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Real Effective Exchange Rate Misalignment in the Euro Area: A Counterfactual Analysis*

Abstract

Were real effective exchange rates (REER) of Euro area member countries drastically misaligned at the outbreak of the global financial crisis? The answer is difficult to determine because economic theory gives no simple guideline for determining the equilibrium values of real exchange rates, and the determinants of those values might have been distorted as well. To overcome these limitations, we use synthetic matching to construct a counterfactual economy for each member as a linear combination of a large set of non-Euro area countries. We find that Euro area crisis countries are best described by a mixture of advanced and emerging economies. Comparing the actual REER with those of the counterfactuals gives sensible estimates of the misalignments at the start of the crisis: All peripheral countries were strongly overvalued, while high undervaluation is only observed for Finland.

Keywords: REER misalignment; Euro breakup; synthetic matching

JEL Classification: C22, F41, G14

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Eine kontrafaktische Analyse zu Fehlbewertungen realer effektiver Wechselkurse im Euroraum*

Zusammenfassung

Waren reale effektive Wechselkurse der Euroländer beim Ausbruch der globalen Finanzkrise dramatisch fehlbewertet? Die Antwort auf diese Frage ist nicht einfach, da die theoretischen Grundlagen der Herleitung gleichgewichtiger realer Wechselkurse umstritten sind. Auch waren die meisten möglichen Bestimmungsfaktoren kurz vor der Krise selbst nicht im Gleichgewicht und lassen daher auch keinen Schluss auf reale effektive Wechselkurse zu. Im Papier wird synthetisches Matching verwandt, um diese Probleme zu umgehen. Dazu wird für jedes frühe Mitgliedsland des Euroraums ein synthetisches Vergleichsland als Kombination mehrerer anderer Länder konstruiert, die den Euro nicht eingeführt haben. Die Peripherieländer des Euroraums werden am besten durch eine Mischung von Entwicklungsländern und entwickelten Volkswirtschaften beschrieben, während für das Matching der Kernländer kein Entwicklungsland notwendig ist. Unsere Methode zeigt, dass reale effektive Wechselkurse in den Peripherieländern zwischen Oktober 2007 und September 2008 teilweise deutlich überbewertet waren, während die der Kernländer mehr oder weniger nah bei ihrem Gleichgewichtsniveau lagen.

Schlagwörter: Fehlbewertungen realer effektiver Wechselkurse, Zerfall des Euroraums, synthetisches Matching

JEL-Klassifikation: C22, F41, G14

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1 Introduction

Before the introduction of the Euro, many economists warned that the sacrifice of exchange rates as an adjustment mechanism might come at a high cost. These concerns were quickly forgotten due to the seeming success of the European Monetary Union. In particular, the countries in the periphery of the Euro area, such as Greece and Portugal, experienced a decade of growing prosperity. It was not until the turmoil in the financial markets initiated by the collapse of the real estate bubble in the US that the severe imbalances that had accumulated over the first decade of the Euro were revealed.[1] While capital flows from the core Euro area countries to the emerging periphery were considered to be one of the benefits of the Euro until the eve of the crisis, the crisis has shown that these capital flows as well as the corresponding current account surpluses in the core (and deficits in the periphery) actually went hand in hand with a severe misalignment of the real exchange rate.

There are two conflicting narratives on the nature of the misalignment. Many economists such as Sinn (2014) focus on the overvaluation of the real effective exchange rate (REER) of periphery countries, most notably Greece. Joining the Euro area essentially gave all Euro area countries access to the global capital market at the interest rate that had previously been paid by the most stable and wealthy countries in Europe. This caused a debt-financed increase in consumption, prices and wages that was not backed by corresponding economic development. This real appreciation induced a loss of competitiveness that now hinders economic recovery. The alternative narrative that has , among others, been proposed by de Grauwe (2009) , focuses (additionally) on German undervaluation. Because German unions accepted low wages ("Lohnzurückhaltung") during the 2000s, Germany experienced a real depreciation compared to the remaining Euro area, thereby widening its current account surplus and enforcing corresponding deficits in the periphery.

Identifying the true source of the misalignment is crucially linked to the concept of an equilibrium real effective exchange rate. Equilibrium in this context does not mean an exchange rate that clears the foreign exchange market on a day-to-day basis. Misalignment is rather defined as the distance from a medium-run equilibrium of the exchange rate that is compatible with macroeconomic equilibrium, with an output gap close to zero, and economic expectations as well as valuations of asset prices that are fundamentally justified.[2] It is difficult to determine an equilibrium effective exchange rate – if it were not, forecasting exchange rate movements would be much easier than it in fact is (Frankel & Rose 1995, Kilian & Taylor 2003). However, in the medium run, although misalignment can be rather persistent, exchange rates tend to move in the direction of their equilibrium. Nevertheless, or rather therefore, there is a rich body of literature on different approaches to determining equilibrium real effective exchange rates, see e.g., Driver & Westaway (2004) for a survey.[3]

[1] For more details on trade imbalances in the Euro area, see Berger & Nitsch (2010). In a broader context, Knedlik & von Schweinitz (2012) and El-Shagi, Knedlik & von Schweinitz (2013) relate a variety of macroeconomic balances to the European sovereign debt crisis.

[2] According to much of the literature, an exchange rate is at its **long-run** equilibrium if it is compatible with the steady state of an economy that is characterized by constant relations between stocks (e.g., foreign assets) and flows (e.g., current account balances) (Driver & Westaway 2004).

[3] Some of these approaches are given by Clark & MacDonald (1998), Clark & MacDonald (2004), and Barisone, Driver & Wren-Lewis (2006).

Important elements are purchasing-power parities, sometimes enhanced by the Balassa-Samuelson effect, estimates of the sustainability of the current account balances (Lee, Ostry, Milesi-Ferretti, Ricci & Prati 2008)), and reduced-form equilibria (Holtemöller & Mallick 2013). In a few cases, these concepts have been used to answer the question at hand. Using Fundamental Equilibrium Exchange Rates (FEER), Jeong, Mazier & Saadaoui (2010) find no misalignments of REER at the European level, but they do find misalignments individually in periphery countries. A similar result is obtained by Coudert, Couharde & Mignon (2013) using behavioral equilibrium exchange rates (BEER, expected to hold at comparably short horizons). Both studies employ a cointegration relationship between the REER and few basic macroeconomic variables such as net foreign assets to calculate an equilibrium REER.

It is, however, far from clear whether the equilibrium real effective exchange rates estimated on the basis of the FEER or BEER approaches are suitable benchmarks for misalignments. Basic macroeconomic fundamentals in the Euro area that determine the equilibrium exchange rates were possibly as misaligned as the exchange rate itself (Knedlik & von Schweinitz 2012). Moreover, both studies use trade models as a foundation for their analysis, thereby abstracting from other potential sources of misalignments.

To avoid these problems, we propose to identify misalignments with an approach that depends neither on a specific theoretical background nor on macroeconomic data that might possibly be misaligned by the creation of the currency union. Instead, we use synthetic matching, which works as follows: the effect of a treatment, in this case, the introduction of the Euro, is estimated by comparing the time path of the variable of interest (here, the REER) with that of a counterfactual counterpart to the treatment subject (i.e., a counterpart to each of the Euro area member countries). This counterpart is a weighted average of subjects (here, of other economies outside of the Euro area) that did not experience the treatment. It is most likely safe to assume that these other economies are not subject to the simultaneous misalignments of several fundamentals that could affect a cointegration analysis. In principle, such counterfactual economies could be chosen by preselecting matching subjects that appear to be economically similar (Hsiao, Ching & Wan 2012). However, in a study of EU-12 countries, the set of potential matching candidates that are intuitively convincing is rather small. Therefore, we follow an alternative approach by Abadie & Gardeazabal (2003), who additionally match a (weighted) set of economic criteria:[4] the weights for the economies forming the counterfactual counterpart are chosen in such a way that this counterpart matches as closely as possible to the treatment economy not only in terms of the pre-treatment development of the variable of interest (in our case, the REER) but also in a set of general economic criteria that might be of importance for this variable. The weighting of these criteria (i.e., their respective importance) is such that the movement of the counterfactual economies' REER mimics that of the treatment economies in the period

[4]Synthetic matching has been used in a number of studies to determine, among others, ETA's negative effect on Basque GDP (Abadie & Gardeazabal 2003), the effect of a Californian tobacco control program on tobacco consumption (Abadie, Diamond & Hainmueller 2010), the effect of natural catastrophes on GDP (Cavallo, Galiani, Noy & Pantano 2013), the effect of German unification on West German GDP (Abadie, Diamond & Hainmueller 2014)or the benefits of membership within the European Union (Campos, Coricelli & Moretti 2014)

before the currency union as closely as possible. Thus, the implicit definition of similarity implies similarity with respect to indicators that matter to the REER. By using a large set of indicators that reflect different theories and narratives on real exchange rate development, we remain agnostic concerning the question of which theory is actually true and are able to host an abundance of potential explanations.

Other than Abadie & Gardeazabal, we consider several treated countries. To have consistent definitions of similarity to be used in the constructions of the synthetic matching countries for each treatment economy, we maintain the importance of criteria identical for all treated countries. To this end a panel version of the synthetic matching algorithm is developed.

We find that Portugal, Greece, and Ireland were strongly overvalued shortly before the outbreak of the great financial crisis. For Portugal and Greece, the overvaluation grew since the introduction of the Euro and has proven to be extremely persistent. Core countries, on the other hand, do not display significant undervaluation (with the possible exception of Finland). Misalignments are in general found to be bigger than in the previous literature, which is possibly due to the above-mentioned problem of simultaneous misalignments in other fundamental variables used in cointegration analyses. However, our results broadly confirm previous estimations. In terms of the composition of counterfactual countries, the core countries can be best approximated by a mixture of advanced economies, while developing countries (or a large share of newly advanced economies) are needed to reproduce periphery countries.

The remainder of the paper is structured as follows. Section 2 summarizes the data we use. Section 3 outlines the synthetic-matching algorithm. In section 4, we present our results, and section 5 concludes.

2 Data: the selection of candidate countries and dimensions of similarity

Our key variable is the seasonally adjusted monthly REER based on consumer price indices as reported by the IMF in its International Financial Statistics (IFS).[5] Our data begin in January 1980 and end in the current margin (September 2013). For the matching process, we use data up to the introduction of the Euro (1999 for the founding countries of the common currency and 2001 for Greece).

We consider 25 transformations of a range of economic and political indicators to identify structurally similar economies in our matching approach.

