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

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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

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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 were revealed that had accumulated over the first decade of the Euro.[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 (Chen et al., 2013).

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:

[1]For more details on trade imbalances in the Euro area, see Berger and Nitsch (2010). In a broader context, Knedlik and von Schweinitz (2012) and El-Shagi et al. (2013) relate a variety of macroeconomic balances to the European sovereign debt crisis. For a further analysis of the current misalignment within the Euro area see e.g. Belke and Dreger (2013) and Körner and Zemanek (2013).

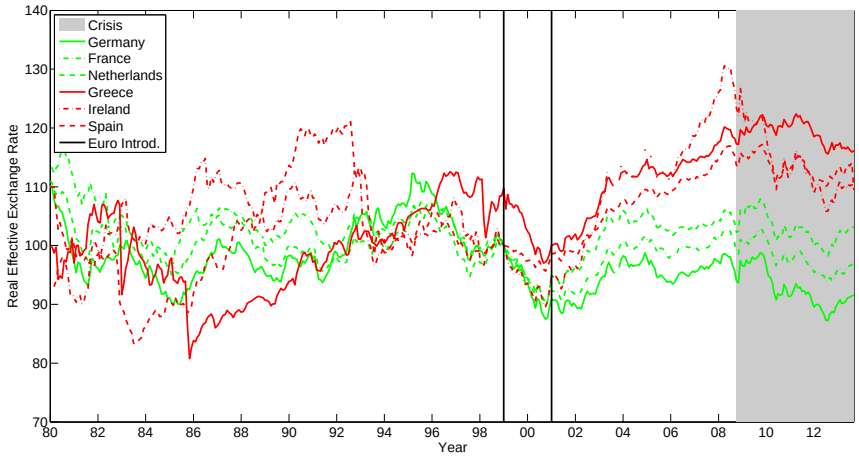

Figure 1: Development of REER in selected European countries, Euro introduction = 100.

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.

Figure 1 shows the development of REER in selected European countries before and after the introduction of the Euro. A rather simplistic way to

assess the degree of misalignments would be to compare the REER with its own value at the time when the monetary union came into existence (or, in the case of Greece, when the economy entered the union). Thus, according to Figure 1, Ireland, Greece, Spain and (to a much lesser degree) the Netherlands would have been overvalued just before the outbreak of the crisis, while Germany would have been slightly undervalued. However, this naïve measure is only valid if (1) the REER was in equilibrium when the Euro was introduced and if (2) the equilibrium has not changed since then. The second assumption is probably even more problematic than the first since REER of economies that become more efficient in producing tradable goods should tend to rise over time (Balassa, 1964; Samuelson, 1964).

More generally, the question whether or not a country is overvalued is crucially linked to the underlying concept of the equilibrium real exchange rate. Usually, misalignment is 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 (nominal) exchange rate movements would be much easier than it in fact is (Frankel and Rose, 1995; Kilian and Taylor, 2003). However, in

[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 and Westaway, 2004).

the medium run, although misalignments 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 and Westaway (2004) for a survey.[3]

Recurring ingredients in empirical approaches to assess real effective exchange rate equilibria are purchasing-power parities, sometimes enhanced by the Balassa-Samuelson effect (Froot and Rogoff, 1995; Bordo et al., 2014), estimates of the sustainability of the current account balances (Lee et al., 2008)), and reduced-form equilibria (Holtemöller and Mallick, 2013). In a few cases, these concepts have been used to answer the question at hand. Using Fundamental Equilibrium Exchange Rates (FEER), Jeong et al. (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 et al. (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

[3]Some of these approaches are given by Clark and MacDonald (1998), Clark and MacDonald (2004), and Barisone et al. (2006).

in the Euro area that determine the equilibrium exchange rates were possibly as misaligned as the exchange rate itself (Knedlik and von Schweinitz, 2012). Moreover, both studies use macroeconomic trade models as a foundation for their analysis, thereby abstracting from other potential sources of misalignments such as the structural composition of the economy (affecting the choice of trading partners) and structural determinants of economic growth in general.

To avoid these problems, we propose to identify misalignments using a synthetic matching approach. By allowing a battery of control variables, we are able to remain agnostic concerning the specific model driving the real effective exchange rate. Contrary to many structural attempts to explain the real effective exchange rate or its misalignment, we can thus cover a broad set of theoretical explanations. Furthermore, by identifying a treatment effect rather than explaining the real effective exchange rate through contemporaneous variables, our method remains robust in the presence of simultaneous disequilibria of several key macroeconomic indicators.

The general idea of synthetic matching is a generalization of the matching procedures traditionally used in microeconometrics. It makes matching more feasible for macroeconomic applications with control groups that are too small for traditional matching. The effect of a treatment, in this case, the introduction of the Euro in that country, 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 et al., 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 and 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 before the currency union as closely as

[4]Synthetic matching has been used in a number of studies to determine macroeconomic treatment effects. These include, among others, ETA's negative effect on Basque GDP (Abadie and Gardeazabal, 2003), the effect of a Californian tobacco control program on tobacco consumption (Abadie et al., 2010), the effect of natural catastrophes on GDP (Cavallo et al., 2013), an assessment of economic liberalization periods (Billmeier and Nannicini, 2013), the effect of German unification on West German GDP (Abadie et al., 2014) or the benefits of membership within the European Union (Campos et al., 2014).

