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Heterogeneity within the Euro Area: New Insights into an Old Story

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Highlights

- This article provides a new framework for assessing the sustainability of the EMU.
- We identify two distinct groups of countries in the run-up to the EMU, Greece being clearly an outlier at that time.
- We find that disparities have increased across and within countries' groups, and that Greece has become more peripheral over time.

RESEARCH AND EXPERTISE ON THE WORLD ECONOMY

Abstract

We assess cross-country heterogeneity within the eurozone and its evolution over time by measuring the distances between the equilibrium exchange rates' paths of member countries. These equilibrium paths are derived from the minimization of currency misalignments, by matching real exchange rates with their economic fundamentals. Using cluster and factor analyses, we identify two distinct groups of countries in the run-up to the European Monetary Union (EMU), Greece being clearly an outlier at that time. Comparing the results with more recent periods, we find evidence of rising dissimilarities between these two sets of countries, as well as within the groups themselves. Overall, our findings illustrate the building-up of macroeconomic imbalances within the eurozone before the 2008 crisis and the fragmentation between its member countries that followed.

Keywords

Euro Area, Equilibrium Exchange Rates, Cluster Analysis, Factor Analysis, Macroeconomic Imbalances.

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F33, F45, E5, C38.

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RESEARCH AND EXPERTISE ON THE WORLD ECONOMY

Heterogeneity within the euro area: New insights into an old story[1]

Virginie Coudert*, Cécile Couharde†, Carl Grekou‡, Valérie Mignon§

1. Introduction

The 2008 financial crisis and the sovereign crisis that followed in Europe have revived debates about the European Monetary Union (EMU). The most lingering question underlying most issues is to know if member states are similar enough to share the same currency in the long run. Whatever the answer, drastic steps had to be taken rapidly in 2012 to avoid a fragmentation of the eurozone. Monetary policy has largely contributed to alleviate the diverging pressures, notably though the quantitative easing strategy, enlargement of collateral and the public sector purchase program (PSPP). Fiscal policy has also been more tightened in the peripheral countries in order to restore the sustainability of public finances. Besides, banking supervision has been strengthened through the banking union. On the whole, the functioning of the euro area has been improved compared to the pre-2008 period.

Despite all these advances, the key question remains to know if the countries are reasonably similar to benefit from sharing the same currency and if differences have been ironed out since the launch of the euro. As pointed out by Lane (2006), this issue was identified as a major challenge for the success of the euro from its beginning. It led to numerous contributions in the wake of the Maastricht Treaty that largely focused on studying convergence in prices and business cycles within the euro area. In particular, earlier empirical studies typically relied on the optimum currency area (OCA) literature (Mundell, 1961; McKinnon, 1963; Kenen, 1969), in order to examine whether future eurozone members meet the OCA criteria that could allow them to be less vulnerable to

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shocks and then to undergo low stabilization costs in joining the EMU.[2] The findings of this literature usually tended to be pessimistic about the possibility for European countries to form a viable monetary union. In particular, in their seminal article, Bayoumi and Eichengreen (1993) highlighted the existence of a core–periphery pattern in the run-up to the EMU. Using pre-EMU data (1960-88) to estimate the degree of supply shocks synchronization, they showed that, over this period, there was a core (Germany, France, Belgium, the Netherlands, and Denmark) where shocks were highly correlated, and a periphery (Greece, Ireland, Italy, Portugal, Spain, and UK) where synchronization was significantly lower. Bayoumi and Eichengreen (1993) suggested that, if persistent, this pattern would be detrimental to the EMU project.

As the single currency seemed to perform successfully until the 2008 crisis despite these bleak predictions, some observers criticized the previous analyses on the ground that they ignored the complex nature of monetary unification and its endogenous character. In particular, Frankel and Rose (1998) presented empirical evidence that countries with more bilateral trade will feature higher business cycle correlations. As monetary unification induced eurozone members to trade more with each other (see Baldwin (2006) for a survey), the process should be matched by an increase in business cycle synchronization among countries. It would then become easier for euro-area members to meet the OCA criteria. The shock caused by the 2007-08 financial collapse, followed by the European sovereign debt crisis, has however raised new doubts about the ability of the single currency to work well in a region with huge economic and political diversity (see Stiglitz, 2017). It has also given a new dimension to this debate by highlighting the building-up of unsustainable macroeconomic imbalances within the eurozone.

The objective of this paper is to revisit such issue of sharing a common currency by taking stock of the consensus reached after the 2008 crisis that highlighted the accumulation of macroeconomic imbalances in the run-up to most financial crises. Specifically, we examine between-country disparities in terms of equilibrium exchange rates, i.e., exchange rates that would prevent currency misalignments resulting from unsustainable macroeconomic disequilibria within the member countries. We consider the oldest members of the EMU, namely the ten founding members and Greece in order to have a long historical record —our sample spanning from 1980 to 2016. First, we assess the equilibrium exchange rate paths for the considered euro-area members. Second, we rely on a cluster analysis to partition the euro-area countries into homogeneous groups or

[2] For a survey, see Bayoumi and Eichengreen (1994), De Grauwe (1997), Lafrance and St-Amant (1999), and Alesina, Barro and Tenreyro (2002).

clusters in order to measure how equilibrium exchange rate trajectories have been distant across euro-area members. Third, we try to identify the characteristics of EMU members that explain the formation of such clusters. In these two last parts, we split the sample into several sub-periods in order to investigate the dynamics of these clusters over time thanks to the identification of their main underlying factors, before and after the monetary union, as well as before and after the 2008 crisis.

Previewing our main results, we find that that the pre-euro configuration of the eurozone can be partitioned into three groups of countries. On the one hand, Belgium, France, Germany, Ireland, and the Netherlands form the most homogenous group; on the other hand, Austria, Finland, Italy, and Spain constitute the second group. We also find evidence of two outliers, namely Portugal and Greece. Indeed, these countries exhibit the most divergent equilibrium exchange rate paths; Greece being the most idiosyncratic country. The comparison with the post-euro period reveals that member states have not moved structurally closer to each other. On the contrary, we find that (i) disparities have increased across and within countries' groups, and (ii) Greece has moved away from the other member states, becoming more peripheral over time. Only Spain seems to gradually converge towards the core countries. Overall, our findings point out the disparities within the euro area and their evolution through time.

The rest of the paper is structured as follows. Section 2 describes our methodological framework to assess equilibrium exchange rates. Section 3 presents the partition of the euro area based on cluster analysis, while that issued from factor analysis is analyzed in Section 4. In both sections, we make the distinction between the period before and after the implementation of the EMU to get evidence of the build-up of macroeconomic imbalances within the euro area. Finally, Section 5 concludes.

2. Equilibrium exchange rates within the euro area

2.1. The relevance of currency misalignments inside the monetary union

There is common sense among economists and policymakers that currency misalignments—i.e., departures of real exchange rates from their equilibrium levels—are likely to cause substantial losses in economic efficiency and social welfare. This conviction is substantiated by the new Keynesian literature in which the equilibrium exchange rate corresponds to a real exchange rate that allocates resources efficiently and thus maximizes social welfare. For example, Engel (2011) argues that any violation of the law of one price is inefficient and, in turn, leads to a reduction in world welfare. This literature also widely recognizes that in a world of imperfect markets, the floating exchange rates cannot fully adjust to an efficient level. As a consequence, minimizing currency misalignments may be a goal for monetary policy, along with domestic objectives regarding inflation and the output gap. If the equilibrium exchange rate matters for efficiency and social welfare, it also plays a key role in allowing any economy to reach simultaneously both its internal and external balances according to more traditional Keynesian open-economy models. Following this literature (see Driver and Westaway, 2004), the equilibrium real exchange rate is compatible with the steady state of an economy that is characterized by (*i*) an output gap close to zero or equilibrium in the non-tradable goods sector (internal balance), and (*ii*) consistent relations between net foreign assets and current account balances (external balance). An optimal mix of consistent policies can make the real exchange rate converge towards its equilibrium, thus wiping out external and internal imbalances.[3]

In the context of a monetary union, currency misalignments are especially detrimental because the nominal parity can no longer be adjusted. The only possible adjustment concerns prices. This is particularly painful when one member country has an overvalued real exchange rate, as it has no choice but to reduce its relative prices by cutting spending and limiting wages. Before the financial crisis, there was a fairly widespread consensus that the single currency will bring about prosperity and these potential shortcomings will be more than compensated by other benefits, such as low-inflation and credibility (Alesina and Barro, 2002). Another prominent argument advocated by the new Keynesian open economy literature was that (*i*) instead of acting as shock absorbers, nominal exchange rates act as sources of shocks, and (*ii*) monetary unification, by eliminating excess volatility of nominal variables, was then superior to a flexible exchange rate regime (Neumeyer, 1998; Devereux and Engel, 2006). Lastly, imbalances in current account positions within the euro area rose for good reasons, as they were mainly driven by productivity differentials and catching-up developments (Blanchard and Giavazzi, 2002). In short, there were widespread expectations that the increased financial integration would play an important role in the adjustment process. However, macroeconomic imbalances initially considered as "good imbalances" turned out to be "bad imbalances" (Belke and Dreger, 2013). They also brought about severe misalignments of real exchange rates within the euro area (Coudert et al., 2013). Moreover, these imbalances as well as

[3]It is also worthwhile noting that the implications of minimizing currency misalignments are in line with the European Commission Reflection paper on the deepening of the EMU (May 31, 2017) especially regarding the first of the four guiding principles (*"Jobs, growth, social fairness, economic convergence and financial stability should be the main objectives of our Economic and Monetary Union"*; see Page 18).

low interest rates and credit boom paved the way to the sovereign debt crisis in several Southern member states. As currency misalignments as well as imbalances are especially harmful in a monetary union, we consider an analysis that emphasizes how the exchange rates have departed from their equilibrium paths.[4]

2.2. Deriving nominal equilibrium exchange rate paths

A preliminary step in our methodology is to reconcile the real approach of the equilibrium exchange rates with the nominal nature of a monetary union. Another is to switch from the multilateral approach of the equilibrium exchange rates to the fixed bilateral parities implied by a single currency.

Regarding the transition from real to nominal, on one side, equilibrium exchange rates are generally defined in real terms; this is also true for currency misalignments that measure the gap between the observed exchange rates and their equilibrium levels. On the other side, a monetary union only deals with nominal parities, by fixing them irreversibly between members, but this does not prevent the real exchange rates to evolve differently across countries along with the relative prices. Regarding the multilateral versus bilateral approach, the equilibrium exchange rate is generally assessed towards a whole set of trade partners, whereas the monetary union defined fixed bilateral parities between member countries.

To sum up, we have to convert our multilateral real equilibrium exchange rates into nominal bilateral parities. Various methods exist to deal with this issue. For example, Alberola et al. (1999) propose a framework that allows determining nominal equilibrium exchange rates that are consistent at the global level. Their approach consists in inverting the weighted matrix of effective equilibrium exchange rates to deduce bilateral equilibrium values. However, as only $(N-1)$ bilateral exchange rates can be derived from N effective rates, one currency—corresponding to the chosen numeraire—has to be discarded. This amounts to assuming that the misalignment of the selected currency (the rest of the world) is the mirror image of the misalignment of all other currencies. Instead of imposing such assumption, we adopt here another approach in which nominal exchange rates that are consistent with minimized currency misalignments follow an equilibrium path independent of each other.

[4] Couharde et al. (2013) have also developed an approach based on the use of equilibrium exchange rates to assess the sustainability of the CFA zone; a sustainable currency area being defined as a zone in which real exchange rates do not deviate persistently from their equilibrium paths. Similarly, Coulibaly and Gnimassoun (2013) fall into this strand of the literature by addressing the optimality of monetary unions in West Africa through the analysis of exchange rate misalignments.