We aim to find synthetic matches for all founding members of the Euro area except for Luxembourg[6] and Greece. All countries that did not enter the Euro area at a later point and

[5]For those countries for which the IFS only reports seasonally unadjusted data, we apply seasonal adjustment ourselves.

[6]Synthetic matching adds the restriction of matching criteria to the calculation of a counterfactual. That is, it is by definition not possible to construct a clear counterfactual for a treatment country whose matching criteria lie outside the convex hull of matching criteria in candidate countries if country weights are required to be positive (Abadie et al. 2014). Luxembourg will be left out of the analysis because its GDP/person (the

for which both the REER data starting in 1980 and the selected matching criteria are available are considered as candidate countries for matching. Altogether, our candidate countries include twelve advanced countries (Canada, Denmark, Iceland, Israel, Japan, New Zealand, Norway, Singapore, Sweden, Switzerland, the United Kingdom, and the United States) and eleven emerging market countries (Brazil, Chile, China, Colombia, Iran, Malaysia, Mexico, Morocco, South Africa, Tunisia, and Venezuela), following the classification of the World Economic Outlook (IMF 2013). Singapore and Israel are a special case among the advanced economies, as they were developing countries before 1997 (IMF 1997).

To apply synthetic matching, it is essential to clearly identify a treatment. By including Denmark and the United Kingdom in the list of eligible candidate countries for matching and by choosing the treatment time of the year 1999 (or 2001 in the case of Greece), we implicitly assume that members of the European Exchange Rate Mechanism (ERM) and its successor, ERM II, can be considered untreated, although this implied pegging the respective currencies in a narrow band to each other. If ERM II membership was a close substitute for membership in the European Monetary Union, candidate countries that are ERM members would imply that the counterfactual countries that we generate in our matching approach are no longer untreated. The analogy is true if the introduction of the Euro had adverse effects on ERM members who opted out of adopting the Euro. The counterfactual would no longer represent an untreated economy but rather an economy with an alternative treatment. Similarly, if ERM membership of Euro area countries had an effect before the introduction of the Euro, this would imply that we match the countries at a time when they are already treated. In most of those cases, though, the approach is not rendered completely invalid. Unless there is an adverse effect of the Euro introduction on ERM members who do not join the Euro, the effects of the introduction of the Euro will merely be underestimated, as noted by Campos et al. (2014). That is, our analysis likely provides conservative estimates.

However, it seems to be economically reasonable to strongly distinguish between the Euro as a joint currency and the ERM. First, joining the ERM was a rather small step for most countries. Denmark already had a fixed exchange rate between June 1982 and 1999 vis-à-vis the German D-mark. Similarly, the exchange rate regimes of Sweden and the United Kingdom remained virtually unchanged. Thus, introducing the ERM was mostly a nominal change. At the same time, many other countries outside the ERM similarly have a currency peg. However, pegging the exchange rate is not the same thing as having a joint currency. In particular, the experience during the European currency crisis of 1992 shows that the system was by far not as binding as the Euro was. More importantly, the behavior of the Bundesbank, who opted to stabilize prices in Germany after the German reunification by increasing the interest rate despite an economic environment that required low interest rates for most ERM members reveals that the ERM was a de facto unilateral peg of other countries vis-à-vis the German D-mark. As a consequence, several currencies were realigned, Italy left the ERM, and the bandwidth for fluctuation increased. A similar conclusion can be drawn from the fact that Greece, during its short membership of two years in the ERM II, lowered its Euro central rate (the middle of the exchange rate band) by approximately 3.5% in January 2000. Contrarily, the ECB and the other Euro area members made great sacrifices to allow the European periphery countries to maintain their Euro membership despite the

highest in the world) and several other important criteria cannot be matched.

apparent misalignment within the Euro area. Thus, membership in the ERM was unlikely to produce a treatment effect as experienced due to the introduction of the Euro.

One of the few pieces of evidence suggesting otherwise is that interest rates on government bonds started converging before the introduction of the Euro (Codogno, Favero & Missale 2003). However, this convergence mostly happened in capital market-related variables in the few years directly before the introduction of the common currency. Because we use a large set of criteria (not including these variables) from 1980 onwards, we can assume that the weight of the changes induced by the expectation of the introduction of the Euro is comparably small.

Finally, with respect to the possibility that ERM members who chose not to introduce the Euro (such as the UK and Denmark) received a simultaneous treatment with the introduction of the Euro, empirical findings in the recent literature suggests otherwise. These econometric analyses find that the introduction of the Euro did not change the relations of different macroeconomic fundamentals. Examples include several studies on the potential benefits of joining the Euro, such as Pesaran, Smith & Smith (2007) and Ferreira-Lopes (2010).

The set of variables used to identify similar countries includes variables on macroeconomic, structural and political/institutional development. Because macroeconomic and structural development interacts strongly with the exchange rate, these indicators are only matched for the time before the introduction of the Euro. The more persistent political variables are matched for the whole time before and after the introduction of the Euro if data are available.

Rather than matching the entire time series of the criteria, we focus on summary statistics, most importantly, the mean (Abadie & Gardeazabal 2003). In the case of GDP, we also consider growth and its standard deviation to capture economic development and the volatility of the business cycle. Similarly, we use the standard deviation of FDI in a robustness check to capture the possibility of sudden stops. For growth rates and standard deviations, we require that data are available for at least five years in the sample. For the mean, we require only one year of data. This restriction, however, is only binding for rather persistent capital controls before the introduction of the Euro and government debt in Venezuela.[7]

Table 1 summarizes all indicators used with their transformation and their respective sources. Descriptive statistics are presented in Table A1 in the appendix. The correlation is particularly high for political variables; see Table A2 in the appendix. The results are remarkably robust to the selection of criteria; see section 4.3.

Macroeconomic variables: The overall strength and dynamics of the economy are reflected in the GDP per person as well as in the rate and volatility of GDP growth. This guarantees that countries are matched with counterfactuals of similar prosperity, capturing the channel via the Balassa-Samuelson effect. Other important macroeconomic determinants are current account positions and government debt. We also include the shares of investment (capital formation) in GDP during the era before the Euro was introduced. Because investment increases the potential output with some lag, important foundations for growth

[7]Another matching criterion with low data availability is the share of fuel in total exports in the case of in Iran, for which data are only available for two years.

Table 1: Variables: fitting periods and sources

Variable	1980 – Euro	Euro – 2012	Data source
Variable of interest			
REER	x		IMF-IFS
Macroeconomic variables			
GDP/person	x		WEO
Growth of GDP/person	x		WEO, own calculations
Volatility of GDP growth	x		WEO, own calculations
Inflation*	x		WDI
Gov. Debt	x		WEO
Current Account	x		WEO
Capital Formation	x		WDI
FDI/GDP*	x		WEO
Volatility of FDI/GDP*	x		WEO, own calculations
Structural variables			
Share of Agriculture	x		WDI
Share of Industry	x		WDI
Share of Services	x		WDI
Exports/GDP	x		OECD/World Bank
Fuel Exports/Total Exports	x		WDI
Tradables/GDP*	x		WTO/WDI
Political variables			
Share of Public Sector		x	WDI
Human Capital Index	x	x	PWT
Gini		x	OECD/Eurostat
Credit regulations	x	x	EFW
Capital controls	x	x	IWH-CC
Trade barriers (w/o customs)		x	EFW
Economic freedom indicator	x	x	EFW
Corruption		x	Transparency
Ease-of-doing-business-indicator		x	EODB
Labor market rigidities		x	EFW

Note: WEO stands for the *World Economic Outlook*, *WDI* for the *World Development Indicators*, both provided by the World Bank. *WTO* denotes data from the world trade organization. *PWT* are the Penn World Tables. *EFW* are data sources from the *Economic Freedom of the World*. *EODB* is the *Ease of Doing Business Business*-Database. *IWH-CC* is the database on capital controls described in El-Shagi (2012). Data on government debt in Brazil and Israel before 2000 are drawn from Oxford Economics.
*: only used in robustness checks.

during the early 2000s had most likely been laid during the previous decade. Similar investment shares in this period therefore indicate a similar potential for economic development (Rogoff 1996).

To further capture the potential for sudden stops (Calvo, Izquierdo & Talvi 2003), we use average foreign direct investment and its volatility. However, because data are not available for Belgium before the introduction of the Euro, we can only include these two criteria in a robustness check by excluding this country; see section 4.3.

While inflation is one of the key variables of economic development, it is also by definition a main component of the variable of interest, the real effective exchange rate. Thus, the inclusion of inflation might entail the danger of giving too much weight to countries that had a path of inflation that was similar to that of the treatment country by chance instead of structural similarity. Therefore, average inflation (measured as growth rate of the GDP deflator) is only used in a robustness check; see section 4.3.

Structural variables: Changes in the real exchange rates are driven by changing global prices for the goods and services a country specializes in. It therefore appears to be important to find synthetic matches with comparable structures of supply and demand before the introduction of the Euro (Rodrik 2008). To capture this, we include the share of exports in GDP, the sectoral shares in the economy (agriculture, industry, and services), and the share of fuel exports in total exports.[8]

The decomposition of the economy used in our setting is not exactly equivalent (although correlated) to the separation of tradable and non-tradable goods underlying the Balassa-Samuelson effect. However, data on tradables are not available for Belgium. We use this indicator in the robustness check excluding Belgium.

Political variables: Finally, we include a block of institutional indicators in our database. Contrary to the macroeconomic and structural indicators, the means of those political variables for the whole time before and after the introduction of the Euro are used. A similar institutional level of development for the synthetic counterpart appears to be particularly important to finding adequate matches for peripheral countries. Easy access to capital, which is crucial for their seemingly strong economic performance, was made possible by the beliefs of financial investors that these countries by and large shared the institutional soundness of the Euro area core. Only after the outbreak of the financial crisis did it become apparent that many of the institutional problems found in peripheral countries before the introduction of the Euro prevailed.

The selection of political variables is mainly inspired by the findings of Rodrik (2008) that bad institutions and market failures affect tradable goods stronger than non-tradable goods. The selected variables encompass a wide array of indicators and coefficients. They include the size of the government sector, equality (Gini), corruption, measured as the corruption perception index, as well as general and specific economic freedoms: the ease of doing business, economic freedom, credit regulations, capital controls, trade barriers and labor market regulations.

[8]Among other variables, the price of oil is used as a determinant of REER by MacDonald (1998). In our setting, this corresponds to the dependence of the economy on oil and related exports.