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.

Like many recent studies (Cavallo et al., 2013; Billmeier and Nannicini, 2013), we consider several treated countries. However, as we look at members of a currency union, our treated subjects should be comparable in the way the general economic situation affects the real effective exchange rate. Thus, our econometric technique enforces consistent definitions of similarity to be used in the constructions of the synthetic matching countries for each treatment economy. To this end a panel version of the synthetic matching algorithm is developed that maintains the importance of criteria identical for all treated countries.

A caveat of our analysis is that we do not strictly measure the degree of REER misalignment, but rather the effect of the introduction of the Euro on REER development. The two measures should be similar (or at least rather close) under two conditions. First, that the REER of the synthetic counterfactual as a weighted average of non-Euro countries is itself close to its equilibrium value. Second, that the major difference between the synthetic counterfactual and the treated economy is indeed the treatment (i.e. the

introduction of the Euro) with all its consequences.[5] Yet, our results are most likely only valid until the outbreak of the financial crisis in September 2008. After this time, the macroeconomic development including the REER has been strongly driven by the response to the crisis, rendering countries with different reactions to the crisis invalid as "statistical twins".

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 of 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

[5]Although our treatment is indeed the introduction of the Euro, we aim to identify the misalignment by including some selected post treatment matching criteria. Most importantly, we only match Euro area members with statistical twins that had a similar institutional development. Thereby we can disentangle the pure currency union aspects of the Euro from the related institutional issues.

the data we use. Section 3 outlines the synthetic-matching algorithm and our approach to several econometric issues. In section 4, we present our results, and section 5 concludes.

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

2.1. Variable of interest

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).[6] Our data begin in January 1980 and end in 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).

2.2. The treatment and control group

We estimate synthetic matches for all founding members of the Euro area (except for Luxembourg)[7] and Greece.

We aim to include as many candidate countries as possible to ensure that the control group is an adequate representation of the global economy. The

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

[7]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 per person (the highest in the world) and several other important criteria cannot be matched.

selection of a suitable control group of candidate countries is rather important as, strictly speaking, the treatment effect estimated by synthetic matching only holds for the chosen control group. A generalization to a larger or even worldwide context (i.e., external validity) is valid if one can safely argue that including additional candidate countries would not affect results. In our case, the intuitively convincing set of candidate countries for members of the Euro area is rather small. Therefore, choosing a small control group of OECD countries would risk that not all individual characteristics of the treated countries can be matched. That is, extending the control group would most likely change our results and external validity would not hold (Billmeier and Nannicini (2013) encounter a similar problem when using regionally fixed control groups). Therefore, all countries are chosen as candidate countries for matching if they did not enter the Euro area at a later point and if both the REER data starting in 1980 and the selected matching criteria are available. 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

effect. Usually, the necessary assumption for identification is that non treated subjects remain unaffected by the treatment. However, a major historical event such as the introduction of the Euro affects the global economy as a whole, thereby violating this assumption. Since our control group economies are affected by the treatment, so are our artificially created counterparts for the treated economies. Economically, this implies that the counterfactual for country X does not represent what would have happened in country X if the Euro area would not have been created at all, but what would have happened in country X when the Euro area had been formed without country X being part of it. Since this is exactly what we are aiming to identify, we consider this " global" violation of a traditionally essential assumption to be irrelevant in our case.[8]

Similarly, 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, including candidate countries that are ERM members would imply

[8]The exception might be Germany. Given its weight in the Euro area economy, the global impact of the Euro might have been different if the Euro area had been formed without Germany.

that the generated counterfactual countries are no longer strictly 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.

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, great efforts were made to keep the European periphery countries in 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 et al., 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 et al. (2007) and Ferreira-Lopes (2010).

However, even if the treatment effect could not be clearly identified, the

approach would not be 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.

2.3. Selection of matching criteria

We consider 25 transformations of a range of economic and political indicators to identify structurally similar economies in our matching approach. The choice of criteria is inspired by variable selection mainly from the literature on purchasing power parities (PPP) and the influence of economic fundamentals on equilibrium exchange rates.

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 and Gardeazabal, 2003). In the case of GDP, we also consider mean growth rate 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.[9] By using the mean of matching criteria, we match the average economic environment over the period from 1980 to the introduction of the Euro, which should considerably lessen the influence of short periods with volatile developments.

Table 1 summarizes all indicators used with their transformation and their respective sources. Descriptive statistics are presented in Table A1 in the annex. Being restricted by data availability, we do not think that this list is by any means extensive. However, the results are remarkably robust to the selection of criteria, see section 4.3. This is because criteria are often quite highly correlated, see Table A2 in the annex.

Macroeconomic variables:. One of the first extensions of the theory of purchasing power parities was the Balassa-Samuelson effect (Balassa, 1964; Samuelson, 1964). In short, it states that the law of one price only holds for tradable goods. Thus, a catching-up economy should experience increasing real effective exchange rates if the catching-up of productivity is mainly confined to the tradable goods sector and if the price index includes non-tradables. Thus,

[9]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.