By definition, the real effective exchange rate of country i, $REER_{i,t}$, is calculated as the weighted average of country i's real bilateral exchange rates against each of its N trading partners j:

$$REER_{i,t} = \prod_{j=1}^{N} RER_{ij,t}^{w_{ij,t}} \tag{1}$$

where $RER_{ij,t} = NER_{ij,t} \times \frac{P_{i,t}}{P_{j,t}}$ is an index of the real bilateral exchange rate of the country i's currency *vis-à-vis* the currency of the trading partner j in period t. $NER_{ij,t}$ is the index of the nominal bilateral exchange rate between the currency of country i and the currency of its trade partner j in period t (number of units of currency j per currency i), and $P_{i,t}$ (resp. $P_{j,t}$) stands for the price index of country i (resp. j). N denotes the number of trade partners, and $w_{ij,t}$ stands is for country i's the trade-based weights associated to the for all its partners j. Note that an increase in $REER_{i,t}$ and $NER_{ij,t}$ denotes an appreciation of currency i.

The definition of the real effective exchange rate thus becomes:

$$REER_{i,t} = \prod_{j=1}^{N} NER_{ij,t}^{w_{ij,t}} \times \frac{P_{i,t}}{\prod_{j=1}^{N}(P_{j,t})^{w_{ij,t}}} = \prod_{j=1}^{N} NER_{ij,t}^{w_{ij,t}} \times \phi_{i,t} \tag{2}$$

with $\phi_{i,t} = \frac{P_{i,t}}{\prod_{j=1}^{N}(P_{j,t})^{w_{ij,t}}}$

Given the observed domestic and foreign price indexes and the trade-based weights, the equilibrium real effective exchange rate ($REER^*_{i,t}$) can be written in terms of the equilibrium nominal bilateral exchange rate ($NER^*_{i,t}$):

$$REER^*_{i,t} = \prod_{j=1}^{N} (NER^*_{ij,t})^{w_{ij,t}} \times \phi_{i,t} \tag{3}$$

where $\prod_{j=1}^{N}(NER^*_{ij,t})^{w_{ij,t}} = NEER^*_{i,t}$ is the equilibrium nominal effective exchange rate.

We express the equilibrium bilateral nominal exchange rate (NER^*_t) of each currency relative to a numeraire currency. To this end, we use the no-arbitrage property on the foreign exchange market that makes all the cross rates consistent, namely: $NER_{ij,t} =$

$\frac{NER_{i,t}}{NER_{j,t}}$, where $NER_{i,t}$ denotes the exchange rate of country i against the numeraire. We choose the Special Drawing Rights (SDR) as the numeraire, as in Housklova and Osbat (2009) for instance. Frankel and Wei (2008) advocated for this choice of numeraire because monetary authorities generally do not monitor their exchange rate towards a single currency, but have rather to focus on several key currencies. Other authors use the dollar, the Swiss franc or several numeraires (Frankel and Wei, 1994; Bénassy-Quéré, 1999), although this choice generally does not affect their results. Although in a bilateral set-up the choice of the numeraire will not qualitatively affect the estimates, the derivation of bilateral misalignments from effective misalignments leads to assessments that are affected by the effective misalignment of the numeraire currency at all points in time (Housklova and Osbat, 2009). The introduction of the SDR avoids this problem. Furthermore, the use of the SDR allows us (i) to define the value of each currency independently of the others, and, in turn, (ii) to derive an equilibrium exchange rate path specific to each country. Recalling that the equilibrium exchange rate of country i is independent from country j's exchange rate level, Equation (3) can thus be rewritten as follows:

$$REER^*_{i,t} = \prod_{j=1}^{N} \left(S^*_{iSDR,t} \times \frac{1}{S_{jSDR,t}} \right)^{w_{ij,t}} \times \phi_{i,t} \tag{4}$$

where $S^*_{iSDR,t}$ is the equilibrium nominal exchange rate of the currency of country i vis-à-vis the SDR and $S_{jSDR,t}$ denotes the nominal exchange rate of the currency of country j vis-à-vis the SDR.

Equation (4) can be rewritten as:

$$REER^*_{i,t} = S^*_{iSDR,t} \times \frac{1}{\prod_{j=1}^{N} S^{w_{ij,t}}_{jSDR,t}} \times \phi_{i,t} = S^*_{iSDR,t} \times \frac{1}{\Omega_{i,t}} \times \phi_{i,t} \tag{5}$$

where $\Omega_{i,t} = \prod_{j=1}^{N} S^{w_{ij,t}}_{jSDR,t}$ corresponds to the weighted average of the nominal exchange rate of the N trade partners *vis-à-vis* the SDR.

The equilibrium value of the currency of country i *vis-à-vis* the SDR that minimizes currency misalignments (i.e., that equalizes $REER_{i,t}$ and $REER^*_{i,t}$) is then given by:

$$S^*_{iSDR,t} = REER^*_{i,t} \times \frac{\Omega_{i,t}}{\phi_{i,t}} \tag{6}$$

The time series of this equilibrium bilateral exchange rate allows us determining the paths of equilibrium parities $S^*_{iSDR,t}$ against the numeraire.

2.3. Assessing equilibrium exchange rates

There are three approaches of equilibrium real exchange rates: (*i*) the fundamental equilibrium exchange rate (FEER; Williamson, 1994) approach also referred to as the macroeconomic approach, (*ii*) the external sustainability approach, and (*iii*) the behavioral equilibrium exchange rate (BEER; Clark and MacDonald, 1998) approach. In the FEER framework, the equilibrium real exchange rate corresponds to the exchange rate level that allows the current account—projected over the medium term at prevailing exchange rates—to converge towards an estimated equilibrium current account, or a current account target. In the external sustainability approach, the equilibrium exchange rate aims at stabilizing the ratio of net foreign assets (NFA) to GDP at an appropriate level. These two approaches share a common drawback since they require defining the long-run equilibrium paths of economies. This exercise involves making assumptions on the long-run values of the economic fundamentals (such as current account norms in the FEER approach, and the appropriate ratio of NFA to GDP), which may be viewed as quite arbitrary. On the contrary, the BEER approach directly estimates an equilibrium real exchange as a function of medium- to long-term fundamentals, taking into account both internal and external balances without any *ad hoc* judgments. In this paper, we rely on such BEER framework for these reasons.

We consider the stock-flow model of exchange rate determination in the long run originally proposed by Faruqee (1995)—followed by Alberola et al. (1999) and Alberola (2003)—which is particularly suitable for describing advanced economies. This model emphasizes the net foreign asset position and the relative sectoral productivity (i.e., the Balassa-Samuelson effect) as important drivers of the real effective exchange rate. Following Clark and MacDonald (1998) among others, we augment this benchmark specification by including the terms of trade as an additional fundamental variable to account for real shocks.[5] These fundamentals are particularly relevant for the euro-area countries

[5]For the sake of robustness, we have also estimated a simpler specification including only productivity differential and net foreign asset position as determinants of real exchange rates; the results remain similar

as they fairly reflect the main sources of macroeconomic imbalances within the EMU that have been stressed: inflation rate differentials exceeding what could be explained by Balassa-Samuelson effects (Belke and Dreger, 2013), presence of large stock imbalances (Lane, 2013), and finally real shocks paving the way for asymmetric shocks. The full specification of our model is then the following:

$$reer_{i,t} = \mu_i + \beta_1 rprod_{i,t} + \beta_2 nfa_{i,t} + \beta_3 tot_{i,t} + \varepsilon_{i,t} \quad (7)$$

where $reer_{i,t}$ is the real effective exchange rate (in logarithm), $rprod_{i,t}$ stands for the relative productivity (in logarithm), $nfa_{i,t}$ is the net foreign asset position (as share of GDP), and $tot_{i,t}$ denotes relative terms of trade, expressed in logarithm. μ_i are the country-fixed effects and $\varepsilon_{i,t}$ is an error term. A positive relationship between the real effective exchange rate and each of the fundamentals is expected. Once the coefficients estimated, the equilibrium real exchange rate $reer^*_{i,t}$ will be calculated as the fitted value of $reer_{i,t}$ in Equation (7). Corresponding currency misalignments, $Mis_{i,t}$, are then given by: $Mis_{i,t} = reer_{i,t} - reer^*_{i,t}$.

2.4. Data and results

Our panel consists of the following eleven eurozone countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, the Netherlands, Portugal and Spain; i.e., the founding members of the euro area in 1999 plus Greece which joined the union in 2001.[6] The data are annual and cover the 1980-2016 period.[7] To assess equilibrium real exchange rates, we collect real exchange rate indexes from the *EQCHANGE* database provided by the CEPII.[8] These indexes correspond to the real effective exchange rates vis-à-vis 186 trading partners computed using time-varying weights representative of trade flows (5-year windows).[9] These REER indexes are defined so that an increase corresponds to a real appreciation of the domestic currency. We use the same trade partners and weights for the calculation of the relative productivity, proxied here by the relative real GDP per capita (in PPP terms).[10] The net foreign asset positions are

and are available upon request.

[6] Luxembourg and the other countries are excluded due to data availability issues during the 1980s and 1990s.

[7] See Table A.1 in Appendix A for details regarding the data.

[8] http://www.cepii.fr/CEPII/fr/bdd_modele/presentation.asp?id=34.

[9] The use of time-varying weights is important to move closer to the reality by capturing trade dynamics. See Couharde et al. (2018) for details regarding the *EQCHANGE* database.

[10] Due to the lack of sectoral data on output and employment for traded and non-traded goods sectors, most empirical studies test the Balassa-Samuelson hypothesis by relating the real exchange rate to the

extracted from the Lane and Milesi-Ferretti (2007) database (extended to 2014) and updated using information on national current accounts provided by the IMF databases (*International Financial Statistics* and *World Economic Outlook*). The terms of trade series are taken from the World Bank's WDI (*World Development Indicators*) database.

We rely on the cross-sectionally augmented pooled mean group procedure (CPMG; see Pesaran, 2006; Binder and Offermanns, 2007; De V. Cavalcanti et al., 2015) to estimate the long-run relationship between the REER and its fundamentals, described by Equation (7). This method has the advantage to provide consistent estimates of a long-run relationship in presence of cross-sectional dependencies. Indeed, CPMG augments the pooled mean group procedure (PMG; see Pesaran et al., 1999) with cross-sectional averages of the variables, therefore accounting for unobservable common factors. Furthermore, the CPMG procedure, compared to other long-run estimation methods (e.g. dynamic OLS, fully-modified OLS), better accounts for potential heterogeneity between countries as it allows short-run dynamics heterogeneity for each member of the panel.[11] The CPMG procedure appears therefore as the most adequate to capture not only interdependencies between countries, but also each country particularities (e.g. resilience to shocks). However, as a condition for the efficiency of the CPMG estimator is homogeneity of the long-run parameters across countries, we also rely on the cross-sectionally augmented mean group estimator (CMG) and test the long-run slope homogeneity hypothesis.[12]

Table A.2 in Appendix A presents the CPMG and CMG estimates, as well as the Hausman test statistic examining panel heterogeneity. According to the test statistic, the long-run homogeneity restriction is not rejected for individual parameters and jointly in all regressions. We therefore focus on the CPMG estimates. Considering the whole period, results reported in Table A.2 appear consistent with the theory since the coefficients have the expected signs. Indeed, the real effective exchange rate appreciates in the long run with the increase in the relative real GDP per capita (in PPP terms), the improvement in the net foreign asset position and in the terms of trade.

The fitted values of real effective exchange rates given by the estimation of Equa-

real GDP per capita (in PPP terms) differential which is a common measure for productivity. We follow here the same approach.

[11] Further note that all the mentioned procedures impose long-run slope homogeneity but, in the case of the CPMG procedure, this hypothesis can be tested (Hausman-test type).

[12] The CMG procedure provides consistent estimates of the averages of long-run coefficients, although they are inefficient if homogeneity is present. Under long-run slope homogeneity, the CPMG estimates are consistent and efficient (De V. Cavalcanti et al., 2015).

tion (7) provide the equilibrium real exchange rates.[13] Then we calculate the nominal equilibrium rates against the SDR ($S^{*}_{iSDR,t}$) from Equation (6). To this end, we deflate the equilibrium real effective exchange rate series by the weighted relative prices ($\Phi_{i,t}$) that are used for the computation of REER indexes in the *EQCHANGE* database.[14] Finally, equilibrium real exchange rates are adjusted for movements in the nominal bilateral exchange rates of trading partners *vis-à-vis* the SDR (variable $\Omega_{i,t}$ constructed as a weighted average).[15]

3. Evaluating the distance between euro-area countries: a cluster analysis

The purpose of this section is (*i*) to identify relatively homogeneous groups of euro-members based on their respective equilibrium exchange rate path, and (*ii*) to examine whether the subsequent partition of the euro area has evolved over time, specifically since the launch of the single currency. To assess the size of dissimilarities across euro-area countries, we implement a cluster analysis, based on the hierarchical ascendant classification (HAC). This method allows us partitioning the eurozone into relatively homogeneous groups of countries without imposing any reference group or leading country as in business cycle synchronization analyses. Moreover, it provides further information on the level of heterogeneity in the euro area, by evidencing interrelationships within and between the different groups of economies.