3 Estimation technique

The general idea behind the synthetic matching approach by Abadie & Gardeazabal (2003) is to match countries receiving a treatment by a counterfactual counterpart that is not subject to the treatment. This counterfactual is a weighted average of a set of candidate countries that meets two objectives: Similarity with respect to a large set of relevant dimensions (matching criteria) and the similarity of the pre-treatment development of the variable of interest (in our case, the REER) before the introduction of the Euro.[9]

The weights of control group countries in the construction of the counterfactual are chosen to mimic the characteristics of a treated economy in terms of matching criteria. Technically, this means that a weighted sum of the squared differences of those matching criteria in the treated country and its counterfactual is minimized. The weights of the squared differences, i.e., the importance of matching the criteria for the definition of similarity, are chosen to guarantee that the counterfactuals also mimic the development of the REERs before the introduction of the Euro in the treated countries. That is, while the vector of country weights w_i is individually estimated for every treated country i, there is only one set of weights v (reflecting the importance of matching criteria for the REER) that is shared by all countries.[10]

Thus, for each of the N_1 treated economies (indexed i), given a diagonal matrix V of the vector of M criteria weights v, we compute a vector w_i containing N_0 country weights (indexed n) by:

$$\begin{aligned} w_i^*(V) &= \operatorname{argmin}\left\{(X_{i,1} - X_0 w_i)' V (X_{i,1} - X_0 w_i)\right\} \\ s.t. & \\ w_{i,n}^*(V) &\geq 0, \text{ for } n = \{1, \ldots, N_0\} \\ \sum_{n=1}^{N} w_{i,n}^*(V) &= 1, \end{aligned} \tag{1}$$

where $X_{i,1}$ is the $(M \times 1)$-vector of matching criteria for treated economy i and X_0 is the $(M \times N_0)$-matrix of matching criteria for the N_0 candidate countries.

Denoting the REER in the treated economy i by the $(T \times 1)$-vector $Z_{i,1}$ (T being the time of the treatment) and the REER of candidate countries by the $(T \times N_0)$-matrix Z_0, we estimate

[9] An alternative is the related method of Hsiao et al. (2012). These authors do not condition weights on a number of additional criteria. Instead, the candidate countries are preselected using economic similarity before the treatment. However, the number of countries that can be convincingly described as "similar" to countries of the European monetary union (EMU) is rather limited. On the other hand, it might well be possible that the average of two quite different countries that would not be included by Hsiao et al. (2012) reproduces countries in the EMU rather well. Therefore, the "agnostic" method of Abadie & Gardeazabal (2003), using additional matching criteria for the selection of the counterfactual, offers a great advantage.

[10] This is particularly important because the candidate countries are the same for all treated economies. When matching, we implicitly assume that the importance of matching criteria for the REER is the same for the treated economy and the candidate economies. Thus, having the same candidate countries implies the equal importance of matching criteria for all treated economies.

the importance matrix V by minimizing the total sum of squared residuals over all treated economies:[11]

$$\begin{aligned} V^* &= \operatorname{argmin} \left\{ \sum_{i=1}^{N_1} (Z_{i,1} - Z_0 w_i^*(V))'(Z_{i,1} - Z_0 w_i^*(V)) \right\} \\ s.t. & \\ v_m^* &\geq 0, \text{ for } m = \{1, \ldots, M\} \\ \sum_{m=1}^{M} v_m^* &= 1. \end{aligned} \tag{2}$$

Unfortunately, the second equation cannot be solved with simple quadratic programming. Instead, we need search algorithms that optimize V. These search algorithms employ a starting value $V^{(0)}$. Ideally, the obtained result should be independent of the starting value. However, in practice, this is not always the case if the surface of the function optimized in (2) is highly irregular. The current application is one of those cases. This seems to be mostly due to the multicollinearity of the matching criteria.[12]

Therefore, instead of using a set of multicollinear economic indicators, we employ the first few principal components of a large set of indicators as matching criteria. This benefits the estimation twofold. First, the principal components are orthogonal by construction, thereby avoiding the multicollinearity problem. Second, this procedure allows a substantial reduction in the dimensionality of the data without losing too much information. This greatly simplifies the surface of the objective function (i.e., the sum of squared residuals) and makes estimation feasible.

We use the first six principal components (those with an Eigenvalues greater or equal to 1). In our dataset, this implies that more than 80% of the total variation is explained. Because most of the information in the dataset is used, this should have no major impact on the optimum results.

Still, the likelihood surface is both flat and irregular. We therefore run the optimization $20,000$ times with different randomized starting values $V^{(0)}$.[13] We find that the best results from blocks of $1,000$ optimizations exhibit similar behaviors of the counterfactual REER before and (more importantly) after the introduction of the Euro. This is mostly due to several highly similar candidate countries (such as the Nordic countries). Therefore, while there might be some uncertainty about which of those countries to include in the counterfactual, the resulting difference in the REER is small.

[11] To be uniquely identified, one restriction needs to be imposed on the diagonal of V. We set the sum of importance weights to 1.

[12] Abadie & Gardeazabal (2003) have a similar problem, although it is more severe in our context due to a lower correlation of the variable of interest in the treated and candidate countries (on average, the correlation of REER is close to zero) and a higher number of matching criteria.

[13] We tested whether a two-step optimization with a genetic algorithm to find a population of good results, using those as starting values for further optimization, led to more stable results. Similarly, we tried to reduce the problem of multicollinearity by using ridge regressions. Both alternatives increased the complexity and run time, but did not improve the results.

The REER of the resulting counterfactual country is then used as a benchmark to assess the size of the misalignments at each point in time after the introduction of the Euro (i.e., at time $T+1, T+2, \ldots$).

We use placebo treatments in January 1999 for candidate countries to assess the significance of misalignments (Abadie et al. 2010, Cavallo et al. 2013). [14] That is, for every candidate country, we calculate a synthetic counterpart, just as we do for the treatment countries. Because neither candidate countries nor their synthetic counterparts introduced the Euro, they are not subject to the treatment effect. Thus, the resulting differences in the development of the (observed and synthetic) REER give an empirical distribution of differences under the null hypothesis of no significant misalignment. This empirical distribution can then be used to obtain p-values for every Euro country and month after the introduction of the Euro.[15] We always employ a one-sided hypothesis: for core countries (Austria, Belgium, Finland, France, Germany and the Netherlands), we test whether the REER is significantly undervalued; for periphery countries (Greece, Ireland, Italy, Portugal and Spain), we test whether the REER is significantly overvalued.

We deviate from the usual estimation of the p-values in the literature in two respects. First, we follow the motivation of the panel synthetic matching that the importance of matching criteria (or their principal components) should be identical for all countries. Therefore, we employ V^* from the estimation of treated countries for the pseudo-treatments as well. Second, to account for differences in the fit for different countries, we normalize all misalignments using the standard deviation of errors from Equation (2), an adjustment also used by Acemoglu, Johnson, Kermani, Kwak & Mitton (2013). That is, our measure accounts for the goodness of fit of the REER before the introduction of the Euro both in treated and control group countries. A significant rejection therefore implies that the misalignment is unusually large compared to the estimation errors before the introduction of the Euro.

However, while this procedure offers some insight if misalignments are severe and significant, the sample size of 23 candidate countries is far too small to infer exact p-values, prohibiting for example the use of the bootstrap method of Acemoglu et al. (2013). A rejection at lower p-values (reducing the size of the test) implies a strong reduction in test power (Davidson & MacKinnon 2000). This problem can be slightly alleviated by testing the significance of misalignments over multiple periods by using multiple-hypothesis tests. We use two of them. First, we use a Bonferoni-type test showing if the misalignment is significant in at least one of the periods (Rom 1990). Second, we use a Fisher-type test showing if the misalignments are jointly significant over multiple periods (Maddala & Wu 1999). Bonferoni-type tests are usually extremely conservative, while Fisher-type tests do not account for the correlation of test statistics. Therefore, these two tests can be seen as upper and lower bounds on true p-values.

[14] An alternative would be the difference-in-difference approach of Campos et al. (2014). Such an approach would test if REERs were on average misaligned after the introduction of the Euro. However, we expect misalignments in the REER to develop slowly over time, instead of experiencing a one-time shift after the introduction of the Euro.

[15] The p-values for Greece are obtained from a placebo treatment of candidate countries as of January 2001.

4 Results

4.1 Fit of the variable of interest

Figures 1 and 2 show how the counterfactual and the actual real effective exchange rates have developed since 1980 in core and peripheral countries. Table 2 gives the average misalignments of the REER for selected subperiods: (1) The period before the introduction of the Euro, where the logarithm of the REER is fitted. (2) The period from the introduction of the Euro to the crash of Lehman Brothers in September 2008, where misalignments slowly unfolded. (3) The period since the great financial crisis, where the slow reduction of imbalances can be observed. (4) As our main period of interest, the year before the crash of Lehman Brothers, from October 2007 to September 2008.). Misalignments during such a period of growing market uncertainty are particularly dangerous, as they might lead to sudden stops of capital inflows.

Before 1999, the counterfactual series fit the actual ones reasonably well, except for some extreme movements due to major political events: the REER of Germany markedly appreciated in the years after reunification in 1990, while the REER of Finland declined by more than one-third when the Soviet Union, its neighbor and major trading partner, collapsed in 1991. The strong appreciation of the Italian REER after 1985 and its collapse in 1992 was a politically induced disturbance as well: the exchange rate of the Italian lira was, contrary to fundamentals, kept fixed inside the European Monetary System until the peg could no longer be defended, and Italy left the System in autumn 1992. Afterwards, the lira undershot for a while, but in 1999, when the monetary union started, the Italian REER was close to the level of its counterfactual, as it was in 1980.

The focus of this paper is, however, on real exchange rate developments since the start of the monetary union in 1999. Here, the depreciation of the Euro during 1999 and 2000 as well as its marked appreciation in the years 2002 to 2004 are visible in the time paths for all actual real effective exchange rates except for that of Greece (Jeong et al. 2010). Greece, Ireland, Portugal, and Spain continue appreciating after 2004 right up to the crisis. Interestingly, the depreciation and the following recovery of the Euro between 1999 and 2004 are reproduced by a number of synthetic countries, although our matching approach does not account for the fit between the two exchange rates after 1999.

Of particular interest is the degree of misalignment of the real effective exchange rates when the crisis unfolded between autumn 2007 and autumn 2008. When looking at the data, it appears sensible to identify three groups (see the last row of Table 2 and Figure 3):

1. Economies that were undervalued relative to their counterfactual values (Finland by approximately 15%) or had a real effective exchange rate that was close to its counterfactual with a divergence of less than ±4%: Belgium, Germany, the Netherlands, and Austria.

