.* (2008), we attempt to detect model selection problems and correct the original series for possible regime changes. In the light of the above, we identify three regimes for both GDP and inflation, broadly consistent across countries: 1960:I-1969:I; 1984:I-1992:I; and 2008:I-2015:I.

$(n^2 - n)/2$, where n is the VAR-dimension (in this case $n = 2$). We calculate $NORD_i$ for different values of γ. Notice that we do not restrict γ to a fixed value *a priori.* Instead, we vary γ in the interval [0.1, 2] We then chose the value of γ which minimizes the total number of rejections in the sample (Table 1A.) Demand and supply shocks are then retrieved by bootstrap, in particular recalculating the VAR parameters (K = 10.000), identifying the SVAR and considering median values of structural disturbances under $\gamma = 1$.

As noted above, the seminal Bayoumi and Eichengreen (1993) paper uses data from 1960 to 1988, that is, prior to the EMU and the euro. In order to assess the effect of the EMU, Campos and Macchiarelli (2016) use the same estimation methodology (SVAR with two lags for all countries, no constant, and yearly data with respect to Germany), sample of 12 countries, and time window (25 years), but with the (median bootstrapped) residuals and over-identifying restriction imposed for the sample 1989–2015. Figure 2 shows their results.

[Figure 2 about here]

A comparison of the results in Figure 1 with those in Figure 2 help shed light on whether the EMU strengthened or weakened the core-periphery pattern. This comparison suggests that the introduction of the euro weakened or loosened the original divide. It is also clear, however, that this now cannot be grasped simply through visual inspection. In other words, the identification of core and periphery groups can not anymore be carried out by "the naked eye." A quantitative measure appears to have become necessary. Using *NORD*, there is now a larger number of countries in the core, a smaller number in the periphery, and the distance between the

two groups is shorter. The new smaller periphery is comprised solely of Spain, Portugal, Ireland and Greece, with the UK and Italy having joined the core since the late 1980s.

4. The Dynamics of Core and Periphery

Three major drawbacks from the existing empirical measures of symmetry in currency unions are that (a) they tend not to be continuous (a country is classified either as core or as periphery), (b) they are often imposed *a priori* and (c) they tend to be time-invariant. One may add that most of these measures are not theory-based. The approach we develop above generates a new type of measure that relaxes these main constraints.

One way of thinking about it is in terms of assessing parameter constancy. Let T be larger than before (55 years, i.e. 1960-2015) and τ denote the width of a sub-sample (25 years) or window and define the rolling sample metrics:

$$NORD_{t_i}(\tau) = \frac{1}{\tau - 1} \sum_{j=0}^{\tau-1} NORD_{(t-j)_i}(\tau) \qquad (7)$$

The windows are rolled through the sample one observation at a time, so that the procedure returns $T - \tau + 1$ rolling estimates of each parameter. Using a fixed 25-year window, we obtain a value representing the end-of-period number of rejections for each year, out of the number of the bootstrap replications. This number thus represents the count of the number of times the over-identifying restriction in the AS-AD framework is rejected for each country for the selected time period. The window is then rolled one observation at a time and new estimates are obtained for the whole time-series.

These results are presented in Figures 3 to 7 which show $NORD_{t_i}$ for various groups of countries, yearly from 1987 to 2015. Figure 3 shows all 16 countries in our sample. We generate our measure for all European countries for which the required data series are available between 1960 and 2015. Figure 3 is shown simply to illustrate as clearly as possible that in our case it is practically impossible to differentiate groups of countries "at the naked eye." Therefore, a more systematic and transparent procedure is needed.

Another criticism to the approach we propose above, particularly in deriving our indicator from bivariate VARs that take into consideration GDP and its deflator only, is that the number of rejections may be capturing common (or, in this case, euro) area factors. In other words, the number of rejections of the symmetry hypothesis may be lower in those countries where common factors are stronger. To try to address this concern in full, we use the panel data model first proposed by Phillips and Sul (2007.) For each time-series of our indicator, the model assumes both common and individual specific components and is formulated as a nonlinear time-varying factor model, allowing for a wide range of possible time paths and individual heterogeneity. This decomposition provides flexibility in idiosyncratic behaviour over time and across cross-sections while retaining some commonality across the panel by means of an unknown common component which we identify as a latent 'euro area factor'. In this case, commonality means that when the heterogeneous time-varying idiosyncratic components converge over time to a constant, a form of panel convergence holds, which is analogous to the concept of conditional sigma convergence. The procedure not only does not impose any particular assumption concerning trend stationarity, thereby being robust to the stationarity property of the time series process, but also has the advantage of singling out a common factor, isolating it from idiosyncratic factors.

The measure we derived above, *NORD*, is a bounded variable [0,100] and cannot be described by a random walk. However, both from an empirical and theoretical point of view, if its adjustment is slow, *NORD* may behave approximately as a random walk over the sample period. That is, within the chosen sample, the process does not show any tendency to be mean-reverting. This is evident by looking at the pattern of the dynamics of our indicator (particularly for what we have identified as peripheral countries.) When a process is close to having a unit

root, the misspecified model introduced by assuming a unit root can be a good approximation to the true data-generating process. In fact, the misspecification introduced by assuming stationarity when in reality there is a unit root leads to more serious errors of inference. The issue may be important in our case if one assumes that structural euro area factors are increasing or reducing the degree of symmetry amongst countries, such that a path dependency of symmetry exists.

Formally, the approach Phillips and Sul (2007, 2009) propose allows to isolate a common factor from the estimated dynamic NOR ($NORD$), distinguishing it from country-specific factors. The common factor may represent the aggregated common behaviour, but it could also be any common variable of influence on individual behaviour.

The starting point of the model is decomposing the panel data of our variable of interest, $NORD_{it}$, as:

$$NORD_{it} = g_{it} + ait \tag{8}$$

where g_{it} represents systematic components (such as permanent common component), and a_{it} reflects country-specific transitory components. In order to separate common from idiosyncratic components, Eq. (1.8) is further transformed as:

$$NORD_{it} = \left(\frac{g_{it} + ait}{ea_t}\right) ea_t = \delta_{it} u_t \tag{9}$$

where δ_{it} is a time varying idiosyncratic element and ea_t is a single common ('euro area') component. Equation 9 is a dynamic factor model where u_t captures some deterministic or stochastically trending behaviour and δ_{it} is the time varying factor-loading.

In the general case, it is impossible to estimate the model directly without imposing some structure on δ_{it} and a_t. Phillips and Sul (2007) propose removing the common factor by scaling so as to obtain the relative loading coefficient:

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}} \tag{10}$$

which they called the "relative transition parameter," measuring the loading coefficient relative to the panel average at time t. By definition, h_{it} traces out a transition path of individual i in relation to the panel average (Phillips and Sul, 2007).

We use the Philipps and Sul econometric toolbox to evaluate the convergence properties of the estimated time-varying idiosyncratic components. Their suggested procedure for clustering panel data into clubs with similar convergence characteristics is as follows:

$$lim_{t\to\infty} \frac{X_{it}}{X_{jt}} = 1 \ for \ \forall \ i, j \tag{11}$$

Phillips and Sul (2007) define this condition as "relative convergence." This condition is equivalent to convergence of the time varying factor-loading coefficient:

$$lim_{t\to\infty} \delta_{it} = \delta \ for \ \forall \ i \tag{12}$$

Showing that the cross sectional mean of h_{it} is unity and the cross sectional variance of h_{it} satisfies the condition $H_{it} = \frac{1}{N}\Sigma_{i=1}^{N}(h_{it}-1)^2 \to 0 \ if \ lim_{t\to\infty}\delta_{it} = \delta \ for \ \forall \ i$, Phillips and Sul (2007) develop a regression test of the null hypothesis of convergence. Specifically, the hypothesis is implemented by means of the following 'log t' regression model:

$$log\left(\frac{H1}{H_t}\right) - 2\log(\log(t)) = a + b\log(t) + \epsilon_t \tag{13}$$

$$for \ t = [rT], [rT] + 1, \dots, T \ with \ r > 0$$

where r is a selection of the initial sample fraction. Phillips and Sul's Monte Carlo simulations indicate that $r \in [0.2, 0.3]$ achieves a satisfactory performance. In line with their results, we set $r = 0.3$ because of the short time series in our panel ($T = 29$).

When we run the *log t* regression for the convergence test under the null hypothesis of convergence for the whole panel, the value of the t statistic is -5.5874 which is less than -1.65, hence the null hypothesis of overall convergence is rejected at the 5% level. However, the

rejection of the hypothesis does not exclude the possibility of the existence of convergence clubs. When testing for convergence among sub-groups, the clustering of convergence sub-groups suggests the following partition:

Club 1: Ireland, Norway, Switzerland

Club 2: Finland, Greece, Portugal, Sweden

Club 3: Denmark, Spain, UK

Club 4: France, Italy

Club 5: Austria, Belgium, Germany, the Netherlands

The results suggest all the clubs fulfil the convergence hypothesis jointly (Appendix 9). However, the interpretation of the t-statistics requires care: while the Phillips and Sul's routine may have a natural interpretation for the extent of incremental economic growth and convergence across countries, the intuition regarding the convergence pattern in the degree of symmetry reflected by *NORD* may be less straightforward. In fact, in our setting countries showing the strongest degree of divergence from the core are often the ones for which the *NORD* has the strongest root.