3.1. The method

The HAC procedure begins by estimating the dissimilarities between any pair of objects (here the dissimilarities between the optimal exchange rate paths for any pair of euro-area countries) using an appropriate metric (i.e., a measure of distance between pairs of objects). Here we use the standard Euclidian distance.[16] Let $X_{i,t}$ be the optimal exchange rate for country i at period t ($t = T_1, \ldots, T_N$), the dissimilarity coefficient defined by the Euclidean distance between the optimal exchange rate of country i and

[13]Figure A.1 in Appendix A displays the calculated real effective exchange rates and estimated equilibrium real exchange rates. Corresponding misalignments are reported in Figure A.2.

[14]Weighted relative prices are computed as a geometric average of the ratios of the Consumer Price Index (CPI) of a country to the CPI indexes of its main trade partners. The CPI series are from the IMF and OECD databases (see Couharde et al., 2018).

[15]Nominal bilateral exchange rates *vis-à-vis* the SDR are extracted from the IMF database.

[16]While other measures exist (Squared Euclidean distance, Manhattan distance . . .), the Euclidian distance is the most common metric. Since we are working in a continuous space where all dimensions are properly scaled and relevant (due to the numeraire currency), the Euclidean distance is the best choice for the distance function. In addition, it does not suffer from sensitivity to outliers and is a real metric.

country j is:

$$d(X_i, X_j) = ||X_i, X_j|| = \sqrt{\sum_{t=T_1}^{T_N} \left(X_{i,t} - X_{j,t}\right)^2} \quad (8)$$

where $d(X_i, X_j)$ or $||X_i, X_j||$ denotes the Euclidean distance between X_i and X_j.

Using distance information, pairs of objects are grouped into clusters that are further linked to other objects to create bigger clusters. The algorithm stops when all the objects are linked. This agglomeration is realized using another metric that measures the distance between two clusters and therefore determines the borders of the homogeneous groups.

We adopt here the following four agglomerative methods: (i) Ward's linkage, (ii) single-linkage, (iii) complete-linkage, and (iv) average-linkage. Let A and B be two clusters with, respectively, n_A and n_B as the number of objects, and $\overline{A}$ and $\overline{B}$ as the centroids. The Ward's method, which is the most commonly used procedure, consists in joining two clusters that result in the minimum increase in the sum of squared errors (so the loss of within-cluster inertia is minimum). The within-cluster sum of squares is defined as the sum of the squares of the distances between all objects in the cluster and the centroid of the cluster. The Ward's method relies on the distance d_W between the centroids of the two clusters $\overline{X}_A$ and $\overline{X}_B$:

$$d_W(A, B) = \frac{2n_A n_B}{(n_A + n_B)} \ \| \overline{X}_A - \overline{X}_B \| ^2 \quad (9)$$

The single-linkage, also called "nearest neighbor", considers the smallest distance d_S between objects in the two clusters. On the contrary, the complete-linkage or "furthest neighbor", as it name suggests, concentrates on the largest distance d_C between objects in two clusters. Finally, the average-linkage method uses the average distance d_A between all pairs of objects in any two clusters.[17] These inter-cluster distances are expressed as follows:

$$d_S(A, B) = min\Big(d\big(X_{Ai}, X_{Bj}\big)\Big) \quad (10)$$

$$d_C(A, B) = max\Big(d\big(X_{Ai}, X_{Bj}\big)\Big) \quad (11)$$

$$d_A(A, B) = \frac{1}{n_A n_B} \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} d\big(X_{Ai}, X_{Bj}\big) \quad (12)$$

[17] For more details regarding these measures, see Kaufman and Rousseeuw (1990).

where $i = 1, \dots, n_A$ (resp. $j = 1, \dots, n_B$) designates the i^{th} (resp. j^{th}) object in cluster A (resp. B).

We use the HAC analysis to measure the distance between the euro-area countries regarding the path of their equilibrium exchange rates. First, we consider the period before the monetary union 1980-1998. Then, we study how the clustering of countries has evolved over time. To do so, we perform the same cluster analysis over different time periods in order to track structural changes. This investigation aims at capturing any change in dissimilarities across the euro area. On the whole, we retain three periods all starting in 1980: (*i*) before the monetary union: 1980-1998; (*ii*) before the global financial crisis: 1980-2006; and (*iii*) the whole period 1980-2016.

3.2. Cluster analysis before the launch of the euro

The groups identified by applying the HAC analysis before the launch of the euro are shown in the four dendrograms reported in Figure 1. These "cluster trees" indicate the order in which successive aggregations were made (and therefore the optimal groupings). The vertical axis of the dendrograms represents the distance or dissimilarity between the objects (i.e., the countries' equilibrium exchange rate paths), while the horizontal axis displays the different countries. The dissimilarity measures are captured by the heights of the links.

As can be seen, the four different methods release consistent information regarding dissimilarities in exchange rate paths across the eurozone members. From these dendrograms, we clearly identify two clusters of countries (two branches that occur at about the same vertical distance). A first cluster can be identified as the "core countries", it includes Germany, Belgium, the Netherlands, France and Ireland. A second group of homogeneous countries is made of Austria, Spain, Italy and Finland. Portugal and Greece are fused separately at much higher distances compared to the other countries and can be considered as two outliers.[18]

The division of the euro area into several groups of countries is quite in line with the existing literature while the composition of the core group may differ depending on research undertaken.[19] For instance, applying clustering techniques to a set of OCA vari-

[18]This can be confirmed by the dissimilarity matrices reported in Appendix C for the 1980-1998 (Table C.1) and 1980-2016 (Table C.2) periods: as shown, Greece and, to a lesser extent, Portugal are the two countries exhibiting the highest values.

[19]Part of these differences can be related to the definition of membership of the core. While the approach suggested by Bayoumi and Eichengreen (1993) defines core countries as those whose aggregate supply and demand shocks are relatively highly correlated with Germany, the clustering approach separates the

ables, Artis and Zhang (2001) also find evidence in support of three groups of countries: 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). Also relying on OCA theory but using a modified Blanchard-Quah decomposition within the aggregate supply – aggregate demand setup, Bayoumi and Eichengreen (1993) identify (i) a core composed of Germany, France, Belgium and the Netherlands, and (ii) a periphery including Greece, Ireland, Italy, Portugal and Spain. Three sets of countries are also obtained by Bayoumi and Eichengreen (1997), distinguishing the economies in terms of readiness for EMU: Germany, Austria, Belgium and the Netherlands which exhibit a high level of readiness; Finland and France which experienced little convergence; and Italy, Greece, Portugal and Spain which are gradually converging.

Looking back on the debates at the introduction of the euro, our results thus confirm that dissimilarities across the euro area candidates persisted until the eve of the EMU. If we restrict our sample to the countries that adopted the euro in 1999 (i.e., excluding Greece), two groups of countries are clearly identified, with Portugal as an outlier. From this point of view, our results are consistent with the findings of the OCA literature that counselled against the pursuit of further and deeper monetary integration within Europe at that time. The partition of the euro area into different groups of relatively homogenous countries called into question (*i*) the effectiveness of Maastricht criteria in making these countries converge before the launch of the euro, and (*ii*) the desirability of a unique monetary policy for all the economies composing these groups. Our results also reflect the argument advanced by Eichengreen (1993) and Feldstein (1997) that much of the driving force for monetary union was political, as in economic terms the eurozone project would have been postponed or designed differently to allow for some flexibilities between the core and the periphery.

3.3. The evolution in the groupings of countries

So far, our findings cannot refute the argument that dissimilarities across the potential eurozone member countries were due to insufficient financial integration and would be swept off by monetary union. We now extend our analysis by including the period after

most similar countries into several clusters, without assuming a representative core country. In this latter approach, core countries are then defined as those that are theoretically suitable for a common currency, i.e., those forming the most homogeneous group.

the launch of the single currency in order to analyze the evolution of cluster memberships over time. The corresponding results are displayed in Figure 2.[20] The configuration of the eurozone shares the same features as before, with a set of core countries and a second group of economies. These two groups are fused at the same distance, suggesting that the monetary union has not reduced dissimilarities between these two clusters of countries. The peripheral countries seem also more fragmented in sub-groupings. In particular, Italy now exhibits slightly distinct features from the other members, and is depicted as a singleton inside the peripheral group. This is also the case for Portugal, which is linked to the peripheral set in a single element group. Greece still appears as an outlier, neither linked to core nor to peripheral members. It has even become more distinct from the other countries over time as the distance to the other clusters has increased. These latter results are in line with those of Wortmann and Stahl (2016) and Ahlborn and Wortmann (2018) who apply different cluster algorithms respectively to the Macroeconomic Imbalance Procedure (MIP) indicators and to output gap series. They also find evidence in support of a strengthening over time of the core–periphery structure of the euro area.

[20] To save space, we only report the results obtained with the Ward method. The three other approaches lead to similar results, which are available upon request to the authors.

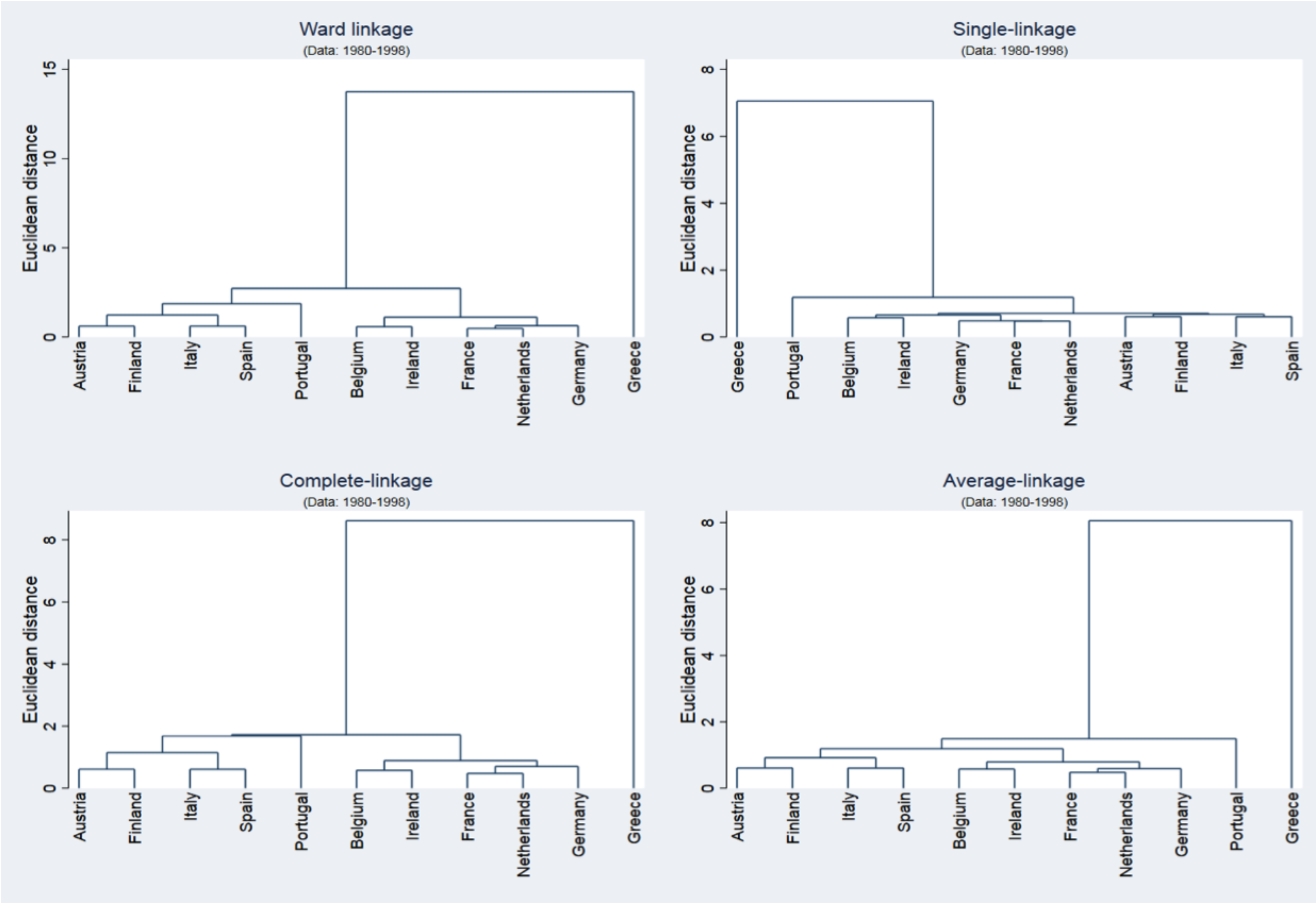

Figure 1 — HAC analysis results (1980-1998)