2. Economies with REERs that were somewhat overvalued (by between 6% and 7.5%): Spain, Italy, and France.

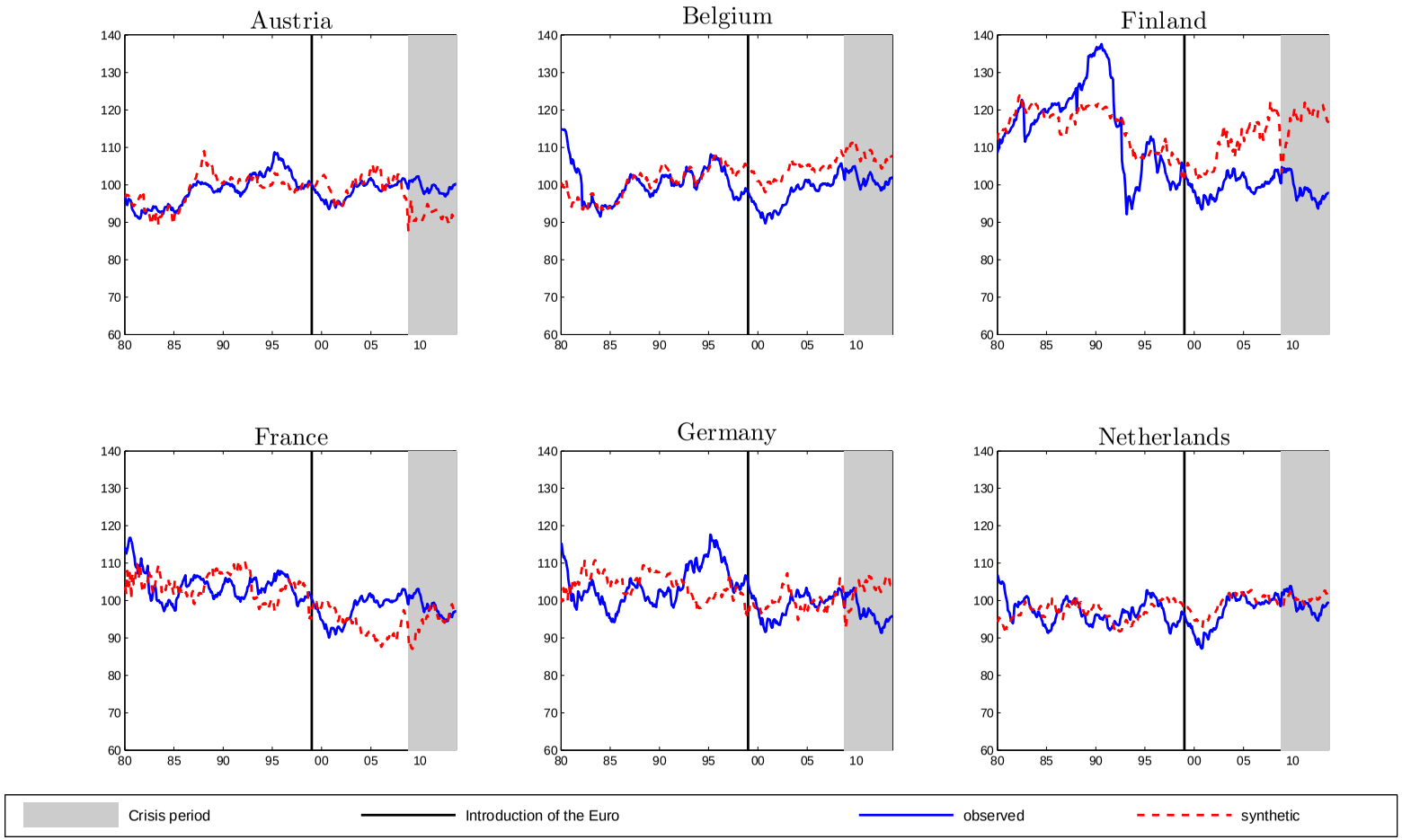

Figure 1: Original (blue) and synthetic (red) development of the REER in core Euro countries from 1980 to 2012. The black line indicates the introduction of the Euro, and the gray area indicates the period of the current crisis.

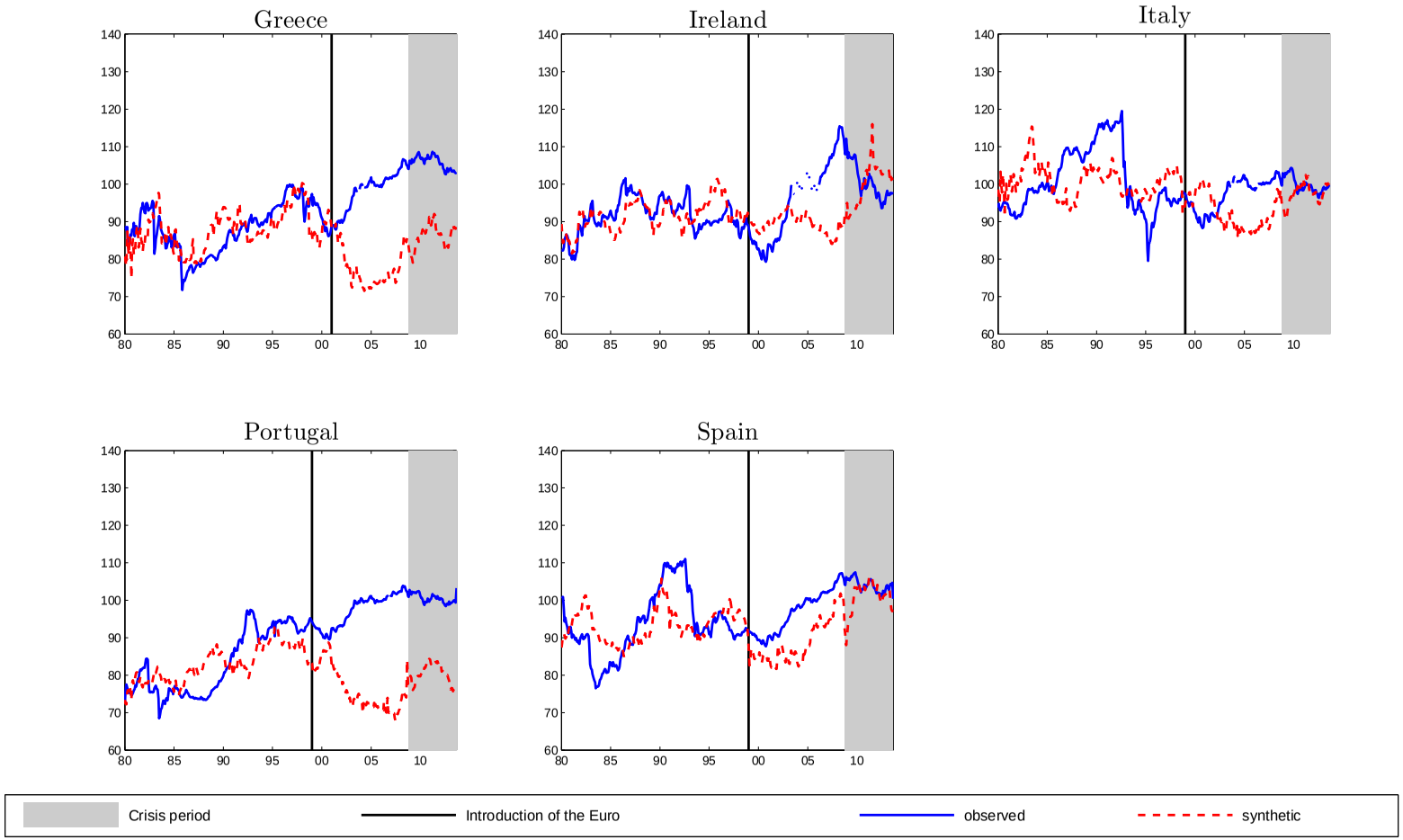

Figure 2: Original (blue) and synthetic (red) development of the REER in peripheral Euro countries from 1980 to 2012. The black line indicates the introduction of the Euro, and the gray area indicates the period of the current crisis.

3. Economies with REERs that were highly (by more than 20%) and significantly overvalued: Greece, Ireland, and Portugal.

Table 2: Deviation of synthetic from the observed REER

Average Deviation	Austria	Belgium	Finland	France	Germany	Netherlands
Pre Euro	-0.05%	-0.07%	-0.23%	-0.15%	-0.29%	-0.08%
Euro – Sep 08	-1.75%†	-6.53%†††	-10.91%††	3.71%	-1.08%	-2.64%
Oct 08 – Sep 13	7.48%	-6.28%††	-18.8%†††	3.63%	-6.26%	-1.59%
Oct 07 – Sep 08	2.69%	-3.92%	-15.47%†††	7.21%	-1.24%	0.92%

Average Deviation	Greece	Ireland	Italy	Portugal	Spain
Pre Euro	-0.19%	-0.12%	-0.42%	-0.37%	-0.36%
Euro – Sep 08	20.43%†††	4.26%	4.52%†††	21.44%†††	8.19%†††
Oct 08 – Sep 13	18.53%**†††	0.44%††	2.35%	20.16%†††	3.00%††
Oct 07 – Sep 08	21.04%**†††	21.65%**†††	6.25%†	27.18%**†††	5.80%

Note: The (average) deviation is calculated as the difference of observed and synthetic REER over observed REER (all measured in levels). Thus, the deviation in September 2008 is the cumulated misalignment at that date, while the average deviation from the introduction of the Euro to September 2008 is the average of the cumulated misalignments. The average deviation before the introduction of the Euro is slightly smaller than zero because the fit is done on logarithmic REERs.
*,** ,***: significance of the Bonferoni-type test (at least one significant misalignment in the evaluated period) at the 10%, 5% and 1% level. We test the hypothesis of no overvaluation in periphery and no undervaluation in core countries.
†,†† ,†††: significance of the Fisher-type test (joint significance of misalignments during the evaluated period) at the 10%, 5% and 1% level.