To further investigate this issue, we perform the tests for possible club mergers Phillips and Sul (2007) suggest. These show statistical support to the possibility that the original Clubs 1 and 2 and 3 and 4 can be merged to form larger convergence clubs. This implies that three main clubs of countries may have emerged since the euro introduction, namely an extended periphery composed by Finland, Ireland, Norway, Portugal, Switzerland, Sweden, Greece, an intermediate group formed by Denmark, Spain, UK, France, and Italy, and a harder core where one would find Austria, Belgium, Germany, the Netherlands. It is noteworthy that these results are consistent with previous analyses (e.g., Campos and Macchiarelli 2016).

Figure 4 shows a first group that have in common a sustained decline in the probability of being classified as periphery (i.e., *NORD*). We call it the core group. Using the convenient 50% mark for these classification purposes, one can see that the three first countries to enter the core are Germany, France and Austria, all by 1999. This is of course the year in which the euro was introduced. Belgium joins the core in 2000, while Italy and the Netherlands join before 2007. If one equates core membership with a strong indication of being part of an optimum currency area (OCA), these results are unique in that they show a somewhat gradual formation over time of an OCA. Moreover, if one accepts this interpretation, the results in Figure 3 provide evidence in favour of endogenous OCA theory (Frankel and Rose 1998) as countries only enter or join the core after the currency union is in place.

The group of countries we call periphery is shown in Figure 5. Not only these five countries all have very high levels of *NORD*, they do so throughout. In other words, their scores are consistently above the 50% mark and these scores are worrisomely trendless. They provide strong, albeit somewhat qualified, confirmation of Bayoumi and Eichengreen (1993) famous early warning about the EMU, specifically about the possibility of an entrenched core and periphery pattern driven by the latter being deep-seated. It is noteworthy that neither Norway nor Switzerland are eurozone countries, although Portugal, Finland and Ireland are.

The Philips-Sul procedure also identifies an intermediary or mixed set of countries. Within this group, one distinguishes between two main sub-sets: one for which *NORD* does not seem to show any clear trends between 1987 and 2015, and another one for which it does. Figure 6 shows that the UK and Denmark are good candidates for the intermediate set. Yet, while Denmark's *NORD* barely moves over time, the opposite can be observed for the UK, displaying high volatility in and out of the core.

Figure 7 shows the remaining three countries, those at intermediate levels of *NORD* but with clearly distinguishable trends instead. Here, Spain's *NORD* is basically flat until 1999 and starts to decline fast afterwards, clearly moving towards the core (linear interpolation suggests it may enter circa 2020.) On the other hand, Greece and Sweden distinctively move *away* from the core. In other words, they become more peripheral over time. It is interesting to note, however, that between the introduction of the euro in 1999 and the onset of the financial crisis in 2007, Greece was instead moving in the "right direction," that is, towards the core.

In summary, the results above reveal that the core and periphery pattern has changed considerably since the late 1980s, both in terms of relative strengths and distances between main groups of countries but also in terms of the trajectories of individual countries (for instance, it is interesting to see how different countries join the core at different points in time.) Overall, our new theory-based index, *NORD*, can be seen to decreases over time for the set of countries that the Philips and Sul (2007) procedure single out and that we call "core" (a result which broadly confirms endogenous OCA predictions), it remains high and basically constant for a more peripheric group (worrisomely confirming Bayoumi and Eichengreen's warning about a deep-seated periphery), and it varies substantially for a mixed set of countries between 1987 and 2015. Denmark's *NORD* remains constant around the 50% mark while the UK's score over time makes it move in and out of the core. The results for Spain are quite optimistic as they show that although the country should still be classified as periphery, it is moving towards the core. This is contrast of two much more worrisome trends: according to their *NORD* scores, Greece and Sweden are slowly moving away from the core group of countries, or in other words, gradually becoming more and more peripheral in the EMU.

5. Evaluating *NORD* ("Number of rejections dynamics")

The objective of this section is to assess our new theory-based continuous measure of the probability of a country being classified as periphery (*NORD* above 50%). Given data availability, we produced this index for 16 European countries on a yearly basis between 1987 and 2015.

In order to shed light on the behaviour of *NORD* across countries and over time, we draw from OCA theory (De Grauwe 2016) and enlist a standard set of candidate explanatory variables. One first group refers to explanatory variables on the fiscal side (Martin and Philippon, 2017). The expectation, in this case, is that countries for which debt to GDP ratios and cyclically adjusted budget balances are larger, should be more likely to be classified as periphery.

A second group of explanatory variables focuses on financial links, more specifically we use corporate bond spreads, 10-year government bond spreads, 3-month interbank interest rate spreads, average consumer loan interest rate spreads, and returns on equity differential. All spreads are computed vis-à-vis Germany. This set of financial variables is consistent with the European Central Bank's definitions of financial integration (ECB, 2017, Spiegel 2009). Our prior in this case is that the more financially integrated an individual country is with the rest of the EU in a given year, the more likely it will not be classified as pertaining to the periphery.

A third group of variables we use to assess the validity of our index covers external links, in particular, the roles of foreign direct investment (FDI) inflows, the real effective exchange rate, and trade openness (Rose 2000, Brouwer et al. 2008). Note that, in this latter case, we examine the potentially different roles of the shares of exports and imports over GDP. Our expectation here is that larger the inflows of FDI, increases in the real exchange rate or in the share of imports plus exports in GDP will, all else equal, make a country less likely to be classified as periphery.

The fourth and last main group of explanatory variables we draw upon in order to try to evaluate *NORD* regards structural reforms. Here we use OECD data on employment protection legislation (EPL), covering both permanent and temporary contracts (Boeri and Garibaldi 2006), and on product markets regulation (PMR-overall economy). Our expectation is that the more extensive reforms different countries have implemented, the more likely is that they will not be classified as periphery. In other words, the more protective is employment legislation and the more extensive are product regulations, the more likely the country can be classified as peripheric.

We include a dummy variable for euro area membership in all specifications as suggested by the results from the Philips-Sul procedure presented in the previous section. Eurozone membership takes the values of one for countries joining the EMU starting from accession year.

The estimation sample includes Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, the Netherland, Portugal, plus three EU non-euro area countries (Denmark, Sweden and UK) and two countries that are not EU members (Switzerland and Norway). We present the results for the period 1990-2015.

In order to address possible endogeneity and omitted variables problems, we employ a GMM approach where the weighting matrix is set to equal the 2SLS.[4] In the estimation, the number of endogenous variables equals the number of instruments, where we select the instruments to be the lagged dependent variables, the constant and the Eurozone (EZ) membership dummy. This choice also addresses concerns about the instrument proliferation issue in GMM (Roodman, 2009).

Table 1 shows our baseline results. We include a dummy variable capturing membership

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[4] The results are qualitatively the same if instead we use a Huber/Eicker/White heteroskedasticity-robust variance-covariance matrix (these are available upon request from the authors).

in the Eurozone throughout and its coefficient is always statistically significant and carrying the expected negative sign. It suggests EZ membership is associated with a smaller probability of being classified as periphery. The first column also shows two important fiscal variables: countries with higher debt to GDP ratios and cyclically adjusted budget balances are more likely to be classified as periphery (as these are positively associated with *NORD*). Regarding financial integration, notice that only one of the four aspects we account for turns out to be statistically significant, namely inter-bank spreads. Regarding external linkages, the coefficients on both foreign direct investment inflows and the real exchange rate carry the expected negative signs and are statistically significant (we confirm below that the FDI result is comparatively more robust.) Everything else the same, lower values of *NORD* are associated with countries receiving higher inflows of foreign investment. The results in column (4) for trade openness show that the larger the share of the sum of exports and imports over GDP, the less likely the country is to be classified as periphery. Globalisation, in this sense, helps countries to avoid being at the margins. The column (5) has results for two structural reforms that have played a big role in the debate so far on Eurozone imbalances and they both seem to support *NORD* as a satisfactory measure. They show that the more protective is employment legislation and the more regulated are the product markets, the higher is the probability of a country being classified as periphery. Overall, these results are strongly supportive of *NORD* as a continuous measure of the probability of a country being classified as periphery. There are, simply put, no unexpected or counter-intuitive results.

[Table 1 about here]

The overall results (last column in Table 1) suggest that a strong role is played by membership in the Eurozone and by the strictness of product market regulation, whereby a high PMR increases the likelihood of being classified as periphery.[5] On balance, this set of results strongly support *NORD* as a continuous time-variant measure of the likelihood of a country being in the periphery. Membership of the currency union, for the countries in our sample, suggests an important role in making countries less "peripheral", with this reduction of likelihood of being classified in the periphery to core being as much as 16 percentage points.[6]

These overall findings are in line with the idea that one of the main concerns in terms of monetary union membership would be again represented by the costs of adjustment in order to deal with asymmetries. In the absence of sufficient labor flexibility, and equally of fiscal transfers at the euro-area level, many countries suffer from severe adjustment problems. As the crisis made clear, the lack of such channels, in the presence of asymmetries, has made the cost of adjustment rather high ex post in terms of the preservation of the monetary union.

Table 2 extends our baseline results. Note the coefficient of the dummy variable for Eurozone membership as well as that on foreign direct investment remain significant throughout. These are robust results. The other key result from Table 1 refers to the role of product market regulations (PMR). In Table 2, we further investigate this latter result. Specifically, we study whether the greater competitive pressures created by decreasing regulations in product markets can be somehow captured in different ways. We have in mind the notion that these competitive pressures can somehow be "imported" instead.