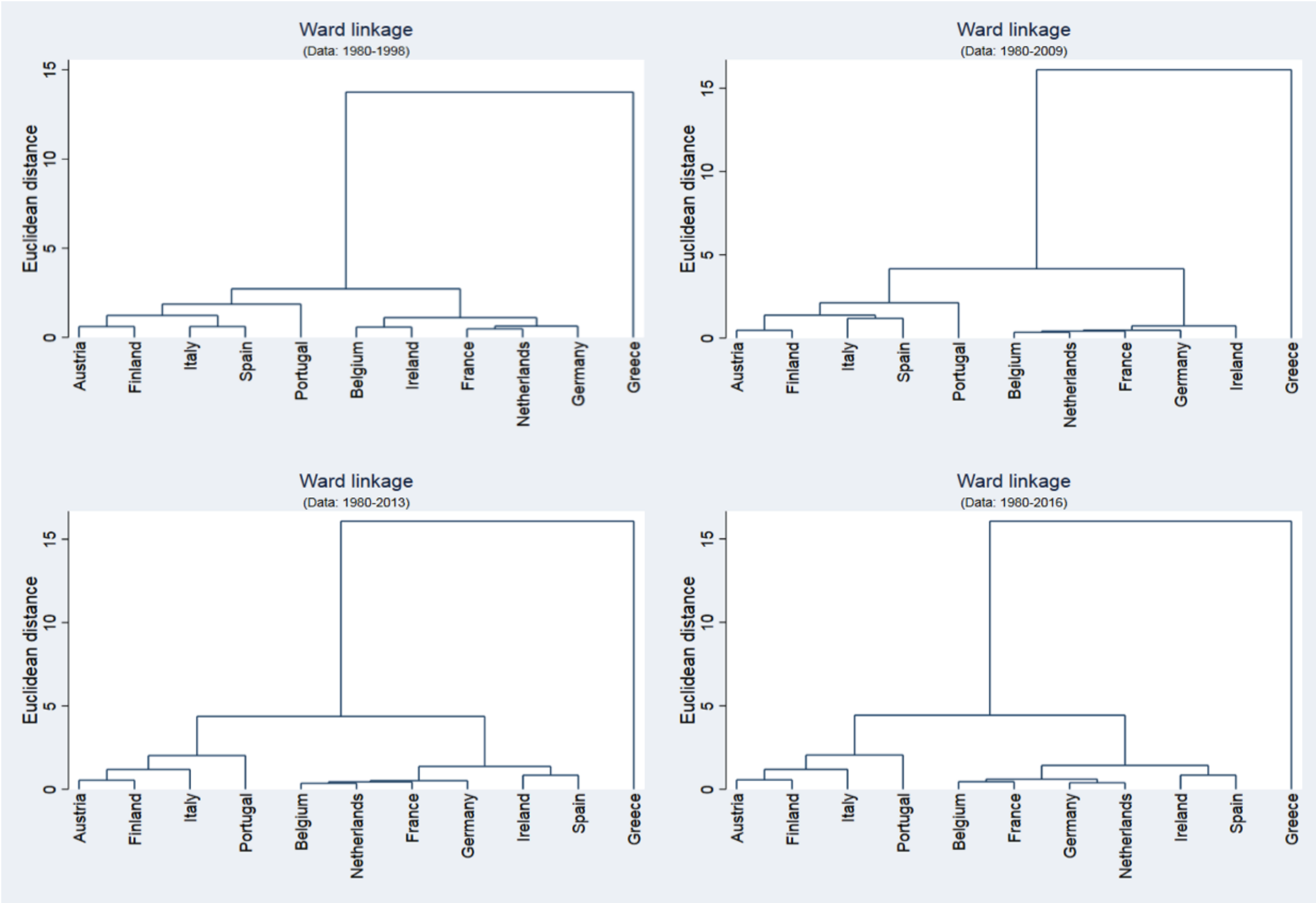

Figure 2 — Recursive HAC analysis results

On the whole, these findings suggest that the configuration of the eurozone since the launch of the single currency has become more fragmented; dissimilarities between groups of countries have augmented. The peripheral countries that are aggregated together exhibit some increased distinct features. The comparison between the graphs before and after the 2007-08 collapse shows that the adjustment that followed the financial crisis has not changed the deal between countries. The clusters have not been brought closer despite all the steps that have been taken to counter imbalances.

4. Identification of heterogeneous patterns: a factor analysis

Apart from the partition of countries by itself, it is also interesting to analyze which variables have mostly explained the formation of such clusters. For this purpose, we now develop a factor analysis in order (*i*) to identify the common features shared by euro-area countries belonging to the same group, and (*ii*) to check if the results are similar to those issued from the cluster analysis. Accordingly, we collect data on several key variables that are more prone to reflect macroeconomic imbalances. Then, we perform a factor analysis to identify the structural economic differences between the EMU members emphasized by the cluster analysis.

4.1. Method and selected indicators

We use factor analysis to select the main relevant indicators, i.e., the variables that underlie the formation of clusters. Specifically, being a multivariate explorative analysis tool, factor analysis gathers together several variables with similar patterns and containing most of the information into a few interpretable unobserved (underlying) variables, called factors. Thus, as a technique of data reduction, the aim is to reduce the dimension of the observations by grouping p observed variables into a lower number, say k, of factors. To this end, the p variables are modeled as a linear combination of the potential factors (i.e., latent unobserved variables that are reflected in the behavior of the observed variables) plus an error term. In doing so, factor analysis is a useful tool to detect the structure of the relationships between the variables. Specifically, let us assume we have a set of p observable random variables $(Y_1, \ldots, Y_p)$. From these p observed variables, factor analysis aims at identifying k common factors which linearly reconstruct the original variables as follows:

$$Y_{ij} = Z_{i1}\gamma_{1j} + Z_{i2}\gamma_{2j} + ... + Z_{ik}\gamma_{kj} + u_{ij} \tag{13}$$

where Y_{ij} is the value of the i^{th} observation of the j^{th} variable ($j = 1, \ldots, p$), Z_{il} is the value of the i^{th} observation of the l^{th} common factor ($l = 1, \ldots, k$), the coefficients γ_{lj} denote the factor loadings ($l = 1, \ldots, k$), and the error term u_{ij} is the unique factor of the j^{th} variable.

The selection of indicators must meet the need for both comprehensiveness and parsimony in order to set out clear factors that can be easily interpreted. We select indicators among a set of fundamental variables often linked to the formation of imbalances within the euro area. This set includes the current account balance, consumer price, inflation, public debt, GDP per capita, real growth, output gap, unemployment rate and unit labor cost, to which we add the currency misalignments that we have calculated. Table A.1 in the appendix details the source of these series. This set of variables is large enough to account for the usual OCA criteria as well as the economies' internal and external balances and their dynamics. For example, inflation obviously accounts for price stability and debt-to-GDP ratios measure the soundness and sustainability of public finances: these two variables, as well as unemployment rates are able to gauge the internal equilibrium of the economies.[21] Regarding the external balance, the current account-to-GDP ratio encompasses various key determinants according to the usual medium to long-term specifications such as net foreign asset position, fiscal position, output gap, population growth rate, dependency ratio, openness, etc. (see e.g. Chinn and Prasad, 2003; Gruber and Kamin, 2007; Cheung et al., 2010); it has thus the advantage of parsimony by synthetizing them in a sole series.

The selected variables should also meet considerations/rules regarding the functioning of the euro area, although rules much changed over the long period 1980-2016 that we consider. For example the Maastricht criteria were important before the monetary union, then the stability and growth pact (SGP) and the "six-pack" legislation, including the MIP, in the aftermath of the 2008 crisis.[22] We therefore take stock of the macroeconomic imbalance procedure (MIP) that the European Commission has been using since 2011 in order to deal with imbalances in the member countries. Most of the 14 headline

[21] Beyond all the technical aspects and rules regarding the limits of the variables mainly defined by the Maastricht Treaty (i.e., an inflation rate that should be lower than a reference value—defined as the average of the inflation rates in the 3 eurozone member states with the lowest inflation plus 1.5 percentage points; a debt ratio that should not exceed 60%) or SGP rules (the unemployment three-year moving average should be lower than 10%), factor analysis ignores such rigidity in the criteria and simply maps out the countries on the basis of their proximity regarding the variable levels, thus potentially underlining clusters of countries.

[22] It should be noted that for the sake of consistency and uniformity of the analysis, the selection of the variables must satisfy both *ex ante* prospective and *ex post* evaluation exercises. This explains why we did not restrict the analysis to the sole convergence criteria.

indicators that are monitored in this procedure are taken into account in our analysis. Indeed, both the 3-year moving average of the current account (% of GDP) and the net international investment position (% of GDP) indicators are considered either (*i*) directly through the current account, or (*ii*) through currency misalignments thanks to the net foreign asset position. As well, the 3-year percentage change of the real effective exchange rate is also accounted for via the currency misalignments.[23]

The detailed results of the factor analysis are presented in Appendix B.2; Table B.1 giving some descriptive statistics on the variables. Specifically, Tables B.2.1.1 and B.2.1.2 (respectively B.2.2.1 and B.2.2.2) are related to the results of the unrotated analysis for the 1980-1998 (respectively 1999-2016) period, the other tables in Appendix B.2 concerning the rotated analysis.[24] Each variable is assigned to the factor in which it has the highest loading. Once (*i*) variables have been assigned to the common factors and (*ii*) the factors and their loadings have been estimated (right-hand side of Equation (13)), the factors must be interpreted. To this end, the factor loadings have to be examined.

4.2. Factor analysis before monetary union

Let us start with the pre-EMU, 1980-1998 period. As shown in Table B.2.1.1 in Appendix B, only the first three factors are retained as the eigenvalues associated with the other factors are negative. The first two factors are the most meaningful, explaining the major part (around 75%) of the total variance (Table B.2.1.3). Table B.2.1.4 shows that the first factor (*Factor 1*) has a high positive correlation with inflation and the debt-to-GDP ratio, and a high negative correlation with the current account balance. *Factor 1* thus principally opposes (*i*) on the left side, the current account balance and, (*ii*) on the right side, the debt-to-GDP ratio and inflation. Accordingly, *Factor 1* may be interpreted as the "Finance/Wealth axis" or reflecting the "Financial position": on the left side, countries with good/sustainable foreign position; on the right side, countries facing external imbalances characterized by a high inflation rate and a high debt-to-GDP ratio, which result in current account deficits. The second factor, *Factor 2*, correlates strongly

[23]Furthermore, we consider the country total debt (government plus private sector) while in the MIP scoreboard a distinction is made regarding the debt indicators. By the same token, we use the total economy unemployment rate instead of the different types/horizons of unemployment.

[24]Recall that factor loadings could be rotated to make easier the interpretation of the factors. Indeed, rotation consists in expressing the factors so that loadings on a quite low number of variables are as large as possible, while being as small as possible for the remaining variables. Here, we retain the usual orthogonal varimax rotation (Kaiser, 1958) which maximizes the variance of the squared loadings within factors.

and positively with the indicators for unemployment and misalignments, and negatively with economic growth. *Factor 2* may thus appropriately reflect internal imbalances (Table B.2.1.4).