Our approach yields results that almost perfectly correspond to the crisis of confidence in the Euro area that followed the world financial crisis: Greece, Ireland, and Portugal were the members of the currency union that in 2010 and 2011 needed to be bailed out by their partner countries and by the IMF. Italy and Spain were on the brink of losing access to capital markets but were rescued by the commitment of the ECB to intervene in bond markets if need be. The other economies in our set, including France, largely avoided a crisis of confidence. Interestingly, the German real effective exchange rate was almost exactly equal to its counterfactual in autumn 2008. This result is in sharp conflict with the assertion that an undervalued exchange rate in Germany was a main cause of the Euro crisis.[16]

The countries that were highly overvalued are also the only ones for which the Bonferoni-type test rejects the hypothesis of no misalignments during the last year before the crash of Lehman Brothers. The Fisher-type test indicates as well that misalignments (in this case, overvaluations) occurred mostly in periphery countries.[17]

[16]According to the UNCTAD trade and development report 2011, for example, *Germany seems to be going the way of Japan owing to deliberate wage compression since the mid-1990s, with vastly destabilizing consequences in the Euro area.* From this perspective, the German wage compression resulted in a *failure to halt downward pressures on prices and domestic demand*, leaving the economy excessively dependent on exports (UNCTAD 2011).

[17]For France, we tested if the REER was undervalued, as it is one of the "core" countries. However, a test of no overvaluation also yields insignificant results.

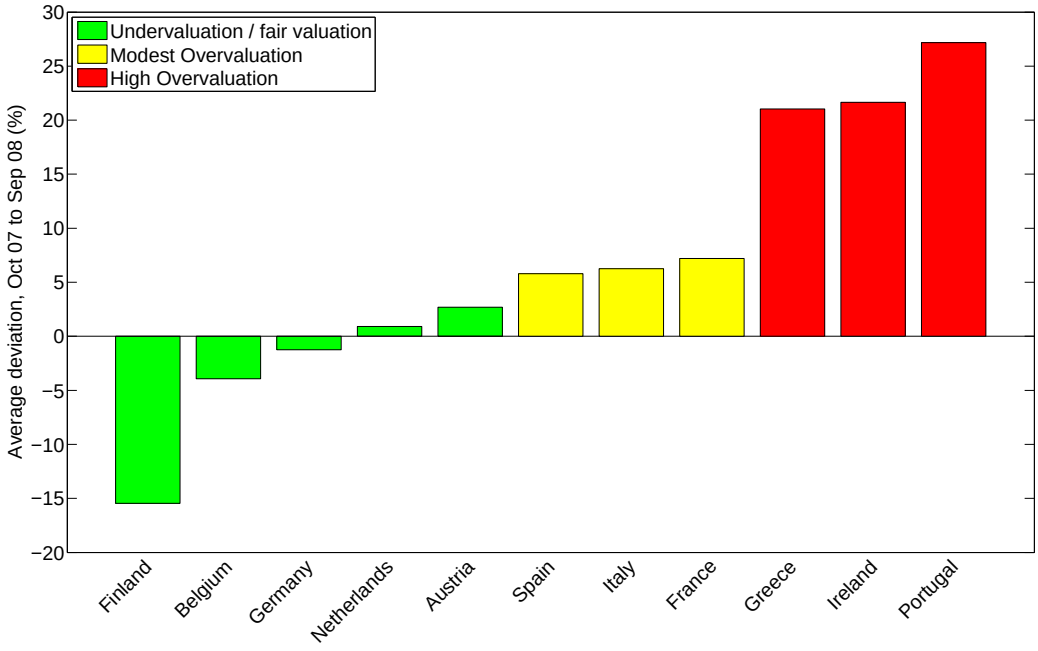

Figure 3: Average difference between the original and synthetic REER from October 2007 to September 2008.

It might be asked whether alternative and possibly much simpler approaches would render the same results. A particularly simple measure is the REER itself at the time when the monetary union came into existence (or, in the case of Greece, when the economy entered the union). This measure is valid if, at that time, the REER was in an equilibrium that has since remained unchanged.

Figure 4 gives a comparison between this naïve measure and the results of our counterfactual approach. The main differences are the following. According to the naïve measure, Ireland and particularly Spain appear to be more overvalued, while Greece and particularly Portugal appear less so. The counterfactual clearly makes more sense: in 2008, the current account deficit of Portugal was no less than 12.6% relative to GDP in 2008 and that of Greece was almost 15%, while the current account of Ireland stood at only 5.6%. Even though Spain's current account deficit (9.6%) was only somewhat lower than that of Portugal, the Spanish export performance between 1998 and 2008 (and also afterwards) was strong: the growth of exports of Spanish merchandise between 1998 and 2008 came close to German export growth (101%) with 94% in US dollar terms and was much higher than that of France (52%), Italy (69%) or Portugal (70%). Furthermore, the undervaluation of Finland is much more pronounced in the counterfactual. This finding confirms a similar result from the cointegration analysis of Coudert et al. (2013). Finally, the REER of Belgium was, according to our approach, close to its equilibrium level but markedly overvalued according to the naïve method. The former result is again more plausible, as the small current account in 2008 was close to balanced, with a deficit of 1.3% relative to GDP in 2008.

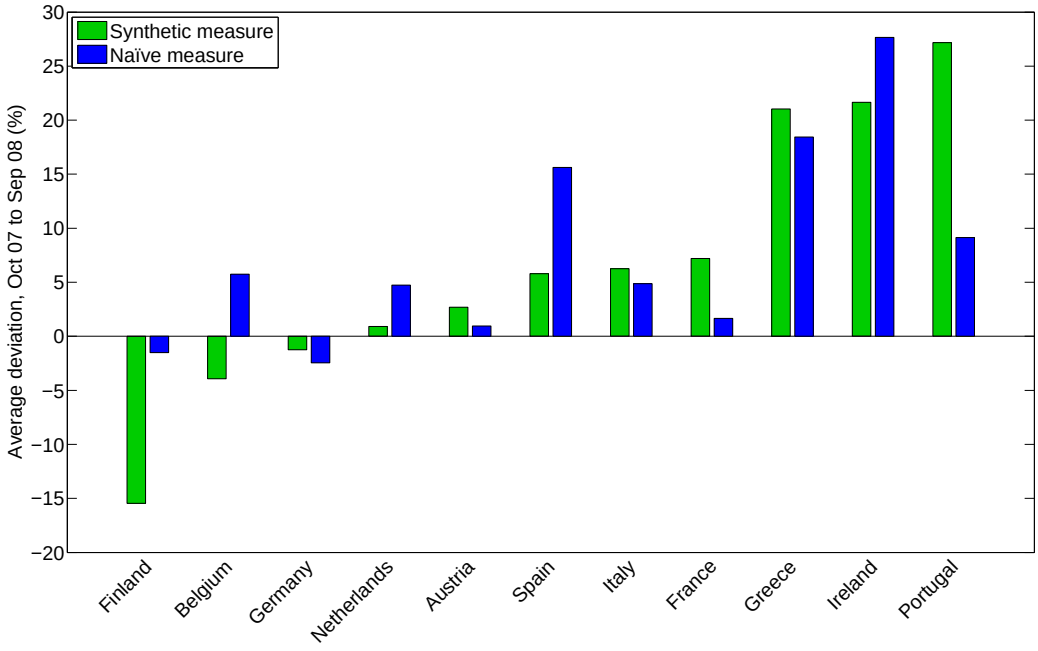

Figure 4: Difference between the original and synthetic REER from October 2007 to September 2008 compared to a simple measure of REER misalignment.

When we compare our results to those obtained by Coudert et al. (2013), we generally find that our misalignments point in the same direction. Exceptions include Austria and the Netherlands, where we find small undervaluations instead of overvaluations, and France, which is slightly overvalued in our estimation. The degree of both overvaluation in peripheral countries and undervaluation in core countries is slightly larger in our estimation. Furthermore, the difference between our estimate and the cointegration analysis increases in most countries if the cointegration sample is restricted to the pre-crisis period.[18] This points to the possible bias that we mentioned in the introduction. Simultaneous misalignments of fundamentals after the introduction of the Euro led to an underestimation of the true degree of misalignment in a cointegration analysis. The recent crisis period, forcing a reduction of misalignments, brought all macroeconomic series back towards a long-run balance. This in turn should have reduced the bias of the cointegration analysis.

Concerning developments after the financial crisis broke out, the actual real effective exchange rates have mostly declined relative to their counterfactuals, with Germany now being somewhat undervalued. This corresponds to the decline in the real effective exchange rate of the currency if the Euro area is treated as a single economy. While the REERs of the economies that were somewhat overvalued in 2008, Spain, Italy, and France, were close to those of their counterfactuals in 2013, and Portugal and Greece still appear to be markedly overvalued. Ireland, the third of the countries that was highly overvalued in 2008, is a special case: it started being overvalued later than Portugal and Greece; indeed, Table 2 shows that

[18] We are grateful to Coudert et al. for providing us with the detailed results of this robustness check.

for the whole period between the introduction of the Euro and the financial crisis, it was not significantly overvalued. Since the outbreak of the crisis, the REER declined by much more than those of the other countries.

4.2 Composition of the counterfactuals

The results presented above appear to be sensible enough, and although our approach is a priori data driven, it suggests an economic interpretation: as already explained, the counterfactuals are chosen in such a way that they resemble the treatment country according to our set of criteria. The weights of the principal components of these criteria are such that they minimize the divergence between the REER of the counterfactual from that of the treatment country for the time before introduction of the Euro. The first two components, which together have a weight of more than 97% (see Table A3), can be characterized as follows: the first draws mainly on criteria that are related to the overall level of economic development of the economy such as GDP per capita and the indicators for economic freedom and the ease of doing business. The second component draws more on criteria that are related to the dynamics of the economy, such as GDP growth and volatility as well as the share of capital formation and exports in total GDP.[19]

The composition of the counterfactuals that results from this is also related to the concept of economic development. For all economies whose REER in 2008 were close to or lower than the REER of their counterfactuals, those counterfactuals are combinations of economies that the IMF classifies as "advanced," see Table 3 and IMF (2013, p. 140). In contrast, the counterfactuals of the economies that were highly overvalued are combinations of advanced economies with one or more emerging market economies such as Brazil or Malaysia, although for Ireland, the share of the emerging market country (Iran) is, at 2.5%, rather small. As to the group of three countries with somewhat overvalued REERs in 2008, those two countries that risked losing access to capital markets in 2011/12, Spain and Italy, have counterfactuals that include emerging market economies. This result is visualized in Figures 5 and 6, where developing countries are shown in red and advanced countries in green. Israel and Singapore (the two countries that were classified as advanced only in 1997) are shown in yellow.