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[5] This is, in turn, not surprising given that our index is based on supply side dynamics and the extent to which those prompt similar GDP reactions among member states.
[6] The results for the EA membership and PMR remain robust when the EA dummy is set to start in 2002, i.e. the year when euro coins were effectively introduced (see Appendix 5).

The first column of Table 2 suggests that including exports and imports instead of trade openness creates a problem of multicollinearity, as not one of the two coefficients is statistically significant.[7] When each of these variables is introduce by itself, their coefficients carry the expected sign and are statistically significant. It is also worth noting that the size of the coefficient on imports is substantially larger (indeed almost twice as large) as that on exports. More importantly for our purposes, note that the coefficient on product market regulations is significant only when trade openness, exports or imports are excluded from the specification suggesting that these two sets of variables (trade and reforms) capture similar mechanisms (competition).

Finally, we have also investigated whether the effects of PMR would be identifiable if we account for possible interactions between trade openness and two different aspects of employment protection legislation (covering either permanent or temporary contracts) and, as it can be seen from the Table, this does not help to further isolate the effects of PMR (as its coefficient remains statistically insignificant).

Table 3 provides an important robustness check on the results above. The Global Financial Crisis that started in 2007 and that affected Europe in full in 2010 (becoming the Eurozone Sovereign Debt Crisis) by its very nature generated a similar response across countries. The extent of symmetry increased rapidly and broadly so one may be justifiably concerned that this would affect our results. Table 3 shows the simplest test for this idea, namely, of whether splitting the sample in 2010 (or in 2007) substantially affect our baseline results for *NORD*. As it

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[7] This is because of the high pair-wise correlation between these two variables (as shown in correlation matrix in the Appendix, multicollinearity is not a problem for any of the variables we use, except exports, imports and openness.)

is clear from the Table, that does not seem to be the case. Some coefficients loose statistical significance but our main individual results remain intact and the broad pattern of signs does not seem to have changed either. Eurozone membership and trade (or reforms) are again key factors.

[Table 3 about here]

One remaining important concern regards the robustness and magnitude of the effect of Euro membership. One way of further investigating this issue is to re-estimate the specifications in Table 1 using the differences-in-differences estimator. This estimator requires that euro membership is modelled as the treatment. The introduction of the euro took place between 1999 and 2002 when twelve European countries started using the single currency.[8] The main coefficient of interest is the interaction between time and the dummy for Eurozone membership. As it can be seen, this coefficient is significant throughout and carries the expected negative sign. Adoption of the single currency, everything else equal, makes the probability of countries being classified as core significantly larger. This coefficient can be interpreted as showing that the "pure" effect of Eurozone membership is to decrease the likelihood that a country is classified as periphery by about 10 (ten) percentage points. In light of the role played by the various other factors suggested by OCA theory, this is a non-trivial and sensible estimate in our view.

[Table 4 about here]

To conclude, this section has shown a sequence of results intended to check whether

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[8] The next country to join was Slovenia in 2017, followed by Slovakia in 2009, Estonia in 2011, Latvia in 2014 and Lithuania in 2015. However, because all of these were communist countries before 1990, data required for our exercise is not available as it does not go back to 1990.

NORD can be said to be satisfactory as a continuous time-variant measure of the likelihood of a country being classified in the periphery or in the core. The associations we uncover are all intuitive and in extremely few cases we encounter results that are not sensible. The role of Eurozone membership behaves according to the predictions from endogenous OCA theory (Frankel and Rose, 1998). The results for foreign investment inflows and trade openness (or otherwise product market regulations) are also very much in line with OCA theoretical predictions (De Grauwe 2016). The results for fiscal and financial liberalisation variables are equally judicious and accord to theoretical priors, despite not being as robust as for other variables. The main results we obtain for *NORD* are also not affected by splitting the sample in before and after the Eurozone crisis of 2010, by using different estimators (like logit or OLS), variations on the measurement of the key variables (such as using 2002 for the Eurozone dummy) and the use of standard differences-in-differences. In sum, these results should give one confidence that *NORD* is a more than adequate continuous time-variant measure of the likelihood of a country being classified as periphery and as such should be given the chance to be further investigated and developed.

6. Conclusions

The objective of this paper is to attempt to further our understanding of symmetry and its dynamics in currency unions, specifically in the context of the European Economic and Monetary Union. One main concern was to try to go beyond the mainly static and binary ways of framing this issue. We put forward a new simple theory-based measure that we think can successfully locate countries in a core-periphery *continuum*. We construct such measure for a set of 16 European countries yearly from 1987 to 2015 and provided an assessment, based on the

endogenous OCA theory, of the main potential underlying explanatory factors of the dynamics of this measure over time and across countries.

Our main conclusion is that this new theory-based measure allows us to clearly identify three clear sets of countries on the basis not only of the level of our new measure but also in terms of its dynamic behaviour. Using the Phillips-Sul (2007) testing procedure, we show the emergence a newer set of core countries (composed by Austria, Belgium, Germany, France, Italy and Netherlands), a mixed set of countries (namely Denmark, Sweden, Greece, Spain and the UK), and a deep-rooted periphery countries (Finland, Ireland, Norway, Portugal, and Switzerland).

There are valuable lessons from the dynamics of this measure. Our findings suggest that the irreversibility of being in the core should not be taken for granted. Our index increases for core countries (which confirms endogenous OCA predictions), remains worrisomely constant for a periphery, and varies substantially for the intermediate set of countries. Spain (Sweden and Greece) becomes consistently more (less) core over time, Denmark's remains constant and the UK moves in and out of core over time. Our panel estimates on a specification suggested by endogenous OCA theory imply that euro membership and stricter product market regulations (or trade openness) make countries more or less likely to be in the core, respectively.

The analysis presented here documents that the introduction of the single currency preceded a substantial increase in symmetry among member states, thus improving the stability of the Euro Area. The main policy implications we can derive, however, are modest. Our results suggest that policy may focus on Sweden. The trajectory of Sweden's *NORD* since the 1990s is deeply worrisome. It indicates that Sweden is one of the few countries continuing to distance itself from the core and has done so in a steady and sustained way. No other country exhibits

such a trajectory. Making matters worse, Sweden is an important trade partner to the Baltics which, despite their euro membership and relative low levels of product market regulation, are often treated as periphery. Moreover, excluding the UK (that is, accounting for Brexit), Sweden becomes the country with one of the lowest *NORD* scores and as such becomes worrisomely closer to the border with the periphery.

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	(1) Fiscal		(2) Financial		(3) External		(4) Trade		(5) Reforms		(6) All	
	Table 1. The Determinants of NORD *(16 countries, 1991-2015)*											
Debt/GDP	0.118	***									0.090	
	(0.042)										(0.141)	
Adj. Budget Balance	0.836	**									1.629	*
	(0.336)										(0.965)	
Corporate bond spread			0.484								0.701	
			(0.617)								(0.679)	
3-month interbank spread			-4.455	***							-0.760	
			(1.435)								(2.742)	
Avg on consumer loans spread			-0.200								-0.360	
			(0.479)								(0.866)	
Return on equity diff.			0.634								-0.623	
			(0.438)								(0.397)	
FDI					-0.479	***					-0.419	**
					(0.152)						(0.202)	
Reer (CPI adj.)					-0.240	**					-0.492	*
					(0.118)						(0.294)	
Trade openness (%GDP)							-0.135	**			-0.457	**
							(0.065)				(0.191)	
EPL temporary									5.300	***	4.468	
									(1.871)		(3.856)	
PMR									6.898	*	1.906	
									(3.537)		(6.872)	
Eurozone membership dummy (1999)	-19.284	***	-28.330	***	-12.038	***	-11.612	***	-8.911	***	-15.363	**
	(2.105)		(3.160)		(1.935)		(2.155)		(3.199)		(6.243)	
C	69.516	***	82.239	***	98.345	***	82.566	***	49.242	***	147.812	***
	(3.135)		(2.252)		(11.891)		(4.693)		(7.951)		(45.754)	
Adj-R2	0.748		0.679		0.680		0.710		0.790		0.702	
Durbin-Watson	0.577		0.970		0.544		0.465		0.717		1.369	
J-Stat (p-value)	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	