Regarding methodological aspects, our results are satisfying as shown by the low values of uniqueness in Table B.2.1.4. Indeed, recall that uniqueness measures the percentage of variance for the considered variable that is not explained by the common factors. Uniqueness could represent measurement error, which is likely if it takes a high value, typically larger than 0.6. The values we obtain being quite low (except for inflation), our retained variables are well explained by the identified factors.

The results regarding the first two factors are synthesized in Figure 3. Specifically, the top chart, i.e., the factor loadings plot, displays the position of each variable in the *Factor 1-Factor 2* plane. Its aim is to identify clusters of variables with similar loadings. The bottom chart ("*Scores*") of Figure 3 displays the score of individual countries on each factor, the values being provided in Table B.2.1.6. The closer the country is to a variable, the more important is the score of the country regarding this variable.

An interesting observation, which is in line with the results of the cluster analysis, is that Greece and, to a lesser extent, Portugal score very high with respect to external imbalances. Their position appears far from that of any other country (except Italy). With the HAC analysis, Greece and Portugal were viewed as outliers among the eurozone countries in the sense that they were the last countries that merged into the final cluster that included all other members. This is reflected by their extreme position in the scores plot, (*i*) close to *Debt* and *Inflation* suggesting the highest debt and inflation levels—on average—, and (*ii*) far away from the other variables (as the current account position), reflecting recurrent current account deficits. The positions of Greece and Portugal as outliers are therefore confirmed by their poor performance reflected in high financing requirements before the launch of euro area.[25]

Another interesting finding which also corroborates the results of the cluster analysis is that some core countries score rather low on the factor of external imbalances: France, Germany, the Netherlands and Belgium. As showed by the bottom chart of Figure 3, these countries form a cluster at the left-center of the scores plot, indicating that they had low inflation rates and debt-to-GDP ratios before the EMU, which resulted in lower current imbalances and/or current surpluses. Other countries either score high on the factor of external imbalances, such as Italy, or score low on this factor, but

[25]The bad performance of Greece is confirmed by the highest score displayed by this country when considering the third factor (see Table B.2.1.6).

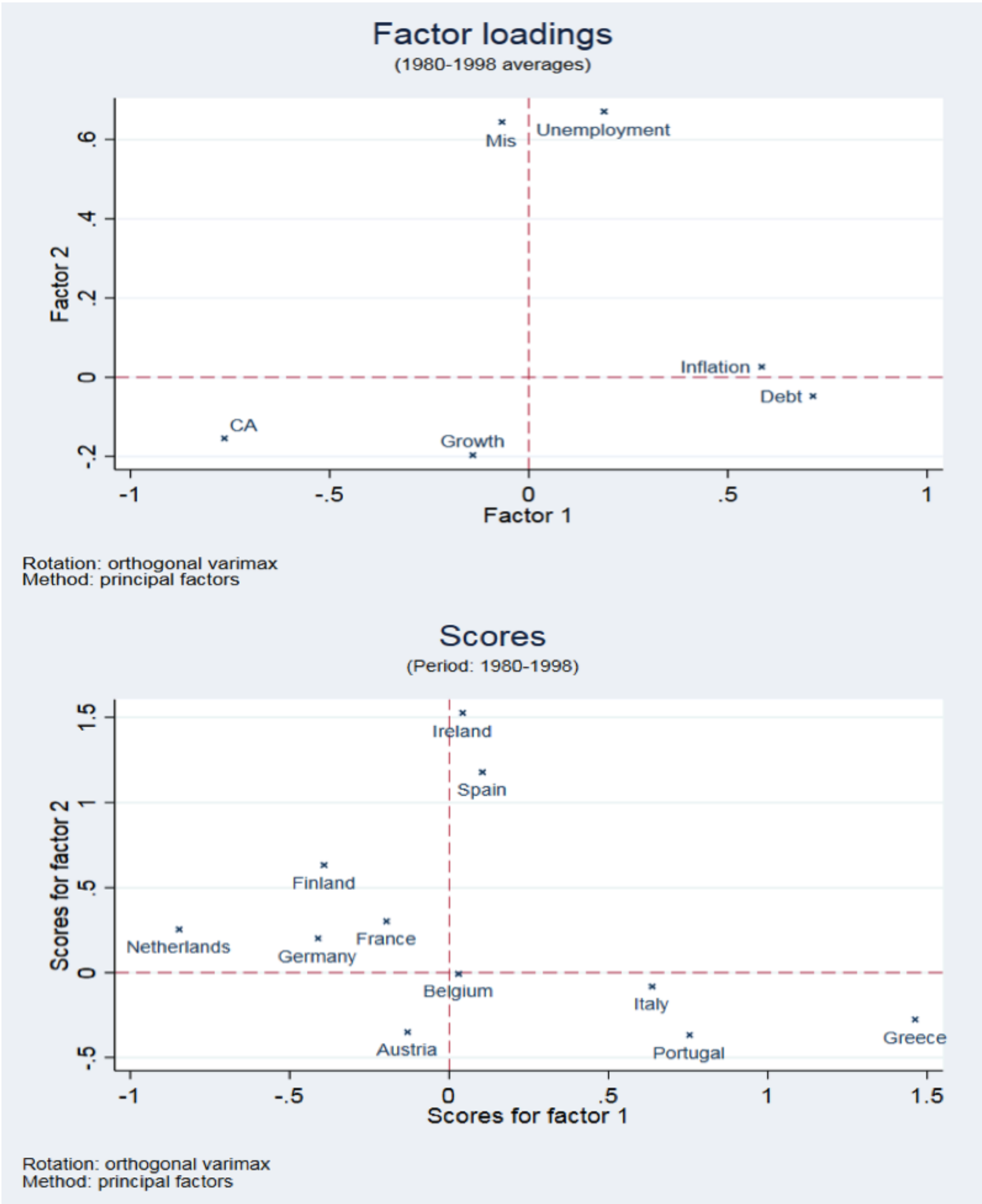

Figure 3 — Factor analysis results (1980-1998)

at the expense of higher internal imbalances, as Spain and Finland. Although Austria appears close to the core group, *Factor 2*—which displays a strong correlation with misalignments—makes this country apart from the group composed by France, Germany, the Netherlands and Belgium, as highlighted by the cluster analysis.[26] Only the position of Ireland gives a picture that is less clear-cut than the one delivered by the cluster analysis. Indeed, whereas Ireland is merged into the core group when the clustering method is used, its high unemployment rate makes it move away from the core in the

[26] It should be noted that the position of Austria is not straightforward as this country is found to be in the core group over the 1980-1998 period when we use the k-means procedure as an alternative clustering method (see Appendix D).

factor analysis. This gap is partly explained by the highest—negative—score regarding the third factor displayed by Ireland. As this third factor is not represented in Figure 3, this may affect the global pattern. Despite these facts, its position issued from the factor analysis remains compatible with our previous findings. Indeed, the factor analysis being performed using data on the total unemployment rate, its result simply highlights that Ireland was one of the countries exhibiting the highest unemployment rate before the monetary union. Meanwhile, Ireland also had a quite high—estimated—NAIRU (Non-Accelerating Inflation Rate of Unemployment) which makes the aforementioned rate of unemployment sustainable, i.e., reflecting a situation of near internal balance.

Overall, this first factor analysis proves to be very informative and comes in support to the findings of the HAC analysis. Indeed, both approaches suggest that Belgium, France, Germany, the Netherlands, and Ireland form the core group. While the picture for the first four aforementioned countries is clear-cut from both the cluster and factor analyses, the inclusion of Ireland—indicated by the HAC approach—is also found relevant by the factor analysis, except for the unemployment figure. The other economies appear quite dissimilar; with persistent imbalances, the participation to the monetary union together with these core countries would imply costs. This is particularly true for Greece and, to a lesser extent, for Portugal.[27]

4.3. Factor analysis after the launch of the euro

Let us now turn to the 1999-2016 period to examine how the observed trends have evolved since the launch of the single currency, and whether they remain consistent with those derived from the cluster analysis.

As for the previous pre-EMU period, two principal factors explain most (about 90%) of the total variance (Tables B.2.2.1 and B.2.2.3), while reflecting different patterns (Table B.2.2.4). The first factor may now be interpreted as reflecting "virtuous countries": this axis opposes the debt-to-GDP ratio on the left side, and growth on the right side. For its part, *Factor 2* can be seen as ranking countries facing macroeconomic imbalances: it displays negative and important correlation with the current account balance, and is positively correlated with unemployment and inflation. Hence, the higher the country's score on this axis is, the larger its macroeconomic imbalances.[28] Thus, the two principal

[27] In contrast with Greece, the analysis indicates that Portugal only suffers from competitiveness problems. This holds for Spain, but to a lesser extent.

[28] Note that the third factor is principally defined by currency misalignments—while opposing them with the current account balance. *Factor 3* can thus be seen as the competitiveness factor: the higher the overvaluations, the lower the trade performances.

factors covering the EMU period point to a stronger divergence across countries inside the eurozone. This result is in accordance with the time-increasing dissimilarities across euro-area members revealed by the cluster analysis.

As regards scores of individual countries on each factor (Table B.2.2.6), it appears from the bottom chart of Figure 4 that the overall economic situation of Greece and, to a lesser extent, of Portugal deteriorated, compared to the previous period. Indeed, these two countries have the highest scores on the macroeconomic imbalances' factor. They have accumulated more imbalances in the first decade of the euro than before because of abundant capital flows and low interest rates—as reflected by the current account deficit, the unemployment rate, their zero-growth rate on average and their considerable overvaluation. This finding is in line with the continuous divergence path of Greece and Portugal revealed by the cluster analysis. Furthermore, Belgium, France, Germany, and the Netherlands appear very close to each other: they have negative scores regarding *Factor 1*, and their performances—especially for the German and Dutch economies—remain better than most of the other countries. Ireland is still quite close to this core group according to the second factor.[29] Finland is located near Austria which, as for the pre-EMU period, is still very close to the core group regarding the first two factors. The main difference making it apart from this group comes from the third factor for which Austria displays a positive score, while the core countries score negatively. As this third factor is mainly related to currency misalignments, this corroborates our findings from the cluster analysis. The situation of Spain has been catching up with those of the core countries thanks to the improvement in its debt-to-GDP ratio, while being still quite distant regarding *Factor 2* with remaining macroeconomic imbalances at play.[30] Turning to Italy, it still faces macroeconomic imbalances but, most importantly, exhibits the second highest negative score regarding *Factor 1*, which tends to distance

[29]Again, the two-dimensional plane representation blurs the perception since its does not allow for the third dimension (i.e., *Factor 3*). Ireland distorts the core group countries' cloud towards the right because of its high growth rate (the highest in average).

[30]As for Ireland, Spain exhibits high values of both unemployment rate and estimated NAIRU. Since the factor analysis is performed using the unemployment levels, the position of the Spanish economy on the graph does not reflect inconsistency between the core group and Spain, but simply the use of the total unemployment data.