GDP per person, the *GDP growth rate* and *volatility of GDP growth* play an important role for the potential future development of the REER. A similar argument holds for *capital formation* (i.e., investment as a share of GDP) as an important foundation of future growth prospectives (Rogoff, 1996) and balanced growth (Clark and MacDonald, 1998).

Equilibrium exchange rate estimations (like the FEER and BEER mentioned above) try to determine exchange rates that are consistent with external and possibly internal balance in the medium run. One of the most important variables for external balance is the *current account balance*, see Abiad et al. (2009) among many others. Internal balance, on the other hand, could be disturbed by high levels of *government debt* (Clark and MacDonald, 1998).

High current account deficits and government debt increase the potential for sudden stops (Calvo et al., 2003), strongly affecting REER (in the short run). To further capture the potential for such disturbances, we use *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:. One reason for changing real effective exchange rates is that shocks may not have homogeneous effects in different industry sectors. Thus, countries specializing in different goods will most likely not experience the same (aggregate) shocks (see Chen et al. (2013) for a study of the influence of external trade shocks in Europe). It therefore appears to be important to find synthetic matches with comparable structures of supply and demand before the introduction of the Euro. 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*.[10]

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. Using political variables after the introduction of the Euro, we account for institutional changes in the treated economies that are driven by the membership in the European Union rather than the existence of the Euro. The selected variables encompass a wide array of indicators and coefficients. They include the *size of the government*

[10]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.

sector; equality (*Gini-coefficient*); 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*.

There are two reasons to include most of these variables. First, transaction costs are one reason for persistent deviations from purchasing power parity (Sarno and Taylor, 2002, Ch. 3). Primary examples for these frictions are *capital controls* and *trade barriers*. Second, bad institutions and market failures are found to affect tradable goods stronger than non-tradables (Rodrik, 2008), further affecting real effective exchange rates.

In addition to this, some variables may have direct effects on the real effective exchange rate. The *size of the government sector* might have a direct effect on exchange rates, if there is a certain degree of pricing-to-market (Betts and Devereux, 2000). High *labor market regulations*, creating labor market frictions and search unemployment, can directly influence the Balassa-Samuelson effect (Sheng and Xu, 2011).

3. Estimation technique

The general idea behind the synthetic matching approach by Abadie and Gardeazabal (2003) is to match countries receiving a treatment by an untreated counterfactual counterpart. 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.[11]

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 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. As our treated economies introduced a common currency at roughly the same time, we can assume that they are (up to a certain degree) comparable. Therefore, our matching criteria should have a similar effect on REER. 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.[12]

[11] 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 and Gardeazabal (2003), using additional matching criteria for the selection of the counterfactual, offers a great advantage.

[12] 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, 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:

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

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 the importance matrix V by minimizing the total sum of squared residuals over all treated economies:[13]

Thus, having the same candidate countries implies equal importance of matching criteria for all treated economies.

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

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

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 Equation (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.[14]

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

[14] Abadie et al. (2010) 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.

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 $V^{(0)}$.[15] 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, while the country weights w_i are not entirely stable. 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 counterfactual REER is small.

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

[15] 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.

assess the significance of misalignments (Abadie et al., 2010; Cavallo et al., 2013). 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, as shown in Figure A1(b) in the annex. This empirical distribution can then be used to obtain p-values for every Euro country and month after the introduction of the Euro.[16] 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

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

adjustment also used by Acemoglu et al. (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 at single points in time, 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 and 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 and 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.

Figure A1 shows the estimation errors for treated economies and for placebo studies. We can see that (normalized) prediction errors in placebo studies (subfigure (b)) are not substantially higher after the placebo treatment than the estimation errors before. Thus, confidence intervals are quite

stable over time. The prediction errors of treated economies (in subfigure (a)), i.e. the misalignments, diverge strongly after 1999. Moreover, they are found to be very persistent, resulting in significant rejections of the Fisher test.

4. Results

4.1. Fit of the variable of interest

Figures 2 and 3 show how the counterfactual and the actual real effective exchange rates have developed since 1980 in core and peripheral countries. Table 2 gives root mean squared prediction error (RMSPE) during the fitted period before the introduction of the Euro (1) and the average misalignments of the REER for selected subperiods: (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:[17] the

[17]The root mean squared prediction errors before the introduction of the Euro, given in Table 2, are quite small and comparable between countries.