Table 2. Importing Competition: How Imports/GDP Substitute for PMR regarding NORD (16 countries, 1991-2015)											
	(1)		(2)		(3)		(4)		(5)		(6)
Debt/GDP	0.057		0.081		0.092		0.090		0.117		0.044
	(0.152)		(0.143)		(0.140)		(0.141)		(0.148)		(0.139)
Adj. Budget Balance	1.609		1.654	*	1.580	*	1.629	*	0.978		1.209
	(1.029)		(0.992)		(0.948)		(0.965)		(0.928)		(0.955)
Corporate bond spread	0.112		0.464		0.873		0.701		0.166		0.929
	(0.928)		(0.724)		(0.656)		(0.679)		(0.661)		(0.672)
Gvt bond spread	-1.022		-0.661		-0.340		-0.617		-3.548	*	-0.581
	(1.926)		(1.717)		(1.649)		(1.718)		(1.919)		(1.704)
3-month interbank spread	-0.725		-0.576		-1.053		-0.760		0.717		-2.971
	(2.935)		(2.802)		(2.696)		(2.742)		(2.504)		(2.426)
Avg on consumer loans spread	-0.478		-0.466		-0.228		-0.360		-0.200		0.439
	(0.927)		(0.887)		(0.850)		(0.866)		(0.837)		(0.754)
Return on equity diff.	-0.785		-0.689	*	-0.576		-0.623		-0.557		-0.557
	(0.493)		(0.411)		(0.392)		(0.397)		(0.378)		(0.404)
FDI	-0.471	**	-0.434	**	-0.415	**	-0.419	**	-0.425	**	-0.482 **
	(0.228)		(0.207)		(0.200)		(0.202)		(0.206)		(0.211)
Reer (CPI adj.)	-0.480		-0.503	*	-0.470		-0.492	*	-0.525	*	-0.296
	(0.313)		(0.303)		(0.289)		(0.294)		(0.291)		(0.296)
Imports	-2.099										
	(1.547)										
Exports	0.863										
	(1.217)										
Imports			-1.105224	**							
			(0.442)								
Exports					-0.718	**					
					(0.332)						
Trade openness (%GDP)							-0.457	**	1.130	**	
							0.191		(0.453)		
EPL temporary	5.508975		4.784		4.336		4.468				
	(4.355)		(3.900)		(3.852)		(3.856)				
PMR	-0.58216		0.101		3.969		1.906		5.197		13.228 **
	(7.914)		(7.358)		(6.523)		(6.872)		(6.798)		(0.017)
Openness * EPL temporary									-0.032976		
									(0.057)		
Openness * EPL permanent									-0.765	***	
									(0.195)		
Eurozone membership dummy 1999	-13.735	*	-14.850	**	-15.600	**	-15.363	**	-12.405	**	-14.147 **
	(6.992)		(6.376)		(6.192)		(6.243)		(5.926)		(6.365)

C	158.885 ***	157.706 ***	135.533 **	147.812 ***	166.534 ***	73.414 *
	(51.121)	(48.545)	(43.761)	(45.754)	(43.135)	(37.856)
Adj-R2	0.658	0.688	0.708	0.702	0.717	0.691
Durbin-Watson	1.462	1.408	1.341	1.369	1.360	1.324
J-Stat (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

	Fiscal		Financial		External		Trade		Labour		All	
Table 3. How Did the Eurozone Crisis affect NORD Dynamics? *(16 countries, 1991-2010)*												
Debt/GDP	0.230	***									0.017	
	(0.085)										(0.228)	
Adj. Budget Balance	0.958	**									-0.398	
	(0.414)										(1.765)	
Corporate bond spread			-0.158								0.794	
			(0.623)								(0.846)	
Gvt bond spread			2.465								-8.156	
			(2.683)								(5.929)	
3-month interbank spread			-4.955	**							2.741	
			(2.106)								(5.042)	
Avg on consumer loans spread			-0.026								0.383	
			(0.506)								(1.194)	
Return on equity diff.			0.519								-0.805	
			(0.418)								(0.611)	
FDI					-0.626	***					-0.370	
					(0.181)						(0.248)	
Reer (CPI adj.)					-0.308	**					-0.820	*
					(0.129)						(0.462)	
Trade openness (%GDP)							-0.041				-0.436	
							(0.096)				(0.385)	
EPL temporary									6.008	***	2.902	
									(2.085)		(4.346)	
PMR									8.987	**	-1.073	
									(4.246)		(12.158)	
Eurozone membership dummy 1999	-16.89	***	-25.437	***	-9.655	***	-12.62	***	-7.104	**	-14.613	**
	(2.213)		(3.289)		(2.187)		(2.409)		(3.389)		(7.170)	
C	62.510	***	79.559	***	105.507	***	75.848	***	43.183	***	185.747	**
	(5.132)		(2.004)		(13.000)		(6.734)		(9.280)		(79.816)	
Adj-R2	0.729		0.677		0.659		0.693		0.785		0.605	
Durbin-Watson	0.643		1.018		0.684		0.535		0.823		1.509	
J-Stat (p-value)	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	

	(1)		(2)		(3)		(4)		(5)		(6)	
	Fiscal		Financial		External		Trade		Labour		All	
Time	-0.231		-0.324	***	0.075		0.187		-0.276		-0.041	
	(0.159)		(0.168)		(0.127)		(0.151)		(0.287)		(0.371)	
Time*EZ membership	-1.093	***	-0.673	*	-0.744	***	-0.744	***	-0.585	*	-0.851	**
	(0.282)		(0.260)		(0.245)		(0.245)		(0.310)		(0.364)	
Debt/GDP	0.260	***									0.135	**
	(0.044)										(0.066)	
Adj. Budget Balance	0.729	***									0.342	
	(0.260)										(0.315)	
Corporate bond spread			0.053								0.307	
			(0.360)								(0.441)	
Gvt bond spread			0.787	*							0.294	
			(0.435)								(0.566)	
3-month interbank spread			-2.758	***							-1.496	
			(0.764)								(1.224)	
Avg on consumer loans spread			-0.487	*							-0.549	
			(0.271)								(0.461)	
Return on equity diff.			0.006								-0.034	
			(0.004)								(0.056)	
FDI					-0.038						0.041	
					(0.072)						(0.071)	
Reer (CPI adj.)					-0.147						-0.255	*
					(0.091)						(0.151)	
Trade openness (%GDP)							-0.094				-0.269	**
							(0.075)				(0.108)	
EPL temporary									1.800		0.314	
									(1.641)		(1.930)	
PMR									-3.960		-2.295	
									(4.590)		(4.964)	
Eurozone membership dummy	4.574		-11.604	**	-0.973		-0.196		-3.748		-11.643	*
1999	(5.116)		(4.877)		(4.665)		(4.518)		(5.317)		(6.684)	
C	62.573	***	84.011	***	87.293		78.055	***	81.737	***	122.577	***
	(3.638)		(2.511)		(9.355)		(4.738)		(12.946)		(23.234)	
Adj-R2	0.758		0.793		0.709		0.709		0.784		0.819	
Durbin-Watson	0.564		0.807		0.471		0.459		0.664		0.948	
J-Stat (p-value)	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	

Table 4. Difference in Differences Evidence on the Effects of Euro Membership on the Dynamics of NORD (16 countries, 1991-2015)

Figure 1 – Post-EMU core-periphery pattern (1960-1987)

Correlation of supply and demand disturbances with Germay
Bayoumi and Eichengreen (1992)
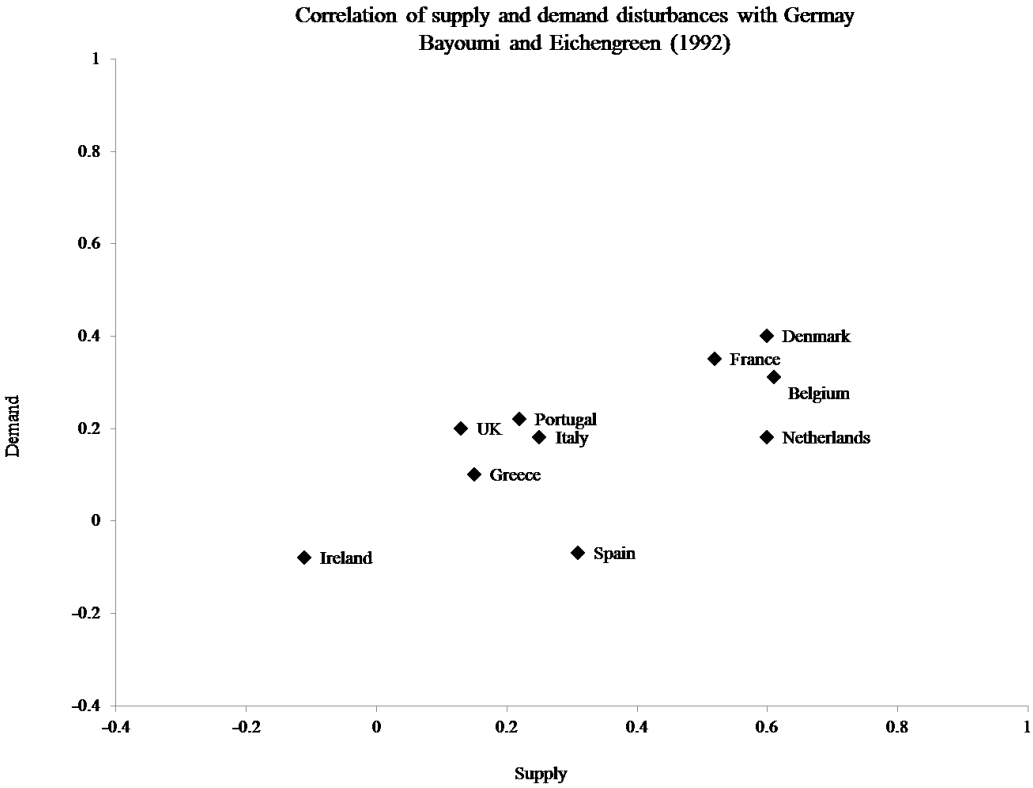
Figure 2 – Post-EMU core-periphery pattern (1990-2015)