The results fit nicely with the following perspective on the misalignment of REER in the Euro area: in the years before the start of the currency union, the peripheral economies (including Spain and Italy) were in some respects not as advanced as those of the other member countries. Because overall production was less efficient, the equilibrium level of their REER was somewhat lower, according to the purchasing power parity theory enhanced by the Balassa-Samuelson effect. With the monetary union, however, investors (being overly optimistic) felt that these economies could catch up swiftly with the more advanced parts of the Euro area by adopting the common monetary framework. Capital inflows triggered an economic boom that led to a much stronger appreciation of their price levels and REER than justified by their production efficiency. In the autumn of 2008, all of these economies were overvalued, albeit to different degrees. Indeed, the REERs of the emerging markets'

[19]The resulting values of the matching criteria for treatment countries and their counterfactuals can be found in Table A4.

Table 3: Optimal country weights, benchmark estimation

	Austria	Belgium	Finland	France	Germany	Greece	Ireland	Italy	Netherlands	Portugal	Spain
Brazil	0.000	0.000	0.000	0.000	0.000	**0.157**	0.000	0.022	0.000	**0.133**	**0.268**
Canada	0.000	0.000	**0.212**	0.000	0.000	0.000	0.000	**0.219**	0.000	0.000	0.000
Chile	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004
China	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.054**	0.000
Colombia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Denmark	**0.455**	**0.868**	**0.059**	0.000	0.000	0.000	0.000	0.000	**0.457**	0.000	**0.187**
Iceland	**0.340**	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Iran	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000
Israel	**0.085**	**0.070**	0.000	**0.444**	**0.234**	**0.843**	**0.076**	**0.654**	0.000	**0.364**	0.000
Japan	**0.120**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.374**	0.000
Malaysia	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	**0.074**	0.000
Mexico	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Morocco	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.106**	0.000	0.000	0.000
New Zealand	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.232**	0.000	0.000
Norway	0.000	0.000	**0.655**	**0.217**	**0.690**	0.000	0.000	0.000	0.000	0.000	**0.541**
Singapore	0.000	**0.062**	0.000	0.000	0.000	0.000	0.000	0.000	**0.053**	0.000	0.000
South Africa	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sweden	0.000	0.000	**0.063**	**0.340**	**0.076**	0.000	0.000	0.000	0.000	0.000	0.000
Switzerland	0.000	0.000	0.000	0.000	0.000	0.000	**0.889**	0.000	0.000	0.000	0.000
Tunisia	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
United Kingdom	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
United States	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.259**	0.000	0.000
Venezuela	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: Country shares above 5% highlighted.

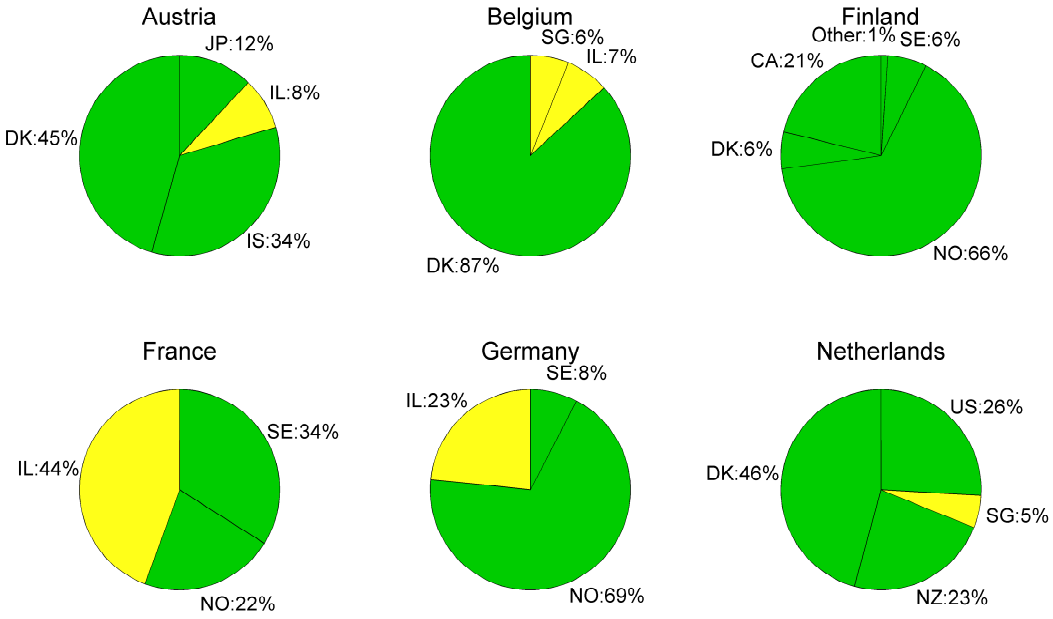

Figure 5: Composition of synthetic core countries

Note: green: advanced economies; yellow: advanced economies as of 1997; red: developing economies.

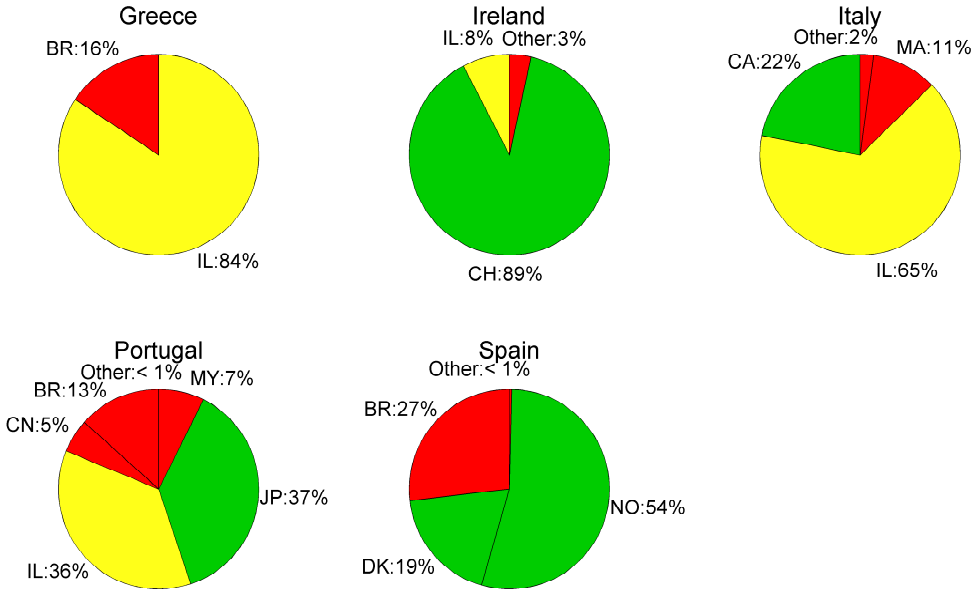

Figure 6: Composition of synthetic periphery countries

Note: green: advanced economies; yellow: advanced economies as of 1997; red: developing economies.

components of their counterfactuals such as those of Brazil and Malaysia did not appreciate markedly between 1999 and 2008. The fiscal and banking crises that evolved in the aftermath of the world financial crisis revealed that this was not the case for Greece, Portugal, Ireland, Italy, or Spain.

4.3 Robustness

Matching with inflation: As mentioned in section 2, the baseline scenario does not include inflation in the set of matching criteria, thereby missing one of the most important macroeconomic determinants. The inclusion of inflation is somewhat controversial. By enforcing a similar development of inflation, we implicitly also enforce a similar development of the nominal exchange rate. This might favor candidate countries with fixed exchange rate systems that aimed to peg their exchange rate to a European country (i.e., most likely Germany in the pre-Euro period). However, including inflation in the matching criteria reveals that the results are fairly robust with strong misalignments in the periphery and, for some countries, a slight need for appreciation in the core, see Figure A1 in the appendix.

Matching without Belgium: Excluding Belgium from the set of treated economies gives us the opportunity to enhance matching criteria by tradables as well as FDI and its volatility, thereby capturing even more dimensions that may be relevant to the development of the REER. Again, the results are quite similar to the benchmark scenario; see Figure A2. However, there is an unreasonably strong development of the counterfactual REER in Austria after the outbreak of the crisis. This points to the possibility that the crisis and its structural effects might have changed economic similarity. That is, Austria might not resemble the same mixture of countries today as it did between 1980 and 1999, even without the treatment effect of the Euro.

5 Conclusions

According to the synthetic matching mechanism applied in this paper, Greece, Portugal, and Ireland had significantly misaligned real effective exchange rates when the financial crisis broke out in 2013. This confirms other recent findings (Jeong et al. 2010, Coudert et al. 2013). The mechanism of our matching algorithm helps to explain how this misalignment came about: Greece and Portugal and to some extent Ireland are best matched by a mixture of advanced and emerging economies. When the Euro was introduced in these countries, it was widely believed that they would develop quickly and soon become as advanced as their partner economies in the monetary union. Such a development would, according to the Balassa-Samuelson effect, have justified an appreciating REER. However, convergence did not materialize as quickly as expected with respect to a variety of important indicators of the level of economic development. A readjustment can, in principle, be reached in two ways: either the actual real effective exchange rates have to come down, or reforms increasing the efficiency of the economies could increase the equilibrium levels of the rates. It appears that Ireland has already gone far enough in both ways such that the economy is no longer

overvalued. According to the synthetic matching mechanism presented in this paper, this cannot be said for Greece and Portugal.