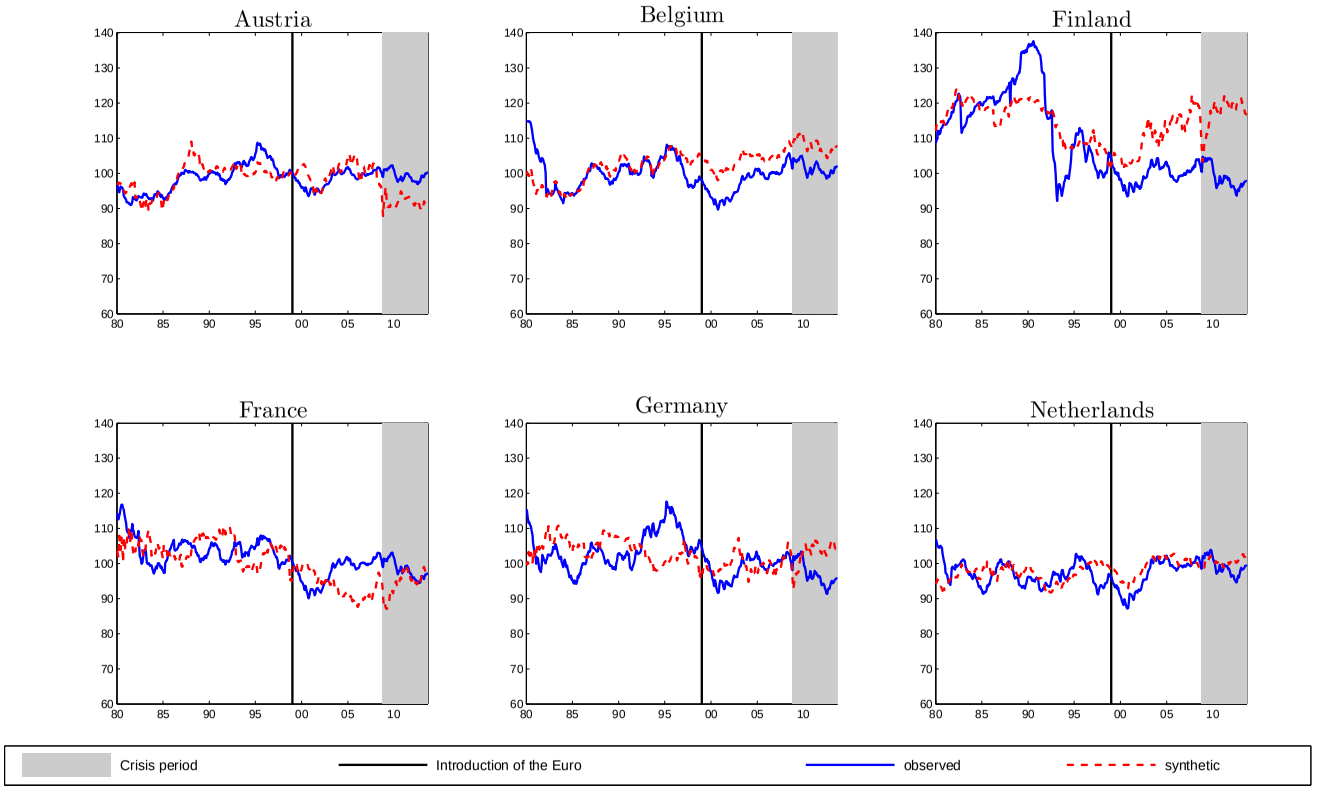

Figure 2: Original (blue) and synthetic (red) development of the REER in core Euro countries from 1980 to 2012. The black line indicates the introduction of the Euro, and the gray area indicates the period of the current crisis.