Correlation of supply and demand disturbances (bootstrapped residuals – median values)
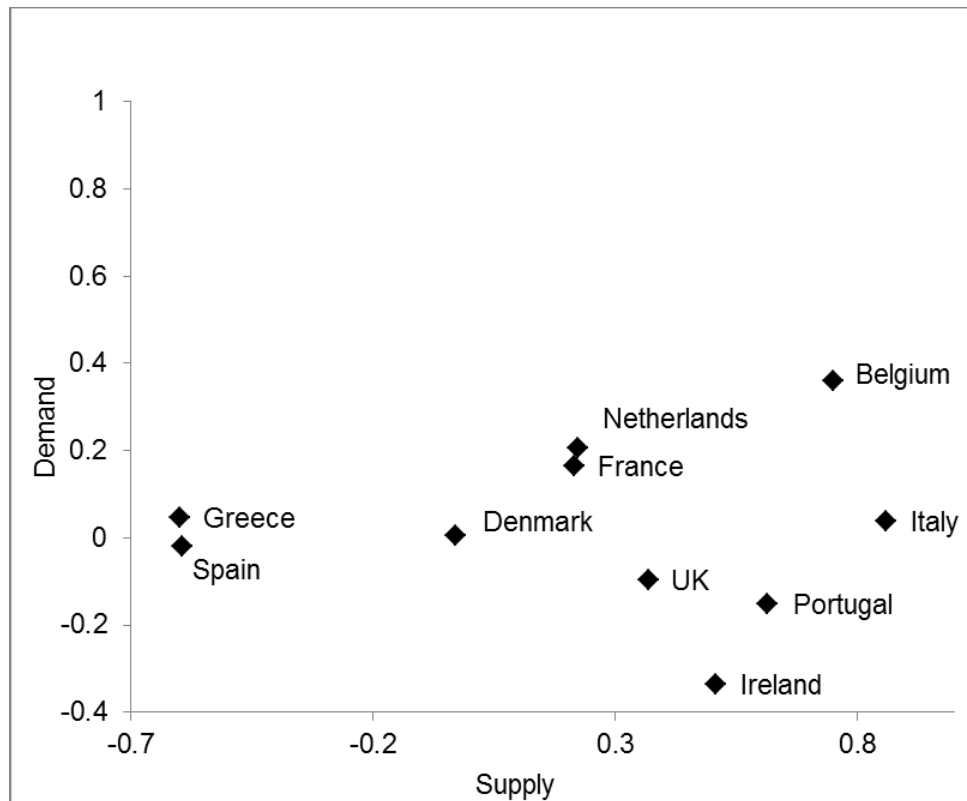
Note: This figure reports median bootstrapped residuals based on 10.000 VAR replications. Structural residuals are retrieved from a SVAR where the over-identifying restriction above is imposed for all countries, with the exception of Ireland, Spain, Greece and Portugal. The sample for this SVAR is 1989–2015, with two lags for all countries and no constant as in Bayoumi and Eichengreen (1993). The demand and supply disturbances correlation coefficients are reported in Appendix Table 4A.

Source: Campos and Macchiarelli (2016)

Figure 3 –*NORD* **for 16 countries, 1990-2015 (Core-periphery dynamics)**
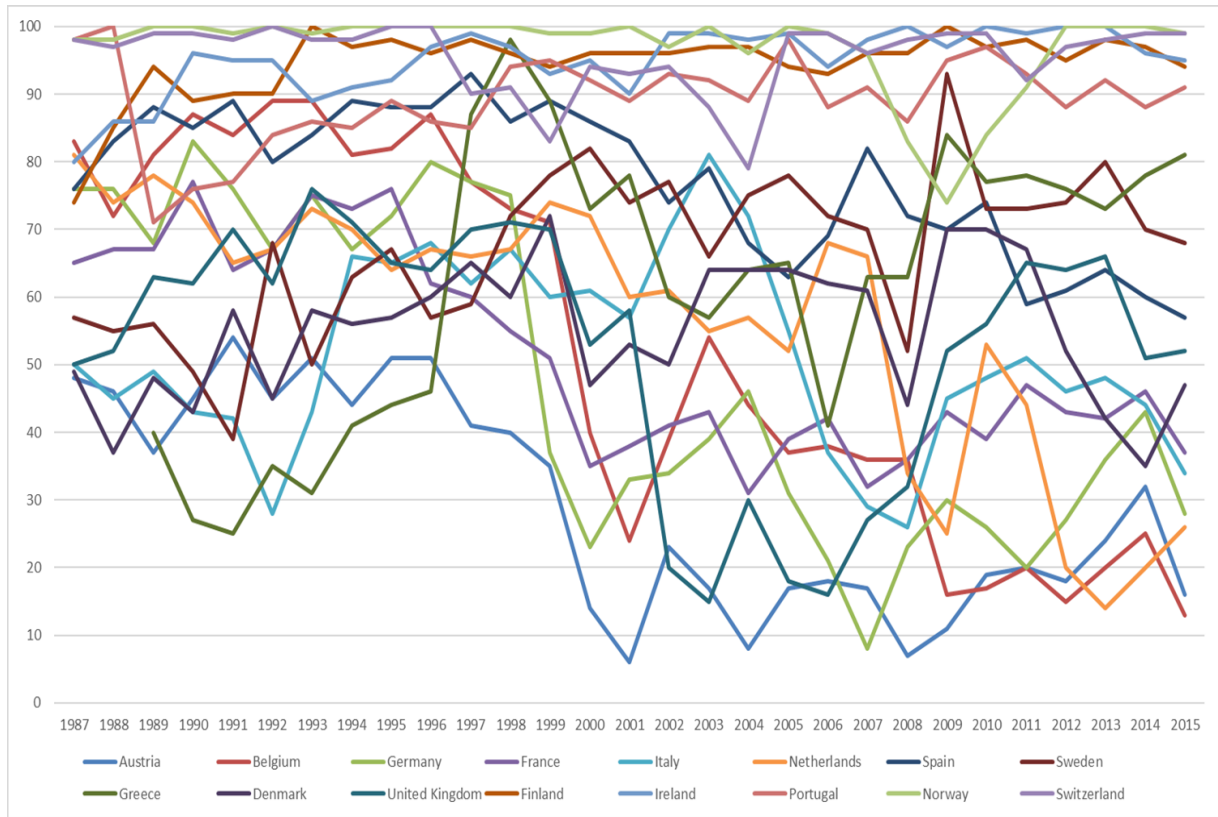
Figure 4 –*NORD* for core countries, 1990-2015 (Core-periphery dynamics)
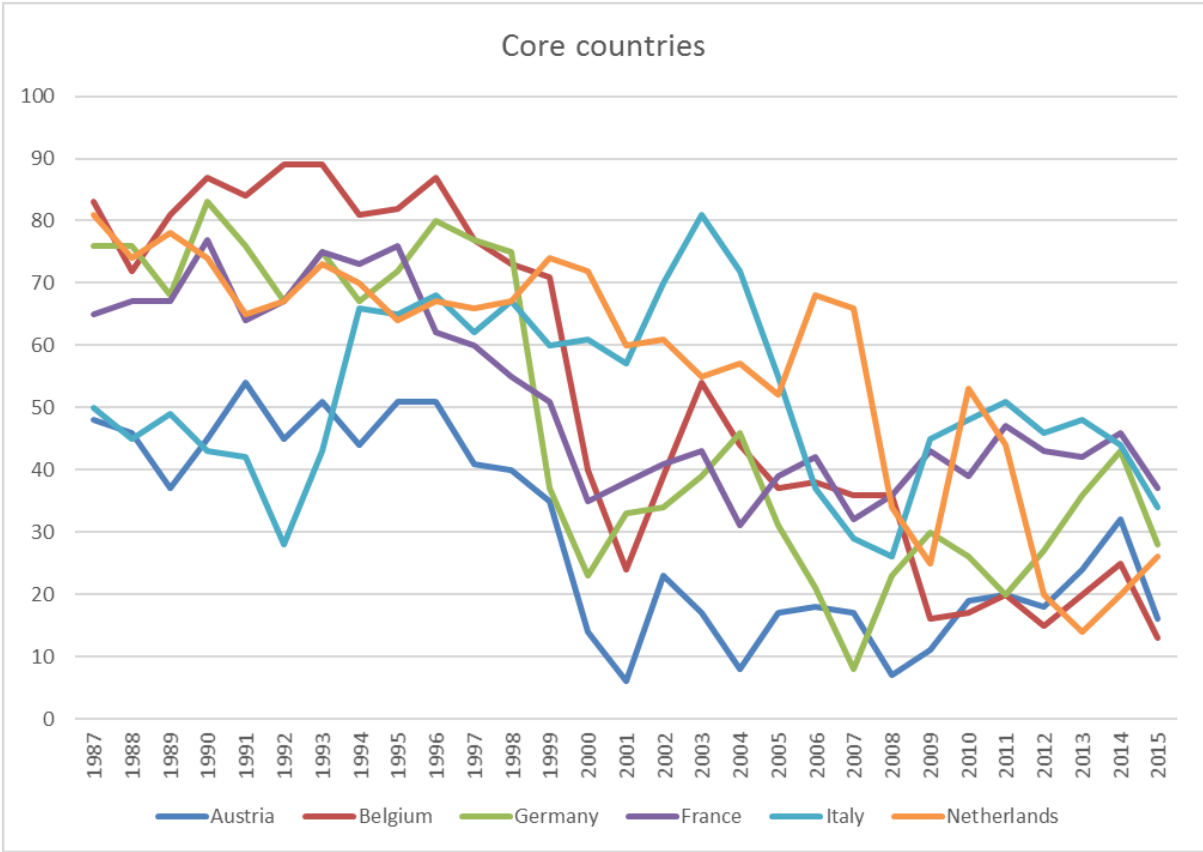
Figure 5 –*NORD* **for periphery countries, 1990-2015 (Core-periphery dynamics)**