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Appendix

Table A1: Descriptive Statistics of matching criteria

	Euro Countries				Candidates	
	mean	std	min	max	min	max
GDP/person (1)	15116	2571	10356	17923	899	23345
Growth of GDP (2)	0.05	0.01	0.04	0.07	0.02	0.12
Growth Volatility (3)	0.02	0.01	0.01	0.03	0.02	0.13
Inflation (4)	6.54	4.45	2.20	16.05	1.28	609.85
Gov. Debt (5)	66.38	28.40	28.67	119.74	5.68	95.99
Current Account (6)	-0.48	2.01	-3.28	3.53	-5.23	5.41
Capital Formation (7)	21.82	2.06	19.17	26.26	17.86	36.66
FDI (pre) (8)	1.16	0.71	0.25	2.40	-0.01	10.22
FDI (post) (9)	1.00	0.92	0.15	2.76	0.03	3.22
Agriculture (10)	5.56	3.10	1.72	10.60	0.62	25.39
Industry (11)	31.42	3.52	25.06	36.42	25.83	49.20
Services (12)	63.02	3.89	55.12	68.71	29.79	71.73
Exports (13)	34.59	17.49	19.48	64.64	9.25	172.87
Fuel Exports (14)	4.31	3.64	0.67	13.38	0.05	83.42
Tradables (15)	44.12	4.19	37.03	51.98	33.02	71.08
Public Sector (post) (16)	47.75	4.25	39.97	54.13	15.84	54.84
Human Cap (pre) (17)	2.66	0.35	2.30	3.47	1.47	3.44
Human Cap (post) (18)	3.04	0.29	2.50	3.49	1.82	3.59
Gini (post) (19)	29.93	3.26	25.70	35.96	24.15	65.27
Credit Reg. (pre) (20)	7.55	1.38	4.95	9.00	1.00	9.48
Credit Reg. (post) (21)	8.56	0.78	7.34	9.62	6.01	9.87
Cap Contr (pre) (22)	0.02	0.05	0.00	0.16	0.00	0.79
Cap Contr (post) (23)	0.06	0.07	0.01	0.23	0.01	0.82
Trade Barriers (24)	7.59	0.55	6.71	8.66	3.94	8.74
EFW (pre) (25)	6.59	0.52	5.75	7.33	4.20	7.98
EFW (post) (26)	7.37	0.32	6.84	7.90	4.56	8.66
Corruption (post) (27)	7.06	1.59	4.11	9.43	2.18	9.42
EODB (post) (28)	0.31	0.07	0.22	0.46	0.11	0.65
Labor (post) (29)	5.48	1.02	3.82	7.30	3.23	8.99

Table A2: Correlation of matching criteria in treatment countries

Corr.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
(1)	**1.00**	0.03	-0.55	-0.24	0.30	0.48	-0.16	-0.06	-0.15	**-0.79**	-0.45	**0.79**	0.17	-0.27	-0.60	0.61	**0.72**	**0.74**	**-0.73**	0.55	0.60	**-0.84**	**-0.82**	0.46	0.69	0.69	**0.79**	-0.68	0.43
(2)		**1.00**	-0.24	-0.22	-0.11	0.14	0.40	0.34	0.38	0.21	0.09	-0.19	0.24	-0.25	0.35	-0.18	0.12	0.05	-0.19	-0.16	-0.13	-0.08	-0.03	0.26	0.07	0.27	0.21	-0.25	0.13
(3)			**1.00**	-0.01	-0.20	-0.23	0.47	0.24	0.21	0.48	0.37	-0.54	0.16	0.45	0.50	-0.53	-0.37	-0.34	0.34	-0.25	-0.34	0.55	0.54	-0.38	-0.14	-0.33	-0.42	0.30	-0.07
(4)				**1.00**	0.07	-0.13	-0.15	-0.10	-0.08	0.05	0.18	-0.14	-0.18	-0.04	0.00	-0.02	-0.27	-0.25	0.40	-0.31	-0.40	0.15	0.07	-0.26	-0.45	-0.29	-0.27	0.33	-0.26
(5)					**1.00**	0.02	-0.09	0.00	-0.15	-0.39	-0.40	0.49	0.28	-0.32	-0.30	0.40	0.28	0.24	-0.32	0.13	0.08	-0.32	-0.37	0.26	0.18	0.21	0.16	-0.15	0.17
(6)						**1.00**	0.27	0.23	0.20	-0.46	0.19	0.20	0.41	0.15	0.02	0.03	0.15	0.17	-0.18	0.27	0.26	-0.33	-0.29	-0.04	0.41	0.16	0.26	-0.15	0.07
(7)							**1.00**	0.59	0.31	0.28	0.26	-0.34	0.55	0.10	0.64	-0.48	-0.23	-0.20	0.02	-0.21	-0.24	0.27	0.33	-0.07	0.12	0.07	-0.03	-0.08	0.11
(8)								**1.00**	**0.73**	-0.01	0.13	-0.07	**0.87**	0.00	0.54	-0.48	-0.03	-0.04	0.16	0.24	0.22	0.00	0.06	0.35	0.37	0.31	0.21	-0.34	0.29
(9)									**1.00**	0.12	0.39	-0.31	0.64	0.06	0.57	-0.30	0.08	-0.04	0.08	0.22	0.28	0.03	0.05	0.32	0.25	0.14	0.22	-0.23	0.13
(10)										**1.00**	0.27	**-0.83**	-0.21	0.24	0.64	-0.50	-0.56	-0.56	0.35	-0.62	-0.65	**0.77**	**0.80**	-0.49	-0.60	-0.55	-0.62	0.52	-0.29
(11)											**1.00**	**-0.76**	0.01	0.32	0.63	-0.47	-0.38	-0.40	0.49	-0.15	-0.21	0.43	0.43	-0.43	-0.14	-0.45	-0.37	0.34	-0.20
(12)												**1.00**	0.13	-0.35	**-0.80**	0.61	0.59	0.60	-0.52	0.51	0.56	**-0.76**	**-0.78**	0.58	0.48	0.63	0.63	-0.55	0.31
(13)													**1.00**	-0.01	0.47	-0.21	0.08	0.08	-0.08	0.32	0.29	-0.12	-0.09	0.39	0.44	0.38	0.34	-0.41	0.28
(14)														**1.00**	0.28	-0.37	-0.35	-0.29	0.22	-0.26	-0.21	0.29	0.38	-0.61	-0.32	-0.56	-0.49	0.46	-0.35
(15)															**1.00**	-0.64	-0.55	-0.55	0.37	-0.29	-0.34	0.62	0.67	-0.28	-0.22	-0.34	-0.36	0.26	-0.15
(16)																**1.00**	0.44	0.47	-0.69	0.26	0.30	-0.59	-0.66	0.42	0.19	0.21	0.46	-0.25	-0.04
(17)																	**1.00**	**0.90**	-0.52	0.44	0.53	-0.66	**-0.73**	0.53	0.58	0.66	**0.71**	-0.69	0.57
(18)																		**1.00**	-0.57	0.42	0.50	-0.63	-0.68	0.53	0.59	0.64	0.68	-0.66	0.48
(19)																			**1.00**	-0.25	-0.37	0.63	0.60	-0.44	-0.45	-0.50	-0.65	0.50	-0.21
(20)																				**1.00**	**0.83**	-0.45	-0.49	0.50	**0.80**	0.60	0.66	**-0.70**	0.51
(21)																					**1.00**	-0.57	-0.52	0.61	**0.73**	0.62	**0.73**	-0.69	0.46
(22)																						**1.00**	**0.92**	-0.58	-0.59	-0.61	-0.67	0.53	-0.24
(23)																							**1.00**	-0.61	-0.54	-0.63	**-0.71**	0.53	-0.27
(24)																								**1.00**	0.55	**0.76**	**0.75**	**-0.72**	0.33
(25)																									**1.00**	**0.78**	**0.74**	**-0.79**	0.69
(26)																										**1.00**	**0.87**	**-0.90**	**0.70**
(27)																											**1.00**	**-0.90**	0.56
(28)																												**1.00**	**-0.70**
(29)																													**1.00**

Note: Row and column headers refer to the numbering of matching criteria in table A1. Absolute correlations above 0.7 highlighted.

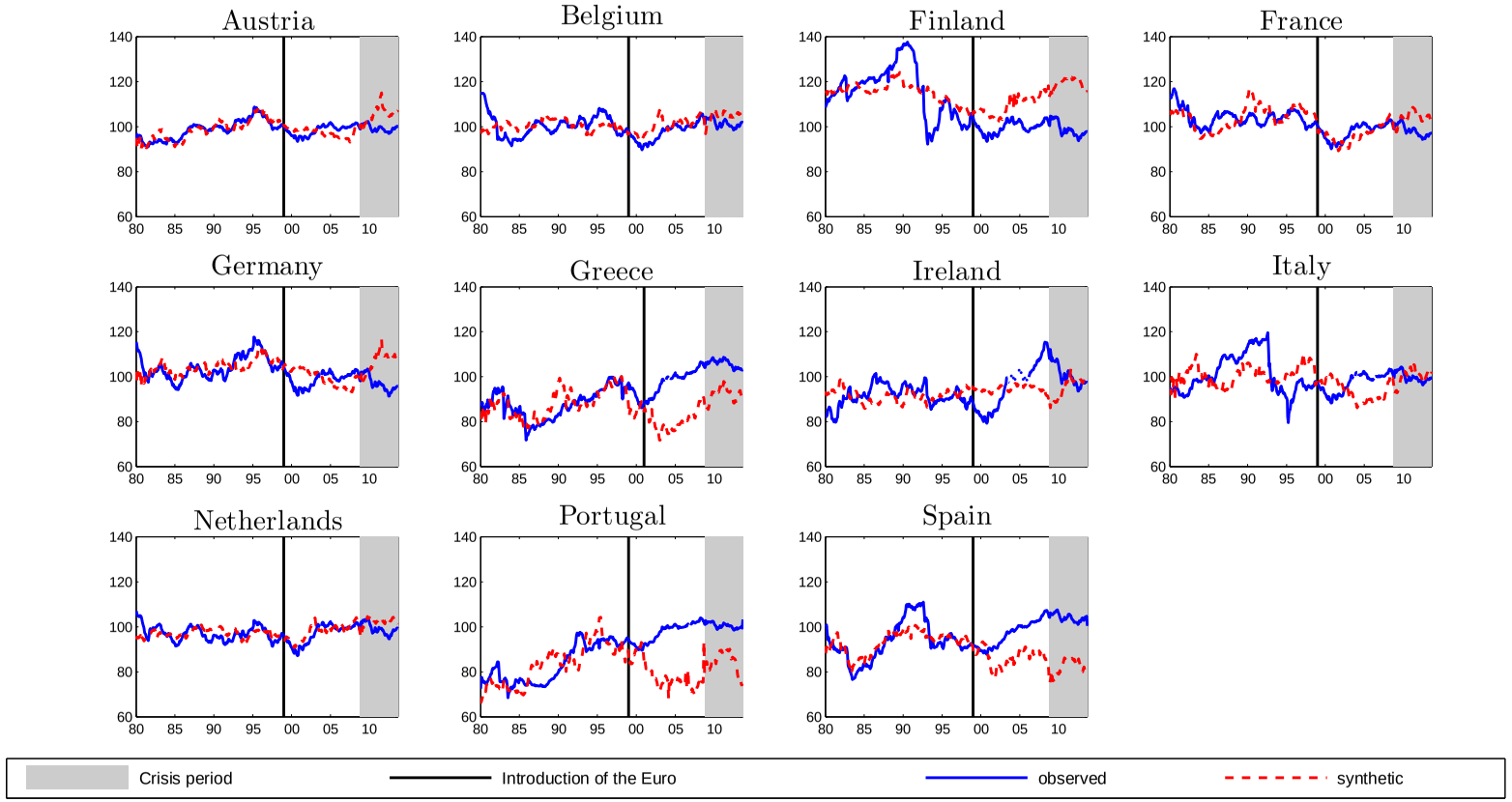

Figure A1: Original (blue) and synthetic (red) development of the REER in Euro-countries from 1980 to 2012. The black line indicates the introduction of the Euro, the gray area the period of the current crisis. The results are from the robustness test including inflation.