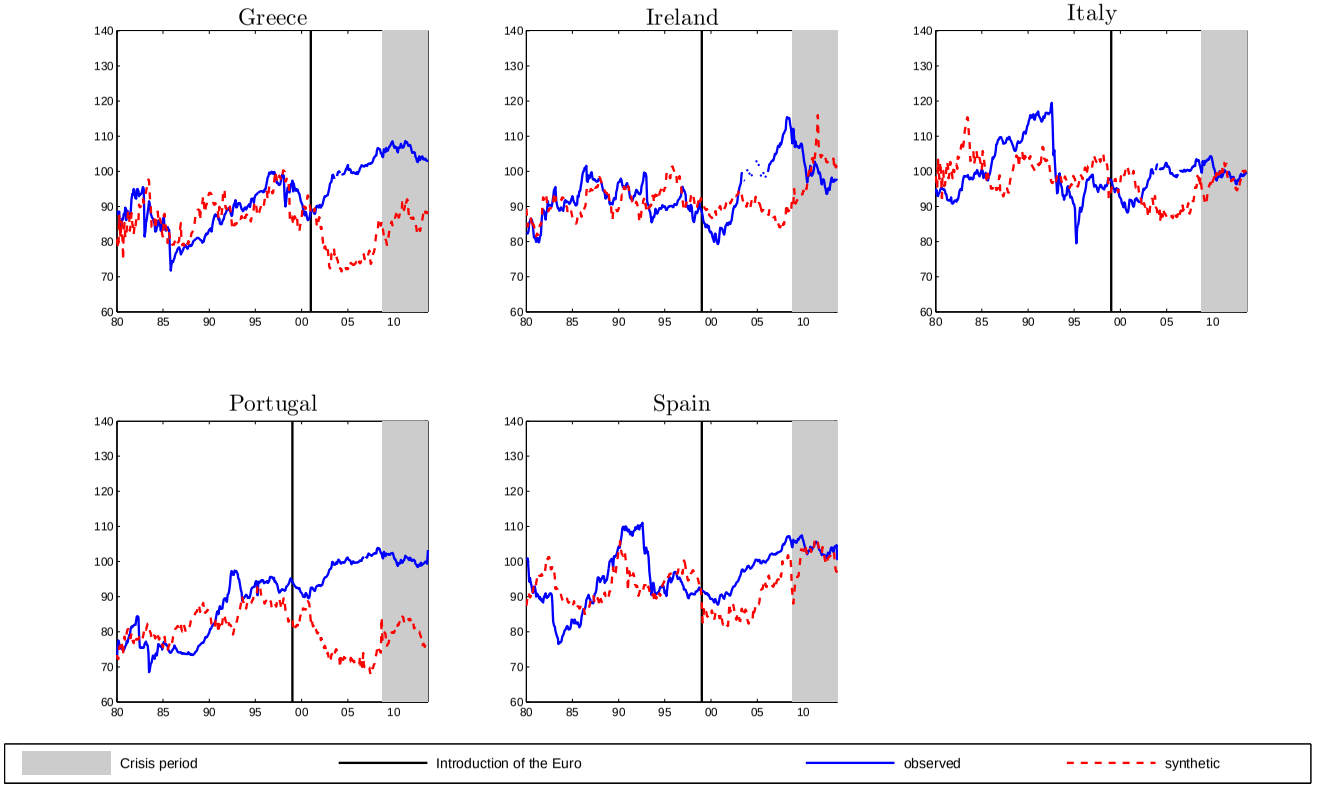

Figure 3: Original (blue) and synthetic (red) development of the REER in peripheral Euro countries from 1980 to 2012. The black line indicates the introduction of the Euro, and the gray area indicates the period of the current crisis.

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

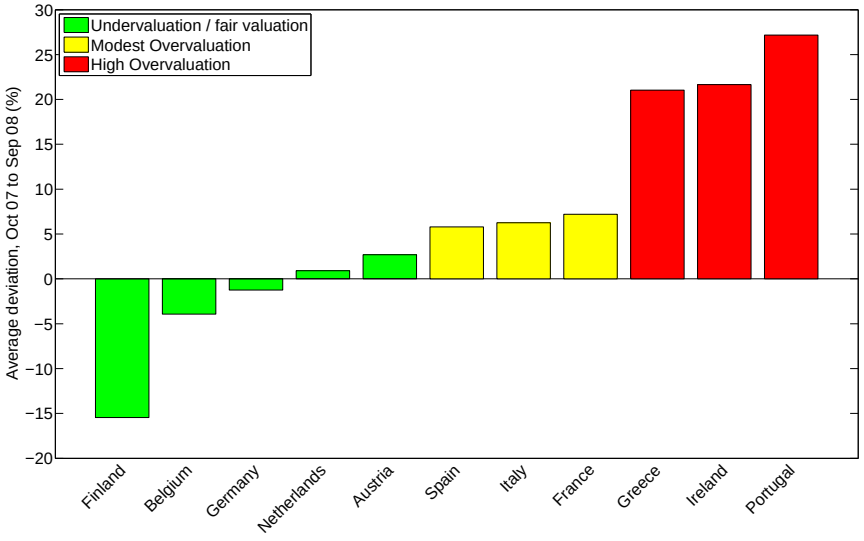

Figure 4: Average difference between the original and synthetic REER from October 2007 to September 2008.

(see the last row of Table 2 and Figure 4):

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.

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

Our approach yields results that almost perfectly correspond to the crisis

Table 2: Deviation of synthetic from the observed REER

Average Deviation	Austria	Belgium	Finland	France	Germany	Netherlands
(1) RMSPE	0.032	0.045	0.067	0.052	0.073	0.042
(2) Euro-09/08	-1.75%†	-6.53%†††	-10.91%†††	3.71%	-1.08%	-2.64%
(3) 10/08 - 09/13	7.48%	-6.28%††	-18.8%†††	3.63%	-6.26%	-1.59%
(4) 10/07 - 09/08	2.69%	-3.92%	-15.47%†††	7.21%	-1.24%	0.92%

Average Deviation	Greece	Ireland	Italy	Portugal	Spain
(1) RMSPE	0.062	0.051	0.090	0.080	0.082
(2) Euro-09/08	20.43%†††	4.26%†††	4.52%†††	21.44%†††	8.19%†††
(3) 10/08 - 09/13	18.53%**†††	0.44%††	2.35%	20.16%†††	3.00%††
(4) 10/07 - 09/08	21.04%**†††	21.65%**†††	6.25%†	27.18%**†††	5.80%

Note: The (average) deviation is calculated as the difference of observed and synthetic REER, in percent. In the first row, we report the RMSPE from the estimation sample (January 1980 to the introduction of the Euro).
*,**,***: 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.

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.[18]

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.[19] A similar result can be drawn from Figure A1 in the annex: the differences between observed and synthetic REER were only unusually large for Greece, Portugal and (from 2006 onwards) also for Ireland.

[18] 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).

[19] 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.

The counterfactual yields economically far more plausible results than the naïve approach described in the introduction: 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 than in the naïve approach. 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.