Periphery countries
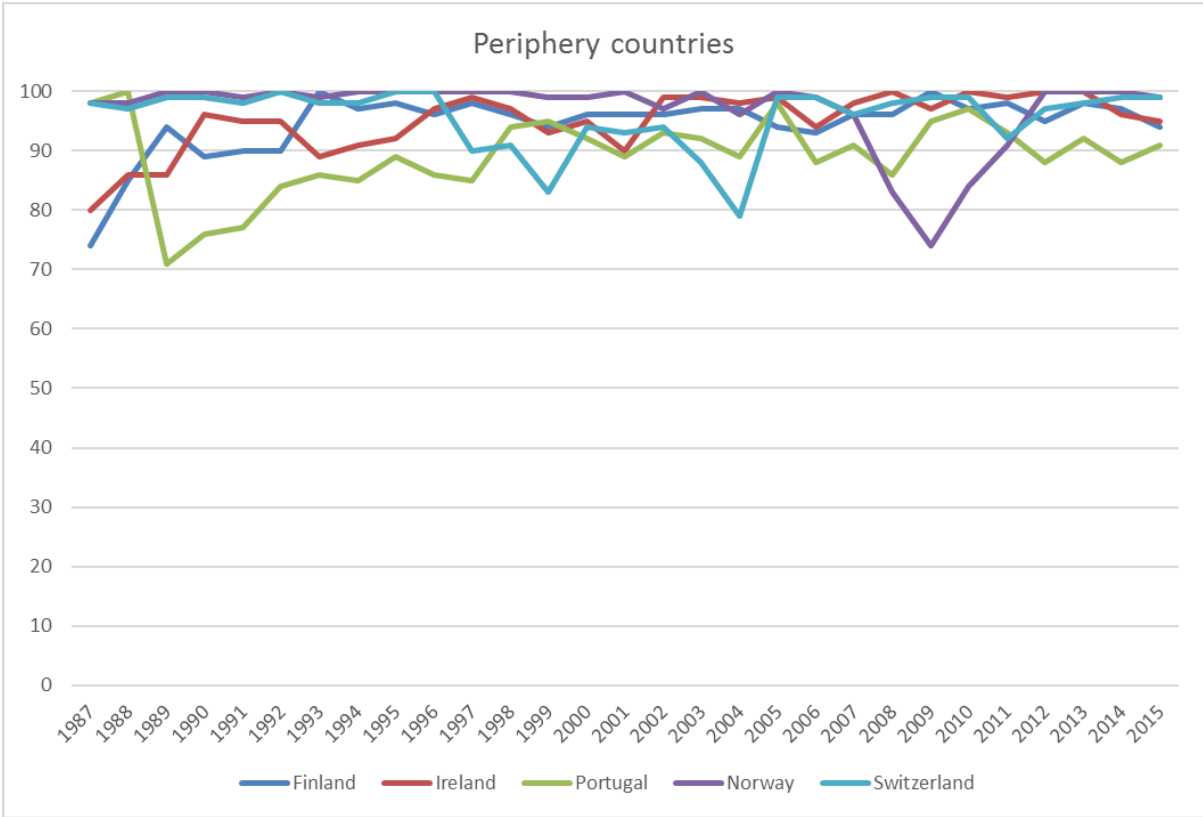
Figure 6 –*NORD* for intermediary countries, 1990-2015 (Core-periphery dynamics)

Mixed Set (I): Denmark trendless low variance, UK high variance
(OLS regression trendline added)
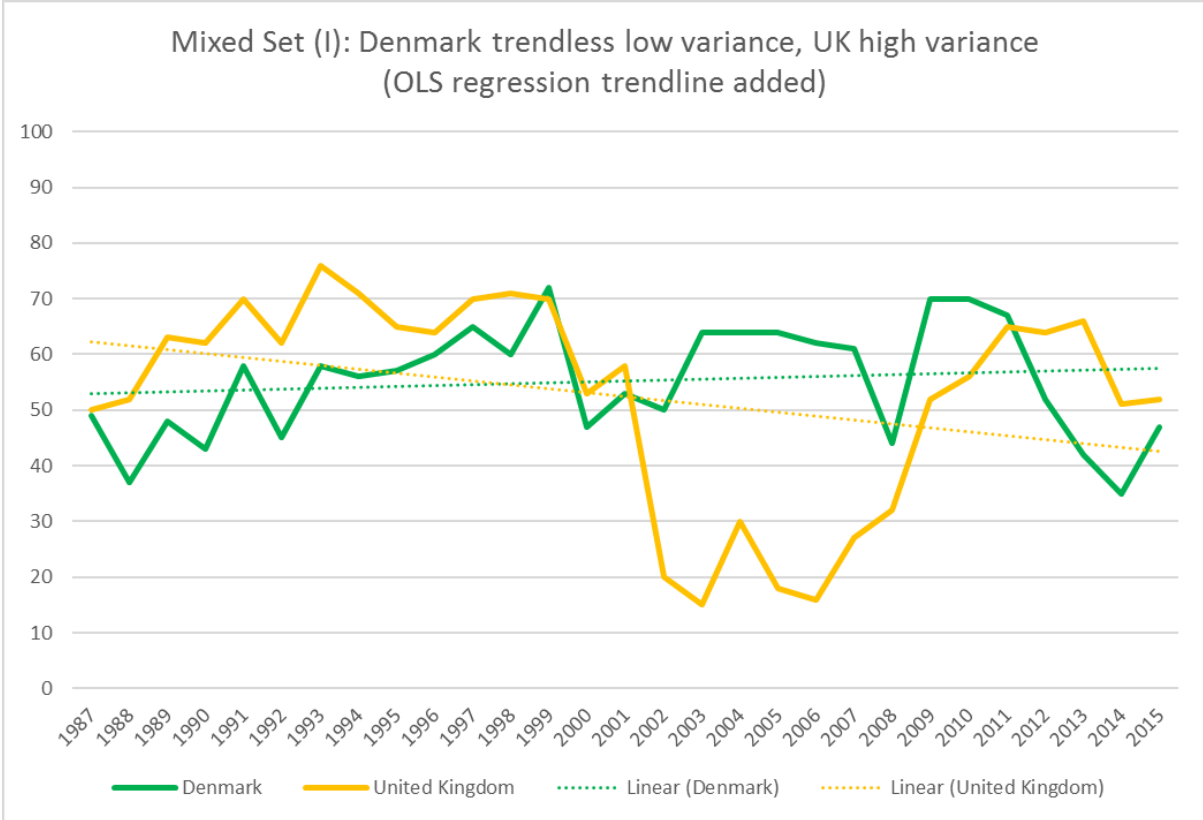
Figure 7 –*NORD* for intermediary countries, 1990-2015 (Core-periphery dynamics)

Mixed Set (II): Spain moving towards core, Greece and Sweden moving to periphery
(OLS regression trendline added)
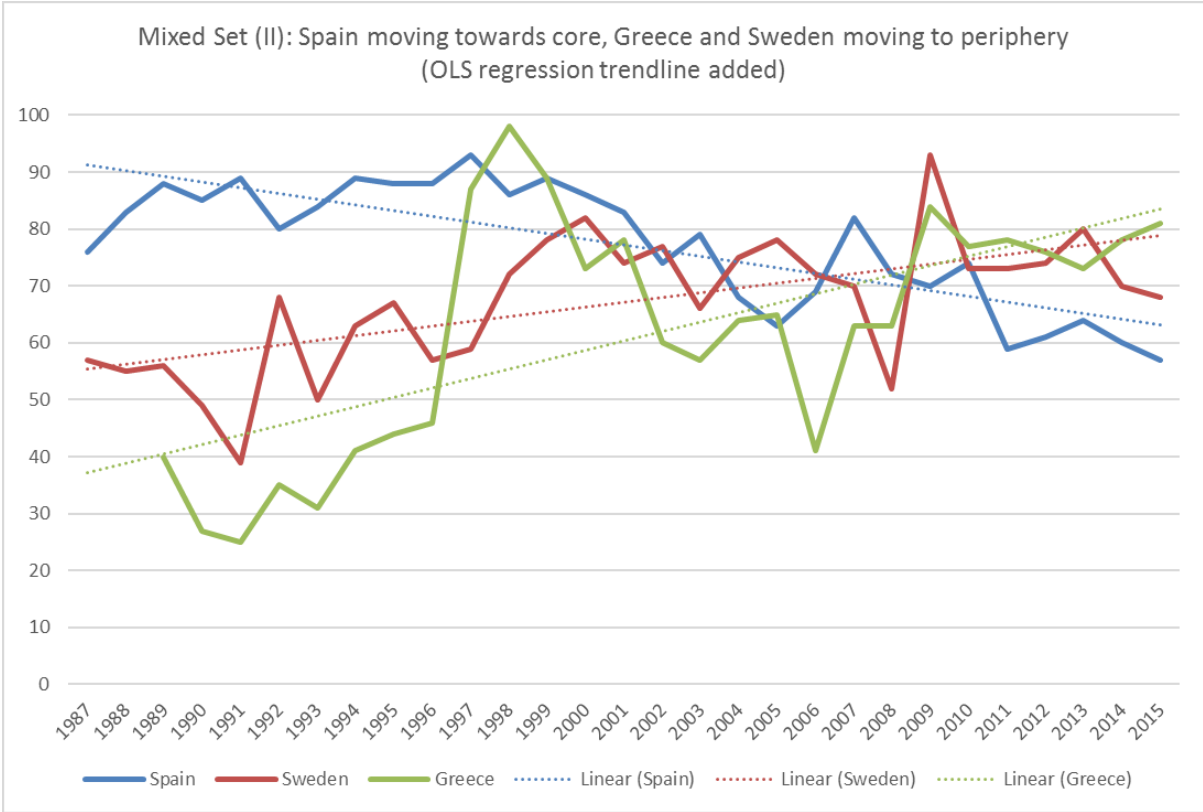
Appendices

Appendix 1 Data, sources and definitions

Annual data spanning the period 1960 - 2015 were collected from the OECD Annual National Accounts (unless otherwise specified) through Datastream for Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Norway, the Netherland, Portugal, Sweden, Switzerland, and the UK. As in Bayoumi and Eichengreen (1993), Germany is used as a numeraire country.