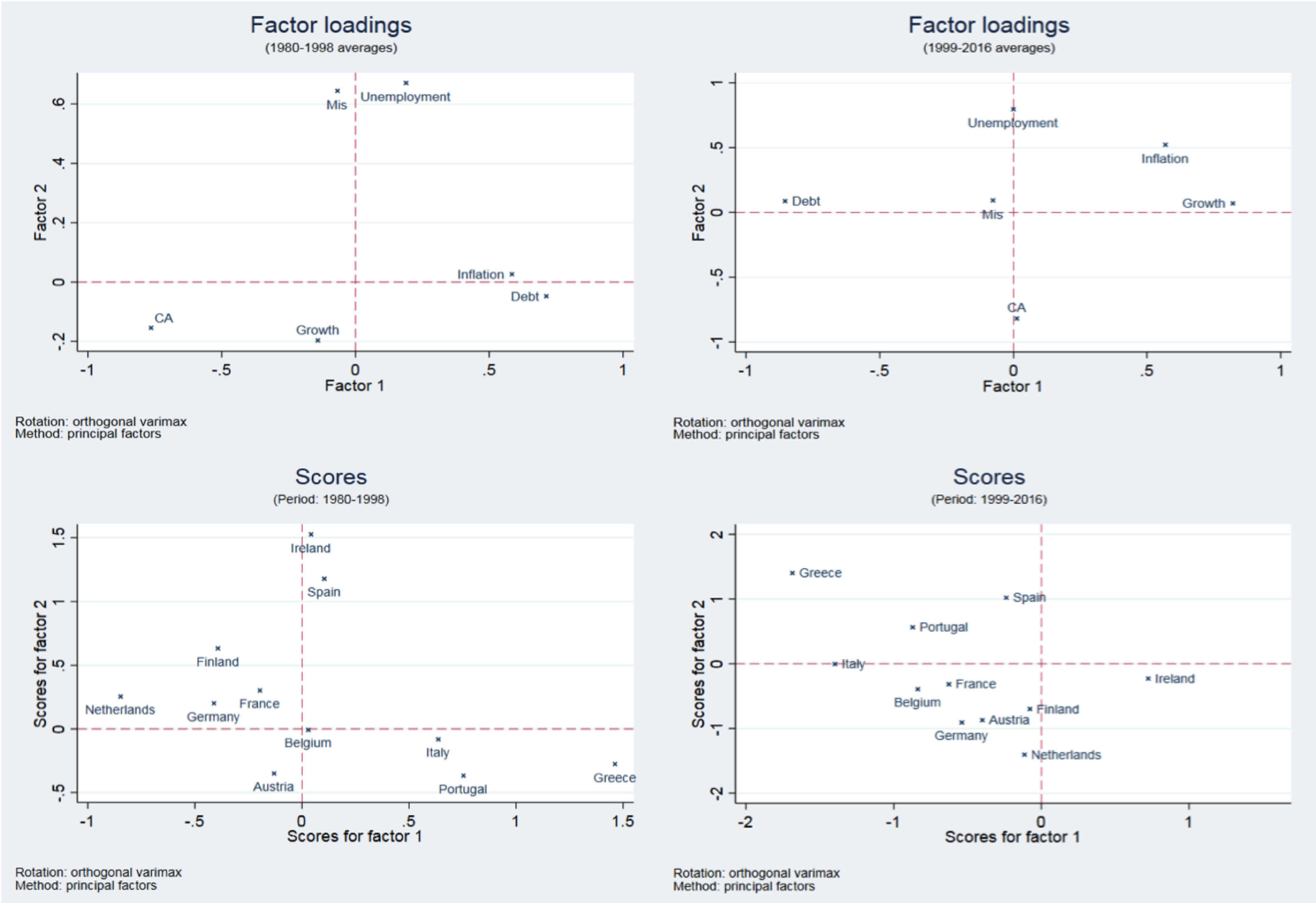

Figure 4 — Factor analysis results (1980-1998 and 1999-2016)

its economy from those of the core, as Portugal. Once again, these findings are in line with the results of the HAC analysis.

Overall, the observations made on economic performances of the eurozone countries over the 1999-2016 period are not far from the predictions based on the cluster analysis. This confirms the relevance of our methodology: by separating the most similar equilibrium exchange rate paths into several clusters, we are able to analyze the extent of dissimilarities across the eurozone members in terms of macroeconomic imbalances and show how they have increased over time.

5. Conclusion

This paper analyzes the degree of dissimilarity among eurozone members by focusing on their equilibrium exchange rate paths. Since a country entering a single currency area gives up its own exchange rate, its equilibrium exchange rate path has rather to be in line with that of the other members in order to prevent unsustainable internal and external imbalances that could undermine the smooth functioning of the currency area. We thus rely on these equilibrium exchange rate trajectories to assess the similarities/dissimilarities of countries inside the euro area.

By applying our methodology to the eurozone project from 1980 to 1998, we are able to identify disparities among the member countries, distinguishing two groups of economies and two outlier countries. On the one hand, Belgium, France, Germany, Ireland, and the Netherlands form the most homogenous group; Austria, Finland, and Spain constitute the second group to which Italy can also be linked. Portugal and Greece are found to be the countries exhibiting very different equilibrium exchange rate paths; Greece being the most idiosyncratic country, because of its structural weaknesses regarding the financing of its economy.

Extending the period further reveals that countries did not move structurally closer to each other. Our findings point to increasing disparities across and within countries' groups over time. This may not be surprising when considering historical examples of monetary unions. Indeed, according to Rockoff (2000), it took decades to the United States to become an OCA, and this happened only after strong institutional steps such as the introduction of interregional transfers. The success of the euro during its first decade of existence may have create the appearance of a convergence process driven by abundant capital flows that fueled consumption and real estate demand in the peripheral countries without however increasing their production capacities. Since the 2008 crisis that undermined this debt-driven growth process, many steps have been taken in order to correct macroeconomic imbalances. However, too little has been done concerning a common fiscal policy. It is now time to recognize that OCA conditions will not arise spontaneously by the mere effect of the single currency. Large reforms of the euro governance are still needed to ensure the optimality of the single currency. Besides, real convergence should be also dealt with, because it was not fostered automatically by monetary union as expected. It is necessary to revive the catching-up process in the Southern members, for example by channeling more EU funds to the development of specific industries, in order to maintain social cohesion inside the area.

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Appendices

A. Data and cointegrating regression estimation results

Table A.1 – Data: definitions and sources

Variable & Definition	Sources
HAC analysis:	
Real effective exchange rate (reer) Calculated as the weighted average of the real bilateral exchange rates against 186 trading partners; an increase indicates an appreciation.	CEPII (EQCHANGE)
Relative productivity (rprod) Proxied by the ratio between the country GDP per capita (in PPP terms) and the trade-weighted average GDP per capita PPP of 186 trading partners.	Computed using data from the WDI database
Net foreign assets position (nfa) Measured as the sum of the foreign assets (held by monetary authorities) and the deposit money banks minus the foreign liabilities.	Lane & Milesi-Ferretti [a,b]
Terms of trade (tot) Net barter terms of trade index calculated as the percentage ratio of the export unit value indexes to the import value indexes, measured relative to the base year 2000.	WDI
Nominal exchange rates vis-à-vis the Special Drawing Rights	IMF
Others:	
CA: current Account balance (%GDP)	WDI, WEO, OECD stat
CPI: Consumer price Index	WEO
Debt: total government debt (%GDP)	WDI, OECD stat
GDPPPP: GDP per capita adjusted from the purchasing power parity	WEO, OECD stat
Growth: real GDP per capita growth rate	OECD stat
Inflation: changes in the consumer price index	WEO
Mis: Currency misalignments	Our calculations
Output gap: deviations of actual GDP from potential GDP (% of potential GDP)	OECD stat
Unemployment: unemployment rate (% total labor force)	WDI, WEO, OECD stat

WDI: World Development Indicators (World Bank)
WEO: World Economic Outlook (International Monetary Fund)
OECD stat: Organisation for Economic Co-operation and Development Statistics
a: Lane & Milesi-Ferretti (2007; extended to 2014)
b: updated to 2016 using information provided by the IMF (International Financial Statistics and WEO)

Table 1 — Estimation of the long-run relationship

Dependent variable:	d.reer			
Estimation procedure:	CPMG		CMG	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*
Long-run dynamic				
rprod	0.242*	0.128	0.170	0.268
nfa	0.189**	0.093	0.448	0.340
tot	0.867***	0.230	1.198***	0.349
Short-run dynamic				
ec.	-0.092***	0.021	-0.202***	0.025
d.rprod	-0.195***	0.074	-0.215**	0.110
L.drprod	-0.033	0.036	-0.084	0.054
d.nfa	-0.098*	0.059	-0.078	0.062
L.dnfa	-0.040	0.036	-0.039*	0.024
d.tot	0.318***	0.111	0.257	0.158
L.dtot	0.253**	0.104	0.186**	0.084
Constant	0.051***	0.012	-0.331	0.397
Specification tests				
Joint Hausman test [a]	2.41			
[$\chi^2(3)$]	[*p*.value = 0.4919]			
No Obs. / No. countries	451/11	451/11	451/11	451/11

Notes: The estimation is done on the 1976-2016 period. Symbols ***, **, and * denote significance at the 1%, 5%, and 10% statistical level. 'd' (resp. "*L.*") is the difference operator (resp. the lag operator); "*ec.*" is the error correction term.
a: Null of long-run homogeneity

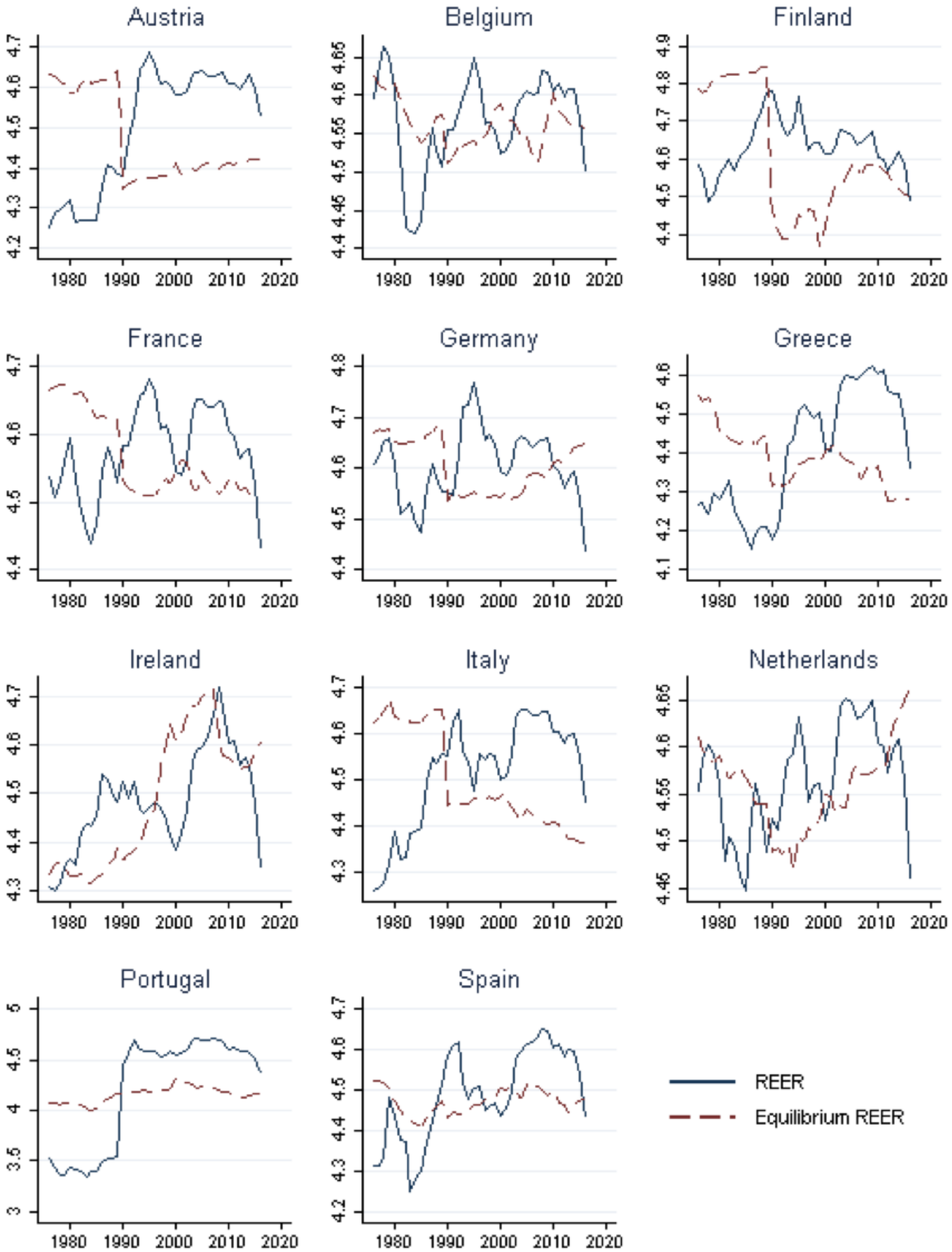

Figure A.1 – Real effective exchange rates: calculated and equilibrium levels

Note: The real exchange rate indexes are in logarithmic scale. An increase (resp. a decrease) indicates an appreciation (resp. a depreciation).