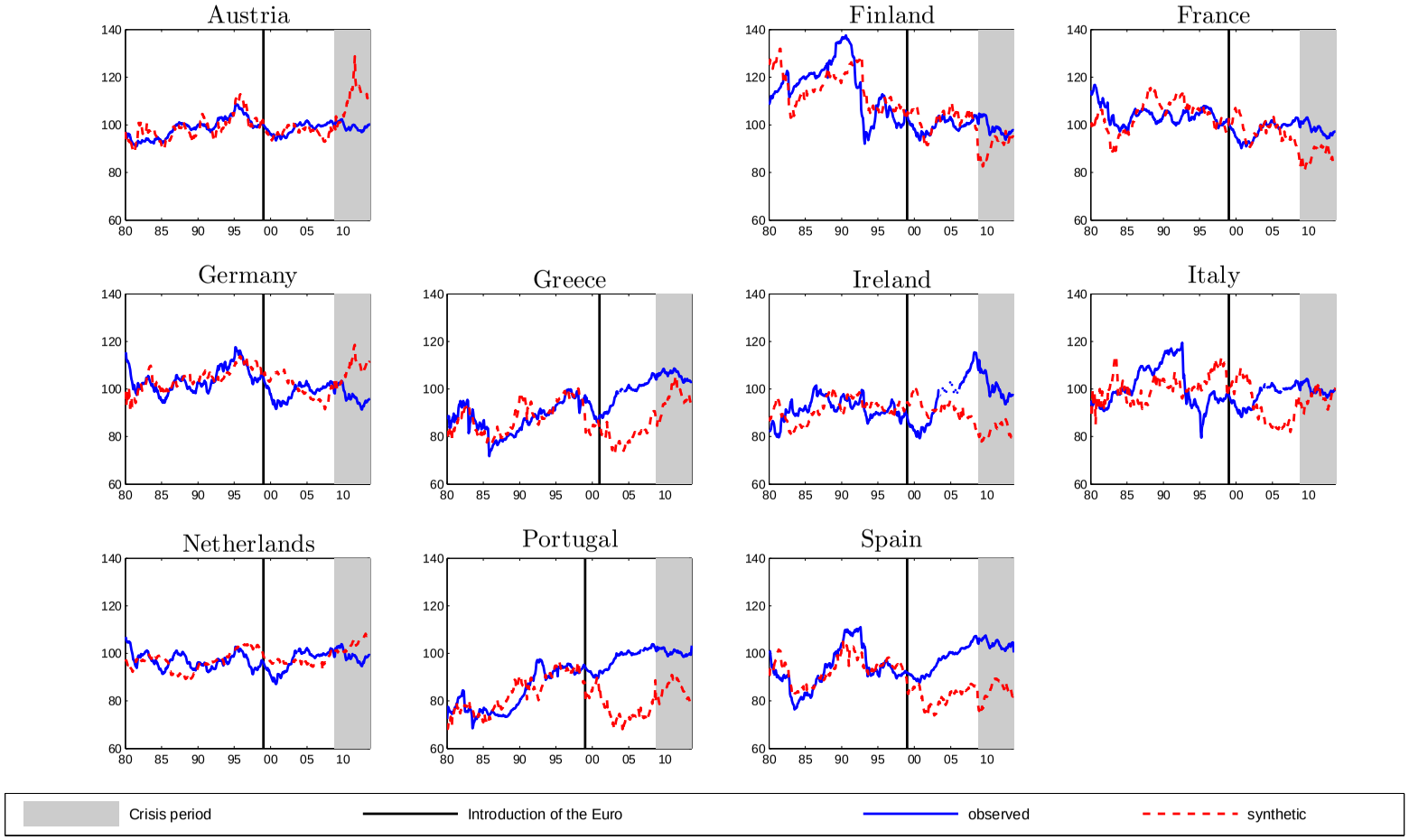

Figure A2: Original (blue) and synthetic (red) development of the REER in Euro-countries from 1980 to 2012. The black line indicates the introduction of the Euro, the gray area the period of the current crisis. The results are from the robustness test excluding Belgium.

Table A3: Importance weights, benchmark estimation

	Importance
1. Component	0.372
2. Component	0.606
3. Component	0.000
4. Component	0.000
5. Component	0.022
6. Component	0.000

Note: The importance is given for the first six principal components of matching criteria that were used in the benchmark estimation.

Table A4: Observed and synthetic matching criteria, benchmark estimation

	Austria		Belgium		Finland		France		Germany		Greece		Ireland		Italy		Netherlands		Portugal		Spain	
	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth	Obs	Synth
(1)	17818	17271	17071	17514	14887	21590	16860	16422	17101	20391	12525	11718	12696	21202	15957	12900	17923	17790	10356	12095	13078	17396
(2)	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.06	0.04	0.05	0.07	0.04	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.05
(3)	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.01	0.02	0.03	0.04	0.02	0.02
(4)	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
(5)	61.18	62.57	119.74	72.36	28.67	50.56	38.13	75.28	51.20	54.49	64.79	91.63	86.83	47.31	107.79	90.01	71.03	63.87	56.31	76.23	44.47	52.36
(6)	-1.14	-1.35	1.95	-0.85	-0.78	0.72	0.09	-0.83	0.79	0.71	-3.28	-2.62	-1.91	4.09	-0.47	-2.71	3.53	-1.76	-2.82	-0.68	-1.23	0.23
(7)	23.82	20.97	19.89	20.28	23.08	22.49	19.17	21.17	22.09	22.89	20.99	21.15	19.48	25.71	21.58	21.29	21.54	20.40	26.26	25.45	22.16	21.80
(8)	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
(9)	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
(10)	3.55	6.20	2.06	3.75	6.40	3.47	4.03	2.93	1.72	3.07	9.93	3.09	9.18	3.13	4.13	4.02	3.94	4.25	10.60	5.38	5.63	4.95
(11)	32.48	29.41	30.70	26.36	34.25	34.14	27.26	29.71	36.42	33.19	25.06	28.23	35.70	30.89	32.59	28.54	29.62	27.75	28.79	33.74	32.71	34.84
(12)	63.97	64.39	67.24	69.89	59.35	62.40	68.71	67.36	61.87	63.74	65.01	68.68	55.12	65.97	63.28	67.45	66.44	68.00	60.61	60.88	61.66	60.21
(13)	34.88	32.92	64.64	44.96	29.78	36.73	22.50	35.83	23.78	37.93	19.96	31.27	60.60	35.93	21.39	32.42	57.14	34.83	26.35	24.47	19.48	30.65
(14)	1.33	1.66	4.83	4.08	2.99	35.09	2.91	11.96	1.97	34.33	8.34	0.72	0.67	2.46	3.06	3.02	13.38	3.72	3.34	2.45	4.64	28.12
(15)	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
(16)	50.91	48.90	50.99	51.96	51.28	44.02	54.13	48.25	46.43	45.19	47.99	46.71	39.97	35.05	48.82	44.48	47.31	44.00	46.03	39.71	41.39	44.16
(17)	2.55	2.86	2.82	2.86	2.66	3.10	2.46	3.19	2.59	3.16	2.59	3.07	3.47	2.89	2.47	3.05	3.07	3.09	2.30	2.90	2.34	2.72
(18)	2.80	3.06	3.35	2.92	2.90	3.34	3.04	3.26	3.31	3.33	3.14	3.08	3.21	2.90	2.78	3.07	3.49	3.21	2.50	3.04	2.94	3.03
(19)	26.50	27.35	26.50	26.21	25.70	26.81	28.98	30.89	28.26	28.32	33.37	40.56	31.10	30.72	31.90	37.01	28.60	30.54	35.96	39.09	32.37	33.88
(20)	7.28	7.38	8.45	8.80	8.90	8.49	8.78	5.87	7.55	7.01	4.95	3.10	8.28	7.32	6.03	4.61	9.00	8.99	5.88	5.10	8.03	7.39
(21)	8.99	8.75	9.27	9.29	9.62	9.21	8.67	8.33	8.09	8.70	7.34	7.00	8.57	8.75	7.69	7.59	9.36	9.32	7.56	7.42	8.98	8.45
(22)	0.00	0.09	0.00	0.01	0.00	0.01	0.16	0.09	0.00	0.04	0.00	0.18	0.00	0.03	0.04	0.16	0.00	0.01	0.00	0.21	0.07	0.10
(23)	0.03	0.13	0.02	0.04	0.02	0.07	0.08	0.05	0.12	0.07	0.03	0.06	0.01	0.06	0.03	0.09	0.01	0.06	0.23	0.15	0.13	0.13
(24)	7.93	7.11	7.77	7.86	8.66	6.36	7.29	7.43	7.57	6.41	7.17	7.06	7.88	6.01	6.71	7.01	7.68	7.85	7.96	6.20	6.90	6.02
(25)	6.63	6.31	7.18	6.52	6.73	6.69	6.38	5.59	7.18	6.02	5.75	4.50	6.88	7.44	6.05	5.28	7.33	7.09	6.18	5.66	6.25	5.88
(26)	7.59	7.52	7.37	7.66	7.62	7.47	7.10	7.08	7.51	7.17	6.84	6.66	7.90	8.03	7.00	6.97	7.63	7.96	7.20	6.90	7.28	7.03
(27)	8.00	8.79	7.26	9.17	9.43	8.74	6.99	7.83	7.86	8.16	4.11	5.98	7.49	8.46	4.75	6.51	8.80	8.87	6.28	6.15	6.67	7.48
(28)	0.28	0.26	0.31	0.22	0.22	0.19	0.32	0.29	0.24	0.23	0.46	0.41	0.22	0.30	0.40	0.36	0.30	0.17	0.33	0.36	0.36	0.28
(29)	5.82	7.16	6.53	6.89	4.86	5.71	5.46	4.86	3.82	4.85	4.24	4.70	7.30	7.27	5.65	5.40	6.45	7.83	4.96	6.18	5.22	5.08

Note: Row headers refer to the numbering of matching criteria in table A1.