GDP and its deflator: For each country growth and inflation were calculated as the first difference of the logarithm of real GDP (OECD base year) and the implicit GDP deflator. In line with BE the deflator was used to measure prices since it reflects the price of output rather than the price of consumption. The series used in the VAR were corrected for different regimes in mean, between 1960-69, for the pre-Bretton Wood, 1984-92 – consistent with the pre-Maastricht period, as well as the British sterling and Italian lira EMS dismissal – and after 2007 (2008-2015).

Debt / GDP : Gross debt (% of GDP) not seasonally adjusted.

Adj. Budget balance: Cyclically adjusted balance (% of potential GDP) not seasonally adjusted.

Reer (CPI adj.): Real effective exchange rate based on consumer price index.

3-month interbank: Short-term interest rate (3 month, interbank) seasonally adjusted. For each country, the spread is obtained as the difference of the yield *vis à vis* Germany.

Gvt bond: Long-term interest rate on government bonds seasonally adjusted. For each country, the spread is obtained as the difference of the yield *vis à vis* Germany.

Corporate bond: Corporate borrowing rate (avg) not seasonally adjusted. For each country, the spread is obtained as the difference of the yield *vis à vis* Germany.

Avg on consumer loans: Interest rate - average on consumer loans not seasonally adjusted. For each country, the spread is obtained as the difference of the yield *vis à vis* Germany.

Share: Share price index (%yoy) not seasonally adjusted. For each country, the return on equity is obtained as the difference of the price index growth *vis à vis* Germany.

FDI: (Balance of Payment) FDI - inward, (%GDP) not seasonally adjusted

EPL permanent: Strictness of employment protection – individual and collective dismissals (regular contracts). The OECD indicators of employment protection are synthetic indicators of the strictness of regulation on dismissals and the use of temporary contracts. For each year,

indicators refer to regulation in force on the 1st of January. For more information and full methodology, see www.oecd.org/employment/protection.

EPL temporary: Strictness of employment protection – temporary contracts. The OECD indicators of employment protection are synthetic indicators of the strictness of regulation on dismissals and the use of temporary contracts. For each year, indicators refer to regulation in force on the 1st of January. For more information and full methodology, see www.oecd.org/employment/protection.

PMR: Product Market Regulation (2013). The indictors measure the economy-wide regulatory and market environments in (or around) 1998, 2003, 2008 and 2013. The indicators cover formal regulations in the following areas: state control of business enterprises; legal and administrative barriers to entrepreneurship; barriers to international trade and investment. A continuous series is obtained by interpolating the last available observation.

Appendix 2 Descriptive statistics (common sample)

	Adj. Budget Balance	*Debt / GDP*	*Corporate bond interest rate*	*Gvt bond interest rate*	*3-month interbank interest rate*	*Avg on consumer loans interest rate*	*Share prices*
Mean	-2.761	67.641	4.682	4.788	3.173	9.225	6.839
Median	-2.444	60.314	4.575	4.328	3.038	8.220	9.520
Maximum	4.354	177.677	13.420	22.498	16.202	45.330	101.320
Minimum	-18.609	22.940	0.000	0.647	0.020	2.690	-44.740
Std. Dev.	3.104	29.023	2.463	2.355	2.275	5.205	22.138
Skewness	-1.059	0.927	0.616	2.972	1.621	3.418	0.120
Kurtosis	5.753	3.554	4.762	18.224	8.304	20.477	3.238
Jarque-Bera	142.784	44.303	54.693	3160.626	457.303	4167.579	1.357
Probability	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.507)
Observations	284	284	284	284	284	284	284
	FDI	*Reer (CPI adj.)*	*Exports / GDP*	*Imports / GDP*	*EPL Permanent contracts*	*EPL Temp. contracts*	*PMR*
Mean	6.331	99.670	43.159	40.097	2.324	1.960	1.596
Median	2.800	99.950	39.936	35.806	2.357	1.563	1.517
Maximum	124.400	125.710	106.776	89.624	4.583	4.750	2.751
Minimum	-6.750	80.930	14.287	18.640	1.095	0.250	0.915
Std. Dev.	12.255	7.010	19.427	15.840	0.635	1.184	0.377
Skewness	5.349	0.667	1.008	1.145	0.525	0.682	1.037
Kurtosis	41.957	4.672	3.540	3.570	4.841	2.691	4.113
Jarque-Bera	19313.540	54.121	51.583	65.918	53.170	23.143	65.514
Probability	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	284	284	284	284	284	284	284

Appendix 3 Correlation matrix

Correlation	NORD	Debt/GDP	Adj. Budget Balance	Avg on consumer loans spread	Gvt bond spread	Return on equity diff.	3-month interbank spread	Exports (%GDP)	Imports (%GDP)	Trade openness (%GDP)	Reer (CPI adj.)	FDI	EPL perm.	EPL temp.	PMR
SORE	1.000														
Debt/GDP	-0.236	1.000													
Adj. Budget Balance	0.087	-0.332	1.000												
Avg on consumer loans spread	-0.027	0.286	-0.189	1.000											
Gvt bond spread	0.041	0.522	-0.285	0.480	1.000										
Return on equity diff.	0.079	-0.169	0.213	0.011	-0.247	1.000									
3-month interbank spread	0.000	0.063	-0.180	**0.765**	0.424	0.050	1.000								
Exports (%GDP)	0.052	-0.087	0.219	-0.315	-0.146	-0.009	-0.307	1.000							
Imports (%GDP)	-0.016	0.036	0.126	-0.211	-0.097	-0.079	-0.299	**0.954**	1.000						
Trade openness (%GDP)	0.022	-0.032	0.179	-0.272	-0.125	-0.041	-0.307	**0.991**	**0.986**	1.000					
Reer (CPI adj.)	-0.189	-0.148	-0.144	-0.197	-0.033	-0.084	-0.015	-0.105	-0.133	-0.119	1.000				
FDI	-0.084	0.023	0.122	-0.104	-0.062	-0.118	-0.100	0.482	0.502	0.496	-0.060	1.000			
EPL all	0.018	0.143	-0.170	0.258	0.120	0.004	0.129	-0.346	-0.249	-0.306	-0.139	-0.110	1.000		
EPL temp.	0.055	0.391	-0.248	0.327	0.203	0.018	0.356	-0.443	-0.377	-0.418	-0.304	-0.168	0.383	1.000	
PMR	0.278	-0.124	0.054	0.112	-0.101	0.116	0.095	-0.091	-0.131	-0.110	-0.185	-0.048	0.138	0.421	1.000

Appendix 4 Table 1A – Test for over-identifying restrictions' count (% of bootstrap replications)

Since we are mostly interested in evaluating the extent to which the number of rejections hold from an OCA point of view and – under the assumption that the euro area is closer to an OCA than the EU or whole Europe itself (see also De Grauwe, 2016) – we select the value of γ which minimizes the number of rejections as in Campos and Macchiarelli (2016), as illustrated in the Table below.

	# of rejections $\gamma = 0.1$	# of rejections $\gamma = 0.5$	# of rejections $\gamma = 1$	# of rejections $\gamma = 1.5$	# of rejections $\gamma = 2$
BE	100.0	66.2	17.4	53.5	83.9
DE	99.8	94.0	25.1	18.3	47.1
DK	100.0	95.6	35.5	16.2	36.8
ES	99.8	99.0	74.2	35.4	21.8
FR	100.0	77.5	20.3	39.3	68.5
GR	94.6	100.0	92.5	63.5	35.8
IE	100.0	100.0	98.4	86.8	64.9
IT	100.0	69.4	14.6	51.8	84.9
NL	100.0	93.7	20.2	17.3	50.0
PT	100.0	99.9	89.2	53.2	24.8
UK	99.8	94.0	50.2	27.2	33.6
Total largest EZ3	99.9	86.7	30.9	32.4	54.5
Total largest EZ5	99.9	88.4	21.9	25.0	55.2
Total EZ9	99.4	88.9	50.2	46.6	53.5
No of countries > threshold	11	11	4	5	4

Note: We bootstrap the original VAR residuals in a i.i.d. fashion and generate 10.000 data sets. For each of the 10.000 samples we recalculate the VAR parameters. At each replication, we proceed with the SVAR analysis proposed by Bayoumi and Eichengreen (1993) and further impose the over-identifying restriction by counting the number of rejections. Cut off value is that of a $\chi^2(1)$ with probability 0.999 (10.828). The results are robust if this probability is reduced to 0.99 (6.635). The countries for which this restriction is rejected on average more than in 50.5% of cases are the ones for which the over-identifying restriction is relaxed. For consistency of the results, the number of cases the SVAR does not converge is excluded from the count.

Source: Campos and Macchiarelli (2016)

Appendix 5 Changing the date for EZ membership (2002)

The following results replicate the results proposed in Table 1 by changing the date for the euro area dummy from the year of formal introduction (1999 – cf. Table 1) to the date of actual adoption (2002).