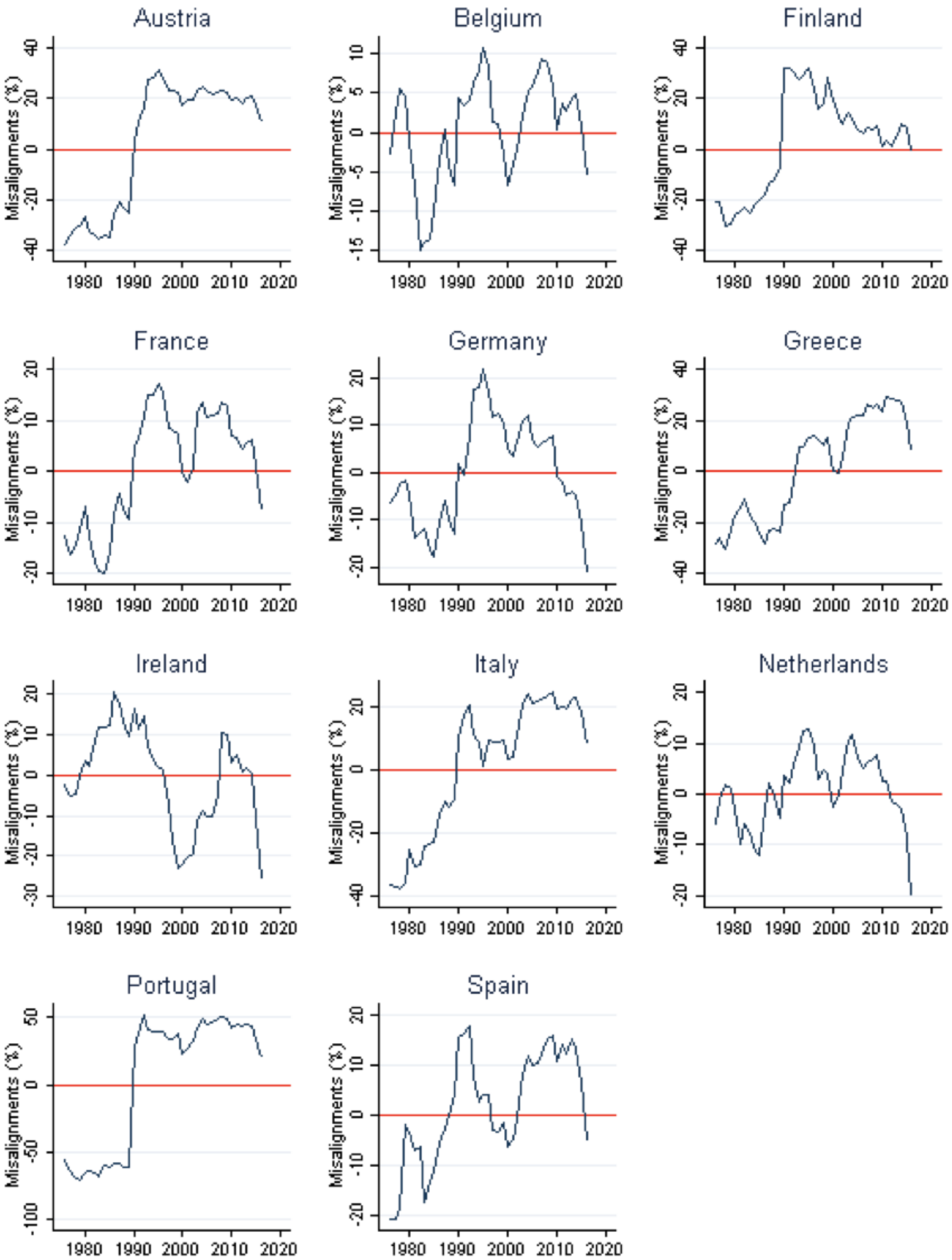

Figure A.2 – Currency misalignments (in percentage)

Note: a positive (resp. negative) value corresponds to an overvaluation (resp. undervaluation).

B. Factor analysis

B.1. The database

Table B.1 – Average data

	Period 1						**Period 2**					
	CA	**Inflation**	**Debt**	**Unemp.**	**Growth**	**Mis**	**CA**	**Inflation**	**Debt**	**Unemp.**	**Growth**	**Mis**
Austria	-0.011	0.033	0.704	0.036	0.023	-0.052	0.018	0.019	0.732	0.047	0.016	0.202
	(0.017)	(0.018)	(0.102)	(0.009)	(0.001)	(0.217)	(0.016)	(0.008)	(0.125)	(0.007)	(0.001)	(0.038)
Belgium	0.019	0.036	1.059	0.089	0.021	-0.017	0.018	0.019	1.013	0.079	0.017	0.046
	(0.031)	(0.026)	(0.182)	(0.014)	(0.001)	(0.048)	(0.024)	(0.011)	(0.102)	(0.006)	(0.001)	(0.057)
Finland	-0.008	0.049	0.450	0.088	0.026	0.024	0.029	0.016	0.453	0.085	0.016	0.092
	(0.033)	(0.035)	(0.213)	(0.047)	(0.001)	(0.143)	(0.035)	(0.011)	(0.115)	(0.010)	(0.001)	(0.076)
France	0.002	0.048	0.682	0.087	0.021	-0.009	0.001	0.014	0.735	0.091	0.014	0.074
	(0.014)	(0.043)	(0.183)	(0.013)	(0.001)	(0.077)	(0.017)	(0.009)	(0.186)	(0.009)	(0.001)	(0.089)
Germany	0.006	0.028	0.656	0.074	0.021	-0.004	0.043	0.014	0.684	0.077	0.013	0.072
	(0.022)	(0.019)	(0.078)	(0.016)	(0.001)	(0.067)	(0.032)	(0.008)	(0.098)	(0.021)	(0.001)	(0.089)
Greece	-0.030	0.160	1.170	0.079	0.013	-0.075	-0.076	0.022	1.284	0.143	0.003	0.191
	(0.016)	(0.062)	(0.277)	(0.021)	(0.001)	(0.086)	(0.048)	(0.019)	(0.311)	(0.071)	(0.001)	(0.103)
Ireland	-0.018	0.061	0.568	0.162	0.048	0.079	-0.010	0.021	0.589	0.080	0.051	0.110
	(0.047)	(0.061)	(0.186)	(0.036)	(0.001)	(0.062)	(0.041)	(0.020)	(0.377)	(0.041)	(0.001)	(0.159)
Italy	-0.004	0.080	1.096	0.091	0.020	-0.051	-0.006	0.018	1.112	0.092	0.003	0.178
	(0.021)	(0.058)	(0.146)	(0.014)	(0.001)	(0.064)	(0.017)	(0.011)	(0.158)	(0.020)	(0.001)	(0.093)
Netherlands	0.032	0.027	0.571	0.082	0.025	0.004	0.065	0.019	0.555	0.044	0.015	0.060
	(0.015)	(0.018)	(0.116)	(0.013)	(0.001)	(0.077)	(0.027)	(0.013)	(0.099)	(0.014)	(0.001)	(0.097)
Portugal	-0.028	0.122	0.726	0.069	0.031	-0.139	-0.072	0.021	0.832	0.089	0.006	0.406
	(0.044)	(0.082)	(0.092)	(0.018)	(0.001)	(0.441)	(0.047)	(0.015)	(0.330)	(0.039)	(0.001)	(0.104)
Spain	-0.014	0.075	0.574	0.155	0.026	0.006	-0.040	0.022	0.610	0.157	0.019	0.097
	(0.015)	(0.042)	(0.173)	(0.033)	(0.001)	(0.100)	(0.037)	(0.015)	(0.261)	(0.061)	(0.001)	(0.096)

Note: Period 1 (resp. 2) corresponds to the 1980-1998 (1999-2016) period. Standard deviations are in parentheses.

B.2. The results

B.2.1. Period: 1980-1998

Table B.2.1.1 — Factor analysis (principal factors, unrotated)

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	1.79817	0.83544	0.6564	0.6564
Factor 2	0.96273	0.46947	0.3514	1.0078
Factor 3	0.49326	0.49570	0.1801	1.1879
Factor 4	-0.00245	0.24153	-0.0009	1.1870
Factor 5	-0.24398	0.02430	-0.0891	1.0979
Factor 6	-0.26828	.	-0.0979	1.0000

Notes: N. obs. = 14; retained factors = 3; N. of params = 15. LR test: *independent* vs. *saturated*: chi2(15) = 20.82; Prob>chi2 = 0.1426. The proportions and cumulative proportions columns are computed using the sum of all eigenvalues as the divisor. This explains cumulative greater than 1.

Table B.2.1.2 — Factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Uniqueness
CA	-0.6271	0.3602	-0.3132	0.3790
Inflation	0.5780	-0.2241	-0.0505	0.6132
Debt	0.7208	-0.2922	-0.1900	0.3590
Unemployment	0.4086	0.3856	0.4125	0.5142
Growth	-0.5052	-0.3400	0.4288	0.4453
Mis	0.3596	0.6581	0.0497	0.4352

Table B.2.1.3 — Factor analysis (principal factors, rotation: orthogonal varimax (Kaiser off))

Factor	Variance	Difference	Proportion	Cumulative
Factor 1	1.49477	0.56347	0.5456	0.5456
Factor 2	0.93130	0.10323	0.3400	0.8856
Factor 3	0.82808	.	0.3023	1.1879

Note: LR test: independent vs. saturated: chi2(15) = 20.82 Prob>chi2 = 0.1426. The proportions and cumulative proportions columns are computed using the sum of all eigenvalues as the divisor. This explains cumulative greater than 1.

Table B.2.1.4 — Rotated factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Uniqueness
CA	-0.7648	-0.1537	0.1117	0.3790
Inflation	0.5841	0.0274	0.2117	0.6132
Debt	0.7130	-0.0475	0.3610	0.3590
Unemployment	0.1879	0.6712	0.0035	0.5142
Growth	-0.1420	-0.1959	-0.7044	0.4453
Mis	-0.0688	0.6448	0.3798	0.4352

Table B.2.1.5 — Factor rotation matrix

Variable	Factor 1	Factor 2	Factor 3
Factor 1	0.8091	0.3799	0.4484
Factor 2	-0.5601	0.7294	0.3928
Factor 3	0.1779	0.5690	-0.8029

Table B.2.1.6 — Country scores on the factors

Country	Scores		
	Factor 1	Factor 2	Factor 3
Austria	-0.1314	-0.3485	0.2882
Belgium	0.0287	-0.0055	0.8777
Finland	-0.3933	0.6349	-0.0379
France	-0.1974	0.3027	0.4071
Germany	-0.4121	0.2030	0.4288
Greece	1.4614	-0.2746	1.0653
Ireland	0.0413	1.5273	-0.9380
Italy	0.6358	-0.0812	0.7774
Netherlands	-0.8481	0.2555	0.3726
Portugal	0.7534	-0.3659	-0.2106
Spain	0.1033	1.1802	-0.1085

B.2.2. Period: 1999-2016

Table B.2.2.1 — Factor analysis (principal factors, unrotated)

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	1.93655	0.51829	0.5975	0.5975
Factor 2	1.41826	1.05895	0.4376	1.0350
Factor 3	0.35931	0.43996	0.1109	1.1459
Factor 4	-0.08065	0.07513	-0.0249	1.1210
Factor 5	-0.15578	0.08059	-0.0481	1.0729
Factor 6	-0.23637	.	-0.0729	1.0000

Notes: N. obs. = 19; retained factors = 3; N. of params = 15. LR test: independent vs. saturated: chi2(15) = 41.81 Prob>chi2 = 0.0002. The proportions and cumulative proportions columns are computed using the sum of all eigenvalues as the divisor. This explains cumulative greater than 1.

Table B.2.2.2 — Factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Uniqueness
CA	-0.4918	-0.6788	-0.1358	0.2789
Inflation	0.7703	0.0588	-0.0419	0.4014
Debt	-0.6201	0.6047	0.0221	0.2494
Unemployment	0.4892	0.6023	-0.2388	0.3410
Growth	0.6910	-0.4311	0.1423	0.3164
Mis	-0.0046	0.1996	0.5112	0.6988

Table B.2.2.3 — Factor analysis (principal factors, rotation: orthogonal varimax (Kaiser off))

Factor	Variance	Difference	Proportion	Cumulative
Factor 1	1.73215	0.13224	0.5344	0.5344
Factor 2	1.59991	1.21785	0.4936	1.0280
Factor 3	0.38206	.	0.1179	1.1459

Notes: N. obs. = 19; retained factors = 3; N. of params = 15. LR test: independent vs. saturated: chi2(15) = 41.81 Prob>chi2 = 0.0002. The proportions and cumulative proportions columns are computed using the sum of all eigenvalues as the divisor. This explains cumulative greater than 1.