When we compare our results to those obtained from the BEER-analysis of Coudert et al. (2013), we generally find that our misalignments point in the same direction.[20] Exceptions include Austria and the Netherlands, where we find small undervaluations instead of overvaluations, and France, which

[20] We are grateful to Coudert, Couharde, and Mignon for providing us with their detailed results.

is slightly overvalued in our estimation. This in in-line with early calls that France needs to improve its competitiveness (Bennett et al., 2008; Knedlik and von Schweinitz, 2012). The degree of both overvaluation in peripheral countries and undervaluation in core countries is slightly larger in our estimation than in Coudert et al. (2013). 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. 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 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. However, the validity of these results rests on the assumption that the financial crisis did not affect the composition of counterfactuals. This implies that the shock of the financial crisis would have affected Euro countries in the absence of the Euro as it affected the (weighted average of) candidate countries. Since this assumption does most likely not hold, we do not put too much faith in the results concerning the period after the the crash of Lehman Brothers.

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. Thus, the method gives weights to the components according to their importance for the REER-development in the analyzed Euro-area country.[21] The first two components, which together have a weight of more than 97% (see Table A4

[21]It should be noted, that we do not assume that the principal components and related matching criteria found to be important for the eleven Euro-area countries would be equally influential for the development of the REER in other countries.

in the annex), 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 structural indicators. 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. Accordingly, criteria can be matched very well if they are to a large extent explained by the first two principial components (like the Ease-of-doing-business indicator or services as a share of GDP). However, criteria are badly matched if they are scarcely related to the first two components, for example fuel exports as a share of total export.[22]

The composition of the counterfactuals that results from this is related to the concept of economic development. For all economies whose REER in 2008 was close to or lower than the REER of their counterfactuals, those counterfactuals are combinations of economies that the IMF classifies as "advanced", see Table A3 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

[22]The values of the matching criteria for treatment countries and their counterfactuals can be found in Table A5 in the annex.

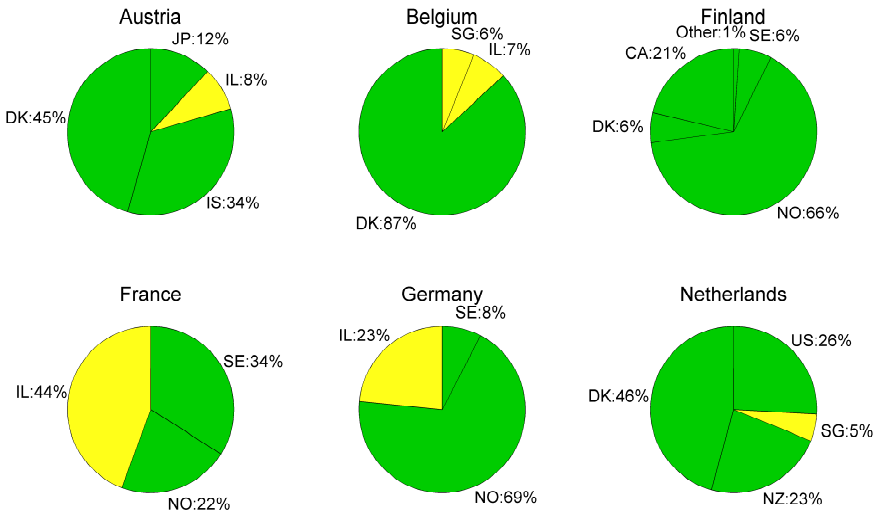

Figure 5: Composition of synthetic core countries
Note: green: advanced economies; yellow: advanced economies as of 1997; red: developing economies.

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

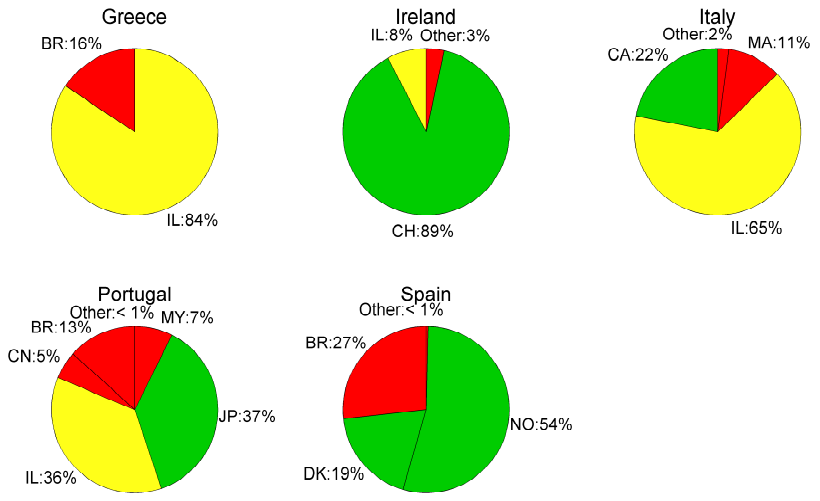

Figure 6: Composition of synthetic periphery countries
Note: green: advanced economies; yellow: advanced economies as of 1997; red: developing economies.

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' components of their counterfactuals such as those of Brazil and Malaysia did not appreciate markedly between 1999 and 2008.

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 A2 in the annex.

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 A3 in the annex. 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 2008. 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. While Ireland already depreciated strongly in real terms, the REER of both Portugal and Greece remained close to it's pre crisis level. While our synthetic REERs for those countries also indicate an improvement in Ireland and constant misalignment for the southern periphery, this has to be taken with a grain of salt, since our approach does not account for the political response to the crisis.

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Annex

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.