	1991-2015					
	Fiscal	Financial	External	Trade	Labour	All
Debt/GDP	0.139 ***					0.136
	(0.043)					(0.132)
Adj. Budget	0.295					1.395
Balance	(0.332)					(0.997)
Corporate bond		1.174 *				0.706
spread		(0.711)				(0.652)
Gvt bond spread		1.211				-0.432
		(0.934)				(1.582)
3-month interbank		-2.917 *				0.877
spread		(1.649)				(2.922)
Avg on consumer		-0.527				-0.808
loans spread		(0.587)				(0.988)
Return on equity.		0.917 *				-0.418
diff		(0.511)				(0.453)
FDI			-0.596 ***			-0.543 ***
			(0.143)			(0.190)
Reer (CPI adj.)			-0.143			-0.282
			(0.120)			(0.265)
Trade openness				-0.165 ***		-0.491 ***
(%GDP)				(0.063)		(0.182)
EPL temporary					6.153 ***	4.809
					(1.880)	(4.565)
PMR					7.568 **	1.453
					(3.476)	(6.781)
EZ membership	-15.497 ***	-22.129 ***	-11.756 ***	-10.324 ***	-5.715 **	-9.541 *
2002	(1.896)	(3.139)	(1.742)	(2.018)	(2.637)	(5.731)
C	63.447 ***	77.157 ***	88.323 ***	83.722 ***	44.175 ***	122.460 ***
	(3.061)	(2.258)	(12.009)	(4.618)	(7.248)	(40.149)
Effect	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Adj-R2	0.739	0.560	0.669	0.708	0.785	0.727
Durbin-Watson	0.579	1.111	0.584	0.477	0.711	1.194
J-Stat (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Appendix 6 Results for Employment Protection Legislation: Temporary vs Permanent

The results in the Table below compare the results in Table 1 (column (1)) to the results when EPL for regular contract is used (column (2)). In column (3) to (5) we further explore the possible interactions between EPL and imports/exports consistent with the idea that some (non-tradeable) sectors may be displaying larger flexibility than others. Our results below do not display any significant effects when these interaction terms are used.

	(1)		(2)		(3)		(4)		(5)	
Debt/GDP	0.090		0.147		0.117		0.128		0.131	
	(0.141)		(0.131)		(0.151)		(0.130)		(0.152)	
Adj. Budget Balance	1.629	*	1.237		1.182		1.487		1.524	
	(0.965)		(1.147)		(0.924)		(0.928)		(0.941)	
Corporate bond spread	0.701		0.448		1.176		0.221		-0.054	
	(0.679)		(0.708)		(0.931)		(0.795)		(1.018)	
Gvt bond spread	-0.460		-2.182		-1.104		-2.231		-2.400	
	(1.669)		(1.798)		(2.136)		(2.014)		(2.208)	
3-month interbank spread	-0.760		0.675		-1.613		1.331		1.451	
	(2.742)		(2.337)		(2.348)		(2.348)		(2.565)	
Avg on consumer loans spread	-0.360		-0.371		0.196		-0.709		-0.640	
	(0.866)		(0.803)		(0.775)		(0.751)		(0.794)	
Return on equity diff.	-0.623		-0.593		-0.500		-0.656		-0.634	
	(0.397)		(0.382)		(0.396)		(0.419)		(0.415)	
FDI	-0.419	**	-0.423	**	-0.474	**	-0.402	*	-0.400	*
	(0.202)		(0.198)		(0.218)		(0.207)		(0.211)	
Reer (CPI adj.)	-0.492	*	-0.487	*	-0.278		-0.601	**	-0.616	**
	(0.294)		(0.289)		(0.294)		(0.288)		(0.291)	
Trade openness (%GDP)	-0.457	**	-0.477	**						
	(0.191)		(0.184)							
EPL temporary	4.468									
	(3.856)									
EPL permanent			-19.657							
			(19.700)							
EPL temporary * Exports					-0.189				0.271	
					(0.446)				(0.605)	
EPL temporary * Imports					0.143				-0.254	
					(0.428)				(0.593)	
EPL permanent * Exports							-0.179		-0.360	
							(0.377)		(0.512)	
EPL permanent * Imports							-0.498		-0.310	
							(0.483)		(0.582)	
PMR	1.906		2.443		14.985	***	-1.750		-2.525	
	(6.872)		(6.728)		(5.488)		(6.545)		(6.955)	

EZ membership 1999	-15.363 **	-17.787 ***	-19.739 ***	-15.368 ***	-14.307 **
	(6.243)	(5.430)	(5.928)	(5.656)	(6.150)
C	147.812 ***	199.591 ***	81.250 ***	194.549 ***	194.926 ***
	(45.754)	(57.976)	(36.193)	(44.349)	(44.027)
Effect	Fixed	Fixed	Fixed	Fixed	Fixed
Adj-R2	0.748	0.715	0.704	0.713	0.717
Durbin-Watson	0.577	1.325	1.287	1.391	1.380
J-Stat (p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Appendix 7 Probit results

The results in Table 1 are replicated using a probit model where Pr(NORD>50%)=1. The results in this table show that our findings are robust to the use of such a model.

	1991-2015 (Probit)					
	Fiscal	Financial	External	Trade	Labour	All
Debt/GDP	-0.004					-0.022 ***
	(0.002)					(0.005)
Adj. Budget Balance	0.037					-0.054 *
	(0.024)					(0.030)
Corporate bond spread		0.000				0.179 ***
		(0.035)				(0.055)
Gvt bond spread		0.129 **				0.373 ***
		(0.063)				(0.084)
3-month interbank spread		-0.324 ***				-0.523 ***
		(0.090)				(0.151)
Avg on consumer loans spread		0.033				0.032
		(0.024)				(0.037)
Return on equity diff.		0.005				0.006
		(0.006)				(0.006)
FDI			0.002			0.000
			(0.006)			(0.008)
Reer (CPI adj.)			-0.015 **			-0.070 ***
			(0.007)			(0.021)
Trade openness (%GDP)				0.003		0.002
				(0.002)		(0.003)
EPL temporary					-0.018	0.273 **
					(0.080)	(0.124)
PMR					0.555 **	-0.149
					(0.258)	(0.367)
EZ membership 1999	-0.887 ***	-1.401 ***	-0.905	-0.901 ***	-0.942 ***	-1.756 ***
	(0.148)	(0.187)	(0.136)	(0.131)	(0.181)	(0.358)
C	1.441 ***	1.411 ***	2.544 ***	0.788 ***	0.312	9.573 ***
	(0.187)	(0.156)	(0.732)	(0.166)	(0.446)	(2.700)
Obs with Dep=1	271	255	335	335	233	199
Total obs	381	360	462	462	320	284
McFadden R-squared	0.112	0.159	0.089	0.084	0.133	0.284
LR statistic	51.437	69.183	48.394	45.730	49.770	98.313
Prob(LR statistic)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Appendix 8 Beta convergence estimates

The results in the Table below regress the change in NORD index on the usual sets of control used in Table 1 plus the value of NORD in the first period, i.e. NORD(0). The results show that there is no convergence across the panel when a test for β-convergence is used.

	1991-2015					
	Fiscal	Financial	External	Trade	Labour	All
NORD(0)	0.003534	0.002187	0.010137	0.003679	0.003471	-0.00102
	(0.027)	(0.032)	(0.026)	(0.026)	(0.032)	(0.043)
Debt/GDP	-0.002					0.035
	(0.019)					(0.032)
Adj. Budget Balance	-0.174					-0.251
	(0.166)					(0.250)
Corporate bond spread		0.089				0.129
		(0.295)				(0.374)
Gvt bond spread		0.278				0.370
		(0.500)				(0.654)
3-month interbank spread		0.540				1.290
		(0.640)				(0.915)
Avg on consumer loans spread		-0.204				-0.660 **
		(0.148)				(0.276)
Return on equity diff.		0.000				0.089
		(0.003)				(0.054)
FDI			-0.110 ***			-0.131 **
			(0.041)			(0.056)
Reer (CPI adj.)			0.015			-0.078
			(0.052)			(0.102)
Trade openness (%GDP)				-0.008		-0.003
				(0.013)		(0.024)
EPL temporary					0.101	-1.387
					(0.547)	(0.926)
PMR					-0.732	1.298
					(1.606)	(2.205)
EZ membership 1999	-1.268	-1.213	-0.951	-1.508	-1.575	0.340
	(1.016)	(1.139)	(0.919)	(0.916)	(1.174)	(1.542)
C	-0.819	-0.821	-1.859	0.423	0.830	4.663
	(2.419)	(2.433)	(6.171)	(1.899)	(2.884)	(11.897)
Adj-R2	-0.002	-0.006	0.016	0.002	-0.007	0.027
Durbin-Watson	2.249	2.326	2.377	2.343	2.215	2.358
J-Stat (p-value)	(0.531)	(0.663)	(0.030)	(0.280)	(0.765)	(0.103)

Appendix 9 Phillips-Sul results

log(t)	Original clubs' log(t) tests					log(t)	Log(t) test for club merging			
	Club1	Club2	Club3	Club4	Club5		Club1+2	Club2+3	Club3+4	Club4+5
Coeff	0.853	-0.585	0.465	1.433	-0.817	Coeff	-0.891	-1.3	-0.398	-1.538
T-stat	0.601	-0.83	0.283	0.798	-1.179	T-stat	-1.378	-1.478	-0.395	-2.895