Table B.2.2.4 — Rotated factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Uniqueness
CA	0.0115	-0.8167	-0.2325	0.2789
Inflation	0.5684	0.5237	-0.0349	0.4014
Debt	-0.8545	0.0890	0.1122	0.2494
Unemployment	-0.0015	0.7980	-0.1493	0.3410
Growth	0.8202	0.0714	0.0757	0.3164
Mis	-0.0777	0.0948	0.5350	0.6988

Table B.2.2.5 — Factor rotation matrix

Variable	Factor 1	Factor 2	Factor 3
Factor 1	0.7893	0.6140	-0.0028
Factor 2	-0.6071	0.7810	0.1465
Factor 3	0.0921	-0.1140	0.9892

Table B.2.2.6 — Country scores on the factors

Country	Scores		
	Factor 1	Factor 2	Factor 3
Austria	-0.4028	-0.8675	0.2877
Belgium	-0.8397	-0.3891	-0.1807
Finland	-0.0808	-0.6958	-0.5925
France	-0.6286	-0.3139	-0.2989
Germany	-0.5415	-0.9036	-0.5632
Greece	-1.6878	1.4056	0.0155
Ireland	0.7229	-0.2253	0.5022
Italy	-1.3998	-0.0008	-0.0857
Netherlands	-0.1176	-1.4009	-0.4481
Portugal	-0.8742	0.5663	0.7849
Spain	-0.2410	1.0243	-0.7789

C. Cluster analysis: dissimilarity matrices

Table C.1 — Dissimilarity matrix (Measure: Euclidean distance; Period: 1980-1998)

	AUS	**BEL**	**FIN**	**FRA**	**GER**	**GRE**	**IRL**	**ITL**	**NTL**	**POR**	**SPA**
Austria (AUS)	0.000										
Belgium (BEL)	2.633	0.000									
Finland (FIN)	1.275	3.335	0.000								
France (FRA)	2.092	0.837	2.620	0.000							
Germany (GER)	2.113	0.942	3.082	1.160	0.000						
Greece (GRE)	23.459	25.216	22.331	24.522	25.249	0.000					
Ireland (IRL)	3.081	0.707	3.606	1.146	1.569	25.231	0.000				
Italy (ITL)	3.552	5.177	2.449	4.495	5.166	20.091	5.295	0.000			
Netherlands (NTL)	3.091	0.776	3.944	1.513	1.035	25.943	1.161	5.886	0.000		
Portugal (POR)	5.757	6.822	4.600	6.076	7.046	19.043	6.768	3.077	7.563	0.000	
Spain (SPA)	2.388	3.170	1.779	2.586	3.320	22.076	3.257	2.135	3.892	4.294	0.000

Table C.2 — Dissimilarity matrix (Measure: Euclidean distance; Period: 1980-2016)

	AUS	**BEL**	**FIN**	**FRA**	**GER**	**GRE**	**IRL**	**ITL**	**NTL**	**POR**	**SPA**
Austria (AUS)	0.000										
Belgium (BEL)	2.931	0.000									
Finland (FIN)	1.575	3.422	0.000								
France (FRA)	2.302	0.925	2.682	0.000							
Germany (GER)	2.497	1.107	3.146	1.284	0.000						
Greece (GRE)	23.466	25.248	22.365	24.542	25.294	0.000					
Ireland (IRL)	3.755	1.219	3.965	1.723	2.053	25.308	0.000				
Italy (ITL)	3.574	5.300	2.647	4.572	5.331	20.093	5.634	0.000			
Netherlands (NTL)	3.353	0.875	4.005	1.571	1.064	25.980	1.640	6.012	0.000		
Portugal (POR)	5.890	7.250	5.077	6.439	7.489	19.085	7.491	3.354	7.963	0.000	
Spain (SPA)	2.568	3.211	1.962	2.614	3.439	22.090	3.486	2.246	3.958	4.744	0.000

D. The *k*-means clustering

This appendix is devoted to the presentation of the alternative clusters based on the *k*-means procedure. It begins with a brief description of the method before presenting the results.

The *k*-means procedure

In contrast with the HAC analysis used in the core of the paper, the *k*-means procedure belongs to the second family of classification techniques. It proceeds by partitioning n objects into k clusters, each object belonging to the cluster with the nearest mean. The number of clusters, k, is specified *ex ante* by the user, and cluster centers are iteratively estimated from the data. The objective of the *k*-means algorithm is to minimize total intra-cluster variance, or, the squared error function:

$$Min\ F = \sum_{j=1}^{k} \sum_{i=1}^{n} \parallel x_i^{(j)} - c_j \parallel^2 \qquad \text{(D.1)}$$

where F is the objective function; k and n indicate respectively the *ex ante* number of clusters and the number of objects, $\parallel . \parallel$ denotes the distance function; c_j corresponds to the centroid of cluster j and x_i refers to the object i.

The results

In applying the *k*-means procedure, we begin by investigating the number k of clusters that would lead to a clear partitioning of the objects. More specifically, we run the algorithm considering k = 2, 3, and 4. While this could be seemed *ad hoc*, it should be noted that these cases are sufficient to confront the *k*-means-based results with the HAC-based results. The clusters obtained relying on the *k*-means procedure are presented in Figure D.1.

As can be seen, when we impose two clusters (top left chart), Greece, in line with our previous results, appears as an outlier. For k = 3 (i.e., 3 clusters), Austria, Belgium, France, Germany, Ireland and the Netherlands form the core countries group; Finland, Italy, Portugal and Spain constitute a second group while Greece still appears as an outlier. For k = 4, the obtained clusters are the same except that Portugal now appears also as an outlier, between Greece and the peripheral countries.

Overall, except Austria, the obtained clusters are consistent with those of the HAC analysis.

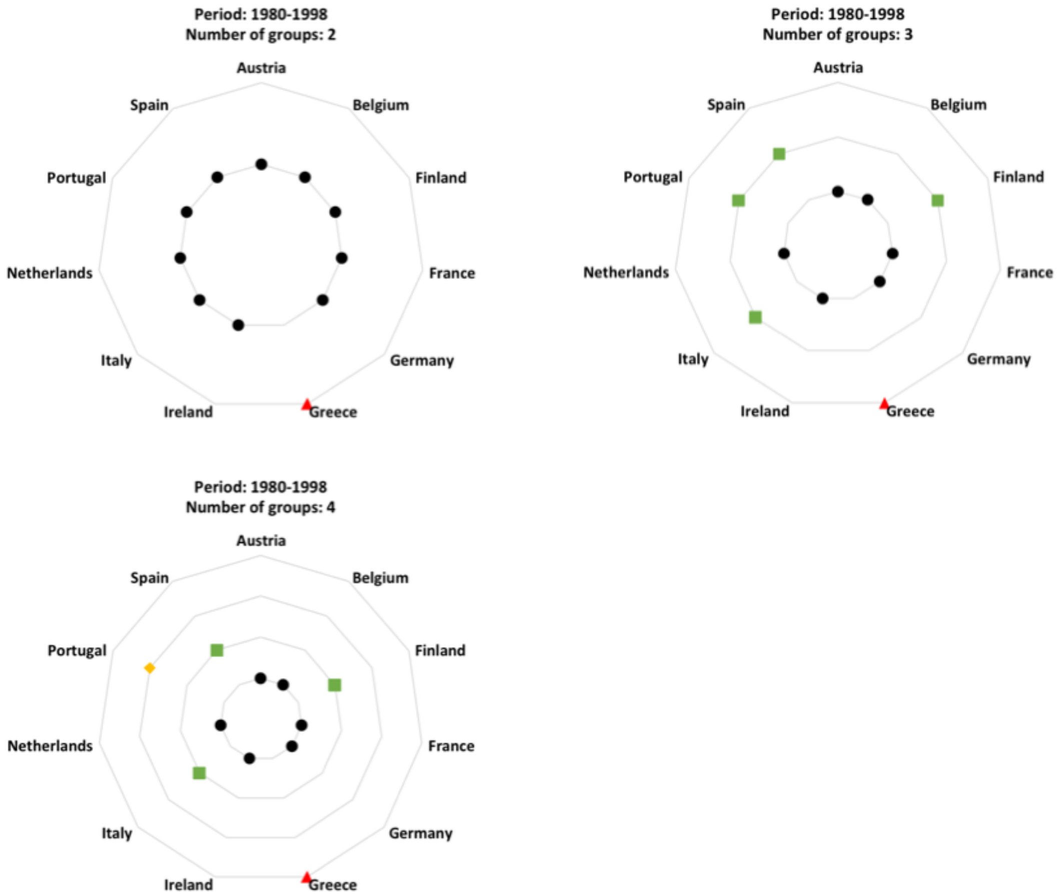

Figure D.1 — *k*-means clustering: the pre-EMU period

For the recursive analysis, we retain $k = 3$. Results are presented in Figure D.2. As can be seen, the clusters obtained are similar to those obtained for the pre-EMU period.

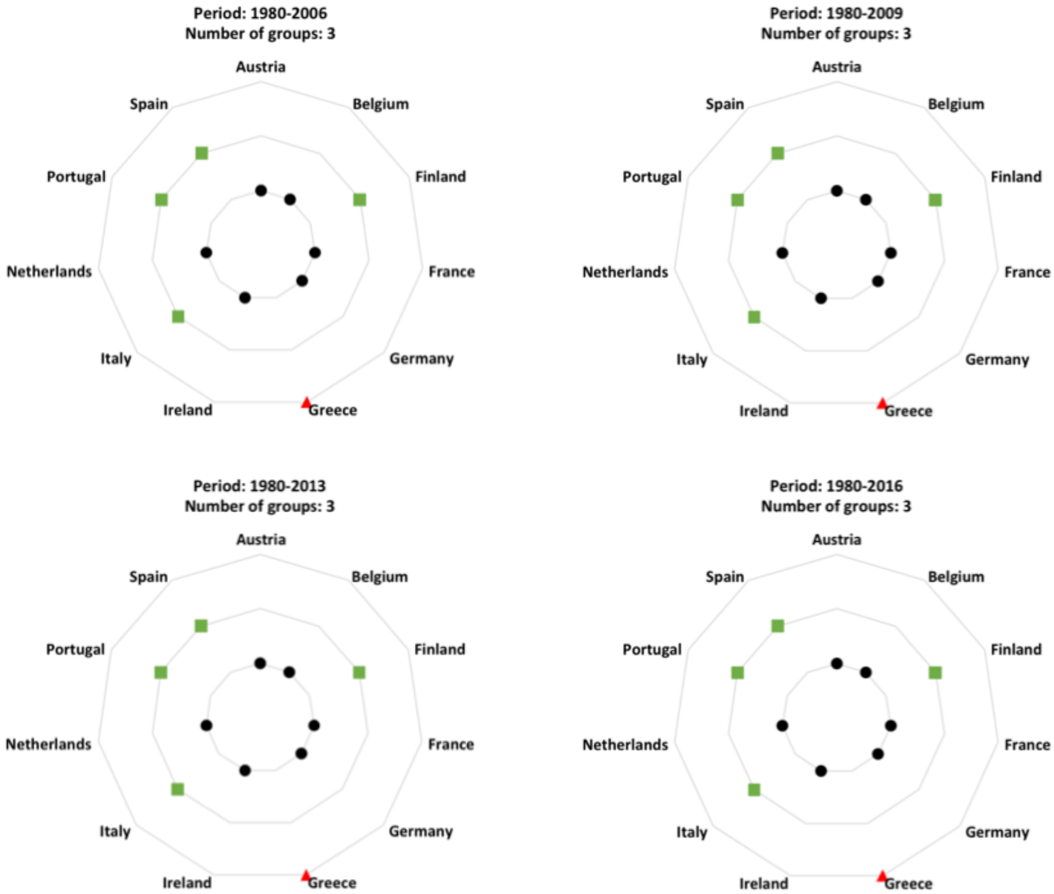

Figure D.2 — *k*-means clustering: recursive analysis