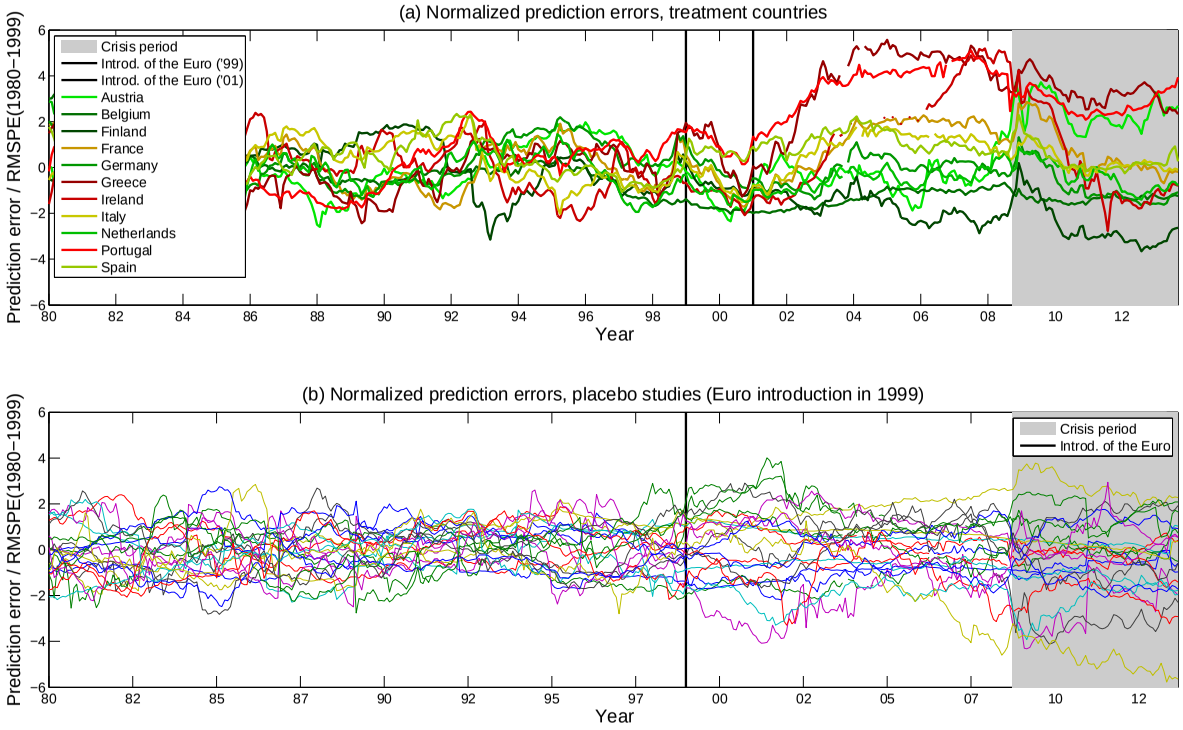

Figure A1: Normalized prediction error of (a) treated economies and (b) candidate countries in placebo studies. Errors are normalized with their country-specific RMSPE between January 1980 and the introduction of the Euro. The plot of placebo studies for the Euro introduction in 2001 looks nearly identical.

Table A3: 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.

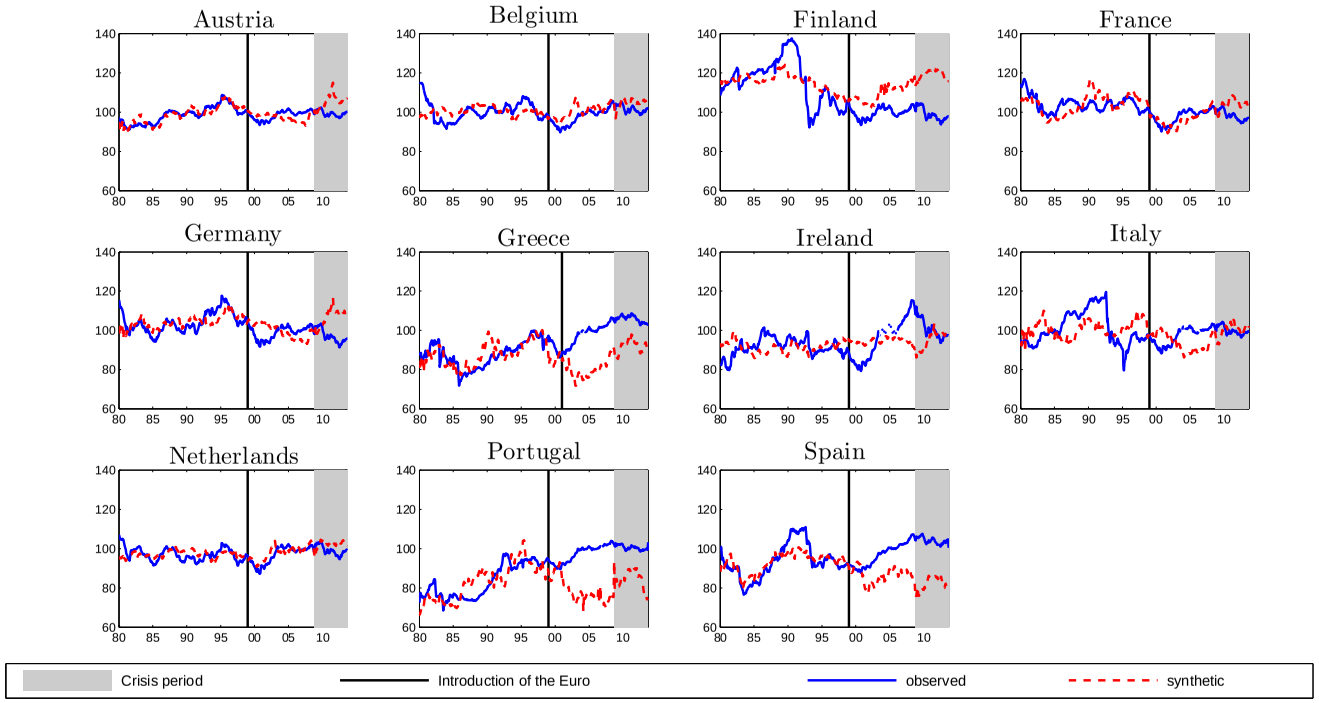

Figure A2: Original (blue) and synthetic (red) development of the REER in Euro-countries from 1980 to 2012. The black line indicates the introduction of the Euro, the gray area the period of the current crisis. The results are from the robustness test including inflation.

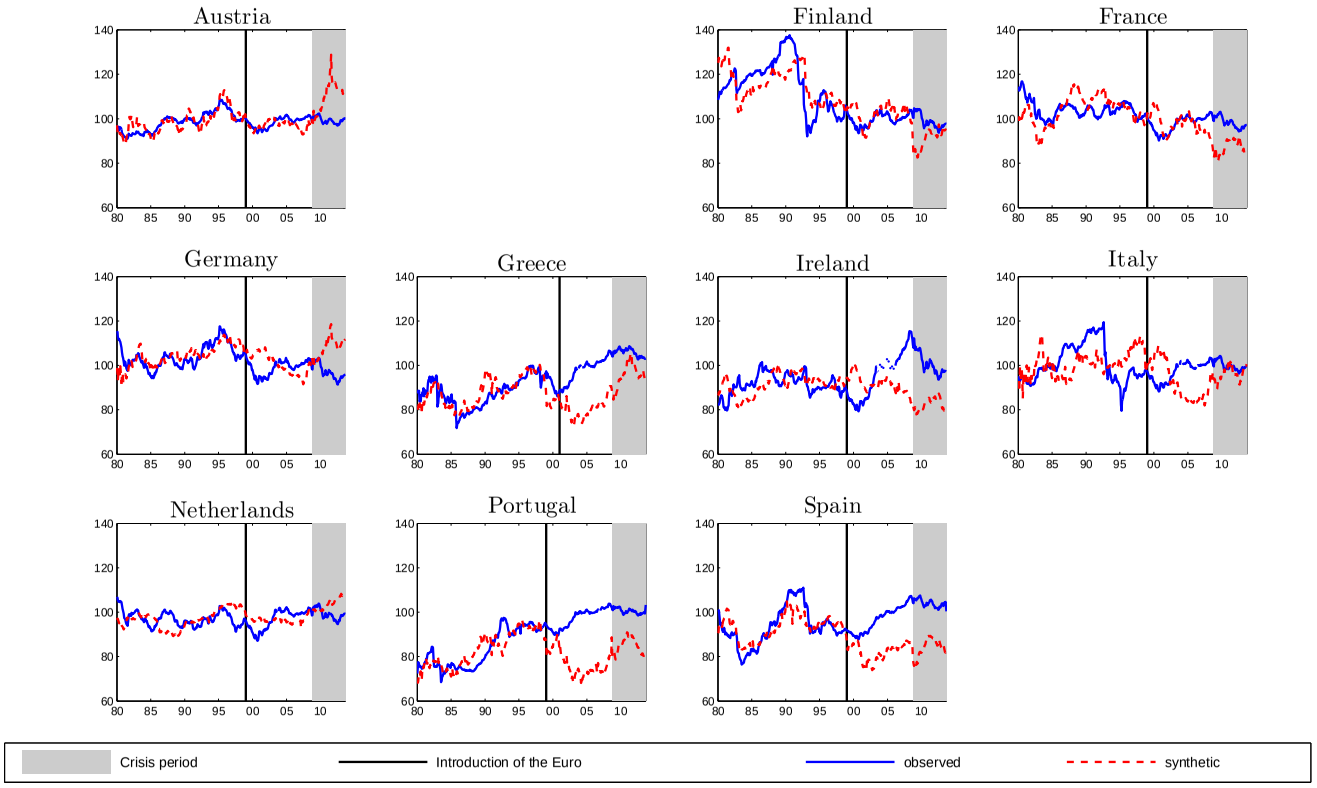

Figure A3: Original (blue) and synthetic (red) development of the REER in Euro-countries from 1980 to 2012. The black line indicates the introduction of the Euro, the gray area the period of the current crisis. The results are from the robustness test excluding Belgium.

Table A4: 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 A5: 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. Rows with NaN entries were not matched in the benchmark estimation